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Water Resources Program

Musquapsink Brook Watershed Restoration and Protection Plan:
DATA REPORT

Developed by the Rutgers Cooperative Extension Water Resources Program

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Watershed Overview

The Musquapsink Brook Watershed, located above U.S. Geological Survey (USGS) streamflow gauge #01377499 at River Vale, is approximately nine square miles in size and is dominated by urban land uses (Figure 1). The New Jersey Department of Environmental Protection (NJDEP) 2002 land use data identifies the urban land uses as primarily consisting of residential (medium and low density), commercial, and roadways (Figure 2). The remainder of the land use consists of forest, wetlands, water bodies, agriculture, and barren land (NJDEP, 2007).

The Musquapsink Brook Watershed encompasses part of Woodcliff Lake Borough, Saddle River Borough, Hillsdale Borough, Washington Township, Westwood Borough, Emerson Borough, Paramus Borough, and Oradell Borough (Figure 3). The Musquapsink Brook is approximately 6.6 river miles from the headwaters to its confluence with the Pascack Brook. The largest surface water body in the drainage area is Schlegel Lake, which encompasses 26.5 acres.

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

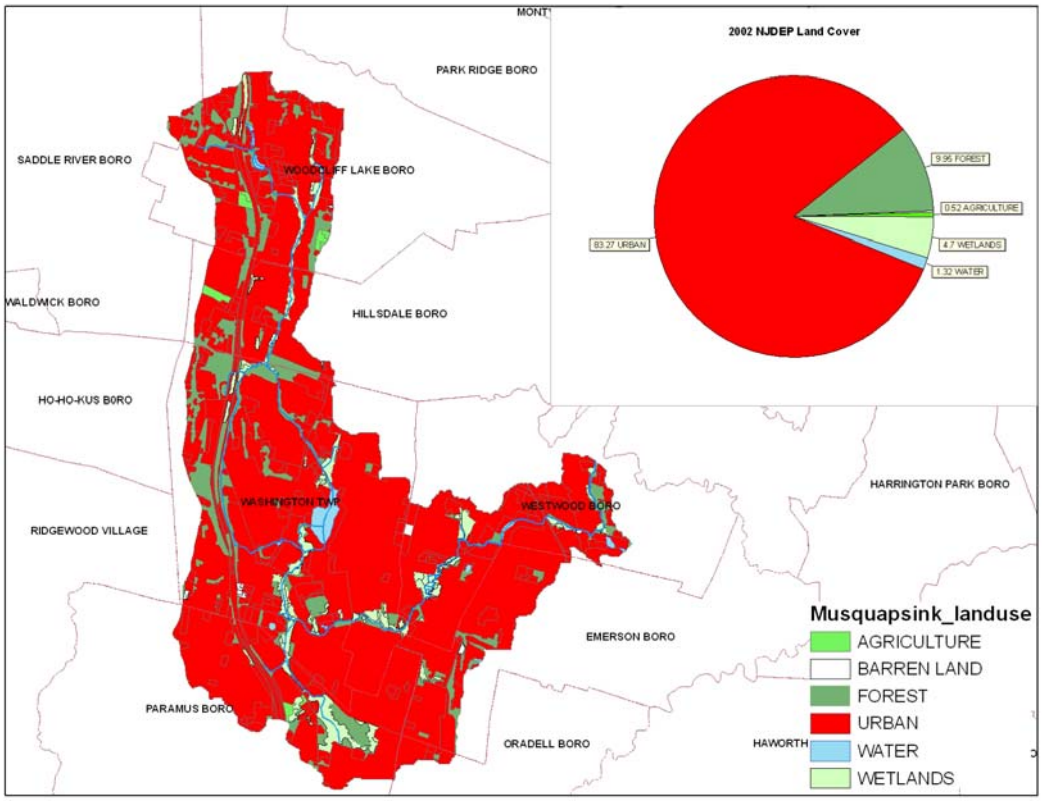

Figure 1: Land use/ land cover map

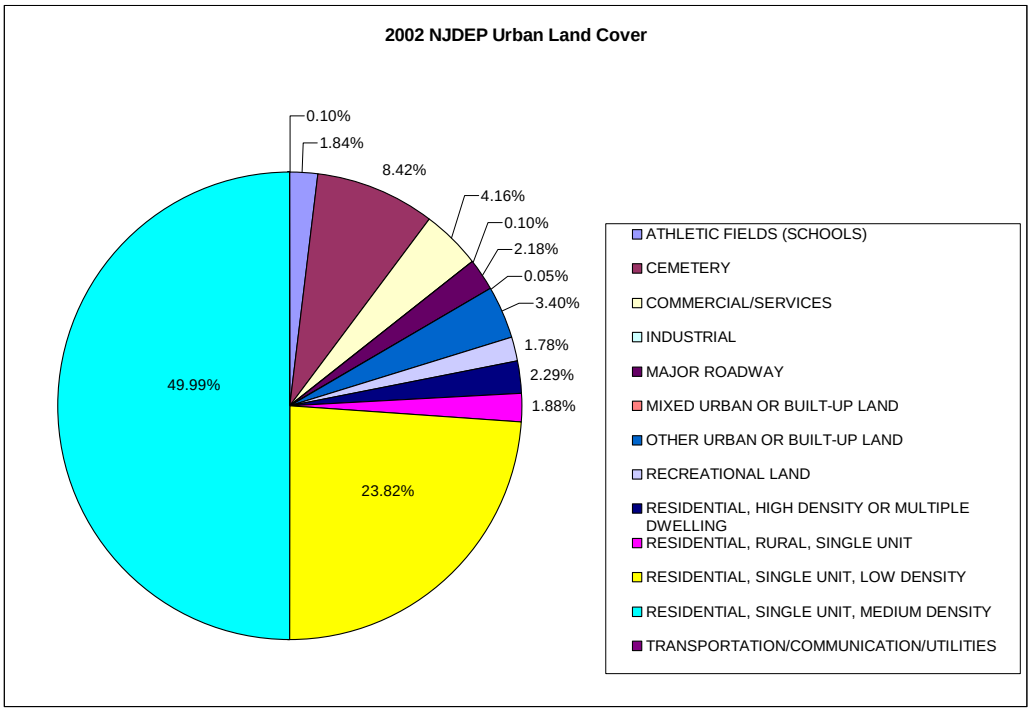

Figure 2: Land use/ land cover types and relative distribution

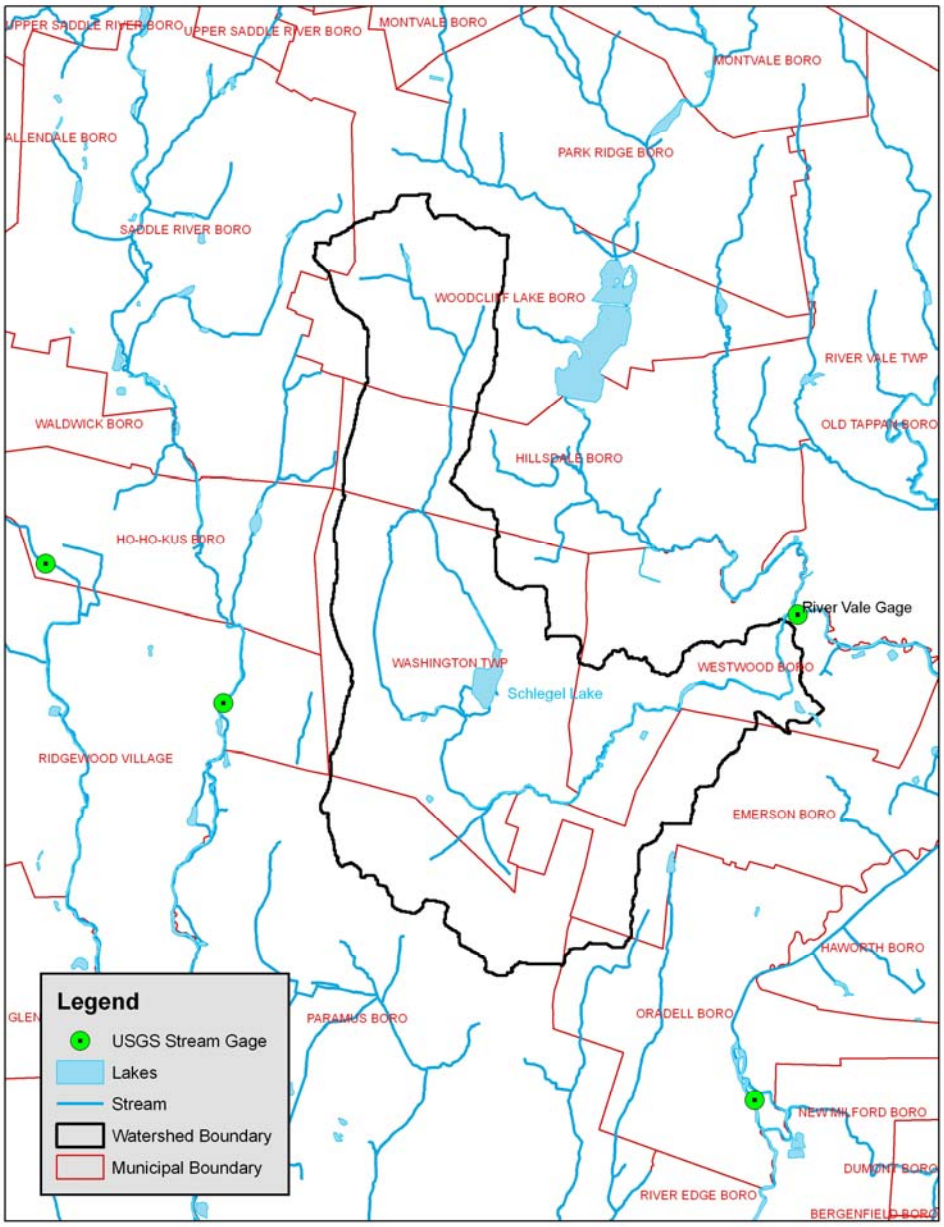

Figure 3: Municipalities and waterbodies located within the Musquapsink Brook Watershed

Project Background and the TMDL Development Process

The development of the Musquapsink Brook Watershed Restoration and Protection Plan was funded in 2007 by the NJDEP (RP 07-002). The project has been established to address a fecal coliform impairment that has been identified in the total maximum daily load (TMDL) developed based on data collected in the Musquapsink Brook at the US Geological Survey (USGS) monitoring station at River Vale (USGS 01377499).

TMDLs are developed by the NJDEP, and approval is given by the US Environmental Protection Agency (USEPA). 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* (NJDEP, 2006). Within this document are lists that indicate the presence and level of impairment for each waterbody monitored. The lists are defined as follows:

- **Sublist 1** suggests that the waterbody is meeting water quality standards.
- **Sublist 2** states that a waterbody is attaining some of the designated uses, and no use is threatened. Furthermore, Sublist 2 suggests that data are insufficient to declare if other uses are being met.
- **Sublist 3** maintains a list of waterbodies where no data or information are available to support an attainment determination.

- **Sublist 4** lists waterbodies where use attainment is threatened and/or a waterbody is impaired; however, a TMDL will not be required to restore the waterbody to meet its use designation.

  ➢**Sublist 4a** includes waterbodies that have a TMDL developed and approved by the USEPA, that when implemented, will result in the waterbody reaching its designated use.

  ➢**Sublist 4b** establishes that the impaired reach will require pollutant control measurements taken by local, state, or federal authorities that will result in full attainment of designated use.

  ➢**Sublist 4c** states that the impairment is not caused by a pollutant, but is due to factors such as instream channel condition and so forth. It is recommended by the USEPA that this list be a guideline for water quality management actions that will address the cause of impairment.

- **Sublist 5** clearly states that the water quality standard is not being attained and requires a TMDL.

Biological monitoring data is available for one location at the outlet of the Musquapsink Brook as part of the **Am**bient Biological Monitoring **Net**work (AMNET), which is administered by the NJDEP. Based upon AMNET and other monitoring sources, water quality impairments have been identified in the Musquapsink Brook. According to the *New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report,* the Musquapsink Brook has been cited with the following listings:

- Sublist 3 - No data or information are available to support attainment determination: cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc;

- Sublist 4 - Attainment is threatened or waterbody is impaired; a TMDL has been developed and/or approved or pollution control measures do not require a TMDL: fecal coliform;
- Sublist 5 - Water quality standard is not being attained and requires a TMDL: aquatic life, total phosphorus, and arsenic. **Arsenic will be addressed by the NJDEP and will not be a focus of this project.**

Based on the TMDL prepared for the Musquapsink Brook at River Vale, USGS 01377499, a 96% reduction in fecal coliform load for 6.6 miles of stream is needed (NJDEP, 2003). Additional aquatic life and total phosphorus surface water quality impairments will also need to be addressed through the TMDL process.

Biological Monitoring Data

Biological monitoring data is available for the Musquapsink Brook Watershed as part of the AMNET program administered by 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. Macroinvertebrates have limited mobility, and thus, are good indicators of site-specific water conditions. 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. Macroinvertebrate communities are a holistic overall indicator of water quality health, which is consistent with the goals of the

Clean Water Act (NJDEP, 2007a). Finally, 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, 2007a). 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.

5. 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 Northeast Basin, habitat assessments were conducted in conjunction with the biological assessments. The first round of sampling under the AMNET program did not

include habitat 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, Bergen County). This station corresponds with the water quality monitoring station MB6. Station AN0206 was sampled by NJDEP in 1993, 1998, and 2003 under the AMNET program. Findings from the AMNET program are summarized in Table 1. 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 1: 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)

The 2007 Biological Assessment by Marion McClary, Jr., Ph.D.

Given these aquatic life impairments, an additional biological assessment was proposed as part of the data collection needed to prepare a comprehensive watershed restoration and protection 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 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 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.

Stream Visual Assessment Protocol (SVAP) Data Collected in the Musquapsink Brook Watershed

Introduction to SVAP

Among the hierarchy of tools used to characterize watershed health, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Stream Visual Assessment Protocol (SVAP) is one method that fills this need. SVAP was originally developed for use by the landowner (USDA, 1998), but it has proved to also be useful by those familiar with the river system and flooding occurrences. The protocol provides an outline on how to quantitatively score in-stream and riparian qualities that includes water appearance, channel condition, and riparian health. There are 10 primary SVAP elements:

- channel condition,
- hydrologic alternation,
- riparian zone,
- bank stability,
- water appearance,
- nutrient enrichment,
- barriers to fish movement,
- instream fish cover,
- presence of pools, and
- invertebrate habitat

In addition, there are elements that should only be scored if applicable. These are canopy cover, manure presence, salinity, riffle embeddedness, and observed macroinvertebrates. Elements are scored 1 to 10 (poor to excellent) with the exception of

observed macroinvertebrates, which uses a scale ranging from 1 to 15. The range of scores is qualitatively described as follows:

- < 6.0 is Poor;
- 6.1-7.4 is Fair;
- 7.5-8.9 is Good;
- 9.0 is Excellent.

The SVAP data sheet was modified to include other reach features that could aid pollution source trackdown in the Musquapsink Brook Watershed. These reach features include the identification of pipes and ditches, details as to erosion or impairment caused by the pipes or ditches, and access to stream reach for restoration. Additionally, all assessed reaches were photo-documented, and a sketch was made denoting important reach characteristics.

SVAP in the Musquapsink Brook Watershed

The visual assessment process in the Musquapsink Brook Watershed began in April 2007. In March 2006, all project partners were trained in using SVAP at the RCE Water Resources Program's SVAP Workshop. The training workshop consisted of a full day of SVAP introduction and use, and the workshop included presentations in a classroom setting and group and paired exercises in the field. Additional training included instructions on how to use the RCE online database entry system for the SVAP data. The Bergen County Department of GIS (geographic information systems) also developed an application to fill out SVAP data on a hand held ArcPad unit, which was used for this project. The Musquapsink Brook watershed was then divided into a grid; grids were assigned to the participating project partners.

Considerations were agreed upon at the onset of the assessment effort. Macroinvertebrates observed were not scored through this SVAP process, since macroinvertebrate data would be collected as part of the NJDEP-approved sampling plan for this project. Also, the manure presence element was expanded to include signs of waterfowl, pet, and wildlife waste. This category is only scored when the presence of manure or animal waste is visible within the reach, which includes the floodplain for that particular reach. As per the SVAP protocol and the agreed upon revisions, the following rules apply:

- A score of "1" indicates that extensive amount of manure is on the banks or in the stream, or, untreated human waste discharge pipes are present.
- A score of "3" indicates occasional manure in the stream, or there is a waste storage structure located on the floodplain.
- A score of "5" indicates evidence of waterfowl, wildlife, or domestic pet access to riparian zone.

Only one reach was scored for manure presence out of the 38 reaches assessed; this location is shown in Figure and had a manure presence score of 3 indicating occasional manure in the stream, or there is a waste storage structure located on the floodplain.

Figure 4: Manure presence at 3rd Street in the Musquapsink Brook Watershed

SVAP Data

Thirty eight stream reaches were evaluated in the Musquapsink Brook Watershed; the stream reaches and the average SVAP scores are identified in Figure . The average overall SVAP score was 6.7, a "fair" score (Table 2). 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" (Table 2). The remaining fifteen reaches were rated as "poor." The reaches that were rated as poor were located along the entire length of the Musquapsink Brook (Figure 5). Tabulated SVAP data are provided in Appendix B.

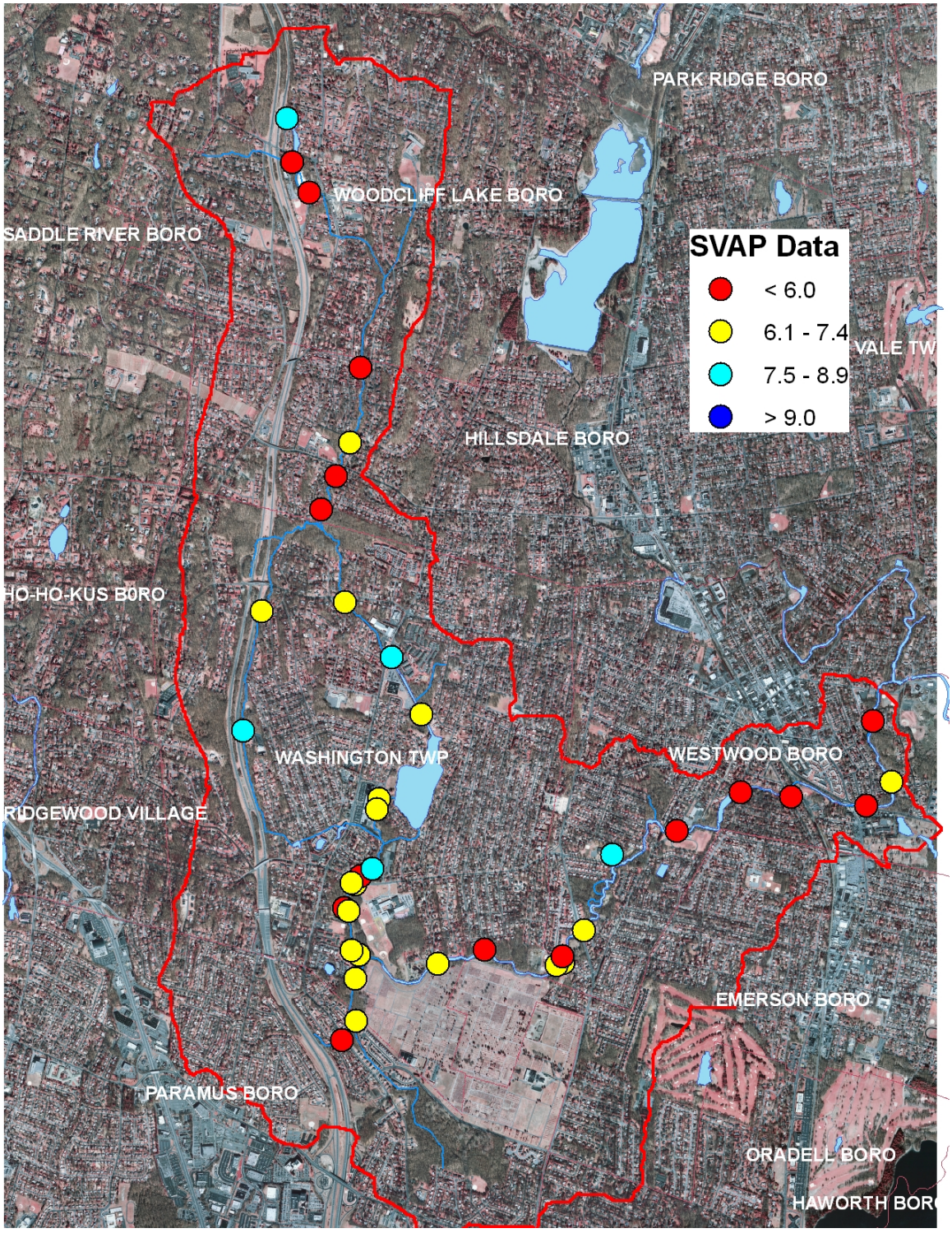

Figure 5: Stream visual assessment reaches with scores in the Musquapsink Brook Watershed

Table 2: SVAP assessment elements and data

	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.*

Using the SVAP Data

SVAP scores will be evaluated as individual assessment elements and combined with other data collected as part of this restoration planning effort. The SVAP results will be 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 will be used to identify sources of pollution and potential opportunities for improved management.

Water Quality Sampling Overview

Project partners, including NJDEP, the RCE Water Resources Program, and the Bergen County Department of Health Services, began water quality monitoring on May 25, 2007. As per the approved Quality Assurance Project Plan (QAPP) provided in Appendix C, *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured across the transect of the stream at each sampling station. Using this information, flow rate was calculated for each event where access to the stream was deemed safe. Water samples were collected and analyzed by two separate laboratories. The Bergen County Utility Authority conducted analyses for total phosphorus (TP), dissolved orthophosphate phosphorus (PO_4^{3-}), ammonia-nitrogen (NH_3-N), total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), total suspended solids (TSS), and fecal coliform. Garden State Laboratories analyzed samples for *Escherichia coli* (*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, total suspended solids, fecal coliform, and *E. coli* and had no specific weather conditions directing the sample collection. Bacteria-only monitoring was conducted in the summer months of June, July, and August 2007, again without conditions set by the weather. The bacteria-only sampling entailed collecting three additional samples in each of those months. Flow was measured, and *in situ* measurements were taken during these events. The dates and the types of monitoring events are summarized in Table 3.

Three storm events were supposed to be collected as part of this project. Due to the weather patterns and timing of storms during the six months of monitoring, only one storm event was encountered that would meet the requirements of the approved QAPP. Surface water samples collected during this storm were taken twice on October 10, 2007 and one the following morning on October 11, 2007. In addition to the one storm sampling event, several sampling events were representative of 'wet' conditions in the watershed.

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;

Table 3: Water quality monitoring events

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

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 also 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” in Table 3.

Surface water samples from eight water quality monitoring stations were regularly collected over the six-month sampling time frame. These stations are depicted in Figure 6. Six stations were located on the Musquapsink Brook, and two were located adjacent to the UWNJ transfer intake located at the confluence of the Saddle River and the Ho Ho Kus Brook. The stations are identified in Table 4 .

A record of the water transfers to the Musquapsink Brook was obtained from UWNJ. It shows that transfers were made on 188 days out of the 214 day interval between June 1, 2007 and December 31, 2007. The total volume of water transferred was 551 million gallons. Figure 7 shows the water transfer record.

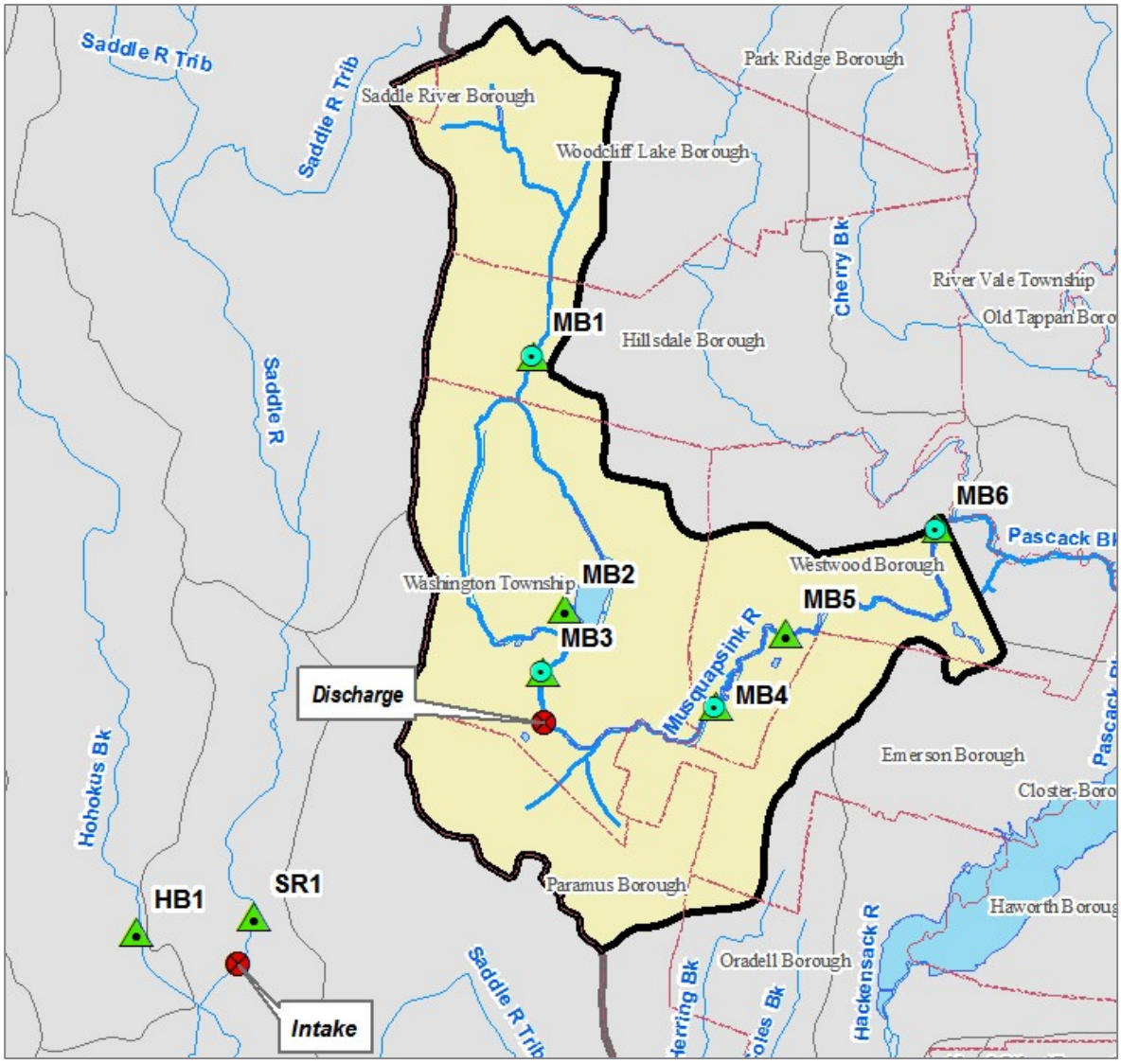

Figure 6: Water quality sampling location map

Table 4: 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

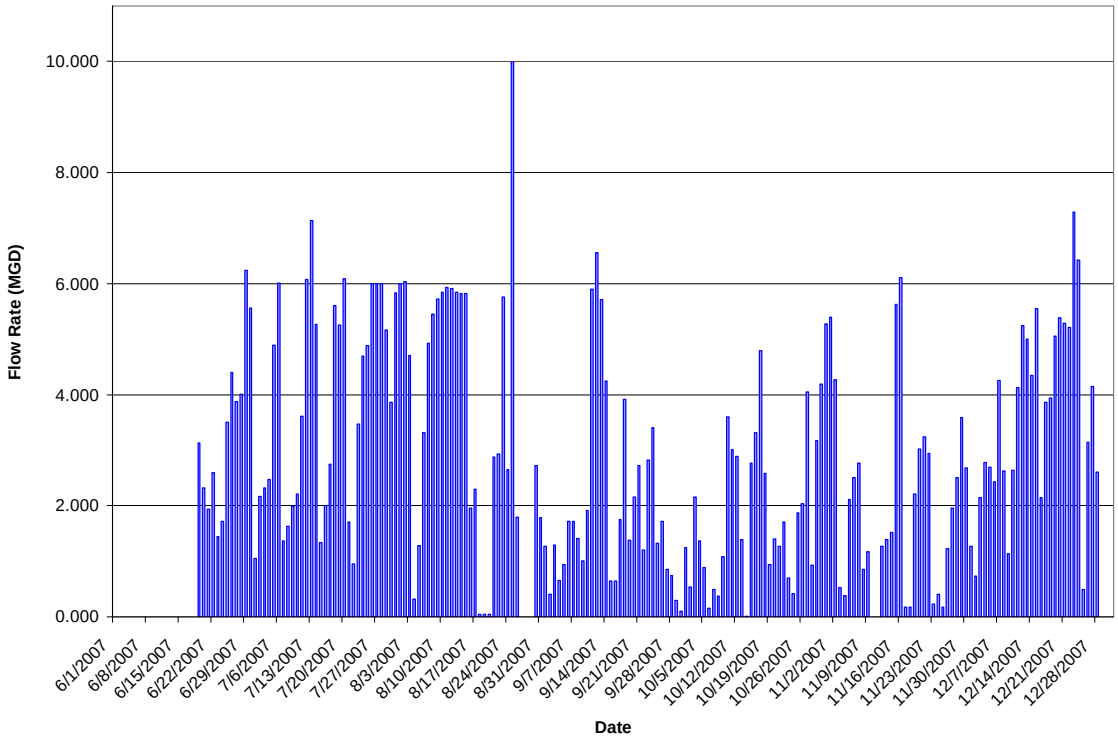

Figure 7: UWNJ transfer record

Data Results and Comparison to Water Quality Criteria

To evaluate the health of the Musquapsink Brook at all the stations, the monitoring results were compared to the designated water quality criteria. Water quality criteria are developed according to the designated uses of the waterbody. The Musquapsink Brook is classified as FW2-NT, or freshwater (FW) non trout (NT). "FW2" refers to waterbodies 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 NT

waters can support other fish species (NJDEP, 2006a). Furthermore, the Musquapsink Brook is a Category One antidegradation waterbody due to its discharge to the Oradell Reservoir, which is a potable water supply.

The USEPA Guidance for the Preparation of the Comprehensive State Water Quality Assessments (USEPA, 1997) advises that an acceptable frequency for water quality results to exceed criteria is 10% of samples. NJDEP has further stated 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 to the project – total phosphorus, fecal coliform, and *E. coli*. The applicable water quality criteria for this project are detailed in Table 5, and the percent of samples that exceeded these standards are given in Table 6. 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 criterion has been replaced by an *E. coli* criterion. Since the TMDL refers to fecal coliform, both fecal and *E. coli* were measured.

Tabulated water quality monitoring results are provided in Appendix D. Water quality monitoring data have also been graphed with surface water quality criterion; these graphs are available in Appendix E.

Table 5: Water quality criteria according to N.J.A.C. 7:9B (NJDEP, 2006a)

Substance	Surface Water Classification	Criteria
TP (mg/L)	FW2 Streams	Except as necessary to satisfy the more stringent criteria in accordance with "Lakes" (above) or where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.
	FW2 Lakes	Phosphorus as 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, except where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.
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.

Table 6: Summary of water quality data collected and comparison to water quality criteria

Monitoring Station ID	TP (mg/L)					
	criterion	*count*	*minimum*	*maximum*	*average*	*% not satisfying criterion*
MB1	0.1	6	0.05	0.14	0.08	44
MB2	0.1	7	0.05	0.11	0.07	10
MB3	0.1	7	0.03	0.09	0.06	0
MB4	0.1	7	0.03	0.35	0.11	50
MB5	0.1	6	0.06	0.35	0.17	60
MB6	0.1	7	0.04	0.19	0.10	50
SR1	0.1	7	0.01	0.11	0.05	30
HB1	0.1	7	0.91	2.20	1.77	90
Fecal Coliform (col/100mL)						
MB1	200	23	200	28,000	3,479	*96*
MB2	200	23	60	12,000	1,481	*87*
MB3	200	23	120	44,000	3,706	*91*
MB4	200	23	410	49,000	5,530	*100*
MB5	200	23	106	58,000	6,627	*100*
MB6	200	22	500	70,000	8,117	*100*
SR1	200	23	110	39,000	5,550	*87*
HB1	200	23	200	41,000	7,270	*91*
***E. coli* (col/100mL)**						
MB1	235	23	170	16,000	2,639	*91*
MB2	235	23	60	2,200	480	*65*
MB3	235	23	160	7,800	1,897	*96*
MB4	235	23	160	25,000	4,809	*96*
MB5	235	23	120	33,000	6,090	*96*
MB6	235	23	210	38,000	5,202	*96*
SR1	235	22	380	23,000	2,860	*100*
HB1	235	22	410	22,000	3,150	*100*

MST Data in the Musquapsink Brook Watershed

Microbial source tracking (MST) techniques have recently been developed that have the ability to identify the origin of fecal pollution. MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods to identify the origin of fecal pollution (USEPA, 2005). MST techniques typically report fecal contamination source as a percentage of targeted bacteria. One of the most

promising targets for MST is group *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 the large quantity 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 species for differentiating fecal sources (USEPA, 2005; Dick *et al.*, 2005; Layton *et al.*, 2006).

Three sets of PCR 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"). This assay is based on published results from a study sponsored by the Tennessee Department of Environmental Conservation (Layton *et al*., 2006).

Methods

Samples were collected in sterile bottles at all six monitoring sites and held at 4˚C until processing. On one sampling occasion, additional samples were collected at stations HR1 and SR1. A 100 mL aliquot of each sample was filtered aseptically onto a membrane filter and DNA was extracted from total filtered biomass using a DNeasy® tissue kit (Qiagen). The protocol used is a modification of the procedure found in the DNeasy Tissue Handbook (Qiagen, 2004).

After extraction, all DNA samples were quantified by spectroscopy (Beckman DU 640) at 260 and 280 nm then diluted in sterile water to a concentration of 1 µg/mL.

This diluted DNA was used as the template for quantitative, real-time PCR reactions to measure the number of *Bacteroides* present.

The number of *Bacteroides* was measured using a TaqMan® based assay using Applied Biosystems reagents and standard conditions on an Applied Biosystems 7300 Real-Time PCR system. Three target sequences were measured. These targets indicate the total number of *Bacteroides* (AllBac) as well as the number of specifically human-sourced (HuBac) and bovine-sourced (BoBac) *Bacteroides*. The copy number of each target was calculated by comparison to a standard curve made with plasmids containing human- or bovine-sourced target 16S RNA genes amplified with the primers Bac 32f and Bac 708r (Bernhard and Field, 2000). Dilutions of plasmid DNA provided standard curves which were linear from 10 to 100,000 copies per µL. Figure presents individual standard curves plotting log copy number vs. threshold cycle (Ct) for AllBac (a), Hubac (b), and BoBac (c) primer sets. All primers and probes were taken from Layton *et al.* (2006) or Bernhard and Field (2000) (Table 7).

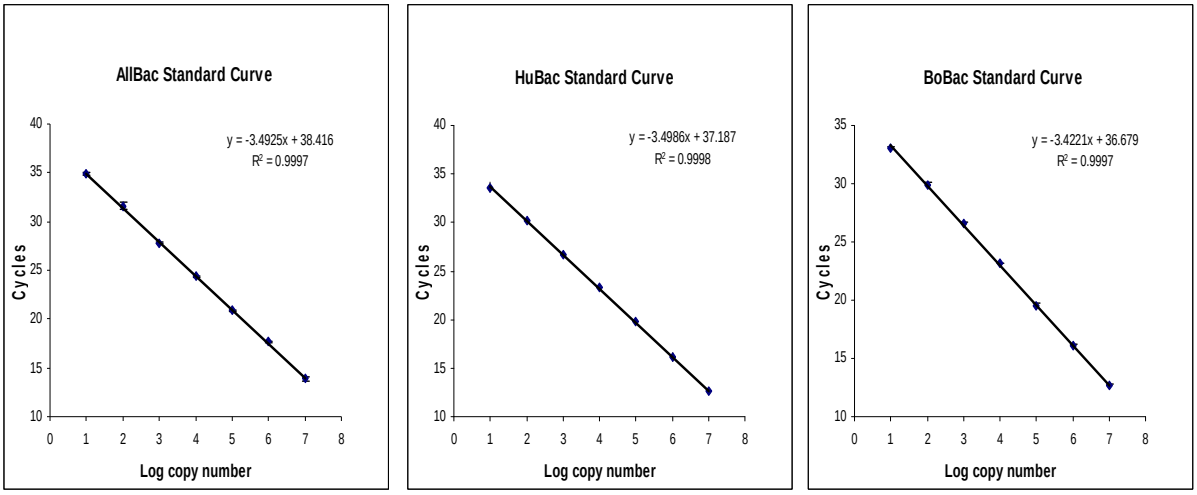

Figure 8: Standard curves for quantification of *Bacteroides*

Table 7: Primers and probes used for the MST effort

PCR Primers	
HuBac 566f	5' GGG TTT AAA GGG AGC GTA GG 3'
HuBac 692r	5' CTA CAC CAC GAA TTC CGC CT 3'
BoBac 367f	5' GAA GRC TGA ACC AGC CAA GTA 3'
BoBac 467r	5' GCT TAT TCA TAC GGT ACA TAC AAG 3'
AllBac 296f	5' GAG AGG AAG GTC CCC CAC 3'
AllBac 412r	5' CGC TAC TTG GCT GGT TCA G 3'
Bac 32f	5' AAC GCT AGC TAC AGG CTT 3'
Bac 708r	5' CAA TCG GAG TTC TTC GTG 3'
TaqMan Probes	
BoBac402Tman	5' 6FAM TGA AGG ATG AAG GTT CTA TGG ATT GTA AAC TT TAMRA 3'
HuBac594Tman	5' 6FAM TAA GTC AGT TGT GAA AGT TTG CGG CTC TAMRA 3'
AllBac375Tman	5' VIC CCA TTG ACC AAT ATT CCT CAC TGC TGC CT TAMRA 3'

Results of qPCR and Source Detection

The Musquapsink Brook Watershed is an urban watershed with no cattle within its boundaries, and the MST confirmed this with no detections of bovine-related *Bacteroides* in any sample. Human-related *Bacteroides* were detected in MB2, MB4, MB5, MB6, and HB1 on at least one sampling occasion (Figure 9). Pollution sources could be determined by the frequency of detection of specific markers at particular sampling locations (

Table 8). These data show that certain stations (MB2, MB4, MB5, MB6, and HB1) have a higher incidence of contamination with human feces.

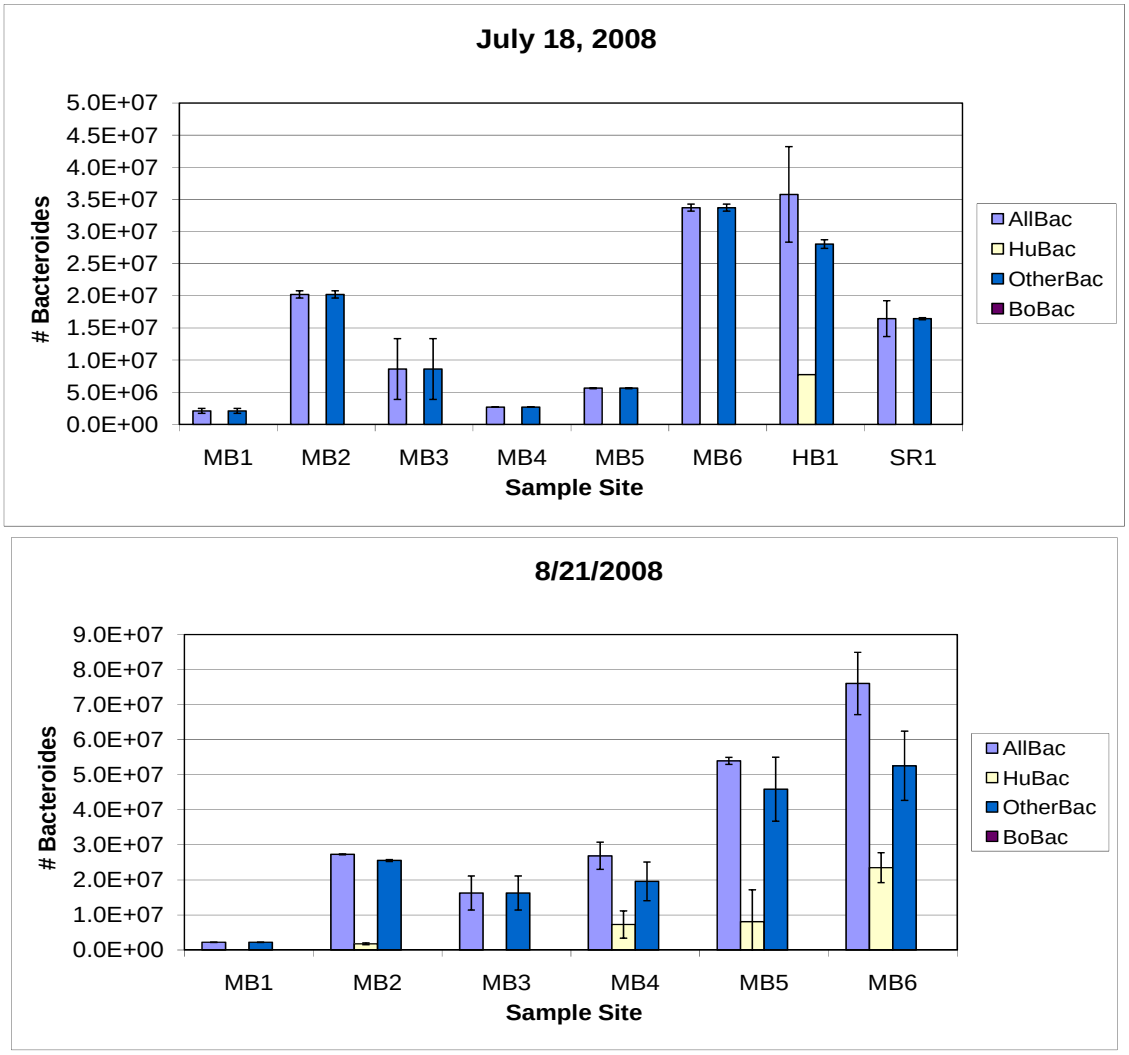

Figure 9: Sample data showing the numbers of *Bacteroides* detected by the three primer sets on two days of sampling

Table 8: Frequency of detection of AllBac, HuBac (human), or BoBac (bovine) target sequences

	% of Samples Containing Target Sequence							
	MB1	MB2	MB3	MB4	MB5	MB6	HB1	SR1
AllBac	100	100	100	100	100	100	100	100
HuBac	0	50	0	50	50	50	50	0

Data Summary

The data show a variety of water quality concerns in the Musquapsink Brook Watershed. The AMNET macroinvertebrate results show moderate impairments to the biological communities within the watershed (Table 1). The biological community may be impacted by environmental stressors or degraded habitat. Habitat quality may be low due to physical alterations as observed during SVAP assessments conducted throughout the watershed. Overall quality of the streams was assessed as "fair" but individual element scores ranged from "poor" to "good" (Table 2). Further analysis of this data may help to explain what physical factors (i.e., erosion, habitat structure, and water availability) may be responsible for the composition of the macroinvertebrate communities seen in the watershed.

While the biological monitoring and SVAP assessments shed light on watershed quality, surface water monitoring provides possible reasons for this quality. Results indicate that total phosphorus and fecal coliform concentrations, and pH levels are in violation of water quality criteria established by the NJDEP (Table 6). All eight (8) monitoring locations were in violation of both pH and total phosphorus water quality criteria in greater than 10% of the samples (Table 6). All eight (8) stations were also in violation of the fecal coliform water quality criterion (Table 6). Tracking of bacterial sources within the watershed indicate a higher human contribution to bacteria at stations MB2, MB4, MB5, MB6, and HB1 (Table 8).

Water quality data will be combined with land use data analyses to determine sources of pollutants. A full analysis of data will be conducted and presented in the Musquapsink Brook Watershed Restoration and Protection Plan.

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