MUSQUAPSINK BROOK WATERSHED RESTORATION AND PROTECTION PLAN

Developed by the Rutgers Cooperative Extension Water Resources Program
Funded by the New Jersey Department of Environmental Protection
RP 07-002

June 6, 2012

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1. Acknowledgements

The Musquapsink Brook Watershed Restoration and Protection Plan was developed by the Rutgers Cooperative Extension Water Resources Program and was funded by the **New Jersey Department of Environmental Protection** (NJDEP) through the 319(h) Grants for Nonpoint Source Pollution Control under Grant #RP 07-002. This document has been produced by the Rutgers Cooperative Extension Water Resources Program (www.water.rutgers.edu).

This document represents the culmination of efforts from all project partners. The Rutgers Cooperative Extension Water Resources Program would like to thank **Marion McClary, Ph.D.**, Associate Professor of Biological Sciences Co-Director, School of Natural Sciences at Fairleigh Dickinson University, who collected and analyzed the biological monitoring data; the **Bergen County Department of Health Services**, who assisted with water quality sampling and fieldwork; **Arnold Vernick, P.E.**, project manager on behalf of the Bergen County Department of Health Services; and **Raymond Cywinski** of United Water New Jersey, who served as project liaison between local watershed organizations, Rutgers University, and Bergen County.

The *Musquapsink Brook Watershed Restoration and Protection Plan* maps were developed using NJDEP Geographic Information System (GIS) digital data, but this secondary product has not been verified by NJDEP and is not State-authorized.

2. Executive Summary

The Musquapsink Brook Watershed Restoration and Protection Plan characterizes the watershed and provides insight into the problems facing the waterway and potential solutions. The Musquapsink Brook is a tributary of the Pascack Brook, which flows along the New York/New Jersey state line to its confluence with the Oradell Reservoir, which provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties.

The watershed area is predominantly urbanized. This intensive land use has caused degradation of stream health, threatening the Category One waters to which the Musquapsink Brook flows. With the introduction of enhanced stormwater management, this watershed can continue these land use practices while achieving sustainability and improved water quality. Management measures that will minimize stormwater runoff will be essential to reducing phosphorus and fecal bacteria loads that now degrade the quality of the surface waters within the watershed.

Working with the Bergen County Department of Health Services, Fairleigh Dickinson University, and United Water New Jersey, the Rutgers Cooperative Extension Water Resources Program has created this plan to provide recommended implementation projects, measureable milestones and suggestions for technical assistance and funding. Along with site specific projects, watershed wide educational components will be essential for obtaining designated use goals for the future.

3. Introduction

The development of the Musquapsink Brook Watershed Restoration and Protection Plan is funded by the Federal Clean Water Act Section 319(h) Program administered through the Division of Watershed Management of the New Jersey Department of Environmental Protection (NJDEP). The project began in September 2006 and was granted an extended deadline of June 30, 2012. This chapter describes the general background of the planning area, the project organizational structure, and the purpose of the watershed restoration and protection plan.

3.1 Background

The Musquapsink Brook Watershed, located above U.S. Geological Survey (USGS) streamflow gauge #01377499 at River Vale, is approximately 6.9 square miles (about 4,407 acres) in area. The Musquapsink Brook Watershed is located in Bergen County and encompasses part of Woodcliff Lake Borough, Saddle River Borough, Hillsdale Borough, Washington Township, Westwood Borough, Emerson Borough, Paramus Borough, and Oradell Borough. Musquapsink Brook is approximately 7.3 river miles from the headwaters in Woodcliff Lake Borough to its confluence with the Pascack Brook at the border between Westwood and River Vale, New Jersey. The largest surface water body in the drainage area is Schlegel Lake, which encompasses 27.0 acres (Figure 1).

Under certain conditions, United Water of New Jersey diverts water from the Saddle River to the Oradell Reservoir through the Musquapsink Brook (Figure 1). The United Water of New Jersey records show that during the surface water sampling period (June 1, 2007 and December 31, 2007) a total of 551 million gallons of river water was transferred.

The NJDEP funded a characterization and assessment for Watershed Management Area 5 (WMA5) in which the Musquapsink Watershed is located. The WMA5 report was released in 2005 and analyzed data for the entire the WMA5 to identify concerns with land-based runoff; groundwater and water supply issues; point and nonpoint sources; and important natural resources.

Based upon numerous monitoring sources including the NJDEP Ambient Biomonitoring Network (AMNET) and the NJDEP and the USGS, the Musquapsink Brook is a moderately-to-severely impaired waterway. According to the 2010 *New Jersey Integrated Water Quality Monitoring and Assessment Report,* the Musquapsink Brook (reported as ‘Pascack Brook (below Westwood gage)’) is reported to not support the following designations:

- Agricultural Water Supply: impairment due to total dissolved solids
- Aquatic Life: impairments due to low dissolved oxygen, pH, and total phosphorus
- Primary Contact Recreation: impairment due to fecal coliform
- Public Water Supply: impairment due to arsenic

A TMDL was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load for 7.3 miles of stream. In 2005, a TMDL for total phosphorus was established for the same 7.3 mile stretch of stream. This TMDL requires a 21.43% reduction in total phosphorus loadings from medium/high density residential, low density/rural residential, commercial, industrial, and mixed urban/other urban land uses to achieve an overall 10.9%

reduction in total phosphorus loadings to the Musquapsink Brook. Additional aquatic life surface water quality impairments will need to be addressed through the TMDL process.

The NJDEP Bureau of Biological & Freshwater Monitoring maintains one AMNET station within the Musquapsink Brook Watershed (Station AN0206, Westwood, NJ). This station, located at Harrington Avenue, has been sampled in July of 1993, 1998, and 2003. For each of the three sampling rounds, the Musquapsink Brook was rated as a moderately impaired site, characterized by reduced macroinvertebrate taxa richness.

3.2 Partnerships and Accomplishments

Development of the Musquapsink Brook Watershed Restoration Plan is a multi-disciplinary and multi-agency collaborative effort. The partner agencies that have collaborated include Bergen County Department of Health Services, Fairleigh Dickenson University, United Water of New Jersey, and Bergen Save the Watershed Action Network (Bergen SWAN).

3.3 Purpose of this Plan

This watershed restoration and protection plan is the culmination of results obtained from the completion of project tasks and objectives. This plan will detail the management measures needed to achieve the necessary reduction in fecal coliform and total phosphorus loadings. In addition, this plan will provide an education component for education and outreach to enhance the public's understanding of the project and its goals. Schedules and measurable milestones for project implementation will also be included.

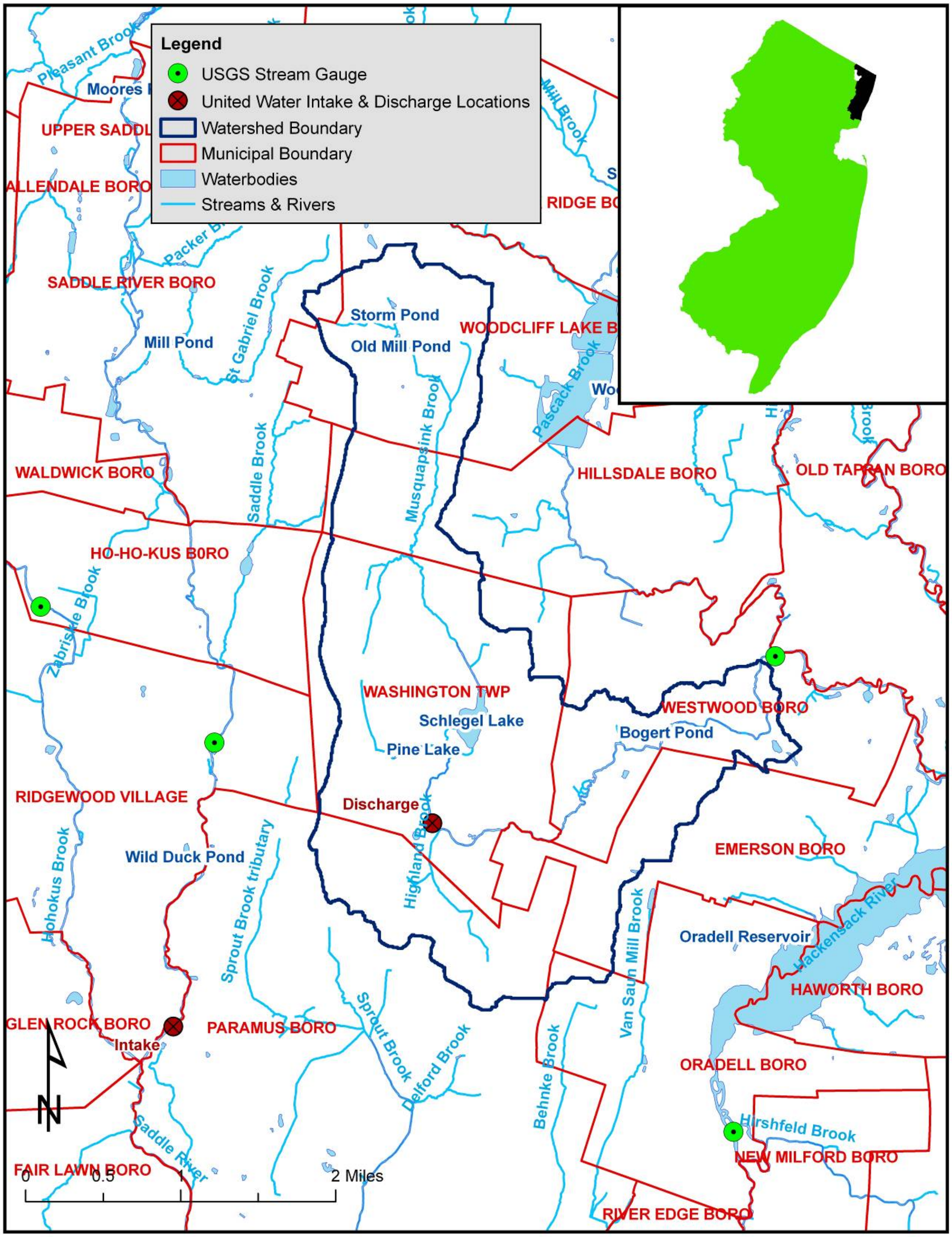

Figure 1: Municipalities and Waterbodies Located within the Musquapsink Brook Watershed

4. Musquapsink Brook Watershed

4.1 Physical Characteristics

4.1.1 Geography and Topography

The Musquapsink Brook Watershed is located in Bergen County in the northeastern part of New Jersey. The headwaters of the Musquapsink Brook are located in Woodcliff Lake Borough. The 7.3 miles of stream flow through Hillsdale Borough, Washington Township, and Paramus Borough to its confluence with the Pascack Brook in Westwood Borough. The watershed area itself is approximately 6.9 square miles (about 4,407 acres) and also includes portions of Saddle River, Emerson and Oradell Boroughs. The geographic location is shown in Figure 2.

The highest elevations within the watershed are at approximately 407 feet above mean sea level (AMSL). The lowest elevations are around 28.9 feet AMSL. Figure 3 shows the spatial distribution of elevation within the watershed.

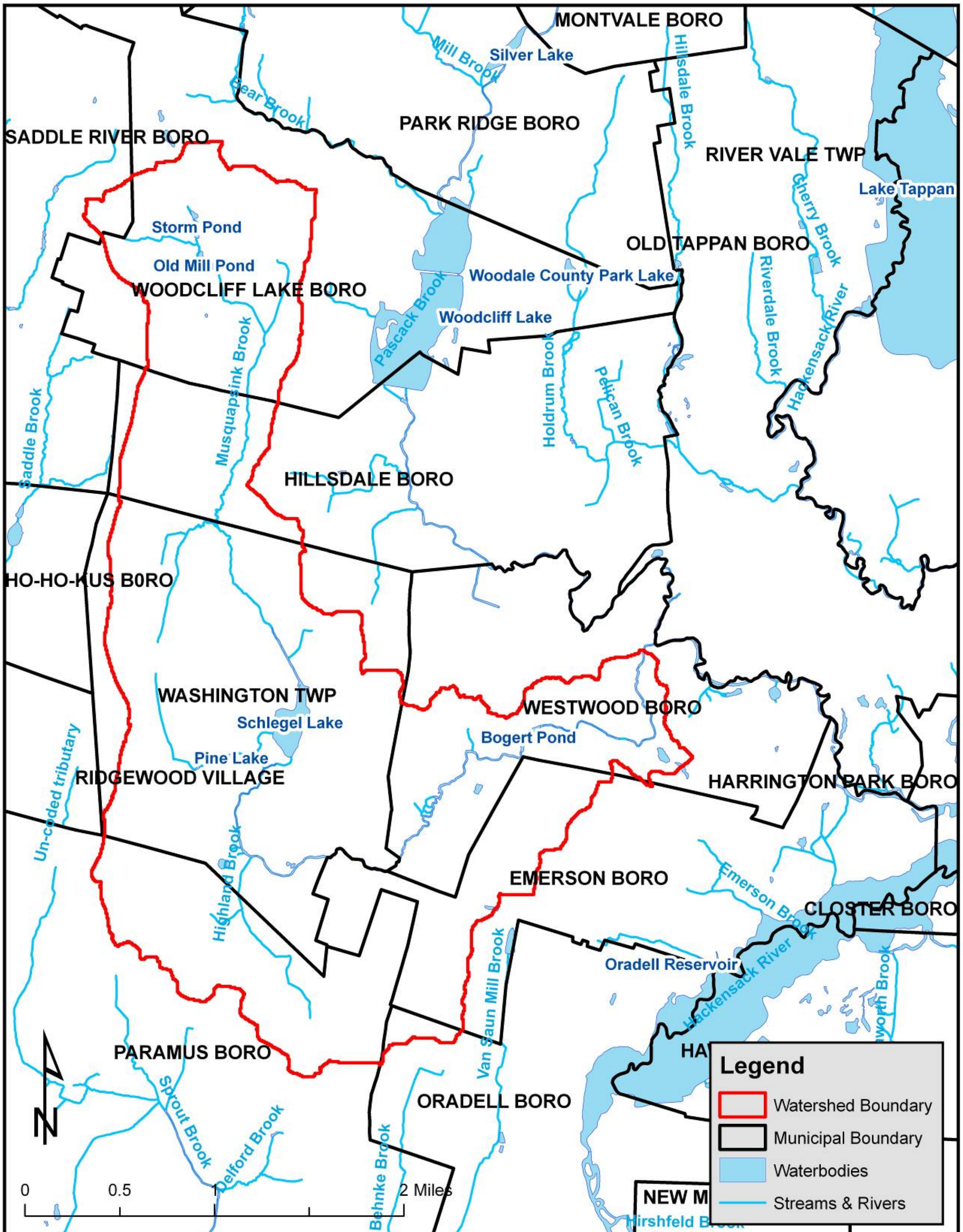

Figure 2: Geographic Location of the Musquapsink Brook Watershed

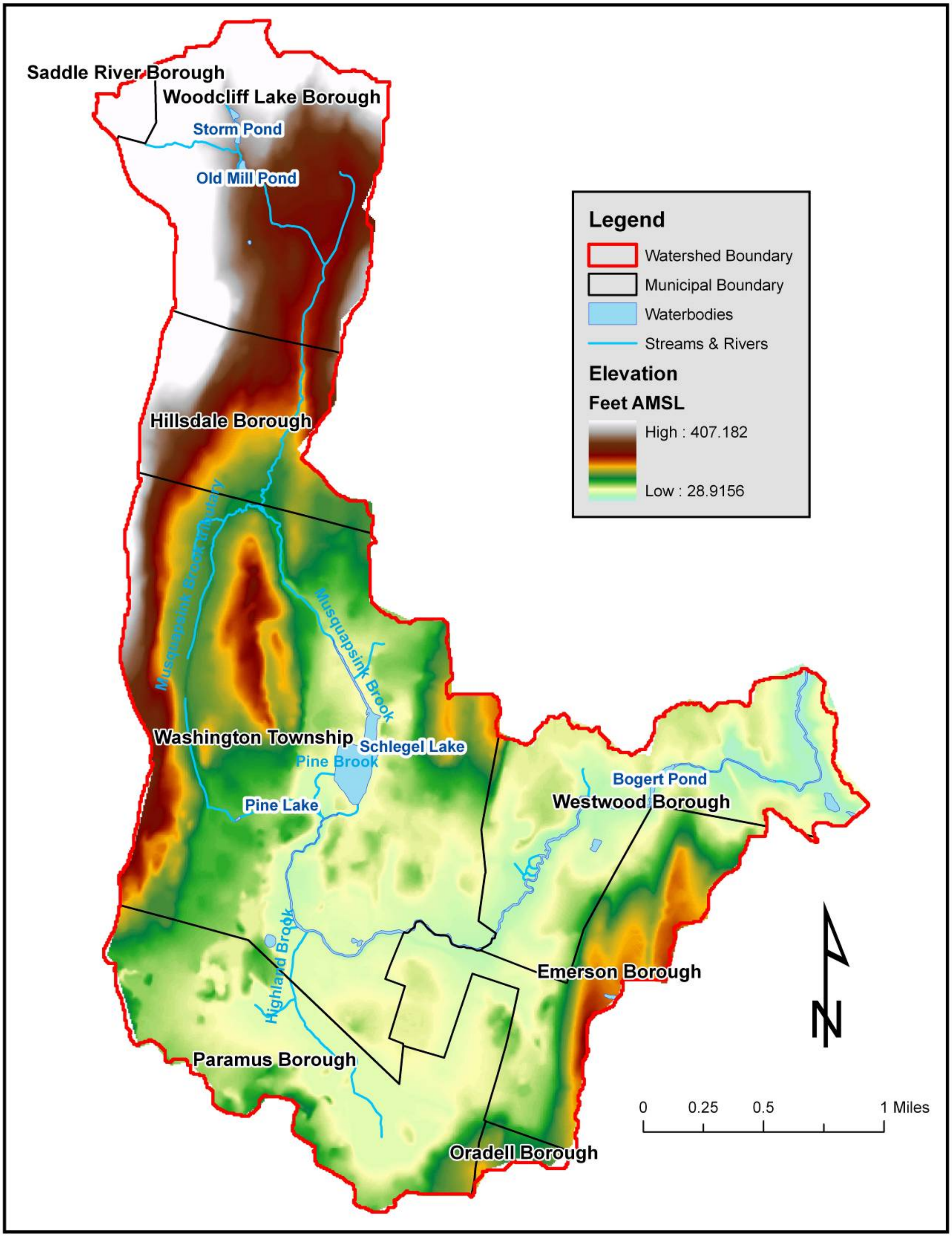

Figure 3: Spatial Distribution of Elevation within the Musquapsink Brook Watershed

4.1.2 Demographics

The Musquapsink Brook flows through eight municipalities all located within Bergen County (Figure 2). Demographic data for these municipalities were obtained from the United States Census Bureau 2010 census.

Bergen County has a population of 905,116 people, which is a 2.4% increase in the population from 2000 (884,118). The majority of the people in Bergen County are White (71.9%) with the next highest race being Hispanics/Latinos (16.1%). There are 352, 388 housing units in the county, and the median household income is $81,708. Similar data is presented in Table 1 for each municipality in the Musquapsink Brook Watershed.

Table 1: Summary of 2010 United States Census Bureau data

Municipality	2010 Population	2000 Population	% Population Change	Housing Units	Median Household Income
Emerson Borough	7,401	7,197	+2.8	2,552	$99,292
Hillsdale Borough	10,219	10,087	+1.3%	3,567	$116,021
Oradell Borough	7,978	8,047	-0.9%	2,831	$123,750
Paramus Borough	26,342	25,737	+2.4%	8,915	$104,986
Saddle River Borough	3,152	3,201	-1.5%	1,341	$97,167
Washington Borough	9,102	8,938	+1.8%	3,341	$117,394
Westwood Borough	10,908	10,999	-0.8%	4,636	$79,133
Woodcliff Lake Borough	5,730	5,745	-0.3%	1,980	$150,404

4.1.3 Climate

The Musquapsink Brook Watershed lies in the Central Climate Zone of New Jersey. According to the Office of the New Jersey State Climatologist (2011), the extensive urbanization in this zone results in a noticeable heat island effect. The concentration of buildings and paved surfaces retains heat, affecting the local temperatures. The observed night-time temperatures in heavily developed parts of the zone are regularly warmer than surrounding suburban and rural areas. The northern edge of the Central Zone is often the boundary between freezing and non-freezing precipitation in the winter months.

Based on recorded observations from years 1981-2010 for Northern New Jersey, the Musquapsink Brook Watershed receives, on average, 49.37 inches of precipitation annually (Table 2). The mean temperature is 51.6 degrees Fahrenheit (^{o}F) from 1981-2010 (Table 2).

Table 2: Total Precipitation and Mean Temperature for Northern New Jersey (includes Bergen County)

Year	Total Precipitation (inches)	Departure from Normal (inches)	Mean Temperature (°F)	Departure from Normal (°F)
1981	40.93	-8.86	50.1	-0.8
1982	42.20	-7.59	50.0	-0.9
1983	64.30	+14.51	51.3	+0.4
1984	54.68	+4.89	50.8	-0.1
1985	42.66	-7.13	51.0	+0.1
1986	50.33	+0.54	50.7	-0.2
1987	47.90	-1.89	50.9	0.0
1988	44.20	-5.59	50.2	-0.7
1989	55.23	+5.44	50.0	-0.9
1990	56.19	+6.40	53.0	+2.1
1991	42.64	-7.15	53.3	+2.4
1992	44.17	-5.62	50.2	-0.7
1993	45.58	-4.21	51.0	+0.1
1994	48.56	-1.23	50.9	0.0
1995	42.41	-7.38	51.1	+0.2
1996	62.96	+13.17	50.4	-0.5
1997	43.25	-6.54	50.6	-0.3
1998	44.05	-5.74	54.0	+3.1
1999	48.99	-0.80	52.6	+1.7
2000	46.22	-3.57	50.4	-0.5
2001	36.96	-12.83	52.4	+1.5
2002	47.44	-2.35	53.0	+2.1
2003	62.41	+12.62	50.5	-0.4
2004	52.71	+2.92	51.8	+0.9
2005	52.14	+2.35	53.1	+2.2
2006	55.05	+5.26	54.4	+3.5
2007	55.85	+6.06	52.8	+1.9
2008	51.35	+1.56	52.9	+2.0
2009	50.35	+0.56	51.8	+0.9
2010	49.31	-0.48	53.9	+3.0
MEAN	49.37	-0.42	51.6	+0.7

4.1.4 Geology

The Musquapsink Brook Watershed is located wholly within the Piedmont Plain physiographic province of New Jersey. The Passaic Formation (formerly known as the Brunswick Formation) is the dominant bedrock unit in the Watershed. The Passaic Formation consists of reddish brown, thin-bedded to thick-bedded shale, siltstone, and very fine-grained to coarse-grained sandstone. It is defined as a reddish-brown shale, siltstone and mudstone with a few green and brown shale interbeds; red and dark-gray interbedded argillites occur near the base of the geologic unit. There are also conglomerate and sandstone beds within the formation. See Figure 4 for the spatial distribution of bedrock in the Musquapsink Brook Watershed.

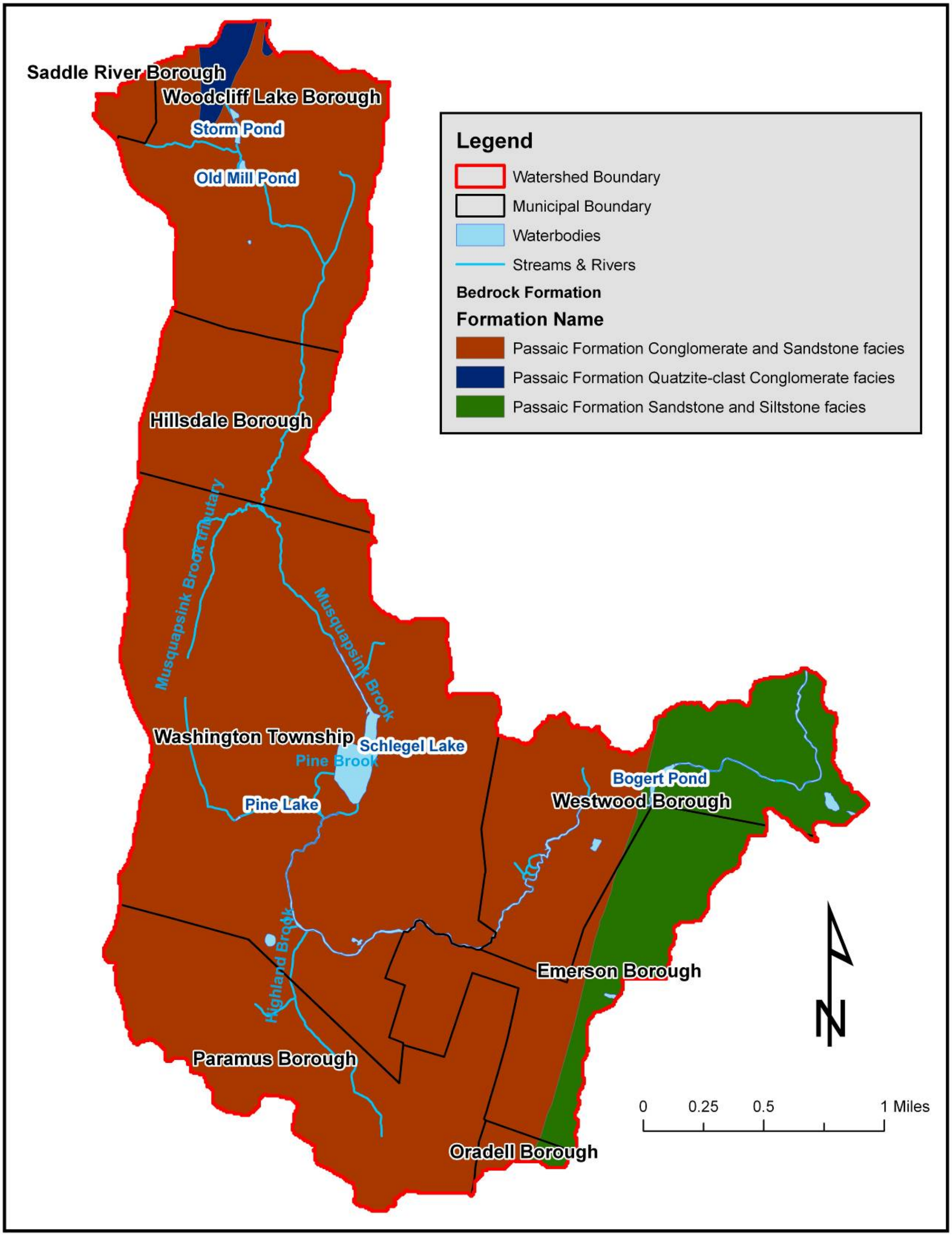

Figure 4: Bedrock Formations within the Musquapsink Brook Watershed

The fine-grained sandstones, shales, and thin-bedded siltstones of the Passaic Formation serve as the primary water-bearing layers. Massive siltstone beds often confine these layers. In the Passaic Formation, vertical to near vertical joints may interconnect water-bearing layers. The New Jersey Geological Survey ranks the Passaic Formation as a 'C' aquifer indicating that these rocks have moderate capacity to support major water-supply wells.

4.1.5 Soils

Major soils types in the watershed are: Dunellen-Urban land complex (DuuA, DuuB, DuuC, and DuuD; 26.7%), Wethersfield-Urban land complex (WeuB, WeuC, WeuD; 21.6%), and Udorthents (UdwB, UdwuB; 11.8%). These three soil types account for 60.1% of the Musquapsink Brook Watershed soils. The details of their area distribution are presented in Figure 5 and described in Table 3.

According to the 1995 Soil Survey of Bergen County, New Jersey, the Dunellen-Urban land complexes consist of 55% Dunellen soil, 30% urban land, and 15% included soils (silt and/or fine sand layers in subsoils and substratum). Typically, the surface layer of the Dunellen soil is characterized by 5 inches of very dark grayish brown loam. The subsoil is brown loam about 21 inches thick. The substratum extends to a depth of 66 inches or more and is characterized by stratified reddish brown gravelly sand, sand, and loamy sand. Urban land consists of areas in which the surface is covered by parking lots, patios, paved walkways, buildings, and other structures. Surface runoff is rapid. Permeability is moderate in the subsoil layer and rapid in the substratum. The available water capacity and hazard of erosion is moderate for this soil layer. The high water table is located at a depth greater than 6 feet in this soil complex. Depth to bedrock is greater than 60 inches.

The Wethersfield-Urban land complexes consist of 55% Wethersfield soil, 30% urban land, and 15% included soils. The surface of the Wethersfield soil is dark brown gravelly loam about 8 inches thick. The subsoil is characterized by an upper 10 inches of yellowish brown gravelly loam and a lower 8 inches of brown gravelly loam. The substratum extends to a depth of 65 inches or more and is characterized by reddish yellow gravelly fine sandy loam that is very firm in place. Surface runoff is moderate. Permeability is moderate in the subsoil and slow in the substratum. The water table is seasonally high from February through April for this soil type, with a depth ranging from 1.5 to 2.5 feet. Depth to bedrock is greater than 60 inches.

The Udorthents, wet substratum units, are located on upland stream terraces in drainageways and in areas of marine or estuarine deposits. Udorthents and urban lands are typically so intricately mixed that they are not mapped separately. Udorthent areas have been filled and smoothed or otherwise extensively disturbed to a depth of three feet or more. In most areas the original soils are presumed to have been deep, somewhat poorly drained soils that were subjected to flooding or prolonged ponding. The fill material generally consists of a mixture of soil material and stone, boulders, or rubble. Urban land consists of areas in which the surface is covered by parking lots, patios, paved walkways, buildings, and other structures.

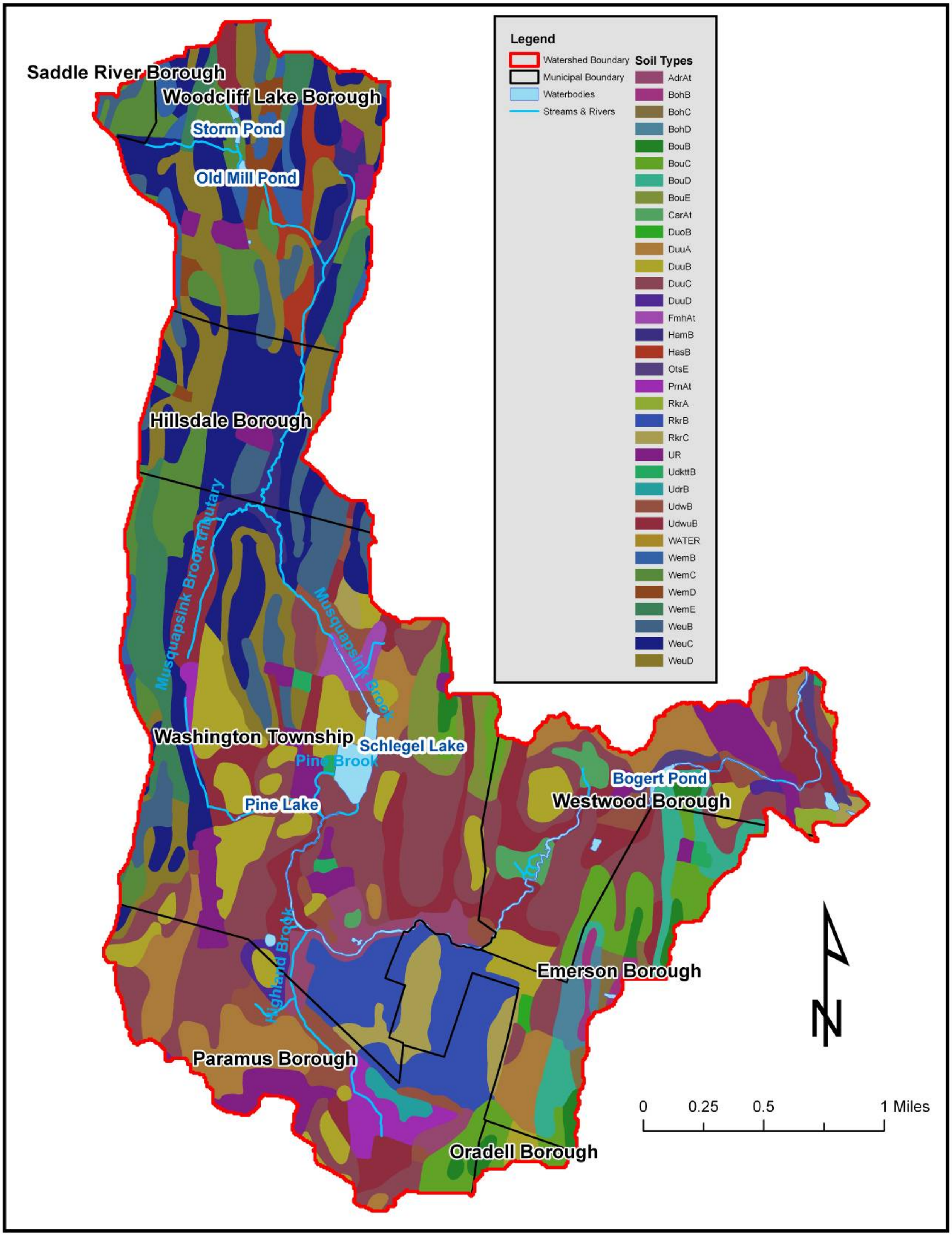

Figure 5: Soil Types within the Musquapsink Brook Watershed

Table 3: Summary of Soil Types Shown in Figure 5 (Soil Survey Geographic (SSURGO) Database, 2010)

Map Unit Symbol	Soil Name	Acres	Percent
AdrAt	Adrian muck, 0 to 2 percent slopes, frequently flooded	82	1.9%
BohB	Boonton moderately well drained gravelly loam, 3 to 8 percent slopes	17	0.4%
BohC	Boonton moderately well drained gravelly loam, 8 to 15 percent slopes	20	0.5%
BohD	Boonton moderately well drained gravelly loam, 15 to 25 percent slopes	30	0.7%
BouB	Boonton-Urban land complex, 0 to 8 percent slopes	50	1.1%
BouC	Boonton-Urban land complex, 8 to 15 percent slopes	149	3.4%
BouD	Boonton-Urban land complex, 15 to 25 percent slopes	84	1.9%
BouE	Boonton-Urban land complex, 25 to 45 percent slopes	63	1.4%
CarAt	Carlisle muck, 0 to 2 percent slopes, frequently flooded	36	0.8%
DuoB	Dunellen loam, 3 to 8 percent slopes	5	0.1%
DuuA	Dunellen-Urban land complex, 0 to 3 percent slopes	264	6.0%
DuuB	Dunellen-Urban land complex, 3 to 8 percent slopes	307	7.0%
DuuC	Dunellen-Urban land complex, 8 to 15 percent slopes	588	13.3%
DuuD	Dunellen-Urban land complex, 15 to 25 percent slopes	19	0.4%
FmhAt	Fluvaquents, loamy, 0 to 3 percent slopes, frequently flooded	27	0.6%
HamB	Haledon gravelly loam, 3 to 8 percent slopes	61	1.4%
HasB	Haledon-Urban land complex, 3 to 8 percent slopes	48	1.1%
OtsE	Otisville gravelly loamy sand, 25 to 35 percent slopes	24	0.5%
PrnAt	Preakness silt loam, 0 to 3 percent slopes, frequently flooded	55	1.2%
RkrA	Riverhead sandy loam, 0 to 3 percent slopes	8	0.2%
RkrB	Riverhead sandy loam, 3 to 8 percent slopes	213	4.8%
RkrC	Riverhead sandy loam, 8 to 15 percent slopes	93	2.1%
UdkttB	Udorthents, loamy, 0 to 8 percent slopes, frequently flooded	15	0.3%
UdrB	Udorthents, refuse substratum, 0 to 8 percent slopes	14	0.3%
UdwB	Udorthents, wet substratum, 0 to 8 percent slopes	137	3.1%
UdwuB	Udorthents, wet substratum-Urban land complex	381	8.6%
UR	Urban land	203	4.6%
WATER	Water	33	0.7%
WemB	Wethersfield gravelly loam, 3 to 8 percent slopes	67	1.5%
WemC	Wethersfield gravelly loam, 8 to 15 percent slopes	181	4.1%
WemD	Wethersfield gravelly loam, 15 to 25 percent slopes	36	0.8%
WemE	Wethersfield gravelly loam, 25 to 35 percent slopes	147	3.3%
WeuB	Wethersfield-Urban land complex, 3 to 8 percent slopes	185	4.2%
WeuC	Wethersfield-Urban land complex, 8 to 15 percent slopes	470	10.7%
WeuD	Wethersfield-Urban land complex, 15 to 25 percent slopes	295	6.7%
TOTAL		4,407	100%

Soils that are described as 'frequently flooded' (Table 3) are soils in which flooding is likely to occur often under usual weather conditions (more than 50 percent chance in any year, or more than 50 times in 100 years). There are 215 acres of these soils in the Musquapsink Brook Watershed (Table 3).

4.1.6 Streams and Groundwater

The Musquapsink Brook is a tributary of the Pascack Brook, which flows along the New York/New Jersey State line to its confluence with the Oradell Reservoir. The Reservoir is managed by United Water of New Jersey and provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties (United Water, 2010). The Pascack Brook and its tributaries are classified as FW2-NT (C1), or freshwater (FW) non-trout (NT) category one (C1) in the 2010 N.J.A.C. 7:9B New Jersey Surface Water Quality Criteria. "FW2" refers to water bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters that have not been designated as trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but can support other fish species. "C1" refers to those waters designated for protection from measurable changes in water quality based on exceptional ecological significance, exceptional recreational significance, exceptional water supply significance or exceptional fisheries resource(s) to protect their aesthetic value (color, clarity, scenic setting) and ecological integrity (habitat, water quality and biological functions) (NJDEP, 2011). The C1 classification for the Musquapsink Brook and Pascack Brook are due to their significance as sources for the Oradell Reservoir.

4.2 Critical Source Areas

4.2.1 Wetlands

According to state Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), a wetland is any "area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation; provided, however, that the [NJDEP], in designating a wetland, shall use the three-parameter approach (that is, hydrology, soils and vegetation)" (NJDEP, 2009). These wetlands include tidally influenced wetlands which have not been included on a promulgated map pursuant to the Wetlands Act of 1970 (N.J.S.A. 13:9A-1 et seq).

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, 1979). Wetlands include swamps, marshes, bogs, and similar areas. The NJDEP Land Use Regulation program primarily regulates wetlands in New Jersey. NJDEP has adopted the federal wetlands program, and thus is the lead regulating agency. The U.S. Army Corps of Engineers (USACOE) and NJDEP both have jurisdiction over tidal wetlands, navigable waters and wetlands located within 1,000 feet of navigable waterways. New Jersey protects wetlands and transition areas under the New Jersey Freshwater Wetlands Protection Act (NJDEP, 1998). The federal Clean Water Act, Section 404 (33 U.S.C. 1344) is enforced by the USACOE and regulates navigable waters, tributaries of navigable waters and wetlands.

NJDEP developed and maintains two types of wetlands information for general planning and regulatory purposes. The first is the delineated wetlands in the NJDEP land use/cover change databases. The second is the linear wetlands database derived from the freshwater wetlands data generated under the New Jersey Freshwater Wetlands Mapping Program. The linear wetlands are intended to serve as a resource for analysis rather than regulatory delineations. The Musquapsink Brook Watershed contains approximately 8.6 miles of linear wetlands and 199.4 acres of delineated wetlands. Over 89% of the delineated wetland area is categorized as Deciduous Wooded Wetlands (Table 4). See Figure 6 below for the spatial distribution of linear and delineated wetlands within the watershed. Table 4 provides a list of wetland types and coverage (in acres) within the Musquapsink Brook Watershed.

Table 4: Wetland Types and Coverage within the Musquapsink Brook Watershed (NJDEP Land Use/Land Cover Database, 2007)

Wetland Type	Area (acres)	Percent of Wetland Area
Agricultural Wetlands (Modified)	2.4	1.2%
Deciduous Scrub/Shrub Wetlands	5.1	2.6%
Deciduous Wooded Wetlands	178.3	89.4%
Disturbed Wetlands	3.2	1.6%
Herbaceous Wetlands	0.5	0.2%
Managed Wetland In Built-Up Maintained Recreational Area	5.2	2.6%
Managed Wetland In Maintained Lawn Greenspace	4.2	2.1%
Mixed Wooded Wetlands (Deciduous Dominated)	0.5	0.2%
TOTAL	199.4	100%

Wetlands provide important hydrological functions, such as filtering pollutants from stormwater runoff, acting as storage areas for flood waters, protecting stream banks from erosion, providing habitat for wildlife, and providing recreational opportunities for humans. The delineated wetlands represent only about 4.5% of the land area in the Musquapsink Watershed. The loss of wetlands to urbanization significantly alters the watershed hydrology and contributes to water quality and quantity problems observed in the Musquapsink Brook Watershed.

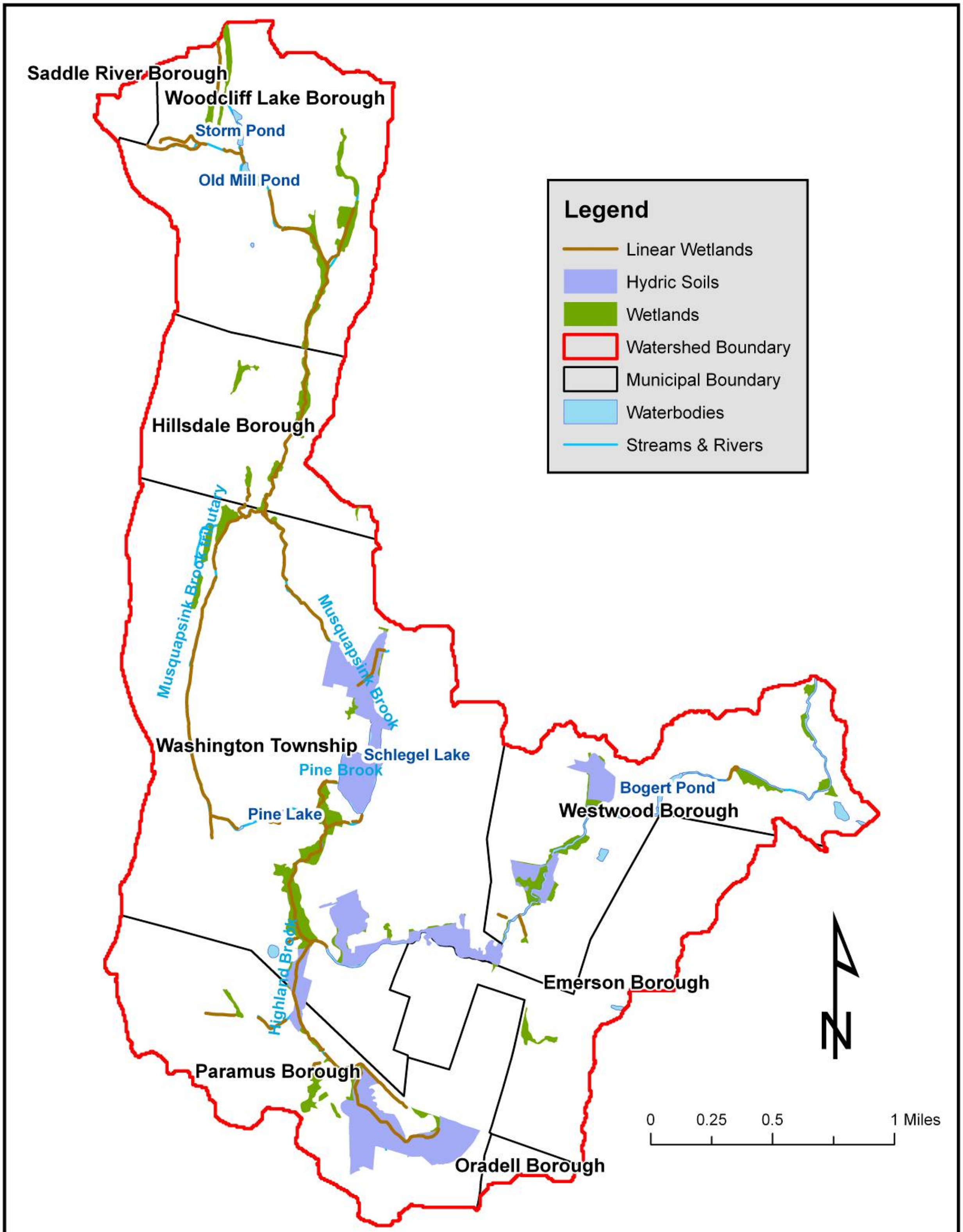

Figure 6: Linear and Delineated Wetlands within the Musquapsink Brook Watershed

4.2.2 Hydric Soils

The New Jersey Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A) defines hydric soils as soils that in their "undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation" (NJDEP, 2009). Hydric soils are commonly associated with wetland areas and are strongly influenced by the presence of water. Wetland conditions may exist without the presence of hydric soils.

There are four different hydric soil types in the Musquapsink Brook Watershed, with coverage of approximately 189 acres as presented in Table 5. The spatial distribution of hydric soils is presented in Figure 6 above. These are the same soils that are described as 'frequently flooded' in Table 3.

Table 5: Hydric Soil Types and Coverage within the Musquapsink Brook Watershed (SSURGO Database, 2010)

Description	Area (acres)
Adrian muck	81.8
Carlisle muck	36.6
Fluvaquents, loamy	27.3
Preakness silt loam	55.0
Udorthents, loamy	15.1
TOTAL	215.8

4.2.3 Riparian Areas

Riparian areas, or riparian zones, are areas of land and vegetation within and adjacent to a regulated water, but not man-made lagoons, stormwater management basin, or oceanfront barrier island, spit or peninsula, nor along the Atlantic Ocean (NJDEP, 2011). Riparian areas are best as undeveloped areas adjacent to streams that are either within the 100-year floodplain, contain hydric soils, contain streamside wetlands and associated transition areas, or are within a 150-foot or 300-foot wildlife passage corridor on both sides of a stream. Riparian zones are important natural filters of stormwater runoff, protecting aquatic environments from excessive sedimentation, pollutants, and erosion. They supply shelter and food for many aquatic animals and also provide shade, an important part of stream temperature regulation. Because the streams within the Musquapsink Brook Watershed are designated as "C1," New Jersey regulations require a 300 foot buffer on either side of the waterway (NJDEP, 2011). Approximately 1,444 acres of land are designated as riparian area in the Musquapsink Brook Watershed using the 300 foot buffer rule (Figure 7).

Riparian zones are instrumental in water quality improvement for both surface runoff and water flowing into streams through subsurface or groundwater flow. The decrease of riparian areas in the Musquapsink Brook Watershed due to urbanization has contributed to poor surface water quality conditions and increased streambank erosion.

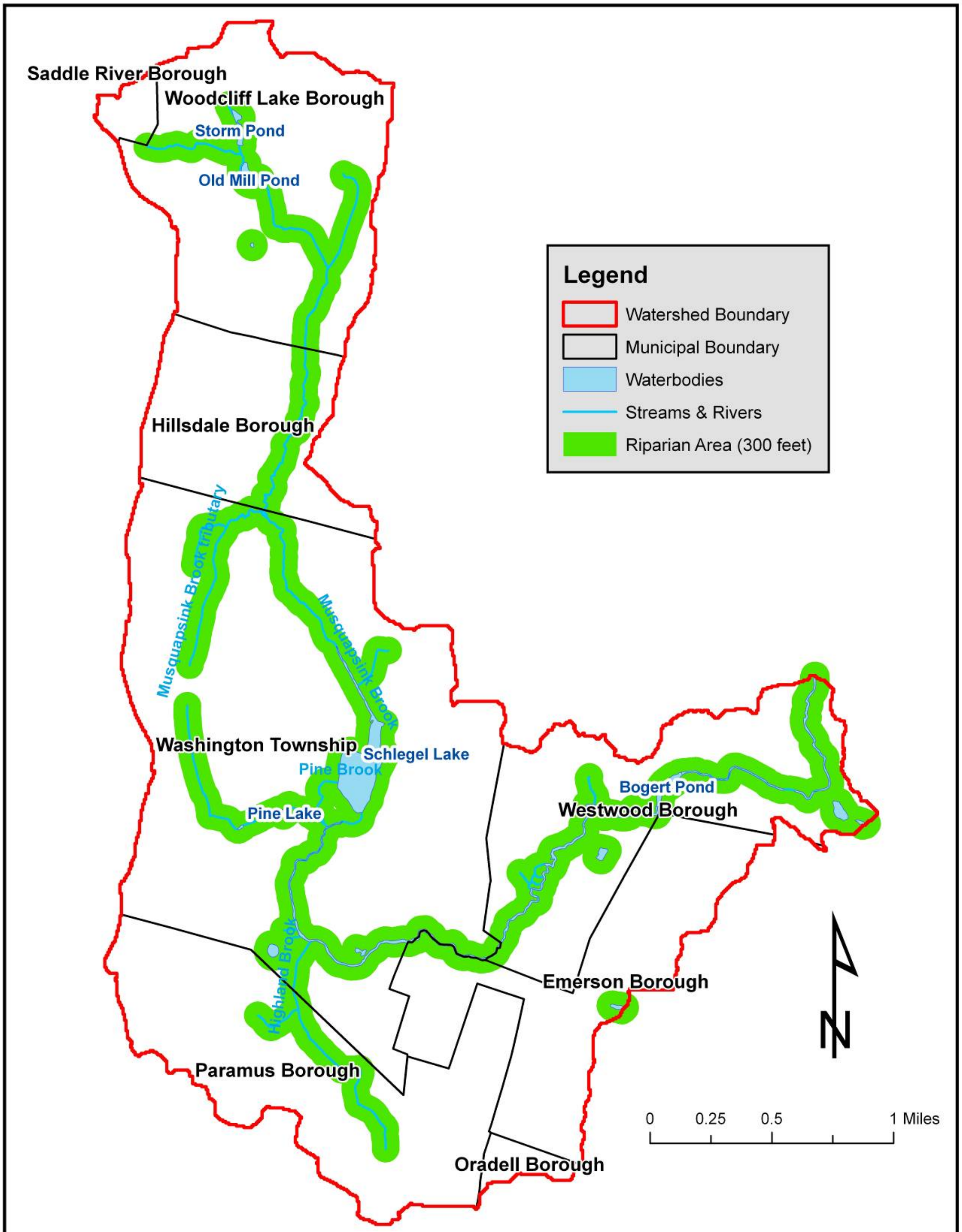

Figure 7: Riparian Areas within the Musquapsink Brook Watershed

4.3 Land Use

The land uses in this watershed are classified under six broad land use categories including agriculture, barren, forest, urban, water and wetlands; these are further defined by 50 subcategories of land use following a 4-digit land use classification code based on a modified Anderson Land Classification system (Anderson *et al*., 1976). Table 6 presents the area and percentages of land uses in the Musquapsink Brook Watershed in 1995, 2002, and 2007. The extent distribution of land use types for the year 2007 is displayed in Figure 8.

Table 6: Area and Percentage of Land Uses within the Musquapsink Brook Watershed (NJDEP Land Use/Land Cover Database)

Land Use	1995		2002		2007	
	Acres	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**
Agriculture	23.2	0.5%	23.4	0.5%	19.7	0.4%
Barren	14.6	0.3%	9.4	0.2%	3.0	0.1%
Forest	427.7	9.7%	438.0	10.0%	405.6	9.2%
Urban	3,647.4	83.1%	3,653.7	83.2%	3,705.4	84.4%
Water	50.9	1.2%	58.5	1.3%	56.9	1.3%
Wetlands	226.2	5.2%	207.0	4.7%	199.4	4.5%
TOTAL	4,390	100%	4,390	100%	4,390	100%

Of the 84.4% of the land use designated as urban in 2007 (Table 6), 49.1%, or 1,821.3 acres (or 2.8 square miles), is classified as single residential, medium density, defined by the NJDEP as residential urban/suburban neighborhoods greater than 1/8 acre and up to and including 1/2 acre lots. These areas generally contain impervious surface areas of approximately 30% to 35%. Urban land use also includes land utilized for commercial, industrial and transportation purposes (Anderson *et al*., 1976). Table 7 provides further information on the types of urban land use in the Musquapsink Brook Watershed.

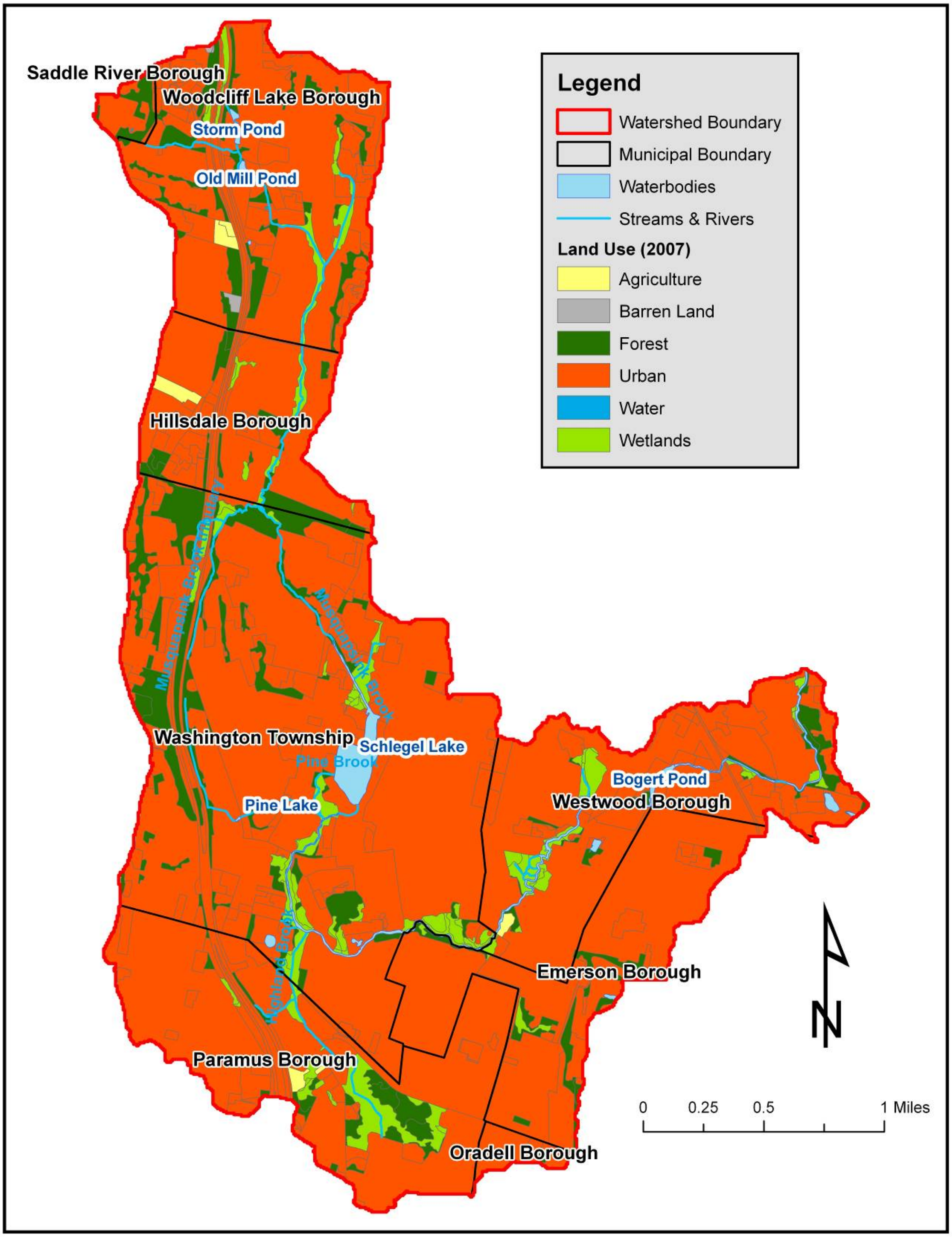

Figure 8: Spatial Distribution of Land Use Types within the Musquapsink Brook Watershed

Table 7: Urban Land Uses in the Musquapsink Brook Watershed

2007 Urban Land Use	Acres	Percent Cover
Athletic Fields (Schools)	64.2	1.73%
Cemetery	308.8	8.31%
Commercial/Services	168.5	4.58%
Major Roadway	68.2	1.83%
Mixed Urban or Built-Up Land	1.9	
Other Urban or Built-Up Land	128.4	3.51%
Railroads	3.2	0.09%
Recreational Land	70.8	1.90%
Residential, High Density or Multiple Dwelling	86.8	2.34%
Residential, Rural, Single Unit	66.0	1.78%
Residential, Single Unit, Low Density	911.0	24.52%
Residential, Single Unit, Medium Density	1,821.3	49.26%
Stormwater Basin	2.2	0.06%
Transportation/Communication/Utilities	4.1	0.11%
TOTAL	3,705.4	100%

5. Causes and Sources of Pollution

5.1 Hydrological Alteration

The loss of wetlands and riparian areas to development has resulted in significant hydrological alterations in the Musquapsink Brook Watershed. Extensive urbanization has direct impacts on both water quality and quantity. The increase of impervious surface coverage (i.e., rooftops, driveways, roads, parking lots) results in decreased infiltration of stormwater and increased surface runoff. This runoff, when managed improperly, is a major pathway for the transportation of pollutants such as debris, fertilizer, bacteria, and/or sediment. These pollutants are washed directly into the Brook, ultimately degrading the surface water quality and necessitating the development of TMDLs. Stormwater runoff also causes recurrent flooding problems in many municipalities, the destruction of habitat along the streambank, and may contribute to manhole discharges.

The Brook is dammed at three locations, two of which are along Musquapsink Brook and one along Pine Brook (Figure 9). The two Musquapsink Brook dams create Schlegel Lake and Bogert Pond, both of which are recreational lakes. Schlegel Lake is the largest waterbody in the watershed covering 27.0 acres. The Pine Brook dam creates Pine Lake, a 0.6 acre waterbody in Washington Township (Figure 9). All of the dams are privately owned.

5.2 Surface Water Quality

5.2.1 Designated Uses and Impairments

NJDEP (2011) designated the Musquapsink Brook (listed as a tributary to the Pascack Brook) as FW2-NT(C1). "FW2" refers to the freshwater bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters are not suitable for trout production or trout maintenance due to their physical, chemical, or biological characteristics. "NT" streams may support other fish species. "C1" refers to its designation for protection from measurable changes in water quality based on exceptional water supply significance as a tributary to the Oradell Reservoir.

According to the designated use of FW2-NT(C1) waters, the New Jersey Surface Water Quality Standards (last amended on April 4, 2011) presented in Table 8 below are applicable to the Musquapsink Brook Watershed. Note that the FW2 designation applies to all streams and waterbodies in the watershed, and encompasses waterways categorized as C1, as well. At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform standard has been replaced by an *E. coli* standard. Because the TMDL established by New Jersey refers to fecal coliform, both fecal coliform and *E. coli* were measured during sampling events in the Musquapsink Brook Watershed.

In accordance with Section 305(b) of the Clean Water Act, New Jersey addresses the overall water quality of the State's waters and identifies impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies*. Within this document are lists that indicate the presence and level of impairment for each waterbody monitored. It is recommended by the EPA that this list be a guideline for water quality management actions that will address the cause of impairment. The 2010 *New Jersey Integrated Water Quality Monitoring and Assessment Report* lists the Musquapsink Brook (reported as 'Pascack Brook' (below Westwood gage) as not supporting the following uses: agricultural water supply use due to total dissolved solids; aquatic life use due to dissolved oxygen, pH, and total phosphorus; primary contact recreational use due to fecal coliform; and, public water supply use due to arsenic.

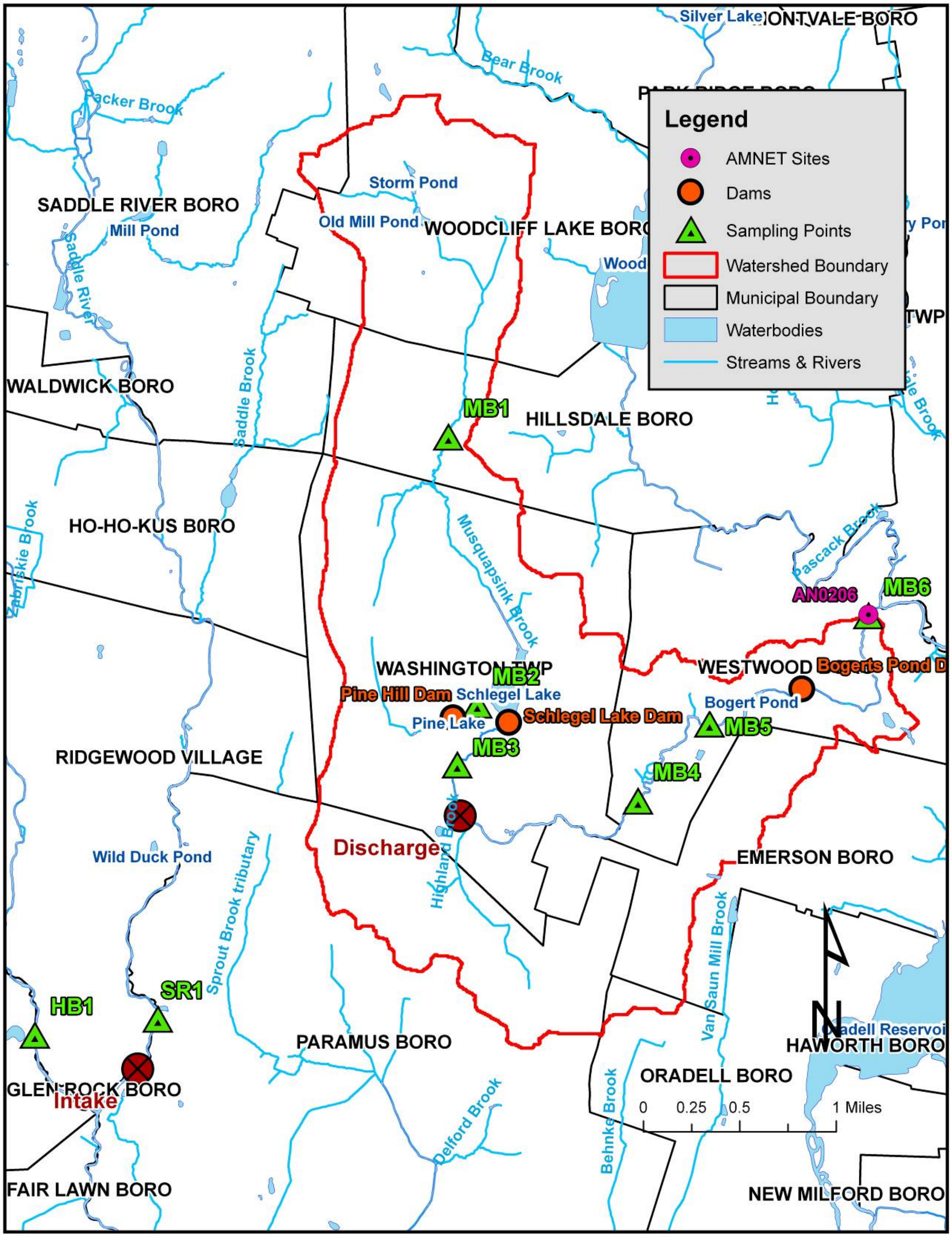

Figure 9: Water Quality Sampling Location Map

Table 8: New Jersey Surface Water Quality Standards for Different Substances and Surface Waters (NJDEP, 2011)

Substance	Surface Water Classification	Standards
Total Phosphorus (mg/L)	FW2 Streams	Total Phosphorus shall not exceed 0.1 in any stream, unless watershed-specific translators are established pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable.
	FW2 Lakes	Concentrations of total P shall not exceed 0.05 in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, unless watershed-specific translators are developed pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable.
Fecal Coliform* (col/100 mL)	FW2	Shall not exceed geometric average of 200/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 400/100 mL.
E. coli (col/100 mL)	FW2	Shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL.

*This standard has been replaced by *E. coli*.

A total maximum daily load was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load for 7.3 miles of stream. In 2005, a TMDL for total phosphorus was established for the same 7.3 mile stretch of stream. This TMDL requires a 21.43% reduction in total phosphorus loadings from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands. Additional aquatic life surface water quality impairments will also need to be addressed through the TMDL process.

The NJDEP Bureau of Biological & Freshwater Monitoring maintains one AMNET station within the Musquapsink Brook Watershed (Station AN0206, Westwood, NJ) (Figure 9). This station, located at Harrington Avenue, was sampled in July of 1993, 1998, and 2003. For each of the three sampling rounds, the Musquapsink Brook was rated as a moderately impaired site, characterized by reduced macroinvertebrate taxa richness.

5.2.2 Monitoring Stations

To better understand the causes and sources of the water pollution in the watershed, surface water samples were regularly collected from eight water quality monitoring stations over a six-month time frame in 2007. These stations are depicted in Figure 9. Note that MB2 serves as a monitoring site for Schlegel Lake and is not included in catchment area calculations (Chapter 6). Six stations are located on the Musquapsink Brook, and two are located adjacent to the United Water Transfer intake on Saddle River and the Ho-Ho-Kus Brook, respectively. The station site descriptions are identified in Table 9.

Table 9: Water Quality Monitoring Location IDs and Descriptions

Site ID	Site Description
MB1	Musquapsink Brook at Hillside Ave, Hillsdale
MB2	Musquapsink Brook at Woodfield Ave, Washington
MB3	Musquapsink Brook at Ridgewood Ave, Washington
MB4	Musquapsink Brook at Forest Ave, Westwood
MB5	Musquapsink Brook at Third Ave, Westwood
MB6	Musquapsink Brook at Harrington Ave, Westwood
SR1	Saddle River at Grove St, border of Paramus and Ridgewood
HB1	Ho-Ho-Kus Brook at Grove St, border of Paramus and Ridgewood

5.2.3 Monitoring Events

Project partners, including NJDEP, Rutgers Cooperative Extension Water Resources Program, and the Bergen County Department of Health Services, began water quality monitoring on May 25, 2007. As per the NJDEP-approved Quality Assurance Project Plan (QAPP), *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured along transects laid across the stream at each sampling station. Using this information, flow (Q) was calculated. Water samples were collected and analyzed by two separate laboratories. The Bergen County Utility Authority conducted analyses for total phosphorus, dissolved orthophosphate phosphorus, ammonia-nitrogen, Total Kjeldahl Nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), and fecal coliform. Garden State Laboratories analyzed the samples for *E. coli*.

Water quality monitoring included two different types of sampling events: regular and bacteria only. Regular monitoring, which included analysis for all parameters, occurred from May 25, 2007 through October 25, 2007. These events were monitored for total phosphorus, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, TSS, fecal coliform, and *E. coli* and had no specific weather conditions directing the sample collection. Bacteria-only monitoring was conducted in the months of June, July, August, and September 2007, again without conditions set by the weather. The bacteria-only sampling entailed collecting three additional samples in each of those months for pathogen analysis. Flow was measured, and *in situ* samples were collected during these events. Specific dates and the corresponding types of monitoring events are presented in Table 10.

Table 10: Types of Monitoring Events for Each Sampling Date

Date	Regular Monitoring for all Parameters	Bacteria Only Monitoring
5/24/2007	X	
5/31/2007	X	
6/7/2007	X	
6/14/2007		X
6/19/2007		X
6/21/2007	X	
6/28/2007		X
7/5/2007	X	
7/12/2007		X
7/24/2007		X
7/26/2007		X
8/2/2007	X	
8/9/2007		X
8/16/2007	X	
8/23/2007		X
8/30/2007		X
9/13/2007		X
9/27/2007		X
10/10/2007	X	
10/11/2007	X	
10/25/2007	X	

Indicates Storm Sampling Event

5.2.4 Summary of Water Quality Data

To evaluate the health of the Musquapsink Brook at all the stations, the monitoring results were compared to the designated water quality standards. The USEPA Guidance for the Preparation of the Comprehensive State Water Quality Assessments (1997) advises that an acceptable frequency for water quality results to exceed criteria is 10% of samples. In the 2010 Integrated Water Quality Monitoring and Assessment Methods, NJDEP further states that a minimum of eight samples collected quarterly over a two-year period are required to confirm quality of waters. Therefore, if a waterbody has a minimum of eight samples collected quarterly over a two-year period with more than 10% of the samples exceeding the water quality criteria for a certain parameter, the waterbody is considered “impaired” for that parameter.

By applying this rule to the water quality data, it is possible to identify which stations are impaired for each parameter that has been identified as a concern in the scope of this project– total phosphorus, fecal coliform, and *E. coli*. The applicable water quality standards for this project are detailed in Table 8 above, and the percent of samples that exceeded these standards are given in Table 11 below.

Table 11: Summary of Water Quality Data Collected in this Planning Effort and Comparison to Water Quality Standards

Monitoring Station ID	Total Phosphorus (mg/L)					
	Water Quality Standard (WQS)	*Count*	*Minimum*	*Average*	*Maximum*	*% Not Satisfying WQS*
MB1	0.1	11	0.01	0.09	0.16	45%
MB2	0.1	11	0.05	0.07	0.13	18%
MB3	0.1	11	0.01	0.06	0.13	9%
MB4	0.1	11	0.01	0.10	0.35	45%
MB5	0.1	11	0.01	0.12	0.35	45%
MB6	0.1	11	0.01	0.12	0.29	55%
SR1	0.1	11	0.01	0.07	0.13	27%
HB1	0.1	10	0.91	1.63	2.20	100%
	Fecal Coliform (col/100mL)					
MB1	200	23	200	3479	28000	96%
MB2	200	23	60	1481	12000	87%
MB3	200	23	120	3706	44000	91%
MB4	200	23	410	5530	49000	100%
MB5	200	23	106	6627	58000	91%
MB6	200	23	500	10373	70000	100%
SR1	200	23	110	5550	39000	91%
HB1	200	23	200	7270	41000	96%
	***E. coli* (col/100mL)**					
MB1	235	23	170	2645	16000	91%
MB2	235	23	60	480	2200	65%
MB3	235	23	160	1897	7800	96%
MB4	235	23	160	4809	25000	96%
MB5	235	23	120	6090	33000	96%
MB6	235	23	210	5202	38000	96%
SR1	235	22	380	2860	23000	100%
HB1	235	22	410	3150	22000	100%

Tabulated water quality monitoring data are provided in the data report (Appendix A). Data has also been graphed with corresponding surface water quality standards and daily precipitation records for Bergen County. These graphs are provided in the appendices of the data report.

5.2.5 Biological Monitoring Data

Biological monitoring data is available for the Musquapsink Brook Watershed as part of the **Am**bient Biological Monitoring **Net**work (AMNET), which is administered by the New Jersey Department of Environmental Protection (NJDEP). The NJDEP has been monitoring the biological communities of the State's waterways since the early 1970's, specifically the benthic macroinvertebrate communities. Benthic macroinvertebrates are primarily bottom-dwelling (benthic) organisms that are generally ubiquitous in freshwater and are macroscopic. Due to their important role in the food web, macroinvertebrate communities reflect current perturbations in the environment. There are several advantages to using macroinvertebrates to gauge the health of a stream. First, macroinvertebrates have limited mobility, and thus, are good indicators of site-specific water conditions. Also, macroinvertebrates are sensitive to pollution, both point and nonpoint sources; they can be impacted by short-term environmental impacts such as intermittent discharges and contaminated spills. In addition to indicating chemical impacts to stream quality, macroinvertebrates can gauge non-chemical issues of a stream such as turbidity and siltation, eutrophication, and thermal stresses. Finally, macroinvertebrate communities are a holistic overall indicator of water quality health, which is consistent with the goals of the Clean Water Act (NJDEP, 2007). These organisms are normally abundant in New Jersey freshwaters and are relatively inexpensive to sample.

New Jersey Impairment Score (NJIS)

The AMNET program began in 1992 and is currently comprised of more than 800 stream sites with approximately 200 monitoring locations in each of the five major drainage basins of New Jersey (i.e., Upper and Lower Delaware, Northeast, Raritan, and Atlantic). These sites are sampled once every five years using a modified version of the USEPA Rapid Bioassessment Protocol (RBP) II (NJDEP, 2007). To evaluate the biological condition of the sampling locations, several community measures have been calculated by the NJDEP from the data collected and include the following:

1. Taxa Richness: Taxa richness is a measure of the total number of benthic macroinvertebrate families identified. A reduction in taxa richness typically indicates the presence of organic enrichment, toxics, sedimentation, or other factors.

2. EPT (Ephemeroptera, Plecoptera, Trichoptera) Index: The EPT Index is a measure of the total number of Ephemeroptera, Plecoptera, and Trichoptera families (i.e., mayflies, stoneflies, and caddisflies) in a sample. These organisms typically require clear moving water habitats.

3. % EPT: Percent EPT measures the numeric abundance of the mayflies, stoneflies, and caddisflies within a sample. A high percentage of EPT taxa is associated with good water quality.

4. % CDF (percent contribution of the dominant family): Percent CDF measures the relative balance within the benthic macroinvertebrate community. A healthy community is characterized by a diverse number of taxa that have abundances somewhat proportional to each other.

6. Family Biotic Index: The Family Biotic Index measures the relative tolerances of benthic macroinvertebrates to organic enrichment based on tolerance scores assigned to families ranging from 0 (intolerant) to 10 (tolerant).

This analysis integrates several community parameters into one easily comprehended evaluation of biological integrity referred to as the New Jersey Impairment Score (NJIS). The NJIS was established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired. A non-impaired site has a benthic community comparable to other high quality "reference" streams within the region. The community is characterized by maximum taxa richness, balanced taxa groups, and a good representation of intolerant individuals. A moderately impaired site is characterized by reduced macroinvertebrate taxa richness, in particular the EPT taxa. Changes in taxa composition result in reduced community balance and intolerant taxa become absent. A severely impaired site is one in which the benthic community is significantly different from that of the reference streams. The macroinvertebrates are dominated by a few taxa which are often very abundant. Tolerant taxa are typically the only taxa present. The scoring criteria used by the NJDEP are as follows:

- non-impaired sites have total scores ranging from 24 to 30,
- moderately impaired sites have total scores ranging from 9 to 21, and
- severely impaired sites have total scores ranging from 0 to 6.

It is important to note that the entire scoring system is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams. While a low score indicates "impairment," the score may actually be a consequence of habitat or other natural differences between the subject stream and the reference stream.

Starting with the second round of sampling under the AMNET program in 1998 for the Passaic Region, habitat assessments were conducted in conjunction with the biological assessments. The habitat assessment, which was designed to provide a measure of habitat quality, involves a visually based technique for assessing stream habitat structure. The habitat assessment is designed to provide an estimate of habitat quality based upon qualitative estimates of selected habitat attributes. The assessment involves the numerical scoring of ten habitat parameters to evaluate instream substrate, channel morphology, bank structural features, and riparian vegetation. Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal, or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200; sites with suboptimal/good habitat conditions have total scores ranging from 110 to 159; sites with marginal/fair habitat conditions have total scores ranging from 60 to 109, and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential within the study area.

The NJDEP Bureau of Freshwater & Biological Monitoring maintains one AMNET station within the project area (i.e., Station AN0206 – Musquapsink Brook, Harrington Avenue, Westwood Borough, in Bergen County). This station corresponds with the water quality monitoring station MB6 (Figure 9). Station AN0206 was sampled by NJDEP in 1993, 1998, and 2003 under the AMNET program. Findings from the AMNET program are summarized in Table 12. A fourth round of sampling was conducted in 2008, but data were unavailable at the time of publication of this plan. The biological condition over the years has been assessed as being moderately impaired, and the habitat has ranged from marginal to sub-optimal within the Musquapsink Brook Watershed.

Table 12: Summary of NJDEP Ambient Biological Monitoring Network Results (NJDEP, 1994; NJDEP, 2000; NJDEP, 2008)

Station	Date	Biological Condition (Score)	Habitat Assessment (Score)
AN0206	7/6/1993	Moderately Impaired (9)	~
AN0206	7/9/1998	Moderately Impaired (15)	Marginal (104)
AN0206	7/1/2003	Moderately Impaired (15)	Suboptimal (147)

Given these aquatic life impairments, an additional biological assessment was proposed as part of the data collection needed to prepare a comprehensive watershed restoration plan for the Musquapsink Brook. A biological assessment was conducted by Marion McClary, Jr., Ph.D., Associate Director of Biological Sciences at Fairleigh Dickinson University and project partner, in the late summer of 2007 at MB1 (Musquapsink Brook at Hillside Avenue, Hillsdale), MB3 (Musquapsink Brook at Ridgewood Avenue, Washington), MB4 (Musquapsink Brook at Forest Avenue, Westwood), and at MB6 (AMNET Station AN0206, Musquapsink Brook at Harrington Avenue, Westwood). The 2007 biological assessment conducted by Dr. McClary is summarized in the Musquapsink Brook Benthic Data Report and Musquapsink Brook Benthic Species List provided in Appendix A of the Musquapsink Brook Watershed Restoration and Protection Plan Data Report. The 2007 assessment revealed that the biological condition within the Musquapsink Brook Watershed had degraded to a severely impaired condition. Marginal to sub-optimal habitat conditions were found within the watershed. There was such a paucity of benthic organisms found that less than 100 specimens were collected from the four sampling locations combined, prohibiting the calculation of the various metrics needed for the NJIS score.

<u>High Gradient Macroinvertebrate Index (HGMI)</u>

New Jersey's benthic macroinvertebrate communities can be grouped into three distinct groupings based on geographical regions: high gradient (above the Fall Line), low gradient (Coastal Plain excluding the Pinelands), and Pinelands. A multimetric index has been developed, using genus level taxonomic identifications, for each distinct region. The NJIS described and presented above is a single index used statewide that is based on family level taxonomic identifications. The NJDEP, in 2009, began using the multimetric indices for each distinct region. The index appropriate to use within the Musquapsink Brook Watershed is the High Gradient Macroinvertebrate Index (HGMI). The HGMI is comprised of the following metrics: total number of genera, percent genera that are not insects, percent sensitive EPT genera, number of scraper genera, Hilsenhoff Biotic Index, number of New Jersey TALU attribute 2 genera, and number of New Jersey TALU attribute 3 genera. Excellent sites have total scores greater than or equal to 63 and are characterized as having minimal changes in the structure of biological community and having minimal changes in ecosystem function. Good sites have total scores ranging from 42-63 and are characterized as having some evident changes in the structure of the biological community and having minimal changes in ecosystem function. Fair sites have total scores ranging from 21-42 and are characterized as having moderate to major changes in the structure of the biological community and having moderate changes in ecosystem function. Poor sites have total scores of <21 and are characterized by extreme changes in the structure of the biological community and a major loss of ecosystem function.

HGMI scores for Station AN0206 (MB6) were reported as 13.75 for the July 2003 AMNET sampling (Round 3) and 18.67 for the 2008 AMNET sampling (Round 4) by NJDEP at http://www.state.nj.us/dep/wms/bfbm under *AMNET Stations Result Comparisons for Round 2 to 4*. These scores correspond to a poor assessment. A poor assessment under the HGMI falls below the acceptable regulatory range, and a site assessed as poor using the HGMI would be considered impaired from a Federal Clean Water Act perspective and not attaining the aquatic life use. Again, given the paucity of organisms collected, the HGMI could not be calculated from the data collected as part of the 2007 assessment conducted by Dr. McClary.

5.2.6 Stressor Identification

Biological assessments have become an important tool for managing water quality to meet the goal of the Clean Water Act (i.e., to maintain the chemical, physical, and biological integrity of the nation's water). However, although biological assessments are a critical tool for detecting impairment, they do not identify the cause or causes of the impairment. The USEPA developed a process, known as the Stressor Identification (SI) process, to accurately identify any type of stressor or combination of stressors that might cause biological impairment (USEPA, 2000). The SI process involves the critical review of available information, the formation of possible stressor scenarios that may explain the observed impairment, the analysis of these possible scenarios, and the formation of conclusions about which stressor or combination of stressors are causing the impairment. The SI process is iterative, and in some cases additional data may be needed to identify the stressor(s). In addition, the SI process provides a structure or a method for assembling the scientific evidence needed to support any conclusions made about the stressor(s). When the cause of a biological impairment is identified, stakeholders are then in a better position to locate the source(s) of the stressor(s) and are better prepared to implement the appropriate management actions to improve the biological condition of the impaired waterway.

The benthic macroinvertebrate community occurring within the Musquapsink Brook Watershed is apparently under some type of stress as evidenced by the extremely low numbers of organisms collected and by sensitive taxa (i.e., EPT taxa) being markedly diminished. Also, the types of organisms found within the study area are indicative of some organic pollution (Hilsenhoff, 1988). In addition, the habitat assessment revealed sub-optimal habitat to marginal conditions which may also account for the impaired condition of the community within the study area.

Candidate causes of impairment within the Musquapsink Brook Watershed include:

1. Elevated nutrient levels (i.e., total phosphorus)
2. Elevated bacteria levels (i.e., fecal coliform and *E. coli*)
3. Degraded instream habitat
4. Altered hydrology
5. Toxicants

Analysis/Evaluation of Candidate Causes:

Elevated nutrient levels and elevated bacteria levels: The role of elevated nutrients and elevated bacteria levels in impairing the biological community was indicated by continual and persistent exceedances of the surface water quality criteria for phosphorus and bacteria throughout the watershed during the surface water quality monitoring portion of this study.

Surface water quality samples were collected from stations within the Musquapsink Brook Watershed over a six month sampling time frame from May 2007 through October 2007, demonstrating a co-occurrence of these candidate causes within the watershed. Approximately 83% of the designated land use within the watershed is urban and comprised of residential (medium and low density), commercial, and roadway land use/land cover types. Stormwater runoff from these land uses is a likely source of elevated nutrients. In addition, microbial source tracking (MST) was conducted within the watershed as part of this study. Human related *Bacteroides* were detected at several locations within the watershed. Aging/leaking/failing infrastructure may be a likely source of the elevated bacteria levels observed within the watershed.

Degraded habitat: The role of degraded habitat in impairing the biological community within the watershed was indicated by the assessed sub-optimal to marginal habitat conditions within the watershed. Also, out of the 38 stream reaches evaluated using SVAP, 18 were rated as only fair and 15 were rated as poor. A likely source observed within the watershed for degraded habitat conditions includes channelization, which reduces channel diversity and promotes a uniform flow regime and ultimately reduces habitat diversity. Another likely source is stormwater outfalls which can increase erosion and scour leading to reduced channel diversity, homogenous flow regime, and unstable habitat. An additional source observed within the watershed is a decreased riparian vegetative zone (i.e., riparian buffer) which leads to increased stream temperatures, depressed dissolved oxygen levels, unstable banks, and an overall reduction in habitat complexity.

Altered hydrology: The role of altered hydrology in impairing the biological community within the watershed was indicated by reduced channel and habitat diversity, a slow and homogenous flow regime, and a potential reduction in baseflow. A likely source for altered hydrology observed within the watershed includes channelization, which reduces channel diversity and therefore promotes a uniform flow regime. Another likely source for altered hydrology observed within the watershed would include stormwater outfalls. Stormwater outfalls can increase erosion and scour leading to reduced channel diversity and homogenous flow regime.

The United Water of New Jersey water diversion from the Saddle River in Paramus Borough which discharges into the Musquapsink Brook in Washington Township may also have an impact on the biological community. According to the USGS Water-Data Report 2007, from May through October 2007, the diversion averaged, 3.27 cubic feet per second. This additional flow to the Musquapsink Brook may also be responsible for increased erosion and scour, similar to stormwater outfalls.

Toxicants: The role of toxicants in impairing the biological community was indicated by the observation of very few macroinvertebrates at each sampling station. Less than 100 organisms were collected from the four sampling locations combined during the 2007 assessment by Dr. McClary. Monitoring for pesticides and herbicides as possible toxicants is recommended in the future given the urban nature of the watershed.

5.2.7 Microbial Source Tracking

Microbial source tracking (MST) is a series of methods employed to determine sources of microbial pollution, whether from bacteria or other pathogens such as viruses and protozoa (Simpson *et al.*, 2002). MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods (e.g., caffeine or optical brighteners) to identify the origin of fecal pollution (Simpson *et al.*, 2002; Scott *et al.*, 2002; Stoeckel and Harwood, 2007).

To gain a better understanding of the sources of contaminants of human origin, tiered approaches can be applied to microbial source tracking studies. Tiered approaches study multiple levels, multiple scales, or multiple parameters with increasing focus as one moves through each tier. This has been recommended by investigators as a successful means of tracking fecal contamination sources (Boehm *et al.*, 2003; Stewart *et al.*, 2003; Noble *et al.*, 2006; Cao *et al.*, 2009). The tiered approach can aid watershed management in abating the most significant sources of fecal bacteria (or other pollutant of concern) (Noble *et al.*, 2006). Objectives and tasks are developed in this approach so that appropriate management practices are implemented and resources are allocated efficiently and economically throughout a watershed.

To track down potential sources of human-related fecal contamination, a tiered sampling approach was used. Tiered approaches study multiple levels, multiple scales, or measuring multiple parameters with increasing focus as one moves through each tier. Three tiers have been identified in which each tier uses a different method of bacterial contamination detection. The tiered sampling scheme for determining human sources as part of the Musquapsink Brook Watershed Restoration and Protection Plan is outlined below:

<u>Tier 1: Screening for fecal coliform contamination</u>
Surface water quality sampling was performed during both wet and dry weather conditions to determine the presence of fecal contamination.

Table 11 provides a summary of the results of surface water quality sampling analyses. Depending upon the sampling station, 87% to 100% of the samples collected in the Musquapsink Brook Watershed exceed the surface water quality standard for fecal coliform (Table 11).

<u>Tier 2: Location of human and non-human fecal “hot spots”</u>
MST sampling and qPCR analysis were used to differentiate between human and non-human sources of bacterial loadings to surface waters.

MST techniques typically report fecal contamination source as a percentage of targeted bacteria. One of the most promising targets for MST is *Bacteroides*, a genus of obligately anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprise up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Due to large quantities of *Bacteroides* in feces, they are an ideal target organism for identifying fecal contamination (Layton et al. 2006). In addition, *Bacteroides* have been recognized as having broad geographic stability and distribution in target host animals and are a promising microbial genus for differentiating fecal sources (USEPA, 2005; Dick *et al.*, 2005; Layton *et al.*, 2006).

Three sets of primers (targets) were used to quantify *Bacteroides* from 1) all sources of *Bacteroides* (“AllBac”), 2) human sources (“HuBac”), and 3) bovine sources of *Bacteroides* (“BoBac”) using quantitative real-time polymerase chain reaction (qPCR). Two sets of surface water quality samples were collected in the Musquapsink Brook Watershed during July and August of 2008 and analyzed for the three target sequences. Human-related *Bacteroides* were detected at sampling locations MB2, MB4, MB5, and MB6 for at least one MST sampling event (August 21, 2008). See Figures 5.2 and 5.3 for *Bacteroides* quantifications at all sampling sites.

The Musquapsink Brook Watershed is a highly-urbanized watershed with little agriculture within its boundaries. The MST results confirmed this with no detections of agriculturally-derived bovine *Bacteroides* (BoBac) in either July or August sampling event (Figures 10 and 11).

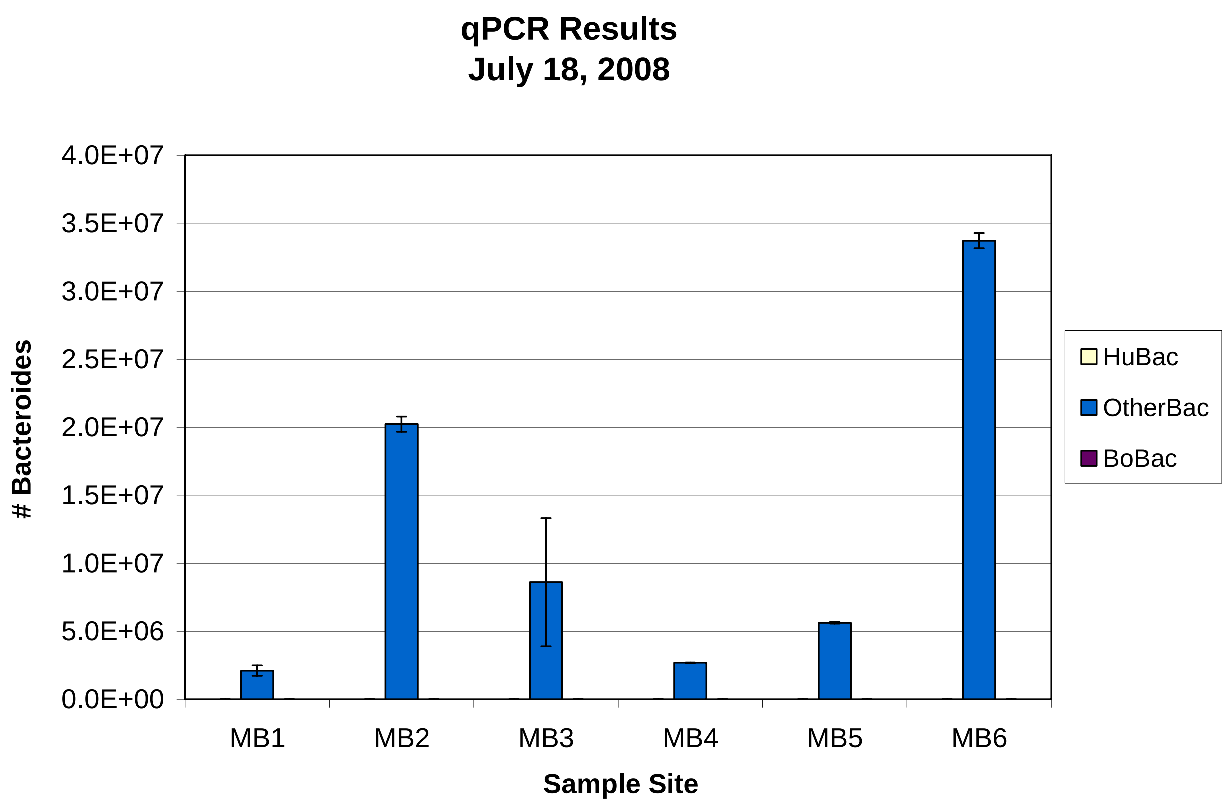

Figure 10: *Bacteroides* Quantifications at Each Sampling Site on July 18, 2008

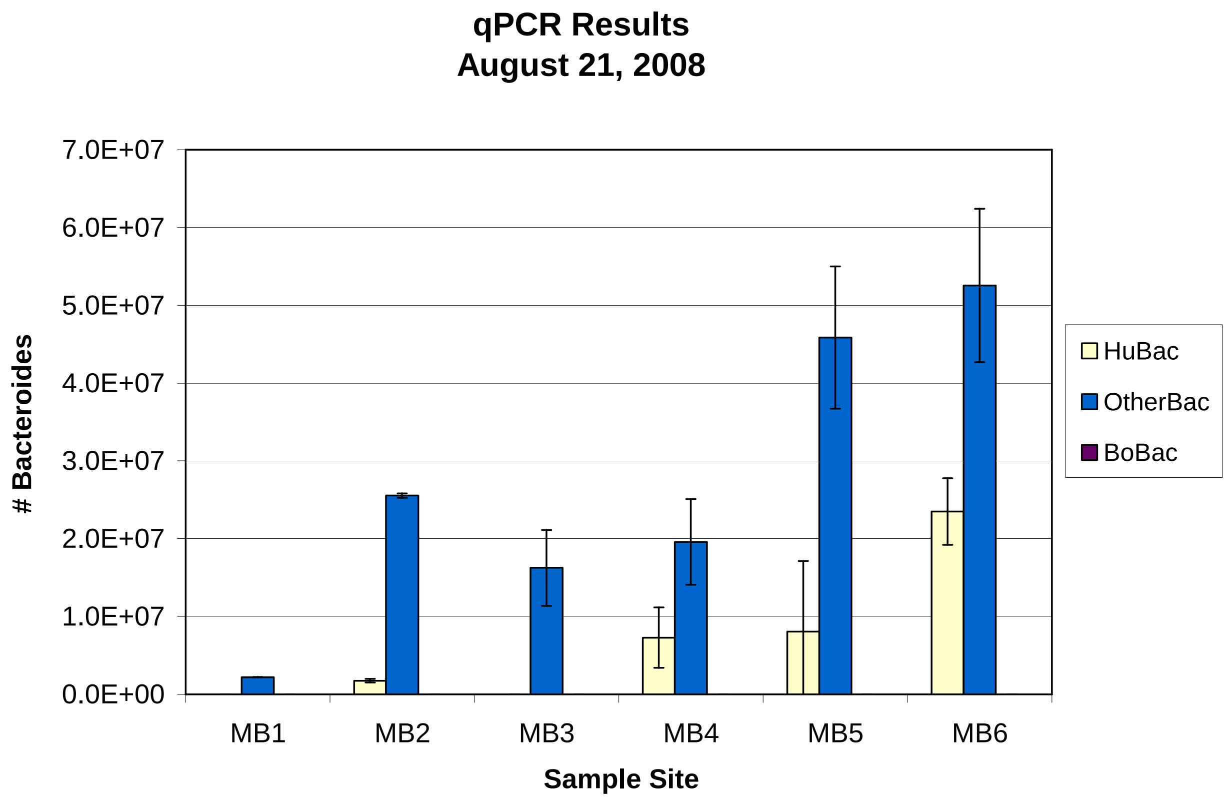

Figure 11: *Bacteroides* Quantifications at Each Sampling Site on August 21, 2008

<u>Tier 3: Source tracking with optical brighteners</u>
Another source tracking method to identify *human* bacterial contamination in surface water is the fluorometric detection of optical brighteners. Optical brighteners are compounds added to laundry detergents and soaps, and have no natural sources. Because household plumbing systems combine effluent from washing machines and toilets, optical brighteners are associated with human sewage in sewer lines, septic systems and wastewater treatment plants (Hartel *et al.*, 2007). Their presence in surface water, therefore, can be an indicator of an illicit connection, leaking collection pipes, or contamination from other wastewater discharges.

Fluorometric analysis was used to detect the presence of optical brighteners in the stream. Optical brightener data was correlated with *in-situ* stream measurements to verify sewer discharges. These compounds enter an excited state when exposed to UV light (360-365nm range) and emit light in the blue range (400-440nm). Fluorescence of these compounds can be measured with a fluorometer.

Two rounds of optical brightener sampling and fluorometric analysis were completed between May and August 2010 during dry conditions (no recorded precipitation within 48 hours of sampling event). Initially, there were 16 sites sampled (Figure 12). Two additional sites were added for the August sampling event. The locations of sampling sites for both events are provided in Appendix B. Fluorometric analysis results and *in situ* pH, DO, and temperature readings are also reported in Appendix B. Average fluorometric readings for the collected samples are presented in Figure 13 below.

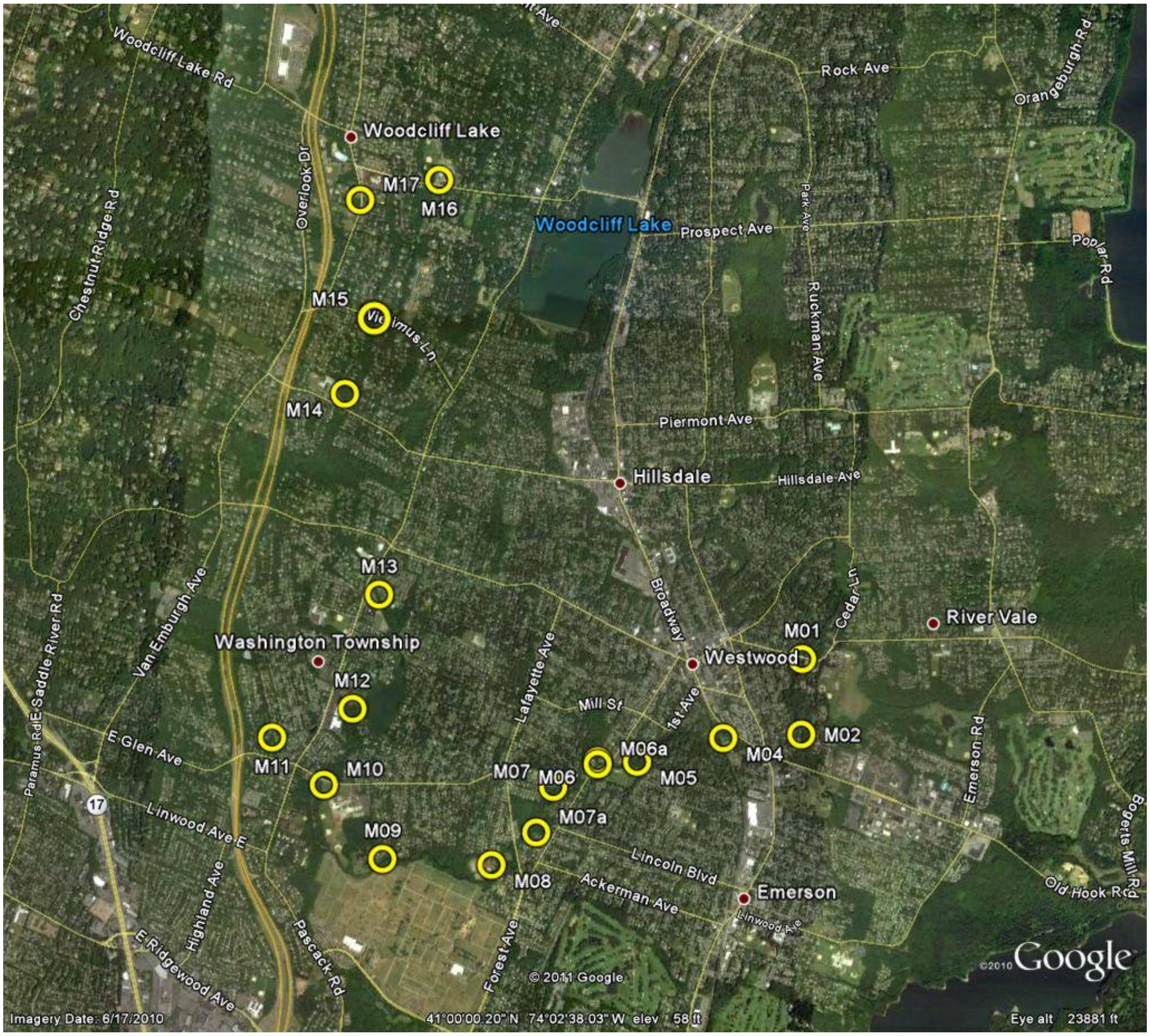

Figure 12: Sampling sites for Optical Brighteners in the Musquapsink Brook Watershed

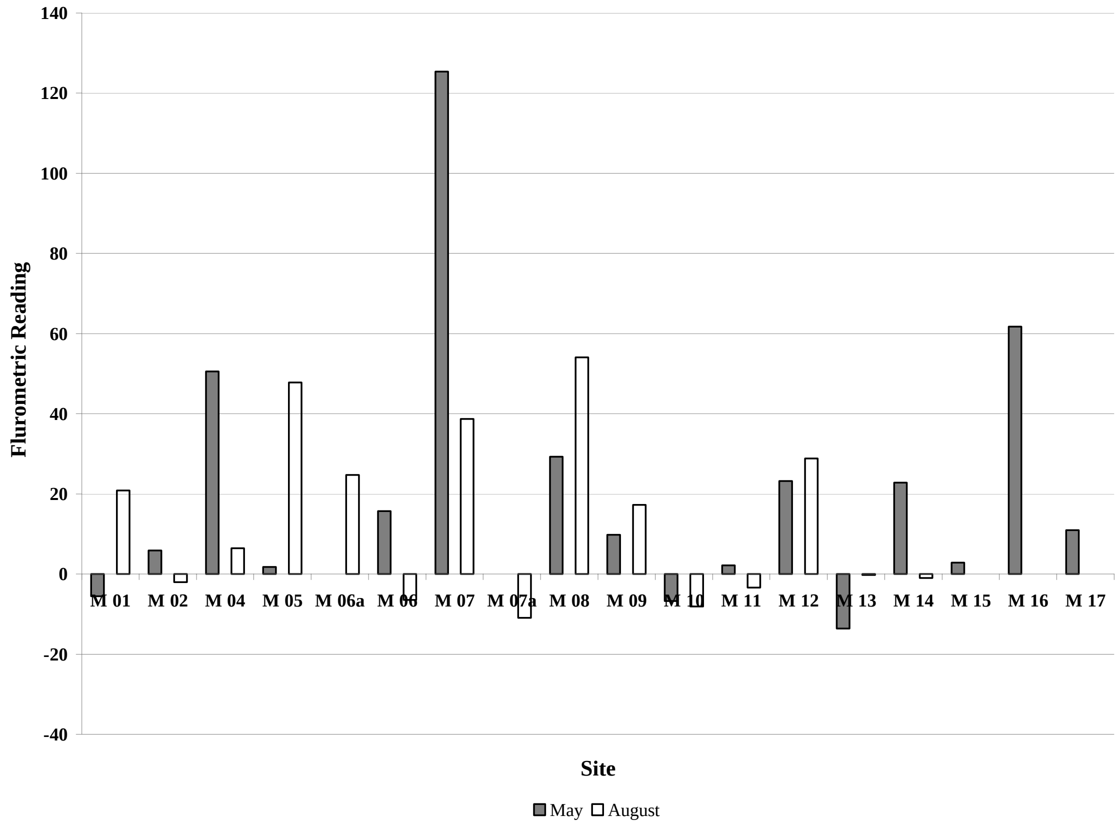

Figure 13: Average Fluorometric Readings for Samples Collected in May and August, 2010

<u>Recommendations</u>

Modeled on a similar optical brightener study conducted by the University of North Carolina (Tavares *et al.*, 2008), bacteria source trackdown was achieved by comparing fecal coliform concentration and MST sampling results to average optical brightener levels at each sampling location. Refer to Table 13 for summary of this data.

Table 13: Summary of Results for Optical Brightener Levels for Each Subwatershed

Subwatershed	Average Fecal Concentration (col/100ml)	MST Human Source Detection	Optical Brightener Sampling Site	Optical Brightener Level[1]
MB1	3,479	No	M14	Low
			M15	Low
			M16	High
			M17	Low
MB2	1,481	Yes	M12	High
			M13	Low
MB3	3,706	No	M11	Low
MB4	5,530	Yes	M08	High
			M09	Low
			M10	Low
MB5	6,627	Yes	M06	Low
			M06a	High
			M07	High
			M07a	Low
MB6	10,373	Yes	M01	Low
			M02	Low
			M04	High
			M05	High

[1]"High" Optical Brightener Level indicates that, for sites sampled in both May and August, at least one fluorometric reading was above 20 and both events yielded samples positive for optical brightener presence. For sites with only one sampling event, "High" indicates a fluorometric reading above 40. All other scenarios indicate "Low" Optical Brightener Levels.

The tiered approach study was intended to provide Bergen County and its included townships with the initial information they need for targeted investigation into sanitary sewer releases to the Brook. Based on the results provided in Table 13, the Rutgers Cooperative Extension Water Resources Program recommends that three general areas be evaluated for sources of human-related bacterial contamination in Westwood Borough and Washington Township. Figure 14 contains maps of the identified regions. Maintenance and inspection records of water and wastewater infrastructure should be reviewed for each of these areas. Video inspections, smoke testing, or dye testing to determine infrastructure conditions may also be considered.

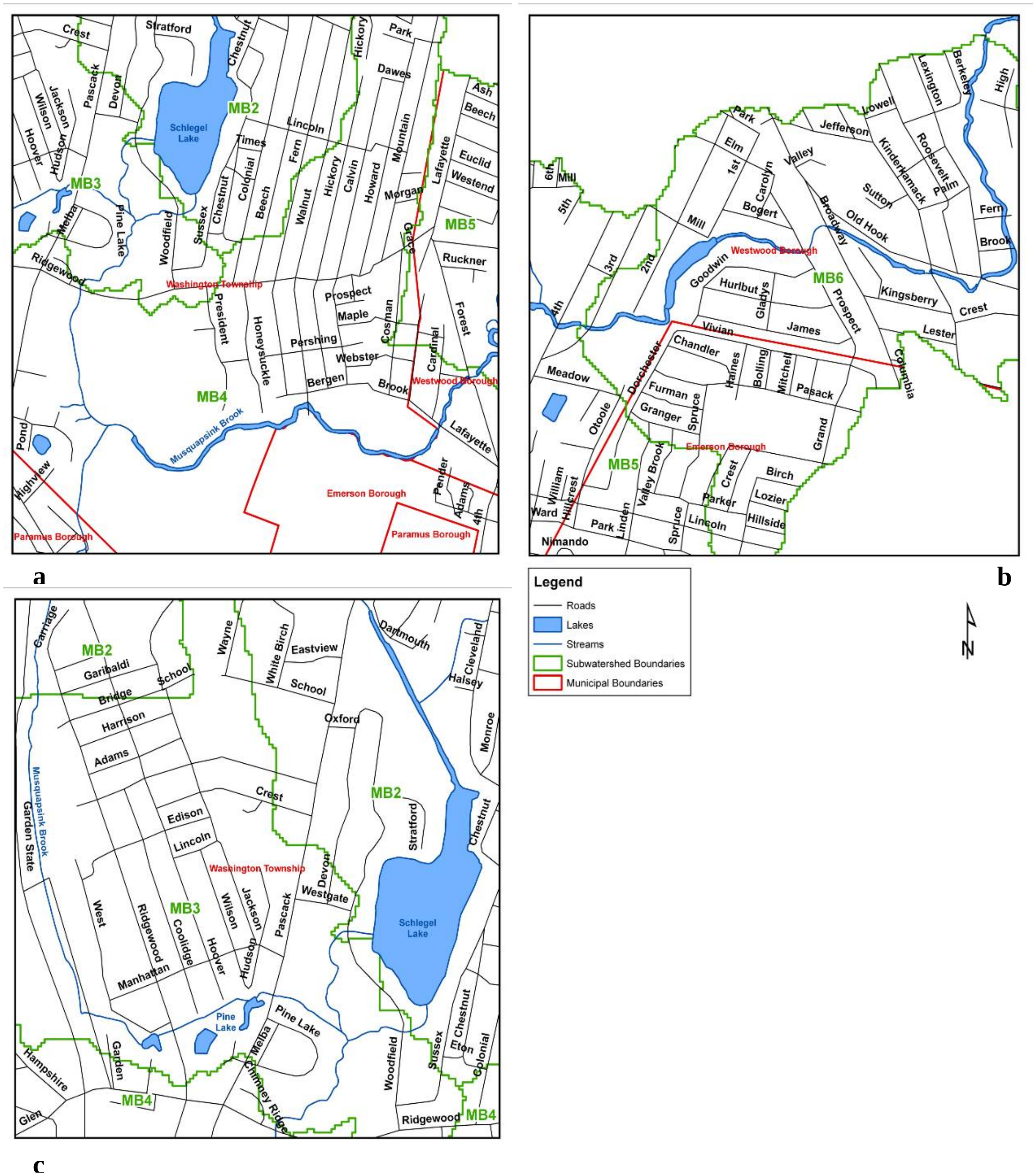

Figure 14: Regions identified for further trackdown of human-source bacteria contamination of surface water (a) Stream segment between Forest Avenue and Pascack Road, Washington Township (b) Stream segment between 4th Avenue and Old Hook Road, Westwood Borough (c) Stream segment along Pascack Road, between Sutton Way and Eastview Terrace, Washington Township

While optical brightener detection by fluorometry shows promise as a method of MST in watershed restoration planning, additional field sampling and comparisons with other methods need to be conducted to determine its effectiveness in watershed management. To this effect, it is important to note that the results of this study are preliminary in nature. Further data collection is necessary before infrastructure investigations are carried out, as the scope of this project (nonpoint source identification) did not provide for the intensive trackdown of wastewater infrastructure failures. Only two rounds of MST sampling were conducted for both qPCR analysis and optical brightener detection by fluorometry. At the time, avian primers were not available for qPCR analysis. Since geese have been identified as a major source of bacterial contamination, this study would be greatly enhanced with data separating avian versus human sources.

Additional lab and field work also need to be conducted to verify the results of the optical brightener detection by fluorometry. This would involve evaluating different excitation wavelengths and determining how best to account for both natural and anthropogenic sources of fluorescent compounds, such as those produced by organic material, newspapers, and cigarette butts. The best approach to this issue is to collect samples where these substances are present, and scan wavelengths to see where fluorescence occurs. Oil-based compounds from oil spills could also potentially contribute chemicals that fluoresce, and lab studies where oils are added to water could be performed to examine this issue. Seasonality is another confounding factor that should be investigated, as there may be particular times of the year when fluorescent signals are more prevalent, and if so, these times should be identified. As fluorescence technology emerges as a source-tracking tool, it would also be valuable to study how well fluorescence is removed by sediment in riverbeds. Such information would be helpful in making decisions regarding where to sample for fluorescence in water bodies and how to interpret fluorescence after it has been found (Hagedorn and Weisberg, 2009).

5.3 Nonpoint Sources

Nonpoint sources of water pollution derive from many different contaminants and landscapes. The extent and locations of these contaminant sources cannot be easily identified due to their diffuse nature, making them difficult to regulate and even more difficult to rectify.

The Musquapsink Brook Watershed is highly urbanized, with very little agricultural land use. Nonpoint source pollution is therefore largely associated with roads, buildings, pavement, and generally compacted landscapes with impaired drainage. Pollutants of concern include: sediment; oil, grease and toxic chemicals from motor vehicles; pesticides and nutrients from lawns and gardens; bacteria and nutrients from wildlife or pet waste; road salts; heavy metals from roof shingles, motor vehicles and other sources; and thermal pollution from dark impervious surfaces such as streets and rooftops are all pollutant concerns within the watershed. As these pollutants, generated by urban development and wildlife, accumulate on the land surface, hydrological processes such as runoff and percolation during a storm event will eventually transport these contaminants into nearby streams and groundwater. The urban land use has caused significant hydrological alteration and thus accelerated the speed and extent of pollutant transportation from sources to stream. The aggregate contribution of all nonpoint sources to the Musquapsink Brook has severely degraded surface water quality over time.

Specifically, sources of fecal contamination most likely include failing infrastructure or septic systems, incorrect disposal of domestic pet waste, and waste from waterfowl populations. Phosphorus impairments may be due to excessive fertilizer applications in residential neighborhoods, resulting in stormwater runoff with high nutrient concentrations. Highway runoff during storm events may also contribute to phosphorus loads (Flint and Davis, 2007). Atmospheric deposition of phosphorus and nitrogen and other airborne pollutants onto impervious surfaces may also contribute largely to stormwater runoff loadings.

5.4 Point Sources

According to the regulation in the United States, generally point sources include municipal wastewater (sewage), industrial wastewater discharges, municipal separate storm sewer systems (MS4) and industrial stormwater discharges (Public Law 100-4. 1987). These facilities are required to obtain New Jersey Pollution Discharge Elimination System (NJPDES) permits or state/local permits. All municipalities within the Musquapsink Brook Watershed have MS4s and state permits for stormwater discharges. There are no NJPDES-permitted surface water discharges within the Watershed.

In addition, there are 10 known contaminated sites in the Musquapsink Brook Watershed (Table 14). Many of these sites have groundwater contamination associated with them and some have soil or other media contaminated by a substance release (Table 14). While the specifics of the source and type of contaminants from these sites are regulated by the NJDEP, they are included here as a possible reason for some of water quality issues not explained by monitoring conducted by the RCE Water Resources Program as part of this restoration planning effort. Confirmation of these known contaminated sites as potential sources of water quality impairments cannot be made at this time. However, future monitoring could be focused on determining the impact of these sites.

Table 14: Known contaminated sites (2009) located within the Musquapsink Brook Watershed

Site Name	Site Address	Status	Remedial Level	Municipality
Soldier Hill Redevelopment	Soldier Hill Road	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Paramus Borough
91 4th Avenue	91 4th Avenue	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Westwood Borough
Westwood Amoco	100 Kinderkamack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Westwood Borough
Washington Town Center	285 Pascack Road	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Washington Township
Lukoil #57301	290 Pascack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
Park Ridge Well #15	Old Mill Pond Road	Active	C3: Multi-Phased RA - Unknown or Uncontrolled Discharge to Soil or GW	Woodcliff Lake Borough
Washington Township	350 Hudson Avenue	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
Sky's Trading, LLC	700 Pascack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
43 Brookview Terrace	43 Brookview Terrace	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Hillsdale Borough
Woodcliff Lake Friendly Service	223 Woodcliff Avenue	Active	C2: Formal Design - Known Source or Release with GW Contamination	Woodcliff Lake Borough

5.5 Erosion and Sedimentation

The Rosgen Stream Classification System and Simon's 1989 Channel Evolution Model were used to assess streams and tributaries in the Musquapsink Brook Watershed. Based on the simplified Rosgen analysis, several typical stream types were identified. Results are presented in Table 15. The geographical location of sites evaluated for the Rosgen Stream Classification analysis and the Channel Evolution Model are depicted in Figure 15. Low flow conditions in subwatershed MB1 prevented complete analysis and stream classification. This portion of stream is not addressed in this section of the Plan.

A significant feature to note is a historic mill dam located in Westwood, New Jersey. Bogert Pond is created by this dam and is surrounded by residential neighborhoods. Impounded waters are subject to frequent floods, destabilizing river banks formerly subjected only to occasional high waters for short periods of time. This causes erosion and downcutting both upstream and downstream of the dam. Sediment deposition at the dam site also causes further erosion downstream. Because there is no bed load just below a dam, the streambed erodes, increasing silt. If there is no equilibrium between bedload entering a stretch of river and leaving it, a river will cut into its streambed and deepen. Such is the case with the Musquapsink Brook, as indicated by findings from both the Rosgen Stream Classification and Channel Evolution Model analysis. Unstable, eroding streambanks and entrenched profiles are typical of MB4, MB5, and MB6, the subwatersheds that contain the segments of stream most closely connected to the mill dam. A Pond Management Plan should be developed for Bogert Pond and should include a sediment survey, recommendations for land use practices, and options for dam removal. This may improve issues associated with flooding and erosion in the Musquapsink Brook Watershed. See project MB6_We_a in Appendix C for further information on this site.

Stream classification based on morphology is meant to provide a common ground for understanding current stream conditions and potential stream conditions in varying settings with vastly different influences. Rosgen stream classification is one such morphology-based analysis. Figure 16 depicts the different stream types and characteristics. Type B is a moderately entrenched, moderate gradient, riffle dominated channel with frequently spaced pools. This stream type is very stable in plan and profile with stable banks. Type C is a low-gradient, meandering stream containing point-bars, riffle/pools, and alluvial channels within a broad, well-defined floodplain. This type of stream is fairly stable in plan and profile. Type D streams are multiple-channel systems that typically do not have a boulder or bedrock channel bed. Type G is an entrenched "gulley" step/pool stream with low width/depth ratio on moderate gradients. This type of stream is unstable with grade control problems and high bank erosion rates (Rosgen, 1994).

Table 15: Rosgen Stream Classifications for Musquapsink Brook Watershed

	MB1a	MB1b	MB2a	MB2b	MB3a	MB3b	MB4a	MB4b	MB5a	MB5b	MB6a	MB6b
Single Threaded Channels		Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Entrenchment Ratio			Entrenched	Moderate	Slight	Slight	Moderate	Moderate	Entrenched	Entrenched	Entrenched	Moderate
Width/Depth Ratio	12		<12	>12	>12	<12	>12	<12	<12	<12	>12	>12
Sinuosity							1.586	1.586	1.510	1.510	1.618	1.618
Stream Type			G	DA	C	DA	B	F	G	C	B	B
Slope							0.0006		0.0013	0.0008	0.005	0.0005
Channel Material	Silt/Clay	Clay/Silt	Cobble	Clay/Silt	Boulders	Clay/Silt	Silt/Clay	Sand/Cobble	Clay/Silt	Clay/Silt	Cobble	Clay/Silt
Stream Classification			G3	DA6	C2	DA6	B6c	F3	G6c	C6c	B3c	B6c

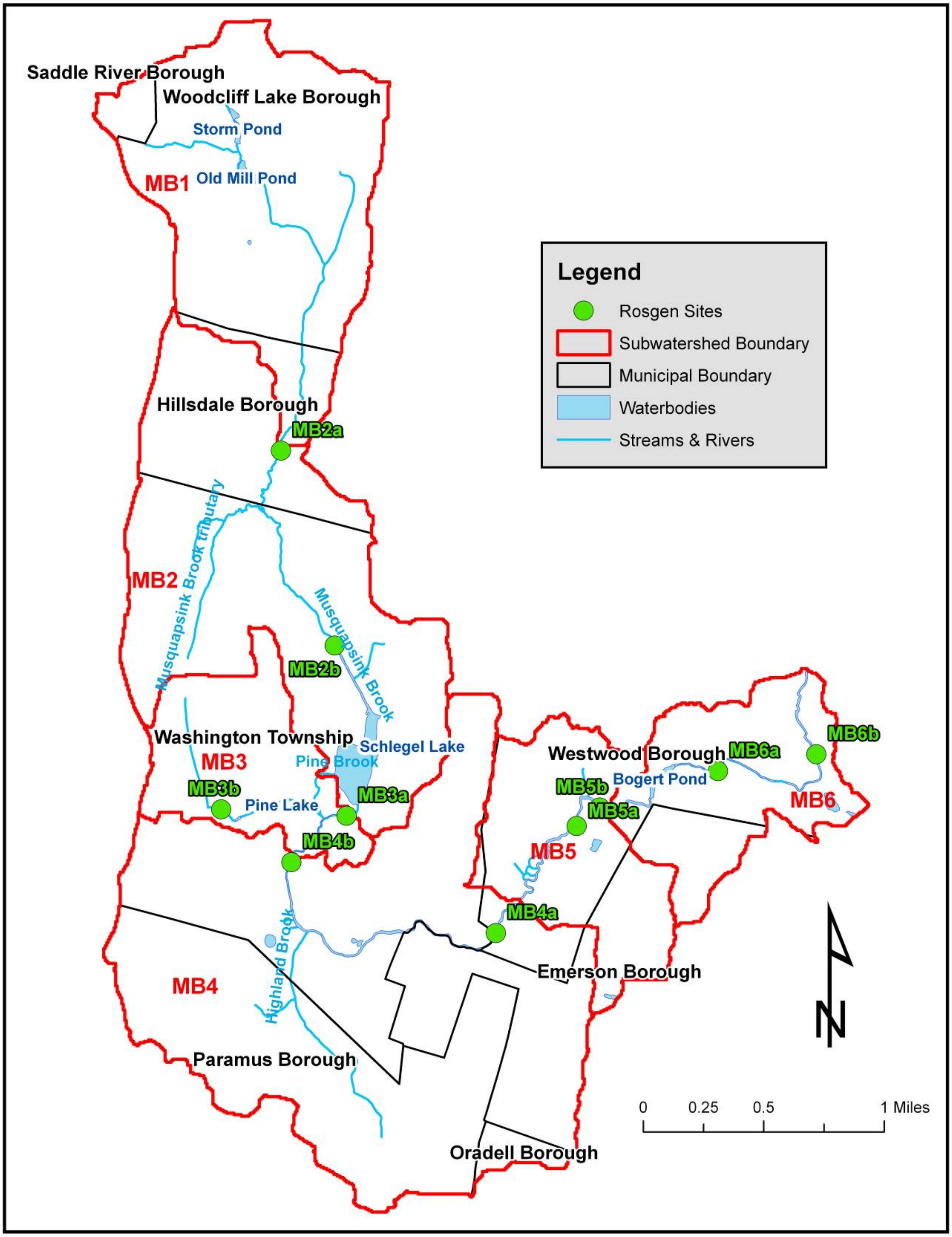

Figure 15: Musquapsink Brook Watershed Sites for Rosgen Stream Classification Analysis

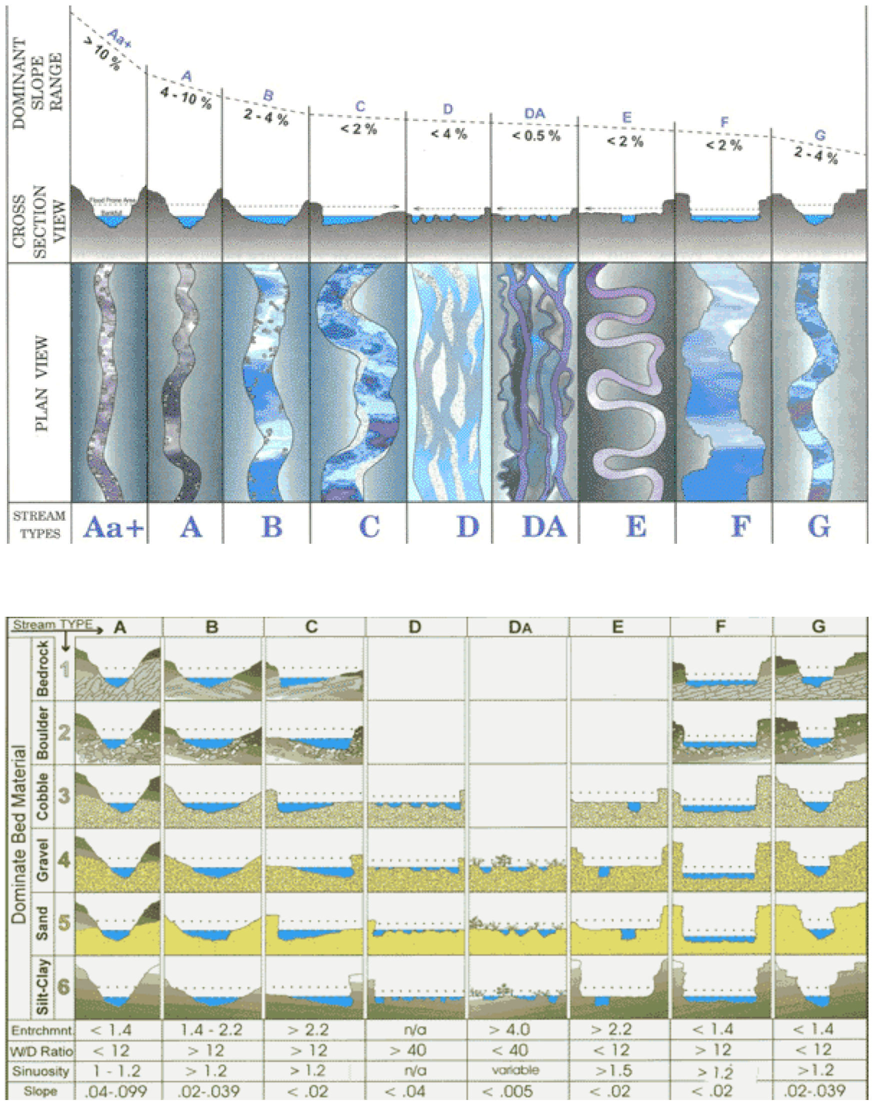

Figure 16: Rosgen Stream Classification Cross Section, Plan and Profile Views (Rosgen, 1994)

Simon's Channel Evolution Model describes a stream's erosive evolution in six stages, starting with a stable, undisturbed channel (Stage I) and ending with a refilled channel (Stage VI). In between, the stream is disturbed by some large-scale event, eroded, and then re-stabilized. Table 16 provides information on the channel evolution conditions in the Musquapsink Brook Watershed. Approximately 80% of the stream reaches assessed are unstable and fall under Stages II and III, characterized by disturbance and incision, respectively. Stage II stream reaches typically have altered channel hydrology and modified sediment input. Woody vegetation near the water line has been removed due to unstable bank conditions. Stage III stream reaches are characterized by excessive downcutting, which liberates sediment and alters the bankfull floodplain (Simon and Downs, 1995). Observations noted in the Channel Evolution Model evaluation reflect the impacts of the high percentage of urban land use in the Musquapsink Brook Watershed. Streams in Stage II or III are most likely suffering from higher peak stormwater flows from urban land use in the upper watershed. In most cases, the downcutting and widening seen in Stages II and III can be linked to impervious cover that is directly connected to the stream, resulting in flashy hydrology. Furthermore, these unstable reaches can contribute a significant amount of sediment to the stream.

Table 16: Channel Evolution Evaluations for Musquapsink Brook Watershed

Site	Sub Watershed	Stage	Description and Observations
MB1a	MB1	-	-
MB1b	MB1	-	-
MB2a	MB2	II	Unstable. Bank slopes of stream are very steep with obvious headcutting occurring. Cultural features are exposed and sediment accumulation in stream.
MB2b	MB2	V	Stable. Well developed baseflow and bankfull channel, along with one stream bank slopes less than 1:1. Floodplain features are easily identified, and one terrace is apparent. A point bar is also present, due to low flow and excess sediment conditions.
MB3a	MB3	III	Unstable. Stream is widening due to stream bank sloughing; the sloughed material is being eroded creating vertical bank slopes. Erosion is especially prevalent on the insides of bends due to fast moving water.
MB3b	MB3	I	Stable. Well developed base flow and bank full channel, in addition to predictable streambed morphology. Floodplain features are easily identified, and there is one terrace apparent.
MB4a	MB4	II	Unstable. Bank slopes are steep with head cuts and exposed cultural features present. There's also some algae and aquatic vegetation.
MB4b	MB4	II	Unstable. Easily identifiable incisions on both banks of stream, in addition to exposed cultural features and considerable amount of sediment deposits in stream.
MB5a	MB5	II	Unstable. Slow moving stream with a storm drain pipe directed from the street on the side. It is very deep in the middle, with steep banks that contain incision and exposed roots.
MB5b	MB5	III	Unstable. Waterfowl present; at least 15 geese and 15 ducks are present. A corresponding amount of feces is on the right bank with very little to no buffer. The site is at a bend in the stream where there is heavy erosion on the inside, making it very deep there. The bank is sloughing, making it almost vertical.
MB6a	MB6	III	Stable. Riprap-lined channel. The banks are steep, and the stream is shallow but fast moving. Some incision is present.
MB6b	MB6	III	Left side of stream is residential with heavy erosion. Bank would be vertical if rocks weren't placed there to prevent further sloughing. Right bank is stable, with some headcutting.

5.6 Stream Visual Assessment Protocol (SVAP) Data

SVAP was developed by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture to assess the health of the stream, identify pollutant sources, and identify potential management measures to control these pollutant sources based on visual inspection of instream physical and biological characteristics (USDA, 1998). The assessment is based on a three-page worksheet modified for New Jersey by the Rutgers Cooperative Extension Water Resource Program. SVAP assesses a set of 15 stream condition indicators and assigns each indicator a numerical score relative to reference conditions. The specific indicators include channel condition, hydrologic alteration, riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, insect/invertebrate habitat, canopy cover, manure presence, riffle embeddedness, and macroinvertebrates observed if applicable. The score for each element is assessed on a scale of 1 to 10, with one being the worst and ten being the best. The scores of the 15 elements at each site are averaged to give an overall rating for that assessed stream reach. A score of less than 6.0 is considered "Poor," a score of 6.0 to 7.49 is considered "Fair," and a score above 7.5 is considered "Good." The numerical assessment is complemented by photographs and drawings of the stream site, as well as notes on visual observations of unusual or unsightly occurrences such as dumping, manure, runoff or outfall pipes, etc.

Thirty eight stream reaches were evaluated in the Musquapsink Brook Watershed; the stream reaches and the average SVAP scores are identified in Figure 17. The average overall SVAP score was 6.7, a "fair" score (Table 17). Canopy cover was the highest scoring element (average of 8.4), and instream fish cover was the lowest scoring element (average of 5.2). No assessed stream reach received a score of "excellent," five reaches were rated as "good," and eighteen were rated as "fair." The remaining fifteen reaches were rated as "poor." The reaches that were rated as poor are located along the entire length of the Musquapsink Brook.

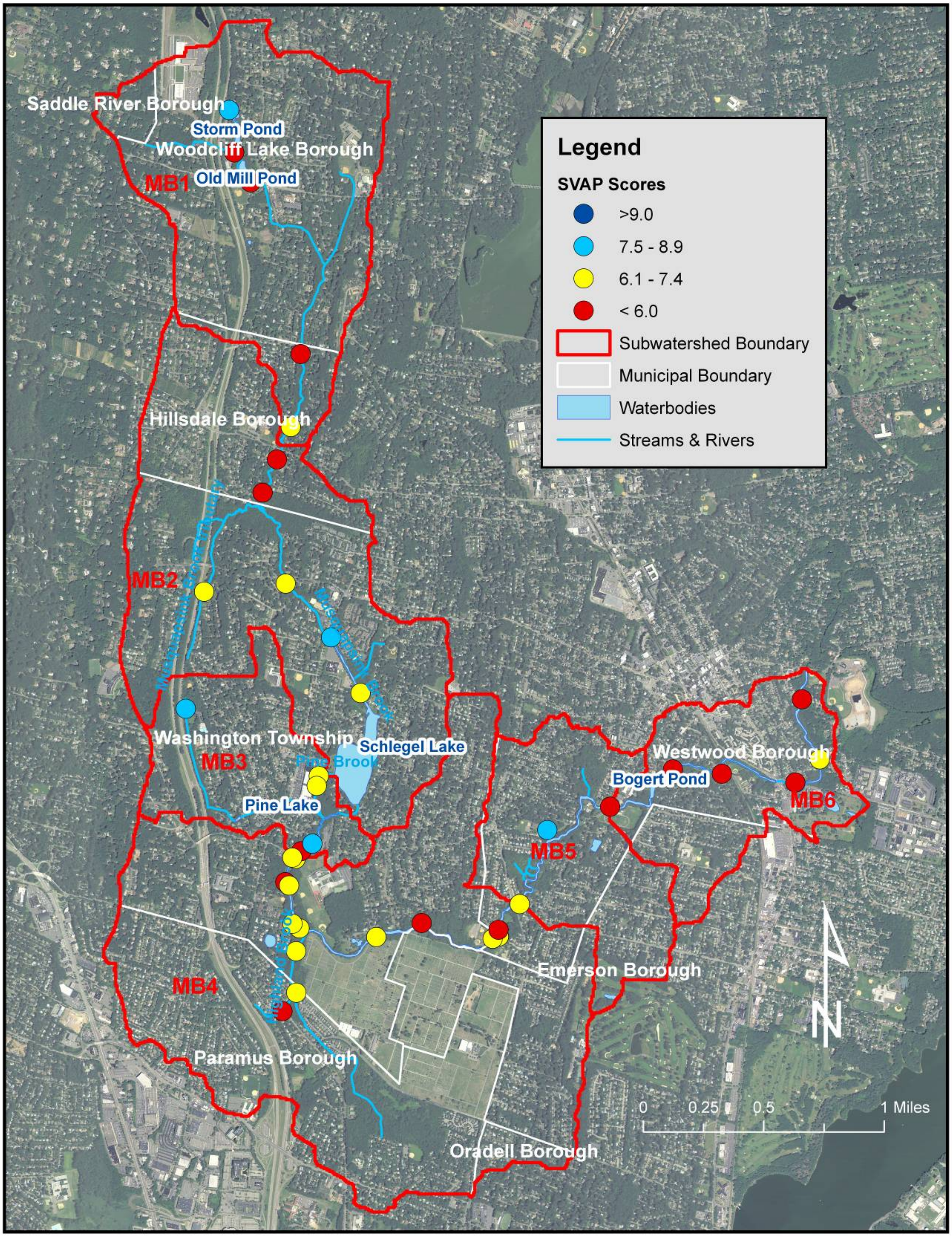

Figure 17: Stream Visual Assessment Reaches with Scores in the Musquapsink Brook Watershed

Table 17: SVAP Assessment Elements and Data for Musquapsink Brook Watershed

	Channel Condition	**Hydrologic Alteration**	**Riparian Zone left bank**	**Riparian Zone right bank**	**Bank Stability left bank**	**Bank Stability right bank**	**Water Appearance**	**Nutrient Enrichment**	**Barriers to Fish Movement**
# of scores	38	20	38	38	38	38	38	38	38
minimum value	1	1	1	1	1	1	3	3	0
maximum value	10	10	10	10	10	10	10	10	10
average	6.4	6.7	7.3	6.3	5.8	5.8	7.6	7.4	5.5
	Instream Fish Cover	**Pools**	**Invertebrate Habitat**	**Canopy Cover**	**Manure Presence**	**Riffle Embeddedness**	**Water Appearance & Nutrient Enrichment Averages**		**Tiered Assessment Averages***
# of scores	38	38	38	38	NA	20	38		36
minimum value	0	1	3	1	NA	0	3		1.5
maximum value	8	8	10	10	NA	10	10		10
average	5.2	6.3	7.9	8.4	NA	6.0	7.5		6.7
	Overall Average - left bank		***Overall Average - right bank***		***Overall Site Average***				
# of scores	***35***		***35***		***35***				
minimum value	***1.3***		***1.3***		***1.3***				
maximum value	***9.7***		***9.7***		***9.7***				
average	***6.7***		***6.6***		***6.7***				

** "Tiered Assessment Averages" refers collectively to Hydrologic Alteration, Channel Condition, Riparian Zones left and right, Bank Stability left and right, Water Appearance, and Nutrient Enrichment.*

5.6.1 Using the SVAP Data

SVAP scores have been evaluated as individual assessment elements and combined with other data collected as part of this restoration planning effort. The SVAP results were compared to land use, soil characteristics, slope and stream gradient, and water quality monitoring results to determine the quality of waters within the Musquapsink Brook Watershed. The SVAP scores, information on pipes, ditches, photos, and remediation notes have been used to identify sources of pollution and potential opportunities for improved management.

6. Estimated Loading Targets and Priorities

6.1. Loading Targets

Load reduction targets will adhere to the TMDL approved by the USEPA. In this plan, reduction targets are defined by the total pollutant load reductions that are required to satisfy the water quality standards for the non-trout FW2 streams. These targets will dictate the management plans developed for the Musquapsink Brook Watershed.

As stated previously, a TMDL was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load. In 2005, a TMDL for total phosphorus was established and requires a 10.9% reduction in total phosphorus loadings from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forested, and agricultural lands.

6.2. Priority Ranking

One of the goals of the watershed restoration and protection plan is to prioritize the implementation of various best management practices. For this project, water quality data and flow data were collected at six sampling locations. Each of these sampling locations represents the outlet of a subwatershed within the Musquapsink Brook Watershed. To identify which subwatershed was contributing the most pollution to the Musquapsink Brook, data from each of these sampling locations was used to determine the annual pollutant load leaving each of the subwatersheds. Average loading rates of fecal coliform, *E. coli*, and phosphorus were calculated for MB1, MB3, MB4, MB5, and MB6. Data at MB2 was analyzed and used for the monitoring of Schlegel Lake, but was not included in the final loading rate calculations. The subwatersheds were then ranked by their annual pollutant load.

The two primary pollutants of concern in the Musquapsink Brook Watershed are total phosphorus and fecal coliform, an indicator of pathogen contamination. Flow and pollutant concentration from each sampling event were used to calculate the daily load at each sampling location. The annual total load for each subwatershed was determined by averaging the daily loads and multiplying this average daily load by 365 days (number of day in a year). For total phosphorus this provides an annual load in kg/year. For fecal coliform, this calculation provided an annual load in colonies per year. At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform standard has been replaced by an *E. coli* standard. Because the TMDL established refers to fecal coliform, both fecal coliform and *E. coli* loading rates were calculated.

The differentiation between 'wet' and 'dry' weather sampling can be used to improve the understanding of the impact of stormwater on pollutant concentrations. To more accurately determine which monitoring events were collected under wet conditions when the stream velocities exceeded baseflow conditions, the HYSEP procedure was used. HYSEP is a data analysis program developed by the USGS to separate river flow into baseflow and storm-flow (Sloto and Crouse, 1996). Normally, this model would be applied to a daily discharge monitoring station within the watershed; however, daily discharge is not recorded by the USGS in the Musquapsink Brook Watershed. Instead, USGS monitoring station 01377500, Pascack Brook at Westwood, which is just downstream of the confluence of the Musquapsink Brook and the Pascack Brook, was chosen. Although it would be preferable to use a flow gauge in the target watershed, the watershed does drain to the Pascack Brook, and the remainder of the drainage area is adjacent to the Musquapsink Brook watershed. The analysis was completed for the Pascack Brook over the length of the field sampling program. A 10% error bar was applied to the baseflow since these data are collected in a watershed other than the Musquapsink Brook. When flow was more than 10% greater than baseflow and rain occurred on the day of or the day preceding sampling, the event was considered as storm-related flow and assigned the term "wet."

Average annual loading rates for these three parameters during both wet weather and dry weather conditions are presented in Table 18. The annual loads were then normalized by the area of each of the individual subcatchments. These loading rates are presented in Table 19.

Table 18: Annual Loading Rates for Individual Subwatersheds

Subwatershed	Fecal Coliform (Colonies/Year)		*E. coli* (Colonies/Year)		Total Phosphorus (Kg/Year)	
	Wet	Dry	Wet	Dry	Wet	Dry
MB1	8.76E+13	3.91E+12	7.33E+13	1.88E+12	5.00E+01	3.15E+01
MB3	2.50E+13	4.36E+12	6.85E+12	2.86E+12	2.66E+01	3.88E+01
MB4	5.31E+14	9.17E+13	5.53E+14	6.26E+13	5.09E+02	1.56E+03
MB5	4.29E+14	-1.48E+13	4.99E+14	6.68E+13	6.92E+02	7.29E+01
MB6	9.59E+14	-5.44E+12	2.50E+14	5.05E+13	1.67E+02	-9.33E+02

Table 19: Annual Loading Rates Normalized to Area for Individual Subwatersheds

Subwatershed	Fecal Coliform (Colonies/Acre/Year)		*E. coli* (Colonies/Acre/Year)		Total Phosphorus (Kg/Acre/Year)	
	Wet	Dry	Wet	Dry	Wet	Dry
MB1	1.12E+11	5.00E+09	9.37E+10	2.41E+09	6.40E-02	4.03E-02
MB3	7.99E+10	1.40E+10	2.19E+10	9.14E+09	8.51E-02	1.24E-01
MB4	3.37E+11	5.81E+10	3.51E+11	3.97E+10	3.23E-01	9.91E-01
MB5	1.17E+12	-4.03E+10	1.36E+12	1.82E+11	1.88E+00	1.98E-01
MB6	2.47E+12	-1.40E+10	6.46E+11	1.30E+11	4.32E-01	-2.41E+00

Fecal coliform counts increase by 48% from station MB3 to MB4 during wet weather events and by over 56% during dry weather. This increase may be due to the discharge of the United Water intake from Saddle River and Ho-Ho-Kus Brook into the Musquapsink Brook Watershed, which occurs directly upstream of the MB4 sampling site. There is a 62% increase in fecal coliform counts between MB5 and MB6 during wet weather conditions, while average dry weather counts decrease, indicating that a significantly large pathogen source is impacting the stream via surface runoff or point source pollution within the MB6 subwatershed.

Total phosphorus loadings during wet weather conditions are most significant in MB4, MB5, and MB6. In subwatersheds MB5 and MB6, total phosphorus loads are dominated by stormwater runoff events, with over 90% of the annual load being contributed during wet weather conditions. Subwatersheds MB4 and MB5 also have total phosphorus loadings during baseflow conditions. Only in subwatershed MB4 do total phosphorus loadings from groundwater discharge exceed those from stormwater runoff.

The calculated annual loads and loading rates were used to rank the subwatersheds. Because stormwater best management practices and implementation projects typically target pollutant loading reductions during wet weather conditions, rankings are based on wet weather loadings.

The subwatershed with the highest loading rate was given one (1) point, the next highest was given two (2) and so on. This method was repeated for the area-normalized loading rate. The points were combined, and the subwatersheds were ranked highest to lowest according to their total points (maximum of 10 points, with lower values indicating highest loading impact). The results of the ranking process are shown in Tables 20 a, b, and c. The loading rates show which subwatershed is contributing the most pollutants into the stream. The area normalized loading rates show which subwatershed is contributing the most pollutant per acre. Combining both parameters ensures that the subwatersheds with the highest priority are those where the greatest impact can be had with the least amount of implementation. For all three pollutants of concern in the

Musquapsink Brook Watershed, loadings from subwatersheds MB4, MB5, and MB6 are the top three contributors to water quality impairments.

Table 20 a.b.c.: Summation of Rankings for Loadings and Area- Normalized Loadings

Subwatershed	a. Fecal Coliform		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	8
MB3	5	5	10
MB4	2	3	5
MB5	3	2	5
MB6	1	1	2

Subwatershed	b. *E. coli*		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	8
MB3	5	5	10
MB4	1	3	4
MB5	2	1	3
MB6	3	2	5

Subwatershed	c. Total Phosphorus		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	5	9
MB3	5	4	9
MB4	2	3	5
MB5	1	1	2
MB6	3	2	5

The final step in this analysis was to combine the priority rankings for total phosphorus, fecal coliform and *E. coli* to create an overall ranking for each subwatershed. These rankings will help prioritize the implementation of stormwater best management practices. Tables 21 a, b, and c summarize overall rankings for total phosphorus, fecal coliform and *E. coli*. Subwatersheds of top priority are in bold.

The prioritization and ranking reflect the conclusions drawn from the surface water quality sampling results, the Rosgen Analysis, and the Channel Evolution Model evaluations. The downstream portion (subwatersheds MB4, MB5, and MB6) of the Musquapsink Brook Watershed is the most significantly impaired, with pollutant loadings due largely to human activities, potential infrastructure failures, and unstable stream conditions. Areas in these segments of the watershed will be targeted for BMP implementation.

Table 21 a.b.c: Priority Watersheds by Surface Water Quality Parameter

	a. Fecal Coliform		
Subwatershed	**Ranking of Annual Loading**	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	4
MB3	5	5	5
MB4	2	3	3
MB5	3	2	**2**
MB6	1	1	**1**

	b. *E. coli*		
Subwatershed	**Ranking of Annual Loading**	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	4
MB3	5	5	5
MB4	1	3	**2**
MB5	2	1	**1**
MB6	3	2	3

Subwatershed	c. Total Phosphorus		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	5	5
MB3	5	4	4
MB4	2	3	3
MB5	1	1	**1**
MB6	3	2	**2**

7. Nonpoint Source Pollution Management Measures

The Musquapsink Brook Watershed Restoration and Protection Plan is dedicated to projects and efforts to control nonpoint source pollution. In the Musquapsink Brook Watershed, fecal coliform (*E. coli* as replacement standard) and total phosphorus are of greatest concern. Implementation of the suggested projects will aid in achieving the goals set up in the appropriate TMDLs. These projects have been prioritized based on a subwatershed basis, percent removal of pollutants, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment. Projects aim to reduce connected impervious cover, improve riparian buffers, control geese access to streams, and improve stakeholder knowledge on the importance of stormwater management.

7.1 Load Reduction Scenarios

Load reduction targets will adhere to those recommended by USEPA-approved TMDLs for the Musquapsink Brook Watershed. Based on the calculated annual loadings and priority rankings of the subwatersheds provided in Chapter 6 of this report, targeted reductions in total phosphorus and fecal coliform in the downstream portions of the watershed will likely have the most measurable effect on overall watershed loadings. Best management practices (BMPs) will be recommended for all subwatersheds, with a specific focus on implementation in subwatersheds MB4, MB5, and MB6.

7.1.1 Total Phosphorus

The 2005 TMDL load allocation for total phosphorus requires a 10.9% reduction in current loadings to the Musquapsink Brook. According to the calculations provided in Table 11 of the TMDL report for the Musquapsink Brook, the 10.9% load reduction equates to 641 kg/year reduction in total phosphorus loadings for the entire watershed. Since there are not significant point sources identified as contributing to the overall water quality exceedances in this watershed, source reduction needs to be allocated to nonpoint sources. Stormwater is considered a nonpoint source, although MS4s are a regulated point source for both Tier A and Tier B municipalities. Due to the fact that the origin of stormwater is from diffuse sources that run off of the land area, solutions will be determined while the pollutant is still considered nonpoint. Land use in each of the targeted subwatersheds has been evaluated for aerial loading and is a key determinant of recommended BMP types. Tables 22 a, b, and c provide information on calculated total phosphorus loading rates in the watershed.

Table 22: Total Phosphorus Loading Analysis According to 2007 Land use/Land cover Data for the Priority Subwatersheds in the Musquapsink Brook Watershed

a.

Land use: Subwatershed MB4	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Agriculture	7.2	0.61	4.4	0.54%
Forest/Water/Wetlands	196.0	0.04	7.9	0.99%
Urban: Recreational	26.9	0.01	0.3	0.04%
Urban: Residential-High, Medium	777.6	0.65	503.5	62.85%
Urban: Residential-Low, Rural	155.9	0.28	44.2	5.51%
Urban: Cemetery	293.4	0.45	130.6	16.31%
Urban: Athletic Fields	25.9	0.45	11.5	1.44%
Urban: Commercial	28.5	0.97	27.7	3.46%
Urban: Other	59.4	0.45	26.4	3.30%
Atmospheric Deposition (Direct)	1570.8	0.03	44.5	5.55%

b.

Land use: Subwatershed MB5	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Forest/Water/Wetlands	45.6	0.04	1.8	0.90%
Urban: Recreational	14.0	0.01	0.2	0.08%
Urban: Residential-High, Medium	283.9	0.65	183.8	89.14%
Urban: Residential-Low, Rural	13.3	0.28	3.8	1.83%
Urban: Athletic Fields	3.9	0.45	1.7	0.84%
Urban: Commercial	2.7	0.97	2.6	1.25%
Urban: Other	4.2	0.45	1.9	0.91%
Atmospheric Deposition (Direct)	367.6	0.03	10.4	5.05%

c.

Land use: Subwatershed MB6	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Forest/Water/Wetlands	38.0	0.04	1.5	0.66%
Urban: Recreational	5.2	0.01	0.1	0.03%
Urban: Residential-High, Medium	250.6	0.65	162.3	69.33%
Urban: Residential-Low, Rural	17.5	0.28	4.9	2.11%
Urban: Cemetery	15.4	0.45	6.8	2.92%
Urban: Athletic Fields	13.8	0.45	6.2	2.63%
Urban: Commercial	38.6	0.97	37.5	16.00%
Urban: Other	8.6	0.45	3.8	1.63%
Atmospheric Deposition (Direct)	387.6	0.03	11.0	4.69%

The export coefficients used in this analysis were provided by NJDEP using the Loading Coefficient Analysis and Selection Tool (LCAST) database of export coefficients (Al-Ebus, 2003; NJDEP, 2001). The export coefficient for recreational areas, which was not provided by NJDEP, was determined by the average of values presented in LCAST. The unit area phosphorus loading from atmospheric deposition, applied as a direct load, was based on a statewide value from the New Jersey Atmospheric Deposition Network (Eisenreich and Reinfelder, 2001). To achieve a total phosphorus load reduction of 641 kg/year, nonpoint source management measures will aim to remove a significant portion of total phosphorus load from subwatersheds MB4, MB5, and MB6. Cemeteries, medium-high density residential areas, athletic fields, and commercial/service areas will be targeted for BMP implementation. See Table 23 below for targeted land use and the proposed area to be treated by BMPs.

Table 23: BMP Implementation Scenario and Total Phosphorus (TP) Load Reductions

a.

Land use: Subwatershed MB4	**Coverage Area**	**Annual Load**	**TP Removal by BMP**	**Area Treated by BMP**	**Total TP Load Reduction**
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	777.6	503.5	60	500	195
Urban: Residential-Low, Rural	155.9	44.2	60	100	16.8
Urban: Cemetery	293.4	130.6	60	290	78.3

b.

Land use: Subwatershed MB5	Coverage Area	Annual Load	TP Removal by BMP	Area Treated by BMP	Total TP Load Reduction
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	283.9	183.8	60	200	78
Urban: Residential-Low, Rural	13.3	3.8	60	8	1.344
Urban: Commercial	2.7	2.6	60	2	1.164

c.

Land use: Subwatershed MB6	Coverage Area	Annual Load	TP Removal by BMP	Area Treated by BMP	Total TP Load Reduction
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	250.6	162.3	60	200	78
Urban: Commercial	38.6	37.5	60	25	14.55
Urban: Cemetery	15.4	6.8	60	15	4.05
Urban: Athletic Fields	13.8	6.2	60	10	2.7

Assuming the installed BMPs will achieve a 60% removal of total phosphorus from stormwater runoff, the extent of implementation proposed in Table 23 will yield a total reduction of 470 kg TP/year. This accounts for 73% of the total phosphorus loading reductions required by the TMDL. The totals in Table 23 do not account for reductions in atmospheric deposition contributions.

7.1.2 Fecal Coliform/E. coli

Fecal coliform and *E. coli* are present in high concentrations in the Musquapsink Brook Watershed. The main sources of total coliform are wildlife and domestic pet waste, and, to a lesser extent, from human inputs. The 2003 TMDL established for fecal coliform requires a 96% reduction in loadings to the watershed and requires that no sample exceeds a 200 col/100 mL maximum concentration. Since the initiation of this project, the indicator organism of bacterial quality has changed for freshwaters in New Jersey to the use of *E. coli*. The newly adopted water quality criterion for *E. coli* requires that no sample exceeds a 236 col/100 mL maximum concentration. All sampling stations violated the water quality criteria for both fecal coliform and *E. coli* for all sampling events.

Surface water quality sampling results indicate that pathogen loading to the brook occurs during both wet and dry events. Furthermore, MST data and fluorometric detection of optical brighteners indicate human sources of pathogenic contamination are present in the Musquapsink Brook Watershed. The potential for human fecal matter in streams is a serious public health threat and needs to be addressed. All subwatersheds in the

Musquapsink Brook Watershed should be considered for control of bacteria contamination due to the high number of samples that violated the water quality criteria for fecal coliform and *E. coli* (Table 11). Particular focus should be placed on MB4, MB5, and MB6 where preliminary MST data indicates the highest likelihood of human source pathogenic contamination (Table 13 and Figure 13). Control and reduction of pathogen contamination presents several challenges, however. Indicator organisms like fecal coliform and *E. coli* are solely indicators of fecal pollution and are not a direct measure of the amount of fecal contamination. Also, the measurement of fecal coliform and *E. coli* does not identify specific sources as these bacteria are found in many mammals. Further bacteria source trackdown is recommended prior to the implementation of remediation strategies for pathogen loading reductions.

Loading coefficients have not been created for fecal coliform or *E. coli*, making estimation of load reductions by this method inappropriate (NJDEP, 2004). Estimation of fecal coliform and *E. coli* is further made difficult due to multiple sources of fecal contamination (wildlife feces, improper pet waste disposal, leaking septic systems, faulty sewer infrastructure) having different bacteria concentrations and loading rates. For example, Canada geese (*Branta canadensis*) have been noted as a possible source of fecal contamination in the Musquapsink Brook Watershed. The number of geese seen during field visits will vary for each site visit due to the migratory nature of these animals. This makes proper enumeration of potential fecal loads extremely difficult to achieve. Beyond the ability to estimate bacterial loads from sampling data, estimation of bacterial loadings needs to be performed on a site by site basis to determine the impact of proposed water quality improvement projects. While rain gardens have been found to remove 90% of fecal coliform from stormwater runoff (Rusciano and Obropta, 2007) other measures described in this report (such as pervious pavement and rain barrels) do not have available information on bacteria removal rates.

7.2 Urban Best Management Practices

As the population within the Musquapsink Brook Watershed has remained fairly stable and land use has not changed significantly in recent years, the observed impacts to the Musquapsink Brook and within the watershed are not likely due to recent changes in the landscape. Similarly, the scope for future land use changes is limited as it has already reached capacity for development. Therefore, restoration and protection efforts need to focus on changes that can be accomplished within the current land use and environmental framework. This may include a combination of both institutional and structural controls. All proposed recommendations will function to decrease stormwater flows, increase infiltration, and ultimately reduce pollutant loading so that the Musquapsink Brook meets the water quality criteria for its designated uses.

7.2.1 Rain Gardens

Designating areas within the watershed for increased stormwater infiltration is one method to reduce stormwater flow and does not require setting aside large tracts of land for construction. The general theory is to provide portions of the landscape where stormwater typically flows overland, and changing the nature of the surface such that some of the stormwater load is allowed to infiltrate into the ground. This requires permeable soils that allow stormwater to quickly seep into the ground surface before becoming saturated to the point of inefficiency. This recommendation is different from a detention/retention basin as it could spread the load of stormwater control over a large number of smaller infiltration areas, including personal property in the form of rain gardens or infiltration strips.

Rain gardens can be a simple and easily implemented BMP for private land owners. Increased infiltration could also be employed on property right-of-ways where stormwater overland flow occurs. A rain garden is a landscaped, shallow depression designed to capture, treat, and infiltrate stormwater at the source before it reaches to a stormwater infrastructure system or a stream. Plants used in the rain garden help retain pollutants that could otherwise degrade nearby waterways. Rain gardens are becoming popular in suburban and urban areas. These systems not only improve water quality, but also help homeowners minimize the need for watering and fertilizing large turf grass areas and promote groundwater recharge. If designed properly, these systems improve the aesthetics of the urban/suburban neighborhoods through the use of flowering native plants and attractive trees and shrubs. See Figure 18 below for an example of a flourishing rain garden capturing rooftop runoff.

Figure 18: Example of a Rain Garden installed at the Rutgers Cooperative Extension of Burlington County, NJ in the Lower Delaware Watershed

A typical rain garden is designed to capture, treat and infiltrate the water quality storm of 1.25 inches of rain from a 1,000 square foot impervious area from an individual lot (i.e., a 25 foot by 40 foot roof for a house or a 20 foot wide by 50 foot long driveway). By collecting runoff generated by the first 1.25 inches of rainfall, the rain garden prevents the “first flush” of runoff from entering the stream, which characteristically has the highest concentration of contaminants. For the water quality storm of 1.25 inches of rainfall, the rain garden needs to be 10 feet by 20 feet and six inches deep. Since 90% of all rainfall events are less than one inch, rain gardens are able to treat and recharge the majority of runoff from these storms. It is fair to assume, if designed correctly, rain gardens will reduce the pollutant loading from a drainage area by 90 percent wherever they are installed. Furthermore, they will reduce stormwater runoff volumes and reduce the flashy hydrology of local streams. This reduction of flashy hydrology will minimize stream bank erosion and stream bed scour, thereby reducing TSS and phosphorus loads in the waterway. According to Rusciano and Obropta (2007), rain gardens are found to remove 90 percent of fecal coliform from stormwater runoff.

Rain gardens can be installed almost anywhere. Ideally the best installation sites are those where the soils are well-drained so that an underdrain system is not required. However, any diversion runoff and filtration through native vegetation in the watershed would help reduce pollutant loading to the stream.

7.2.2 Permeable Pavement

Reduction of impervious surfaces with the installation of permeable or pervious surfaces is another BMP that can help reduce stormwater flow, increase groundwater recharge and improve water quality. Pervious surfaces can include asphalt, concrete, or even interlocking concrete blocks with soil and grass growing within the voids. These surfaces allow water to pass through the surface into an underlying reservoir (stones or gravel) that provides temporary runoff storage until infiltration to the subsurface soils can occur. Figure 19 demonstrates the ability of pervious concrete to infiltrate stormwater runoff as opposed to causing sheet flow like the impervious counterpart. Primary applications for these surfaces are low traffic or parking areas that do not see a high volume of vehicular traffic but have significant areas of impervious surfaces (Hun-Dorris, 2005).

Figure 19: Example of previous concrete allowing water to flow through it[1]

7.2.3 Green Streets

Roadways cover a significant percentage of land in most urban communities, and thus offer a unique opportunity for stormwater management. Green streets can include combinations of features such as vegetated curb extensions, flow-through planter boxes, and permeable paving to reduce stormwater flow and improve water quality.

[1] "Pervious Concrete Pavement". September 2009. U.S. Environmental Protection Agency. < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=137&minmeasure=5>.

A curb extension is an angled narrowing of a roadway with a concurrent widening of the sidewalk space. Rain gardens can be incorporated into these extensions to capture stormwater flow from streets. Flow-through planter boxes are long, narrow landscaped areas with vertical walls and flat bottoms open to the underlying soil. They allow for increased stormwater storage volume in minimal space. The plants and topsoil within the boxes contribute to stormwater filtering and treatment for improved water quality. Planters may also incorporate street trees. Figures 20 and 21 show common applications of green street features in Portland, Oregon.

Figure 20: Example of a Green Street with incorporation of a Curb Extension and Rain Garden in Portland, OR[2]

Figure 21: Example of a Green Street with incorporation of a flow-through planter in Portland, OR[2]

7.2.4 Rain Barrels

An additional recommendation that may help reduce a limited volume of stormwater flow from personal properties is the installation of rain barrels at roof gutter down spouts. Considering that a vast majority of the watershed is occupied by residential properties,

[2] "Curb Bump-Out Rain Garden". May 2009. Flickr. 2011. <http://www.flickr.com/photos/dcgreeninfrastructure/5036625486/in/photostream>.

there is a large total surface area of roofs that contribute to impervious surface runoff. While many gutter systems drain to lawns where infiltration can occur, a significant portion of drainage systems were observed that drain runoff directly to street curbs and therefore directly to the Musquapsink Brook. With education and awareness, rain barrels could become part of an overall approach for homeowner action. Figure 22 shows an example of an installed rain barrel collecting stormwater from a residential rooftop.

Figure 22: Example of an installed Rain Barrel in the Lower Delaware Watershed

7.2.5 Bank Stabilization and Riparian Buffer Restoration

As presented in Chapter 4 of this plan, there are a number of areas along the Musquapsink Brook where steep and unstable or unvegetated banks are eroding. Figure 23 illustrates an example of these conditions in the watershed. There are several bank stabilization methods that alleviate excessive sedimentation and allow for the interception of direct storm flow. The installation and planting of native riparian plant species in unvegetated areas of the Musquapsink Brook Watershed would stabilize the exposed and eroding bank areas and reduce the sediment load. This form of bank stabilization can be conducted in a relatively cost-effective manner. See Figure 24 for an example of installed live stakes and coir fiber mat for erosion control and stabilization.

Figure 23: Example of an Eroded and Unstable Streambank in Musquapsink Brook Watershed

Increased buffer areas in the riparian corridor can reduce both stormwater flow and pollutant loading. Riparian zones are recognized for their ability to perform a variety of functions, including erosion control by regulating sediment storage, stabilizing stream channels, serving as nutrient sinks, reducing flood peaks, and serving as key recharge points for renewing groundwater supplies. They create better macroinvertebrate habitat within the stream by increasing canopy cover and reducing water temperatures. Additionally, riparian buffers can also deter geese and other waterfowl from entering the waterway.

Figure 24: Erosion control and streambank stabilization with live stake plant material, North Carolina[3]

Finally, there are sections of the Musquapsink Brook where down-cutting is occurring. This is the deepening of the river so that it loses its ability to rise beyond its banks into the floodplain. This disconnection from the floodplain makes the stream flow much faster during storm events and limits its ability to provide stormwater detention in its floodplains. Several of these areas should be examined for possible reconnection to the

[3] Charlotte-Mecklenburg Storm Water Services

floodplain. Once reconnected to the floodplain, flood waters will move much slower downstream and receive treatment by floodplain vegetation. Caution needs to be taken in these reconnection projects so as to not put infrastructure and buildings in danger as a result of flood waters.

7.3 Site Specific Restoration Projects

The major emphasis of the remediation strategies is to retain stormwater runoff and loadings by disconnection of impervious surfaces, riparian corridor restoration, implementing goose/waterfowl deterrents, and initiating or enhancing education for students, homeowners, businesses, etc. on the proper management techniques for runoff and pollutant control. Watershed-wide strategies should readily produce enhancements to the flow regime and water quality throughout Musquapsink Brook Watershed. Site-specific strategies should provide localized remediation for sources of stormwater runoff and the associated contaminants while also serving as a demonstration for universal application to foster a more effective restoration and protection program.

For each subwatershed, BMP opportunities were identified in each municipality. The figures that illustrate theses opportunities are presented in Appendix C. Each site was field inspected and a brief description of the site and possible BMPs are also presented in Appendix C. Each potential project was given a unique identification code. In Tables 24 through 47, information for each project is presented including site description, land use, area of project, existing pollutant loading from each project site as calculated using aerial loading coefficients, recommended management measures and BMP type, estimated implementation costs, and load reductions anticipated by the BMP. Aerial loading coefficients were used to determine the load reductions for total phosphorus, total nitrogen, and total suspended solids. These loading coefficients were multiplied by the area disconnected for each of the identified project sites. Annual pollutant loading reductions and water quantity reductions are based on 90% volume reductions as management measures are designed to capture all runoff from two-year rainfall events and are estimated to capture 90% of the annual rainfall (44.1 inches in Bergen County).

7.3.1 Subwatershed MB1

<u>Borough of Woodcliff Lake</u>

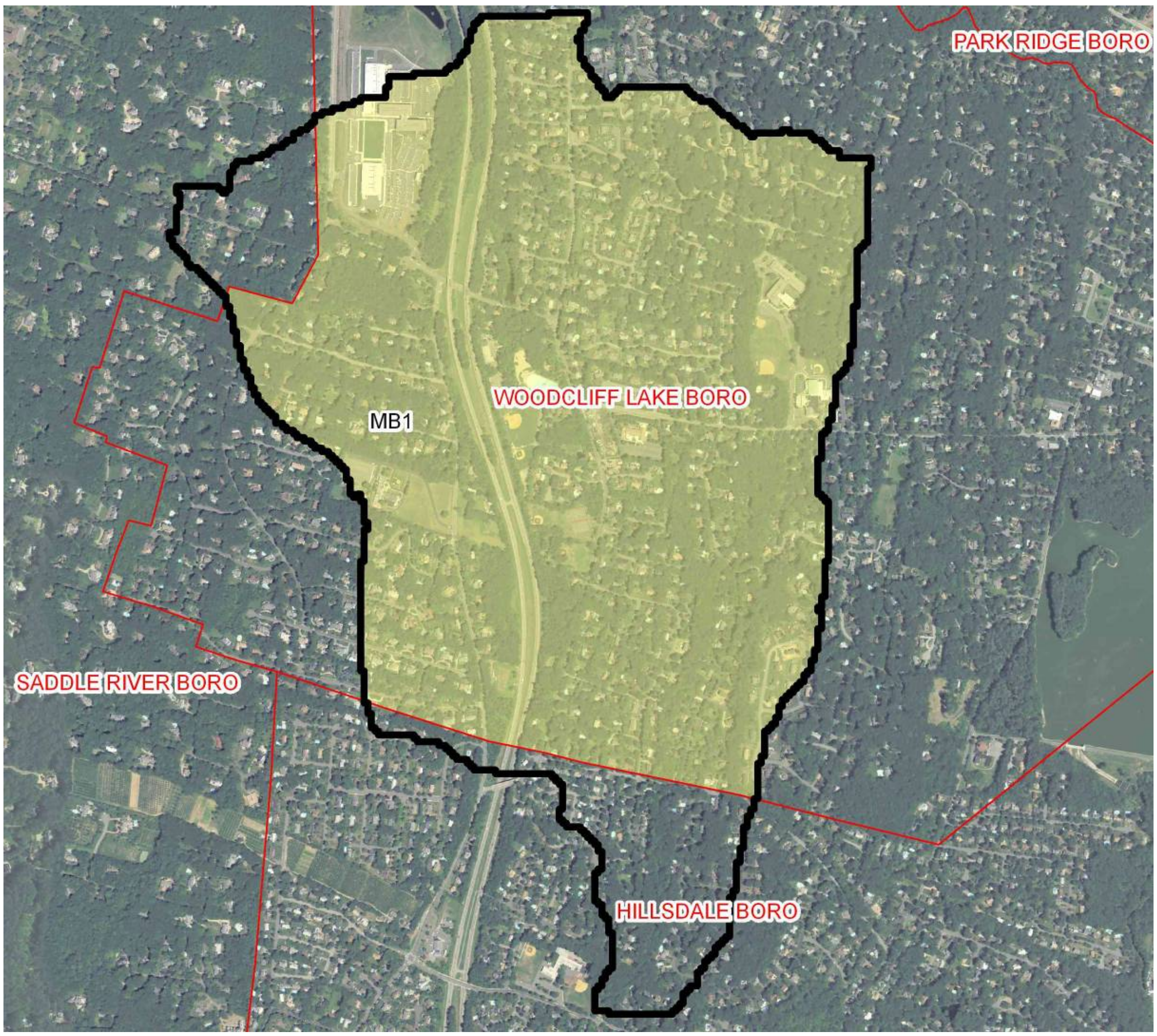

Figure 25: Aerial View of Subwatershed MB1, Borough of Woodcliff Lake Study Area

Table 24: Projects Identified in Subwatershed MB1, Borough of Woodcliff Lake with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB1_WL	a	COMMERCIAL (PARKING)	25	53	47	550	495	5,000	4,500	27
MB1_WL	b	RESIDENTIAL	50	30	27	250	225	5,000	4,500	54
MB1_WL	c	RESIDENTIAL	38	23	21	190	171	3,800	3,420	41
MB1_WL	d	RESIDENTIAL	124	174	156	1,860	1,674	17,360	15,624	134
MB1_WL	e	RECREATIONAL	8	8	7	80	72	960	864	9
MB1_WL	f	RECREATIONAL	16	16	14	160	144	1,920	1,728	17
MB1_WL	g	COMMERCIAL (PARKING)	1	2	2	22	20	200	180	1
		Total	262	303	273	3,090	2,781	34,040	30,636	282
		Total Impervious Cover (Acres)	73							

Table 25: BMP Management Measures for Project Locations in Subwatershed MB1, Borough of Woodcliff Lake

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB1_WL	a	Car Dealership	Disconnection of Parking Lot	Rain Garden Pervious Asphalt	$12,000-$720,000
MB1_WL	b	Residential Neighborhood	Disconnection of Roadway	Rain Garden	$2,000
MB1_WL	c	Residential Neighborhood	Disconnection of Roadway	Pervious Asphalt	$300,000
MB1_WL	d	Residential Neighborhood	Disconnection of Roadway, Rooftops Educational Programs	Rain Garden Grassed Swales Rain Barrels	$6,000-$20,000
MB1_WL	e	Park	Disconnection of Parking Lot, Rooftop	Rain Garden Pervious Asphalt	$2,000-$100,000
MB1_WL	f	School	Disconnection of Parking Lot	Rain Garden	$2,000
MB1_WL	g	Church	Disconnection of Parking Lot	Pervious Asphalt	$450,000

7.3.2 Subwatershed MB2

Hillsdale Borough

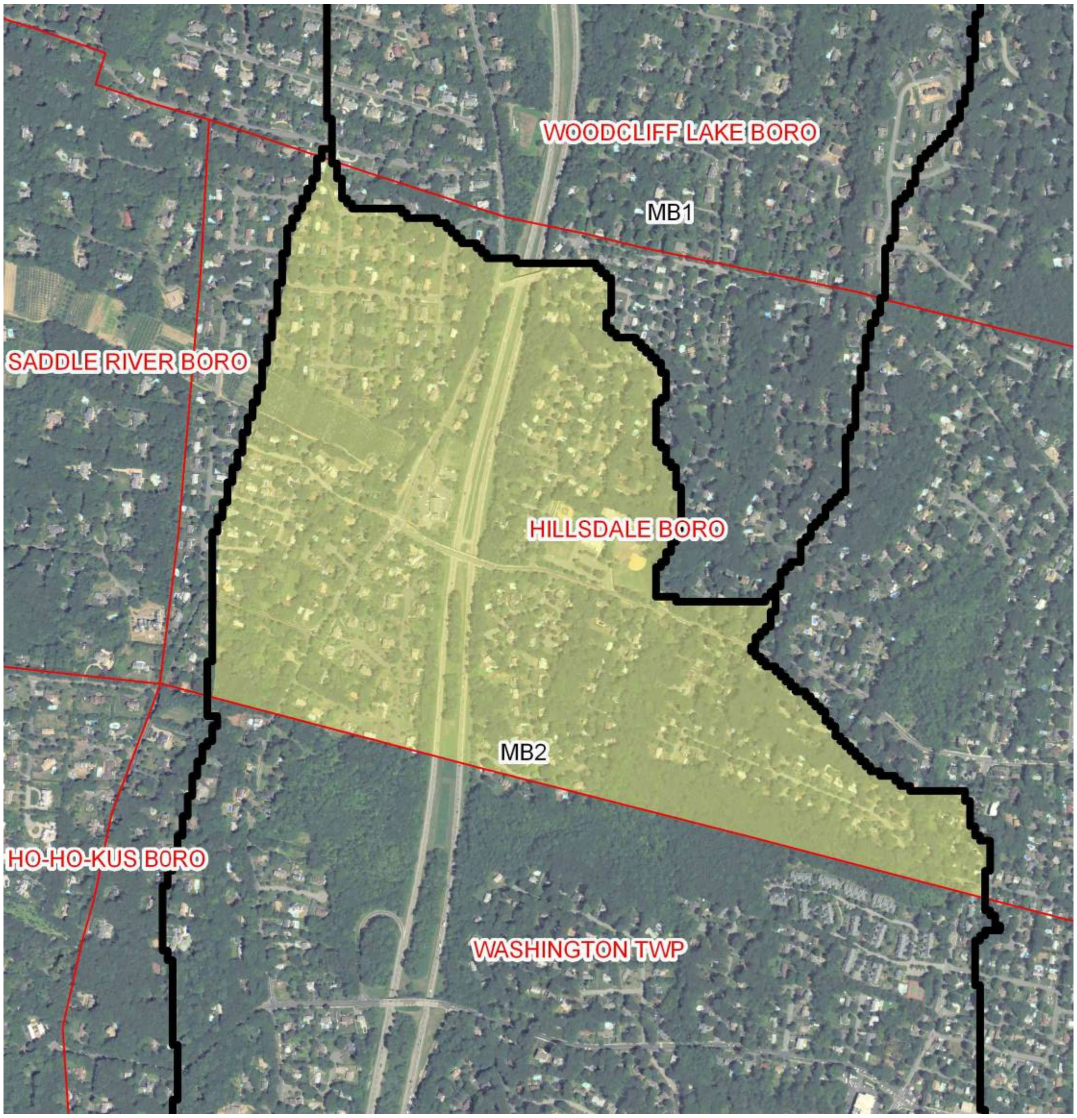

Figure 26: Aerial View of Subwatershed MB2, Hillsdale Borough Study Area

Table 26: Projects Identified in Subwatershed MB2, Hillsdale Borough with Load Reduction Scenarios

Project ID		LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB2_H	a	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB2_H	b	RESIDENTIAL	40	24	22	200	180	4,000	3,600	43
MB2_H	c	RESIDENTIAL	32	19	17	160	144	3,200	2,880	34
MB2_H	d	RECREATIONAL (SCHOOL)	8	8	7	80	72	960	864	9
		Total	83	58	52	506	455	8,760	7,884	89
		Total Impervious Cover (Acres)	19							

Table 27: BMP Management Measures for Project Locations in Subwatershed MB2, Hillsdale Borough

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB2_H	a	Business	Disconnection of Parking Lot	Pervious Asphalt Planter Boxes	$150,000
MB2_H	b	Residential Neighborhood	Disconnection of Rooftop Educational Programs	Rain Gardens Rain Barrels	$10,000-$20,000
MB2_H	c	Residential Neighborhood	Disconnection of Roadway	Green Streets	$1,540,000
MB2_H	d	School	Disconnection of Parking Lot	Rain Garden	$2,000-$4,000

Washington Township

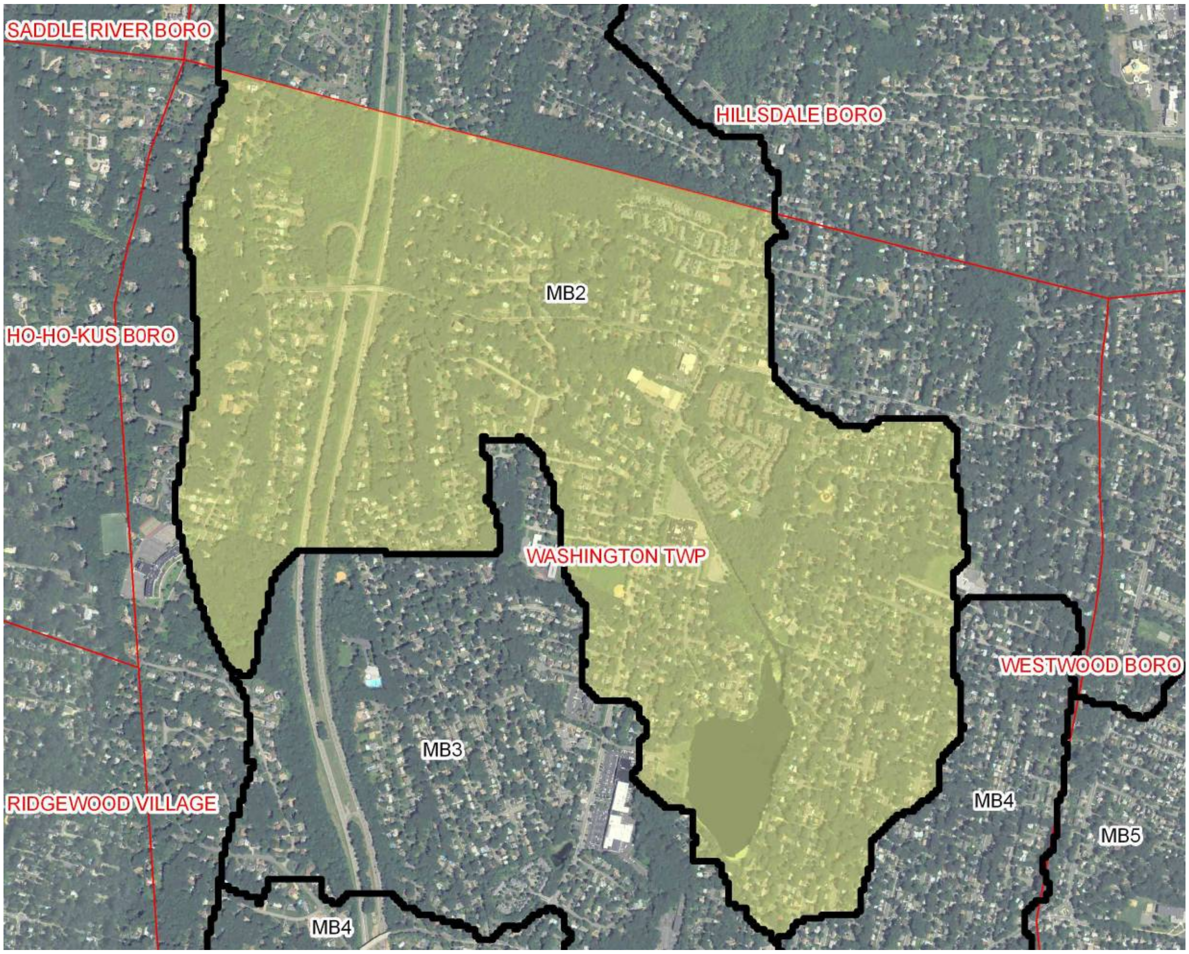

Figure 27: Aerial View of Subwatershed MB2, Washington Township Study Area

Table 28: Projects Identified in Subwatershed MB2, Washington Township with Load Reduction Scenarios

Project ID		LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB2_Wa	a	COMMERCIAL	8	17	15	176	158	1,600	1,440	9
MB2_Wa	b	COMMERCIAL	7	15	13	154	139	1,400	1,260	8
MB2_Wa	c	COMMERCIAL	1	2	2	22	20	200	180	1
MB2_Wa	d	RESIDENTIAL	18	11	10	90	81	1,800	1,620	19
MB2_Wa	e	RESIDENTIAL	35	21	19	175	158	3,500	3,150	38
MB2_Wa	f	RESIDENTIAL	12	7	6	60	54	1,200	1,080	13
MB2_Wa	g	RESIDENTIAL	27	16	15	135	122	2,700	2,430	29
MB2_Wa	h	RECREATIONAL (SCHOOL)	6	6	5	60	54	720	648	6
		Total	114	95	85	872	785	13,120	11,808	123
		Total Impervious Cover (Acres)	50							

Table 29: BMP Management Measures for Project Locations in Subwatershed MB2, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB2_Wa a	Recreation	Disconnection of Parking Lot	Naturalize basin, swale Rain garden Pervious pavement	$12,100
MB2_Wa b	Commercial	Disconnection of Parking Lot	Pervious Pavement	$100,000
MB2_Wa c	Commercial	Disconnection of Parking Lot	Pervious Pavement Rain gardens	$96,200
MB2_Wa d	Residential	Disconnection of Rooftop	Rain barrels Green Alleyway	$70,680
MB2_Wa e	Residential	Disconnection of Rooftop	Rain Gardens Rain Barrels	$22,000
MB2_Wa f	Residential	Disconnection of Rooftop	Rain Gardens Rain Barrels Naturalize Basin, Swale	$22,040
MB2_Wa g	Park	Disconnection of Parking Lot	Rain Garden Shoreline Stabilization	$3,300
MB2_Wa h	School	Disconnection of Parking Lot	Rain Garden Pervious Pavement	$50,400

7.3.3 Subwatershed MB3

<u>Washington Township</u>

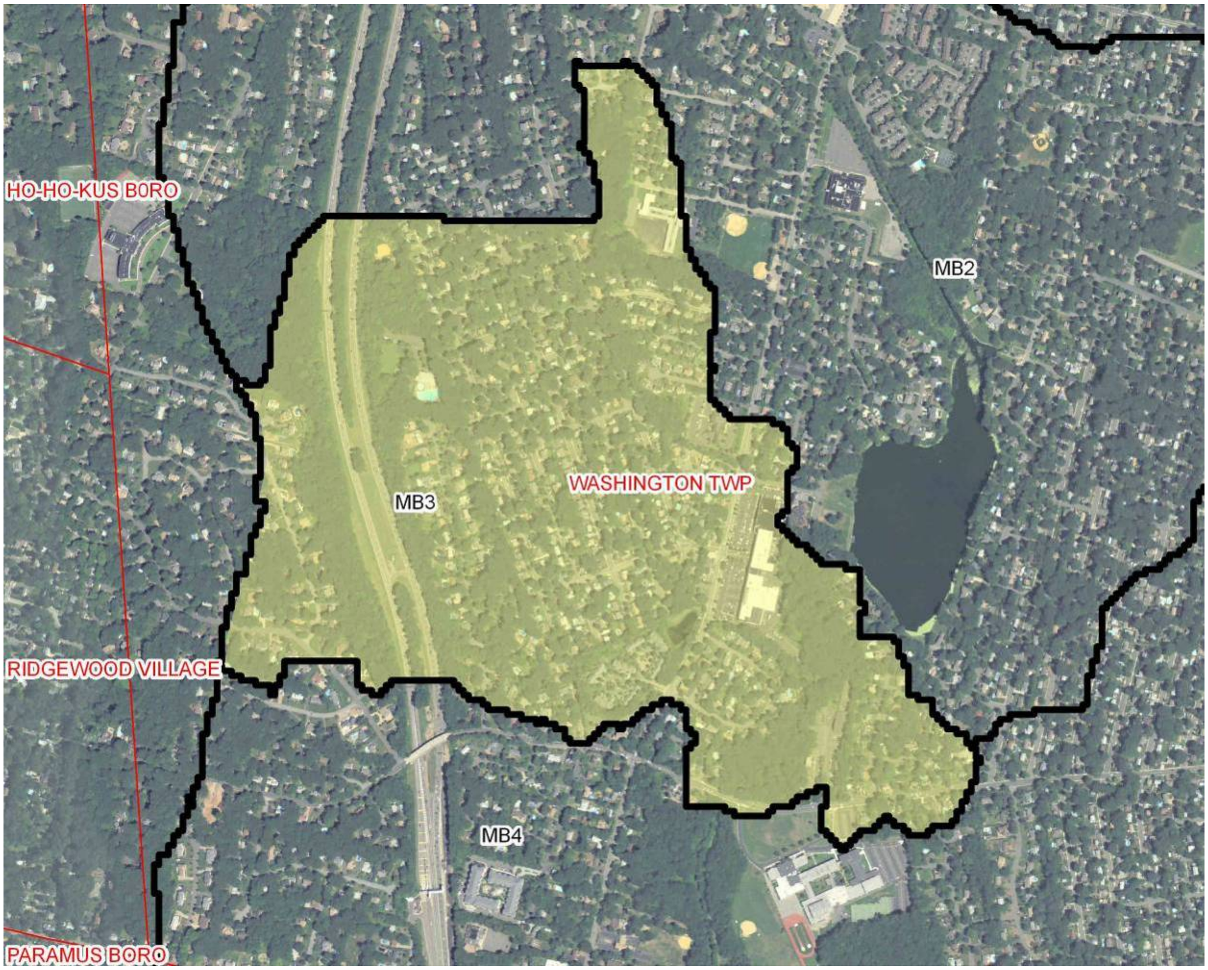

Figure 28: Aerial View of Subwatershed MB3, Washington Township Study Area

Table 30: Projects Identified in Subwatershed MB3, Washington Township with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB3_Wa	a	COMMERCIAL (PARKING)	14	29	26	308	277	2,800	2,520	15
MB3_Wa	b	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB3_Wa	c	RESIDENTIAL	4	2	2	20	18	400	360	4
MB3_Wa	d	RESIDENTIAL	9	5	5	45	41	900	810	10
MB3_Wa	e	RESIDENTIAL	11	7	6	55	50	1,100	990	12
MB3_Wa	f	RESIDENTIAL	37	22	20	185	167	3,700	3,330	40
MB3_Wa	g	RECREATIONAL	3	3	3	30	27	360	324	3
MB3_Wa	h	RECREATIONAL (SCHOOL)	4	4	4	40	36	480	432	4
		Total	85	79	71	749	674	10,340	9,306	92
		Total Impervious Cover (Acres)	40							

Table 31: BMP Management Measures for Project Locations in Subwatershed MB3, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost ($)
MB3_Wa a	Commercial	Disconnection of Parking lot	Rain Garden/Pervious Asphalt/Swale/Increase buffer	$156,800
MB3_Wa b	Church	Disconnection of Parking lot	Disconnect downspouts/Rain Gardens	$840
MB3_Wa c	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels	$11,680
MB3_Wa d	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$33,900
MB3_Wa e	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$13,500
MB3_Wa f	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$79,800
MB3_Wa g	Recreation	Disconnection of Parking lot, Rooftop	Pervious Asphalt, Increase Buffer	$106,000
MB3_Wa h	School	Disconnection of Rooftops, Parking lot	Rain Gardens, Pervious Asphalt, Swales	$102,000

7.3.4 Subwatershed MB4

<u>Borough of Emerson</u>

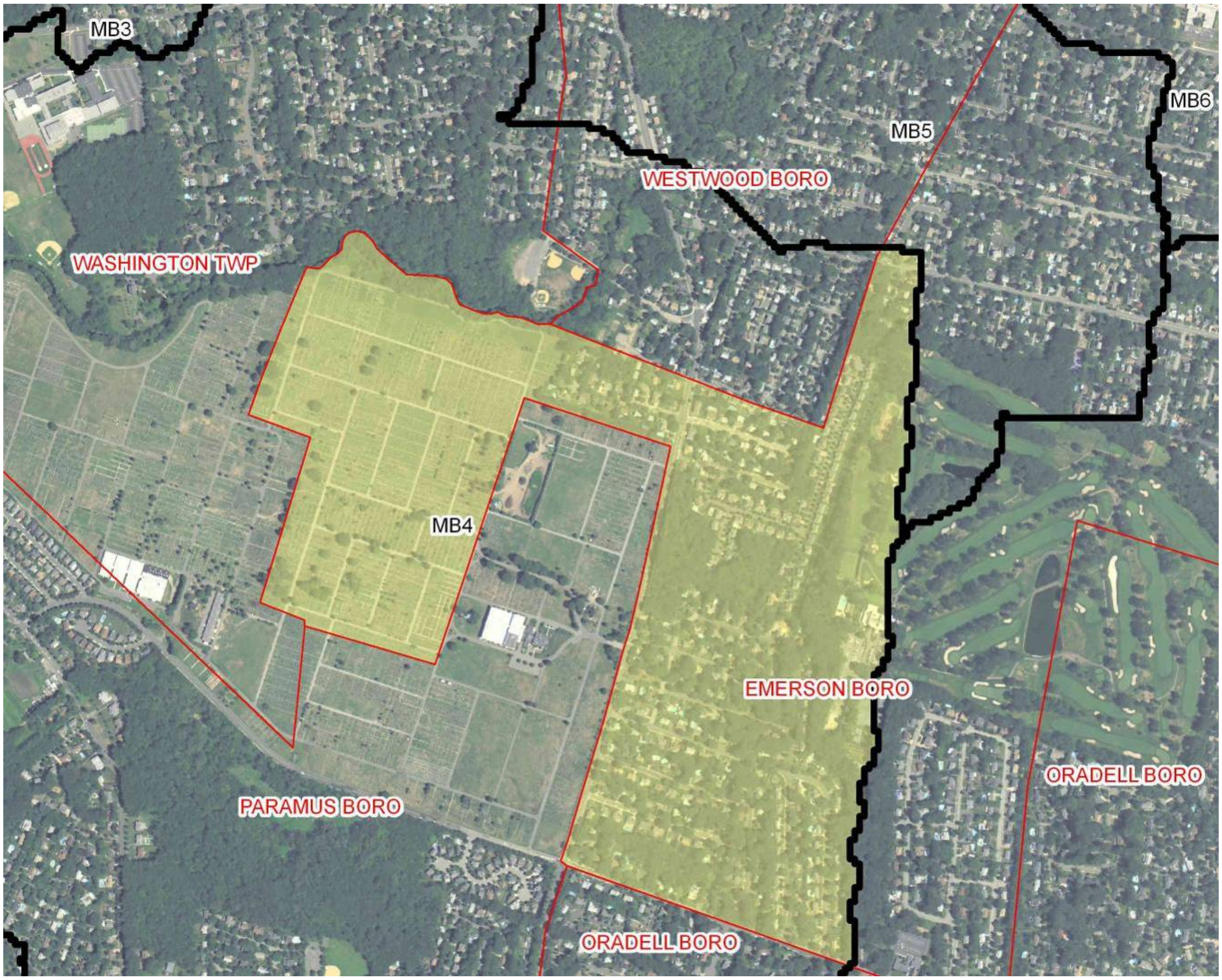

Figure 29: Aerial View of Subwatershed MB4, Borough of Emerson Study Area

Table 32: Projects Identified in Subwatershed MB4, Borough of Emerson with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_E	a	CEMETERY	82	82	74	820	738	9,840	8,856	88
MB4_E	b	RESIDENTIAL	27	16	15	135	122	2,700	2,430	29
MB4_E	c	RESIDENTIAL	61	37	33	305	275	6,100	5,490	66
MB4_E	d	RECREATIONAL	17	17	15	170	153	2,040	1,836	18
		Total	187	152	137	1,430	1,287	20,680	18,612	202
		Total Impervious Cover (Acres)	38							

Table 33: BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Emerson

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_E	a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes	$60,000
MB4_E	b	Residential	Disconnect Rooftops	Rain Gardens/Rain Barrels	$39,600
MB4_E	c	Residential	Disconnect Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$73,400
MB4_E	d	Golf Club	Disconnect Parking Lot	Pervious Pavement	$200,000

Borough of Paramus

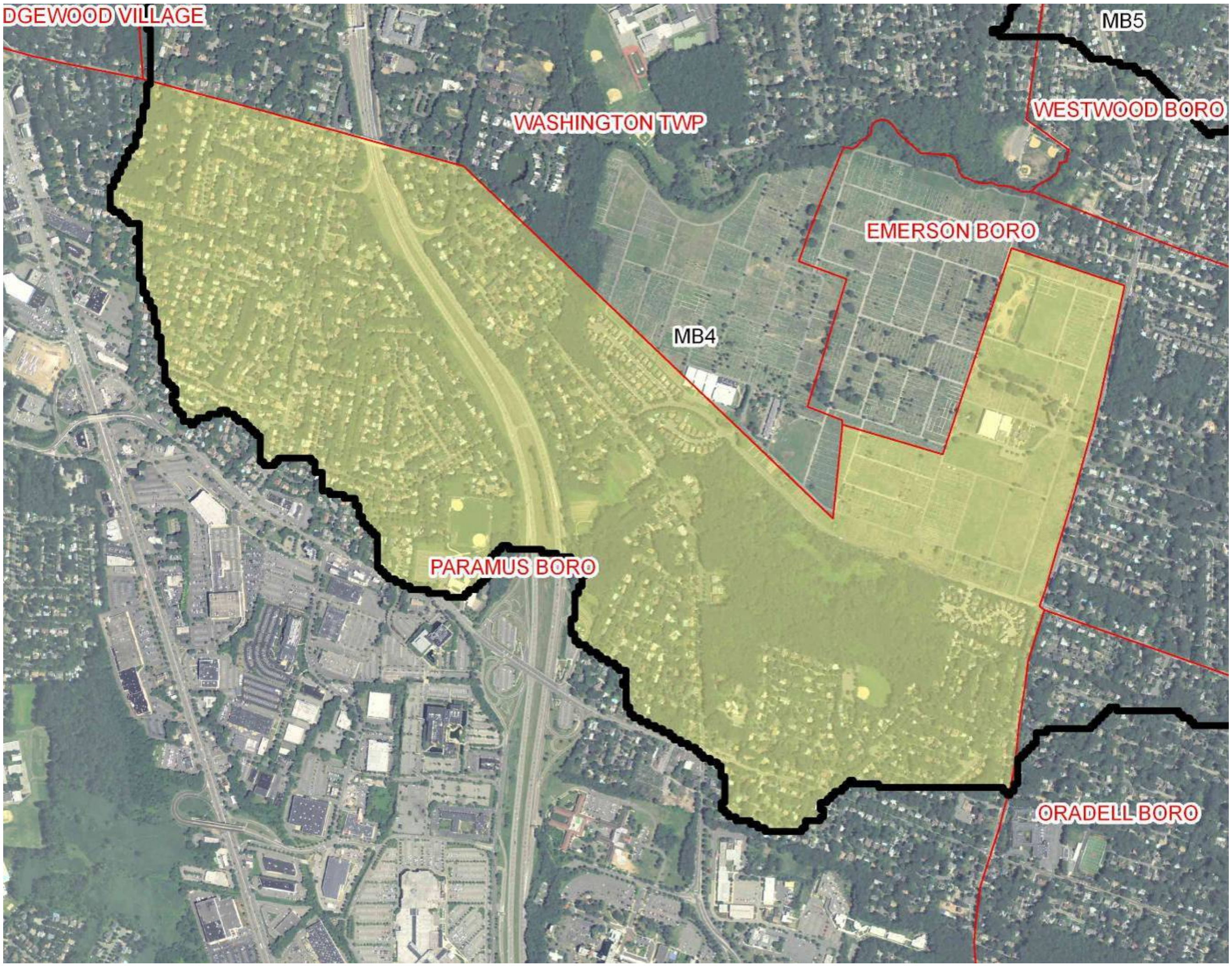

Figure 30: Aerial View of Subwatershed MB4, Borough of Paramus Study Area

Table 34: Projects Identified in Subwatershed MB4, Borough of Paramus with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_P	a	CEMETERY	100	100	90	1,000	900	12,000	10,800	108
MB4_P	b	RESIDENTIAL	42	25	23	210	189	4,200	3,780	45
MB4_P	c	RESIDENTIAL	22	13	12	110	99	2,200	1,980	24
MB4_P	d	RESIDENTIAL	86	52	46	430	387	8,600	7,740	93
MB4_P	e	RESIDENTIAL	29	17	16	290	261	3,480	3,132	31
MB4_P	f	RECREATIONAL (SCHOOL)	12	12	11	120	108	1,440	1,296	13
MB4_P	g	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
		Total	305	228	205	2,230	2,007	33,320	29,988	329
		Total Impervious Cover (Acres)	81							

Table 35: BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Paramus

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_P	a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes	$65,000
MB4_P	b	Residential	Disconnection of Rooftops	Rain Gardens/Rain Barrels	$17,600
MB4_P	c	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$17,600
MB4_P	d	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$89,600
MB4_P	e	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$164,000
MB4_P	f	School	Disconnection of Parking Lot	Rain Gardens/Pervious Pavement	$244,600
MB4_P	g	Residential	Disconnection of Rooftops	Rain Gardens/Rain Barrels	$19,800

Washington Township

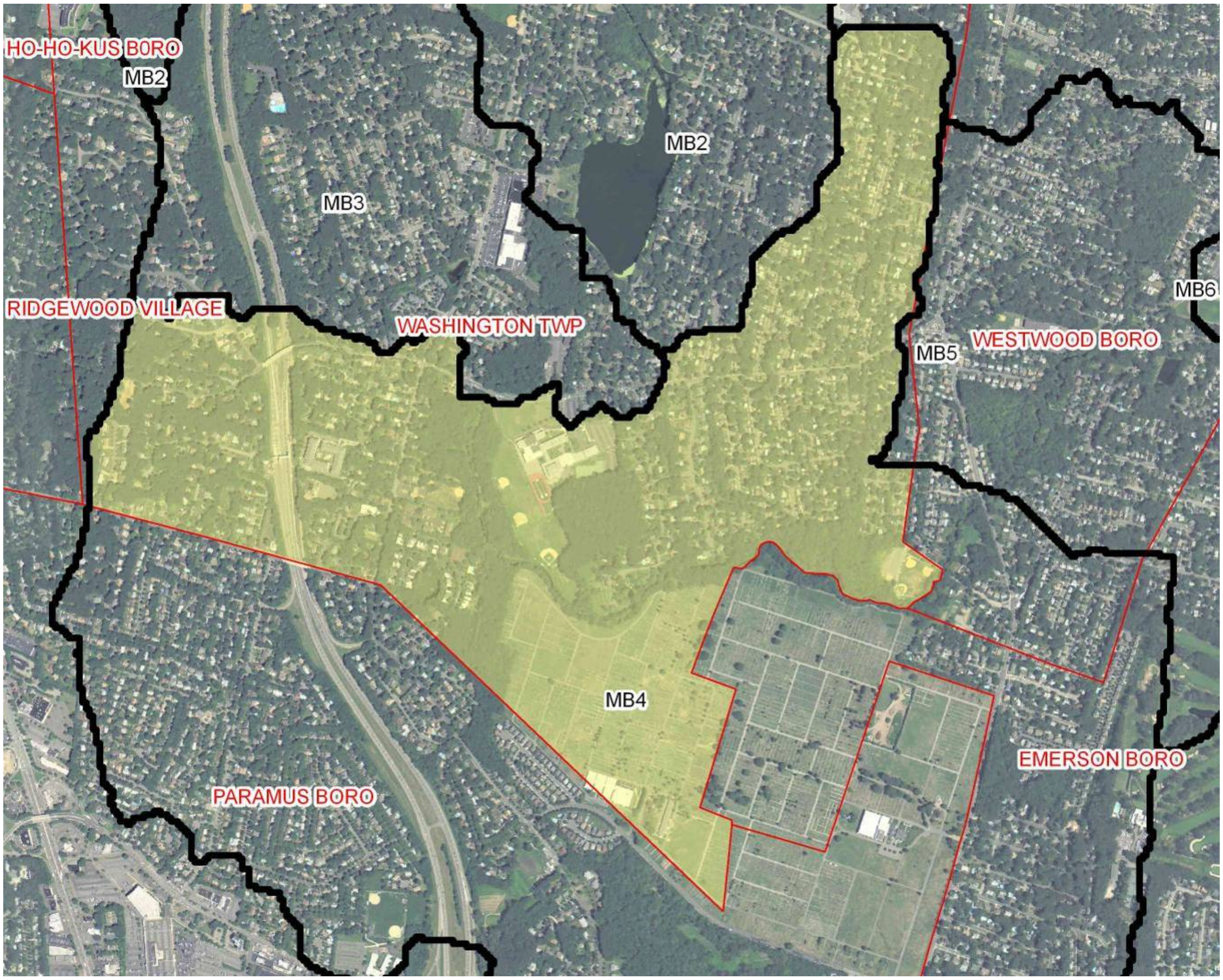

Figure 31: Aerial View of Subwatershed MB4, Washington Township Study Area

Table 36: Projects Identified in Subwatershed MB4, Washington Township with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_Wa	a	CEMETERY	89	89	80	890	801	10,680	9,612	96
MB4_Wa	b	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB4_Wa	c	COMMERCIAL (PARKING)	4	8	8	88	79	800	720	4
MB4_Wa	d	COMMERCIAL (PARKING)	2	4	4	44	40	400	360	2
MB4_Wa	e	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
MB4_Wa	f	RESIDENTIAL	3	2	2	15	14	300	270	3
MB4_Wa	g	RESIDENTIAL	73	44	39	365	329	7,300	6,570	79
MB4_Wa	h	RECREATIONAL	3	3	3	30	27	360	324	3
MB4_Wa	i	RECREATIONAL (SCHOOL)	27	27	24	270	243	3,240	2,916	29
		Total	218	192	173	1,838	1,654	25,080	22,572	235
		Total Impervious Cover (Acres)	55							

Table 37: BMP Management Measures for Project Locations in Subwatershed MB4, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_Wa a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes Rain Garden	$50,800
MB4_Wa b	Public Building	Disconnection of Parking Lot	Rain Garden	$1,600
MB4_Wa c	Church	Disconnection of Rooftops, Roadways	Rain Garden	$800
MB4_Wa d	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$150,000
MB4_Wa e	Recreation	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$12,600
MB4_Wa f	Residential	Disconnection of Rooftops	Cluster Rain Gardens	$20,000
MB4_Wa g	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt	$532,800
MB4_Wa h	Recreation	Disconnection of Roadways	Increase Buffer	$8,000
MB4_Wa i	School	Disconnect Parking Lot, Rooftops	Rain Garden/Pervious Pavement	$151,000

Borough of Westwood

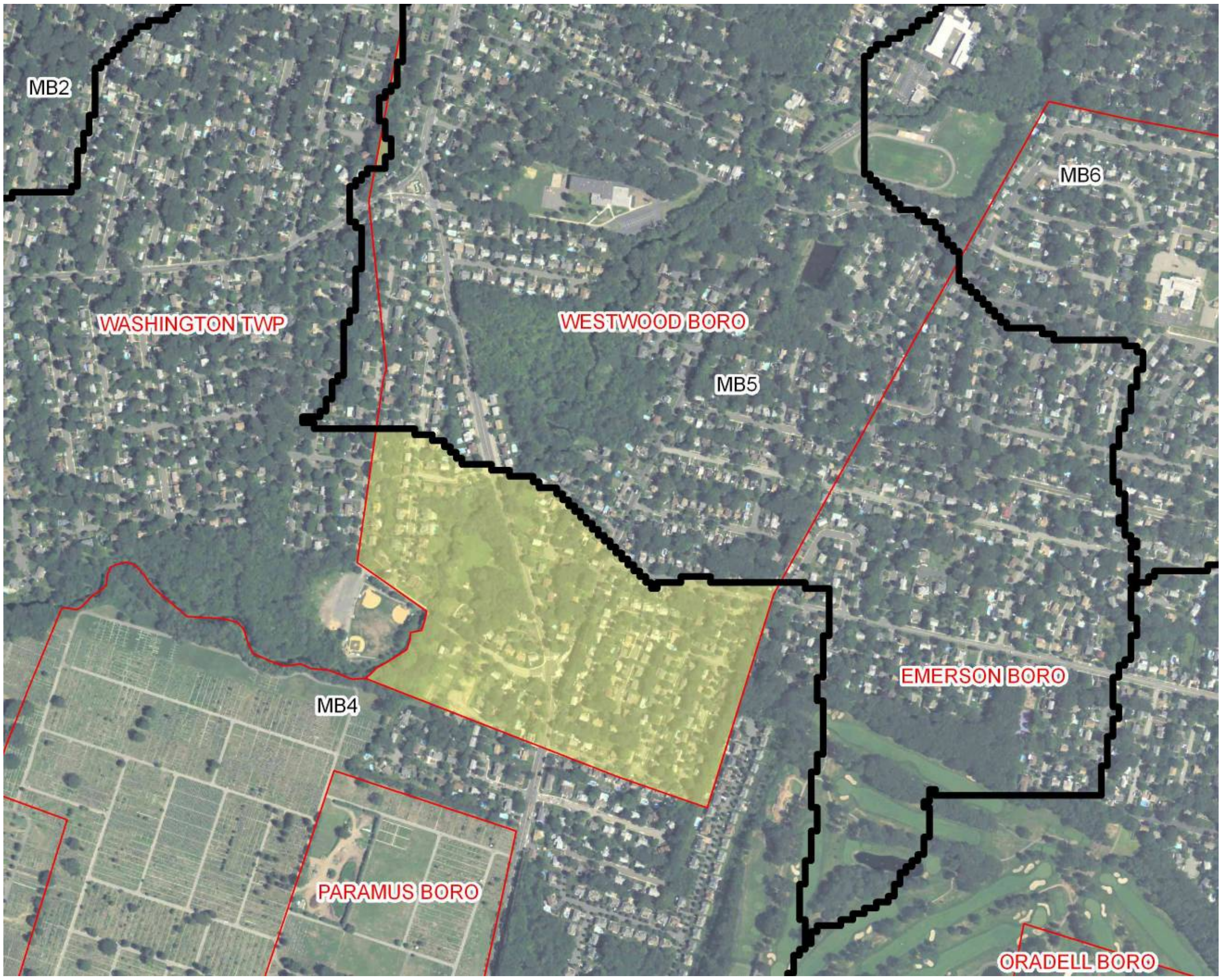

Figure 32: Aerial View of Subwatershed MB4, Borough of Westwood Study Area

Table 38: Projects Identified in Subwatershed MB4, Borough of Westwood with Load Reduction Scenarios

Project ID		LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_We	a	RESIDENTIAL	19	11	10	95	86	1,900	1,710	20
MB4_We	b	RESIDENTIAL	8	5	4	40	36	800	720	9
		Total	27	16	15	135	122	2,700	2,430	29
		Total Impervious Cover (Acres)	10							

Table 39: BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Westwood

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_We	a	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt/Swales	$225,000
MB4_We	b	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt/Swales	$157,300

7.3.5 Subwatershed MB5

Borough of Emerson

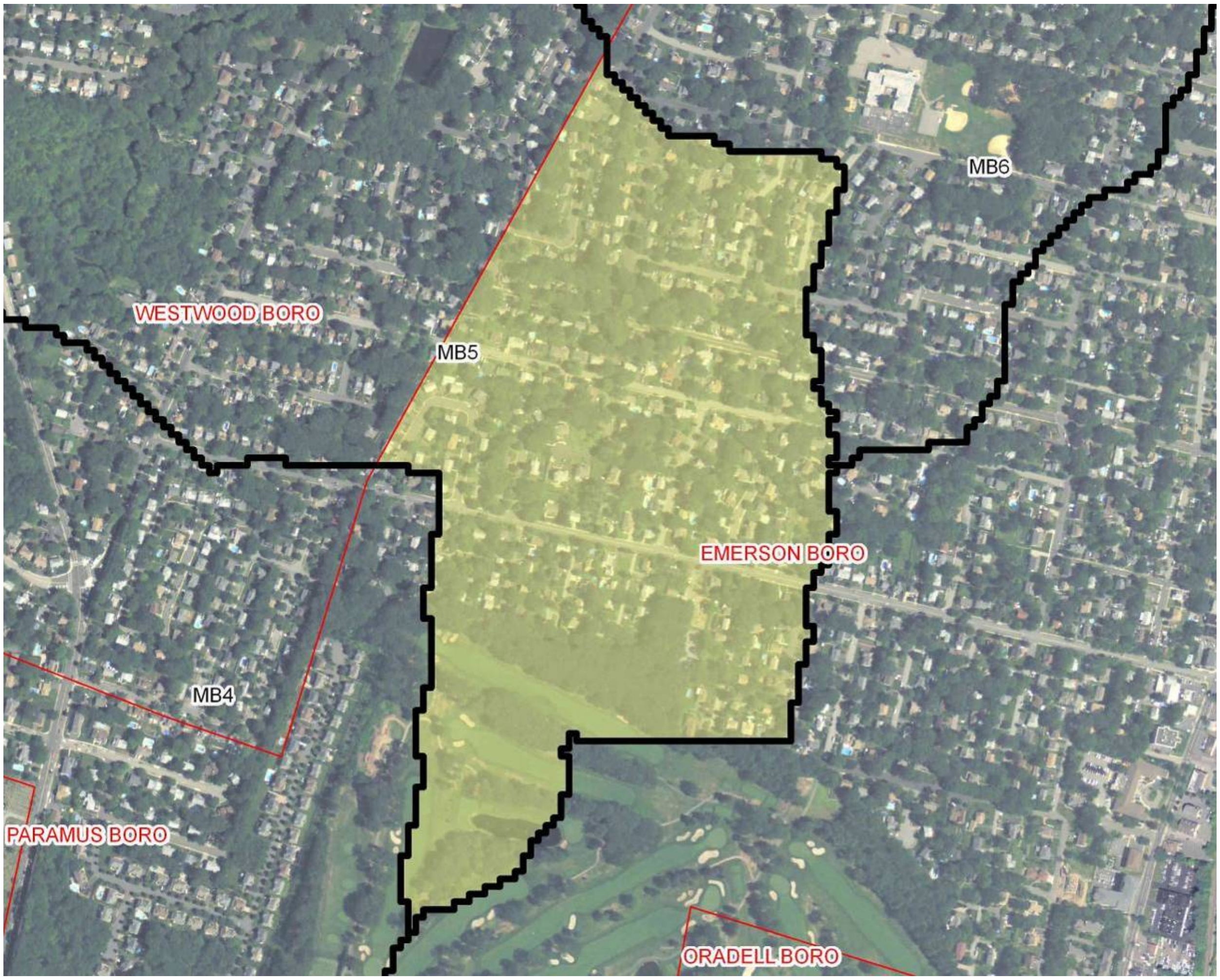

Figure 33: Aerial View of Subwatershed MB5, Borough of Emerson Study Area

Table 40: Projects Identified in Subwatershed MB5, Borough of Emerson with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB5_E	a	RESIDENTIAL	17	10	9	85	77	1,700	1,530	18
MB5_E	b	RESIDENTIAL	11	7	6	55	50	1,100	990	12
		Total	28	17	15	140	126	2,800	2,520	30
		Total Impervious Cover (Acres)	12							

Table 41: BMP Management Measures for Project Locations in Subwatershed MB5, Borough of Emerson

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB5_E	a	Residential	Disconnect Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt	$659,200
MB5_E	b	Residential/Recreation	Disconnect Roadways, Rooftops	Rain Garden	$17,600

Borough of Westwood

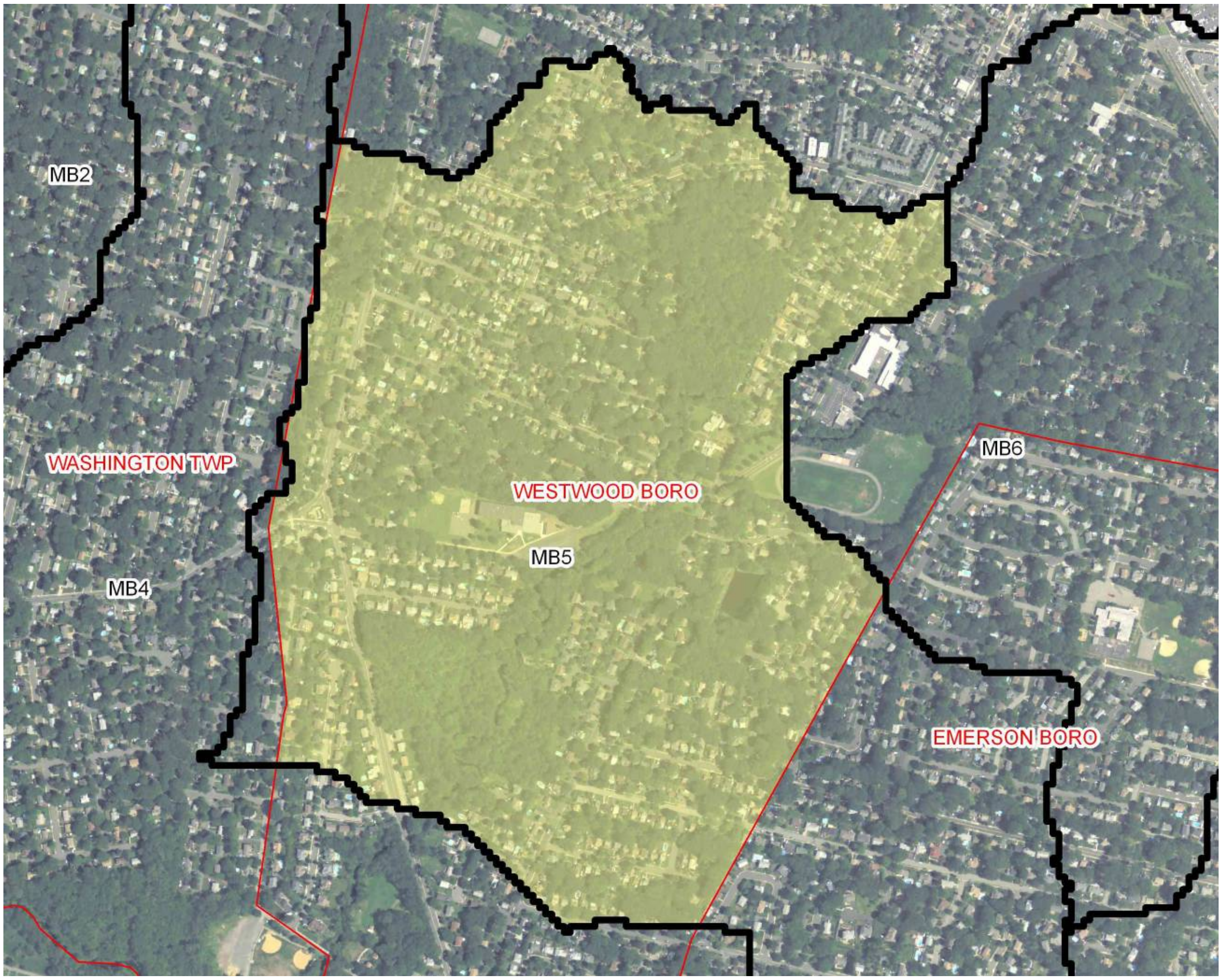

Figure 34: Aerial View of Subwatershed MB5, Borough of Westwood Study Area

Table 42: Projects Identified in Subwatershed MB5, Borough of Westwood with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB5_We	a	RESIDENTIAL	6	4	3	30	27	600	540	6
MB5_We	b	RESIDENTIAL	3	2	2	15	14	300	270	3
MB5_We	c	RESIDENTIAL	20	12	11	100	90	2,000	1,800	22
MB5_We	d	RESIDENTIAL	7	4	4	35	32	700	630	8
MB5_We	e	RESIDENTIAL	10	6	5	50	45	1,000	900	11
MB5_We	f	RESIDENTIAL	3	2	2	15	14	300	270	3
MB5_We	g	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
MB5_We	h	RECREATIONAL	1	1	1	10	9	120	108	1
MB5_We	i	RECREATIONAL (SCHOOL)	6	6	5	60	54	720	648	6
		Total	70	45	40	385	347	7,140	6,426	75
		Total Impervious Cover (Acres)	24							

Table 43: BMP Management Measures for Project Locations in Subwatershed MB5, Borough of Westwood

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB5_We a	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$183,200
MB5_We b	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$93,600
MB5_We c	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$211,000
MB5_We d	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$152,800
MB5_We e	Recreation	Disconnection of Roadways	Increase Buffer	$77,760
MB5_We f	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$76,600
MB5_We g	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$906,000
MB5_We h	Recreation	Riparian Buffer Restoration	Increase Buffer	$20,000
MB5_We i	School	Disconnect Roadways, Rooftops	Rain Garden	$800

7.3.6 Subwatershed MB6

<u>Borough of Emerson</u>

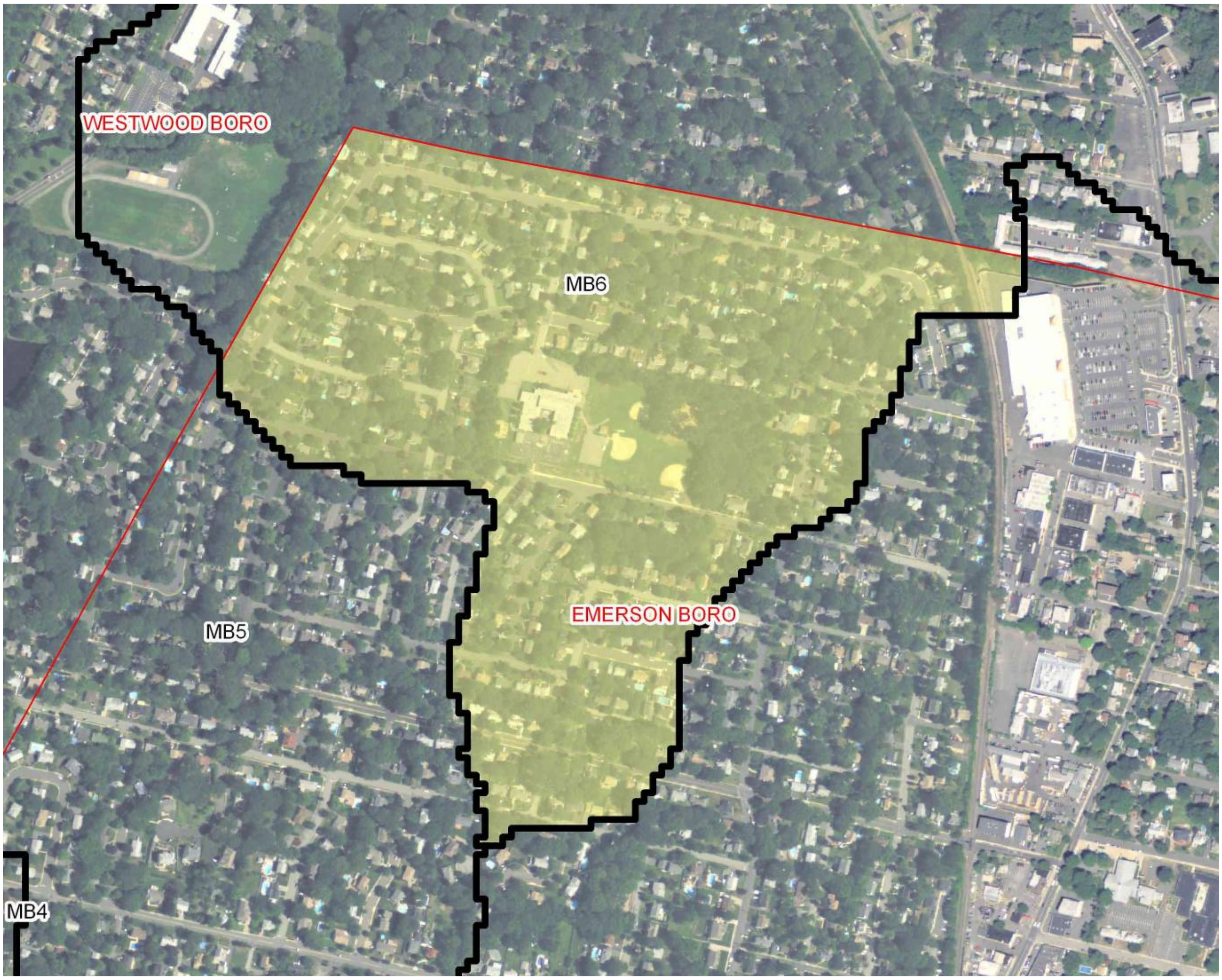

Figure 35: Aerial View of Subwatershed MB6, Borough of Emerson Study Area

Table 44: Projects Identified in Subwatershed MB6, Borough of Emerson with Load Reduction Scenarios

Project ID	LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB6_E a	RESIDENTIAL	19	11	10	95	86	1,900	1,710	20
MB6_E b	RECREATIONAL (SCHOOL)	7	7	6	70	63	840	756	8
	Total	26	18	17	165	149	2,740	2,466	28
	Total Impervious Cover (Acres)	9							

Table 45: BMP Management Measures for Project Locations in Subwatershed MB6, Borough of Emerson

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB6_E a	Residential	Disconnect Roadways	Green Street	$65,000
MB6_E b	School	Disconnect Rooftops	Rain Garden/Rain Barrels	$37,400

Borough of Westwood

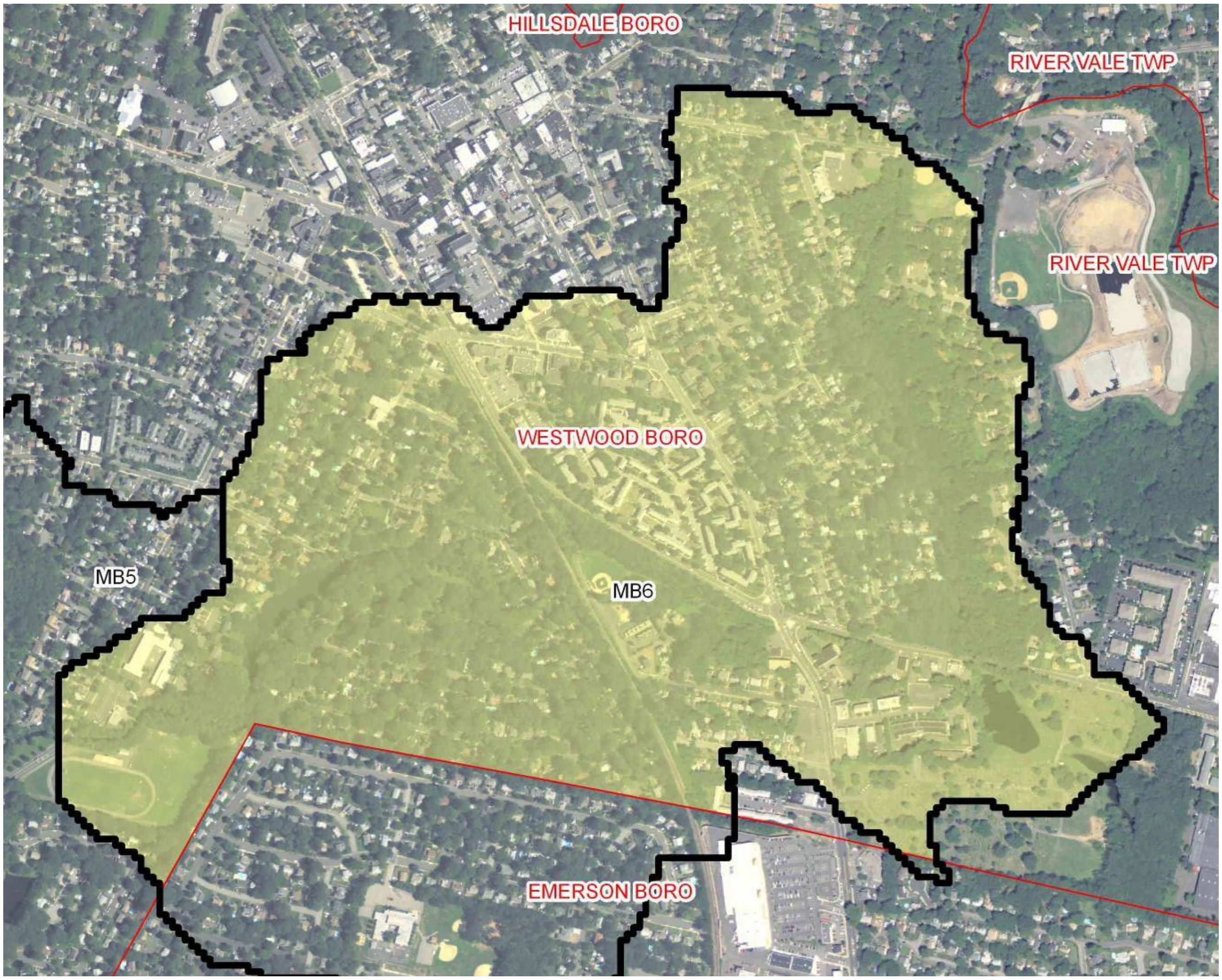

Figure 36: Aerial View of Subwatershed MB6, Borough of Westwood Study Area

Table 46: Projects Identified in Subwatershed MB6, Borough of Westwood with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB6_We	a	RESIDENTIAL	4	2	2	20	18	400	360	4
MB6_We	b	COMMERCIAL	10	21	19	220	198	2,000	1,800	11
MB6_We	c	RESIDENTIAL	4	6	5	20	18	400	360	4
MB6_We	d	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	e	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	f	COMMERCIAL	4	8	8	88	79	800	720	4
MB6_We	g	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	h	RESIDENTIAL	15	9	8	75	68	1,500	1,350	16
MB6_We	i	RESIDENTIAL	4	2	2	20	18	400	360	4
		Total	50	68	61	641	577	7,300	6,570	54
		Total Impervious Cover (Acres)	25							

Table 47: BMP Management Measures for Project Locations in Subwatershed MB6, Borough of Westwood

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB6_We a	Recreation	Disconnection of Roadways	Increase Buffer	$10,000
MB6_We b	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$95,000
MB6_We c	Residential	Disconnection of Parking Lot, Rooftops	Rain Gardens/Rain Barrels	$12,500
MB6_We d	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$75,000
MB6_We e	Commercial	Disconnection of Parking Lot	Pervious Asphalt/Increase Buffer	$99,500
MB6_We f	School	Disconnection of Parking Lot	Rain Gardens	$2,200-$5,500
MB6_We g	School	Disconnection of Rooftop, Parking Lot	Rain Gardens/Permeable Pavement/Green Roof	$90,000-$200,000
MB6_We h	Residential	Disconnection of Rooftop	Rain Gardens/Rain Barrels	$26,500
MB6_We i	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$17,500-$120,000

7.4 BMP Concept Designs

BMP concept designs for five (5) priority projects located in subwatersheds MB4, MB5, and MB6 are included in Appendix D of this report and provide the following project information:

- Summary of current conditions at the location or in the watershed
- Anticipated pollutant removal
- Potential funding sources and project partners
- An estimate of cost

These projects have been prioritized based on a subwatershed basis, percent removal of pollutants, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment. Projects aim to reduce connected impervious cover, improve riparian buffers, control geese access to streams, and improve stakeholder knowledge on the importance of stormwater management.

7.5 Point Source Recommendations

Although the primary focus of this plan is addressing nonpoint source pollution, microbial source tracking was completed and human bacterial contamination was detected, particularly in subwatersheds MB4, MB5, and MB6. Even though the significance of human sources compared to other sources is unknown, it is highly recommended that further study be completed to better track down and then remediate these human sources. A common practice among sewage authorities is to videotape the sanitary sewer lines to identify breaks that might allow wastewater to leak. Municipalities in MB4, MB5, and MB6 should consider videotaping sewer lines and possibly installing liners in areas where leaks are detected.

8. Information and Education

Although site specific projects will address the physical nature of the nonpoint source entry into the waterway, true source reduction is exceedingly enhanced by watershed wide information and educational programs that will bring about a true change of behavior. Programs addressing the use of the land, streamside living, landscaping practices and how it impacts the waterways can be distributed by Rutgers Cooperative Extension, Bergen SWAN, and many other entities.

The Musquapsink Brook Watershed would benefit from the implementation of extension programs similar to New Hampshire's "Landscaping at the Water's Edge" program. "Landscaping at the Water's Edge" was developed by a team of water resource and horticulture specialists to train landscapers and decision makers in ecological landscape practices for protection of water quality in lakes, rivers, streams, and coastal areas. Through collaboration with the USDA NIFA Regional Water Center for Northeast States and Caribbean Islands, a pilot training session has already been offered in New Jersey with great success. States such as Pennsylvania and Virginia also have their own versions of “Streamside Living” educational programs that could be used as models for the development of programs specific to New Jersey needs and conditions. The extension programs should include pertinent information on: limiting the use of pesticides, herbicides, and fertilizer; establishing a no-mow zone along banks; protecting storm drains from debris; planting native trees, shrubs, perennials and grasses; and identifying and removing invasive plants. The curriculum should also include the state and local regulations.

Rutgers Cooperative Extension Water Resources Program offers extension programs that would benefit homeowners, landscapers, and local officials in the Musquapsink Brook Watershed. Descriptions are provided below:

- *Stormwater Management in Your Backyard* program was developed by the Rutgers Cooperative Extension Water Resources Program in collaboration with the USDA Regional Water Program and New Jersey Sea Grant. The program provides educational lectures, hands-on training, and community-level outreach for homeowners and other groups on the topics of water quality issues and management practices such as rain gardens and rain barrels. County Master Gardener and Environmental Steward volunteers play an important role in many aspects of the program;
- *Stormwater Management in Your School Yard* educational program is designed to provide fourth and/or fifth grade students with an opportunity to apply their science, math, and communication skills to real-world environmental problems through the building of a rain garden on the school’s campus. The main focus of the *Stormwater Management in Your School Yard* program curriculum is rain gardens. However, topics such as water, soil, and plant ecology are presented, and connections between these topics and rain gardens are introduced and discussed with the students;
- *Rain Barrel Workshops* are designed to teach participants how to build their own rain barrel and learn how to install it at home. A rain barrel is placed under a downspout next to a house to collect rain water from the roof. The barrel holds approximately 50 gallons of water which can be used to water gardens. The use of collected rain water can save money on water bills, prevent basement flooding, and reduce flooding in local rivers and streams.

Many of these programs have been developed and tested with great success throughout New Jersey. Some may have to be adapted to the specific conditions and issues affecting the Musquapsink Brook Watershed prior to being delivered. Depending on the scope of the need for these programs, additional funding will have to be acquired by the RCE Water Resources Program to deliver the appropriate programs.

9. Implementation Plan and Measurable Milestones

The list of recommendations provides a guide for potential projects to be implemented to improve surface water quality and improve the overall health of the Musquapsink Brook Watershed. The key to successfully implementing these projects in the watershed will be working closely with NJDEP, municipalities, and nonprofit groups to develop a goaloriented schedule and time table. This plan is intended to be a guide for the project partners as they work to achieve water quality improvements in the watershed. The study and recommendations should be viewed as a working document and periodically updated as new issues arise, new data is collected, and when projects have been successfully completed. Modeling and monitoring will be key components in the assessment of restoration project successes.

Five years after the acceptance of an implementation plan, a detailed evaluation should be conducted to quantify the improvements attained in the watershed with respect to water quality. Based upon this evaluation, the priorities in the plan can be modified to further refine the recommendations for management measures, which are needed to ultimately attain the goal of the plan. The project partners should work together to secure funding for this effort.

10. Estimated Budget, Source of Funding, and Technical Assistance

The implementation of the proposed BMPs could be funded through various federal, state and local programs that provide cost-share for implementation. The NJDEP 319(h) program is a viable source of funding for these efforts. In addition, utility companies may also be able to provide monetary contributions and technical assistance. United Water donates close to $1.5 million each year in direct contributions and in-kind services to nonprofit groups across the country who are dedicated to the environment, education, and humanitarian services.

11. Conclusions

The Musquapsink Brook is a valuable resource for New Jersey as it ultimately drains to a reservoir that provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties. Urbanization threatens the water resources within this watershed, and management measures have not been implemented to mitigate the impacts of development. The pollutants entering the waterways of the Musquapsink Brook Watershed impair its uses, including recreational uses and the macroinvertebrate habitat. This plan provides cost effective solutions to improve water quality while maintaining the character of the watershed. It is in the best interest of future generations to create a system of sustainable water resources that will provide for all the needs of the watershed.

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APPENDICES