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Water Resources Program

Tenakill Brook Watershed Restoration and Protection Plan:
DATA REPORT

Developed by the Rutgers Cooperative Extension Water Resources Program

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RP 07–001

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Acknowledgements

This document has been produced by the Rutgers Cooperative Extension (RCE) Water Resources Program (more information at www.water.rutgers.edu). Data collection was carried out by staff from the RCE Water Resources Program and project partners including the Bergen County Health Department and the Bergen County Utilities Authority.

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Watershed Overview

The Tenakill Brook Watershed is located in northeastern New Jersey above the Oradell Reservoir. It has a drainage area of approximately nine square miles. The watershed is dominated by urban land uses (Figure 1). The urban land uses are divided into residential, commercial, industrial, transportation, mixed urban and other urban land uses (Figure 2) according to the categorization based on the data provided the New Jersey Department of Environmental Protection (NJDEP).

The Tenakill Brook Watershed includes portions of Demarest, Closter, Alpine, Haworth, Cresskill, and Tenafly Boroughs in Bergen County (Figure 3). Small portions of Dumont Borough and Englewood City also lie within the watershed area (Figure 3). There are approximately 11 miles of river and streams within the watershed; these include the mainstem Tenakill Brook and its tributaries Cresskill Brook, Demarest Brook, and Charlie's Creek (Figure 3). The largest surface waterbody in the drainage area is Demarest Pond, though several other lakes exist within the watershed on private and public lands and golf courses (Figure 3).

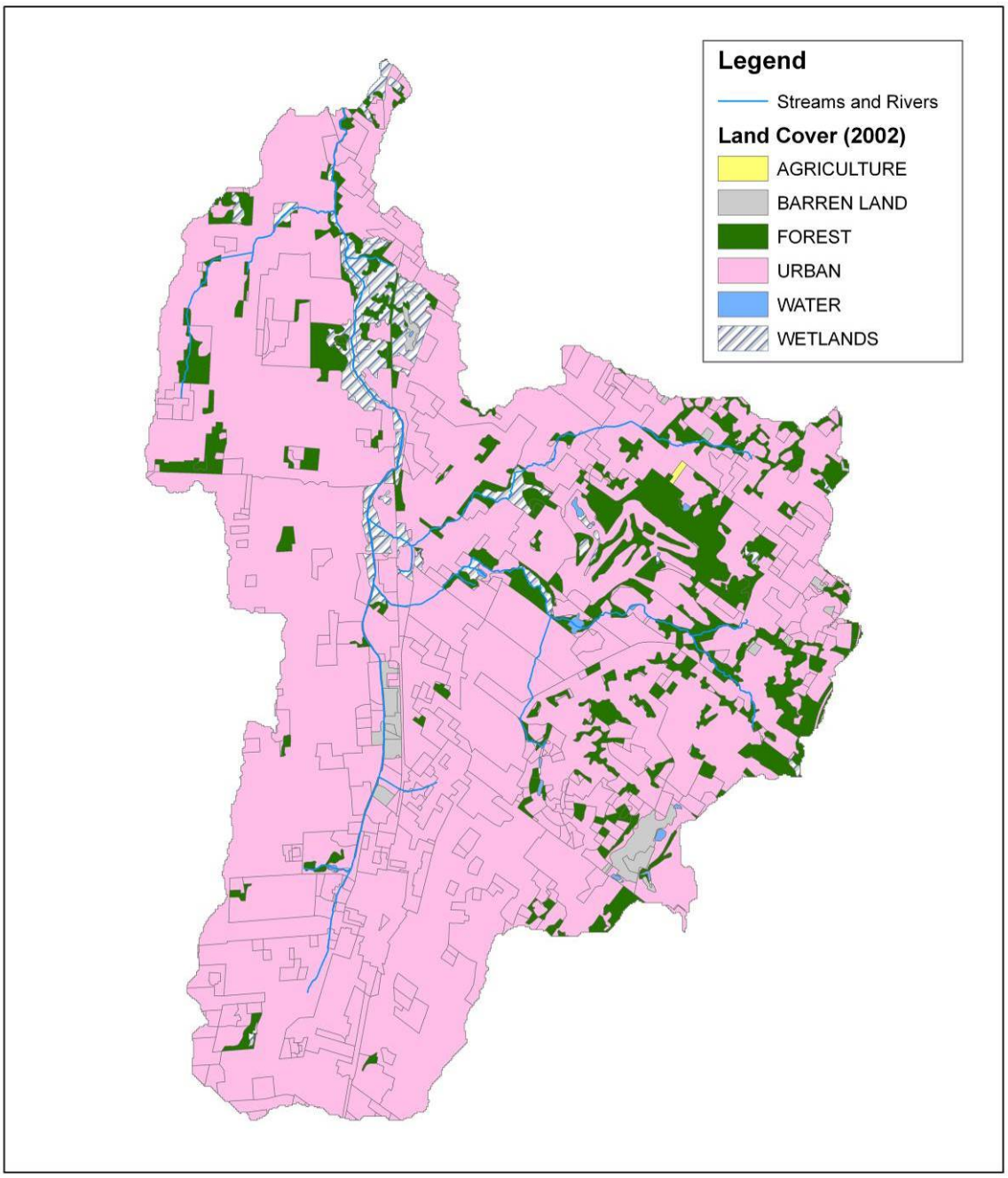


Figure 1: Land uses in the Tenakill Brook Watershed.

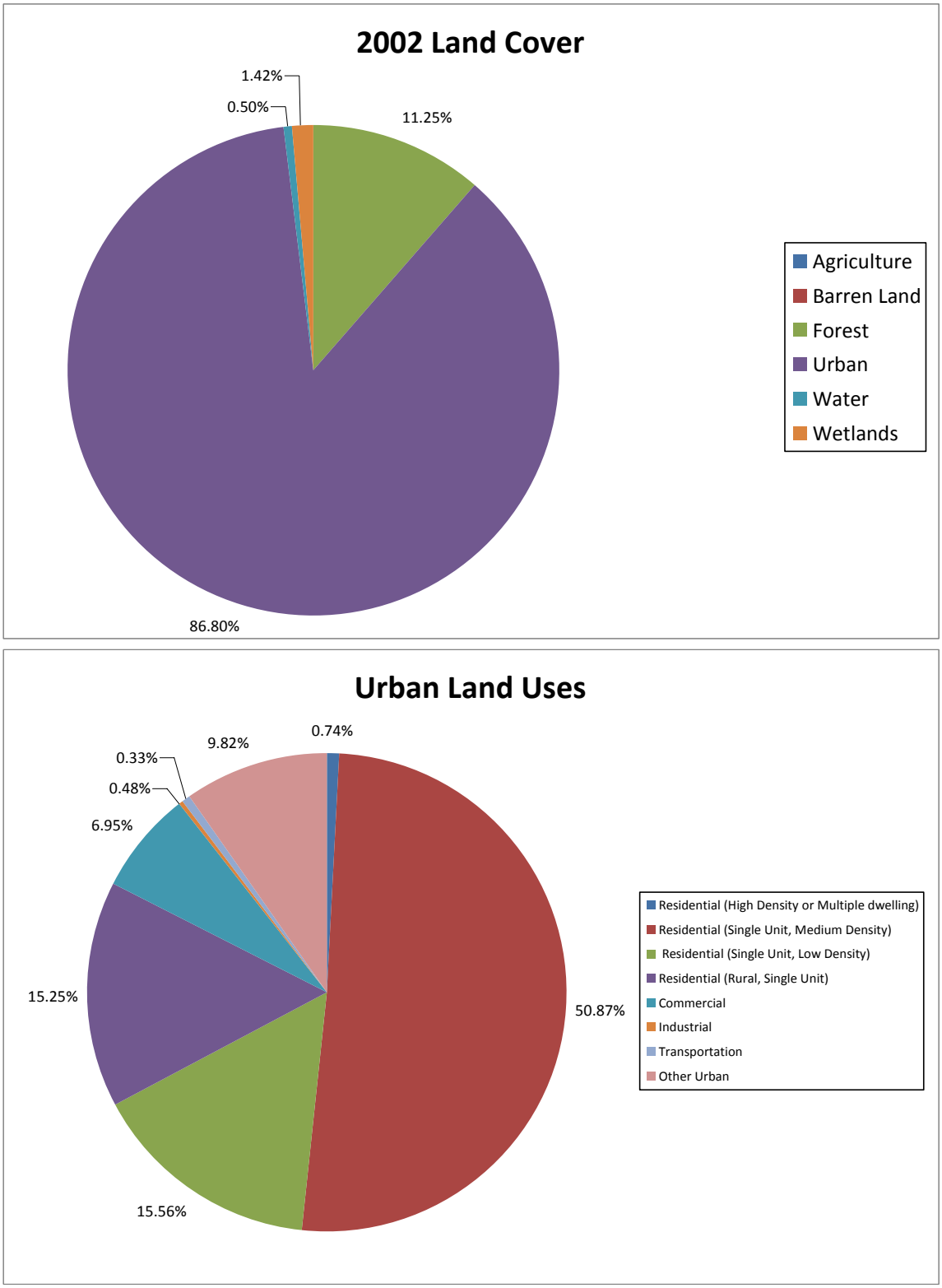


Figure 2: NJDEP 2002 urban land uses in the Tenakill Brook Watershed.

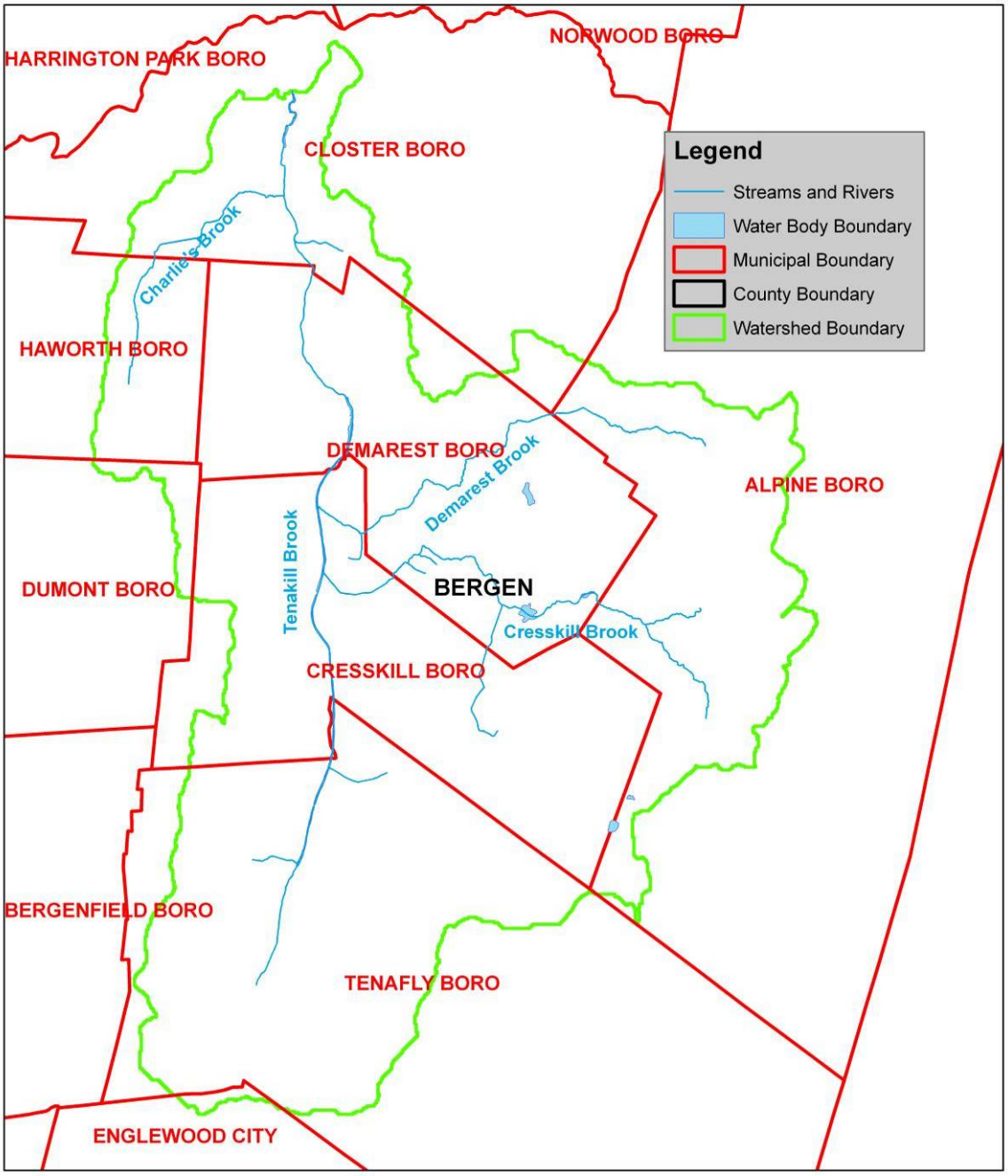


Figure 3: Municipalities and waterbodies located within the Tenakill Brook Watershed.

Project Background and the TMDL Process

The development of the Tenakill Brook Watershed Restoration and Protection Plan was funded in 2007 by the NJDEP (RP 07-001). The project has been established to

address a fecal coliform impairment that has been identified in the total maximum daily load (TMDL) developed from data collected in the Tenakill Brook at U.S. Geological Survey (USGS) monitoring station 01378387 at Cedar Lane, Closter Borough (NJDEP, 2003).

TMDLs are developed by the NJDEP, and approval is given by the U.S. Environmental Protection Agency (USEPA). In accordance with Section 305(b) of the Clean Water Act, New Jersey assesses 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 a TMDL is required.

According to the 2006 Integrated Water Quality Monitoring and Assessment Report's Integrated List (NJDEP, 2006), the Tenakill Brook at Cedar Lane was listed (according to surface water use) on Sublist 5 for aquatic life impairments and drinking water supply; Sublist 4a for primary and secondary contact recreation; Sublist 3 for fish consumption; and Sublist 2 for agricultural and industrial water supply. Fecal coliform impairment has been addressed through the New Jersey TMDL process; therefore, this parameter has been moved to Sublist 4a. A 96% reduction in fecal coliform loading to the Tenakill Brook is needed to achieve water quality standards (NJDEP, 2003). The TMDL was developed based on summer monitoring results from 2001 and 2002.

Data collected on the Tenakill Brook at the USGS monitoring station for the 2006 Integrated List was insufficient to declare the impairment status of total phosphorus (TP) and total dissolved solids. Additional data were collected as part of this study to further examine the possibility of TP impairment. These data will be discussed later in this report.

The purpose of this report is to provide a summary of available water quality data for the Tenakill Brook Watershed, as well as describe the protocols and results of data collected by RCE Water Resources Program and its partners. A complete analysis of this data to target pollution sources and remediation measures will be presented in the *Tenakill Brook Watershed Restoration and Protection Plan*.

Biological Monitoring Data

Biological monitoring data is available for the Tenakill Brook Watershed as part of the Ambient Biological Monitoring Network (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. 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, 2007). 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, 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.

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, suboptimal, 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 AN0209 – Tenakill Brook, Cedar Lane, Closter Borough, Bergen County). This station corresponds with the water quality monitoring station TB1. Station AN0209 was sampled by NJDEP in 1993 (Round 1), 1998 (Round 2), and 2003 (Round 3) 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 severely to moderately impaired, and the habitat has been assessed as suboptimal within the Tenakill 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)
AN0209	7/6/1993	Severely Impaired (6)	~
AN0209	7/9/1998	Severely Impaired (6)	Suboptimal (121)
AN0209	7/1/2003	Moderately Impaired (12)	Suboptimal (111)

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

Given these aquatic life impairments, an additional biological assessment was conducted as part of the data collection needed to prepare a comprehensive watershed restoration and protection plan for the Tenakill Brook Watershed. 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 CB1 (Cresskill Brook at Morningside Avenue, Cresskill), DB1 (Demarest Brook at Maple Avenue, Demarest), TB1 (AMNET Station AN0209 -

Tenakill Brook at Cedar Lane, Closter), and at TB4 (Tenakill Brook at Tenafly Road, Tenafly) (Figure 4). The 2007 biological assessment conducted Dr. McClary is summarized in Appendix A. The 2007 assessment revealed that the biological condition within the Tenakill Brook Watershed is severely impaired. Marginal/suboptimal habitat conditions were found at the Demarest Brook site; suboptimal habitat conditions were found at the two Tenakill Brook sites, and optimal habitat conditions were found at the Cresskill Brook site. Unfortunately, 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.

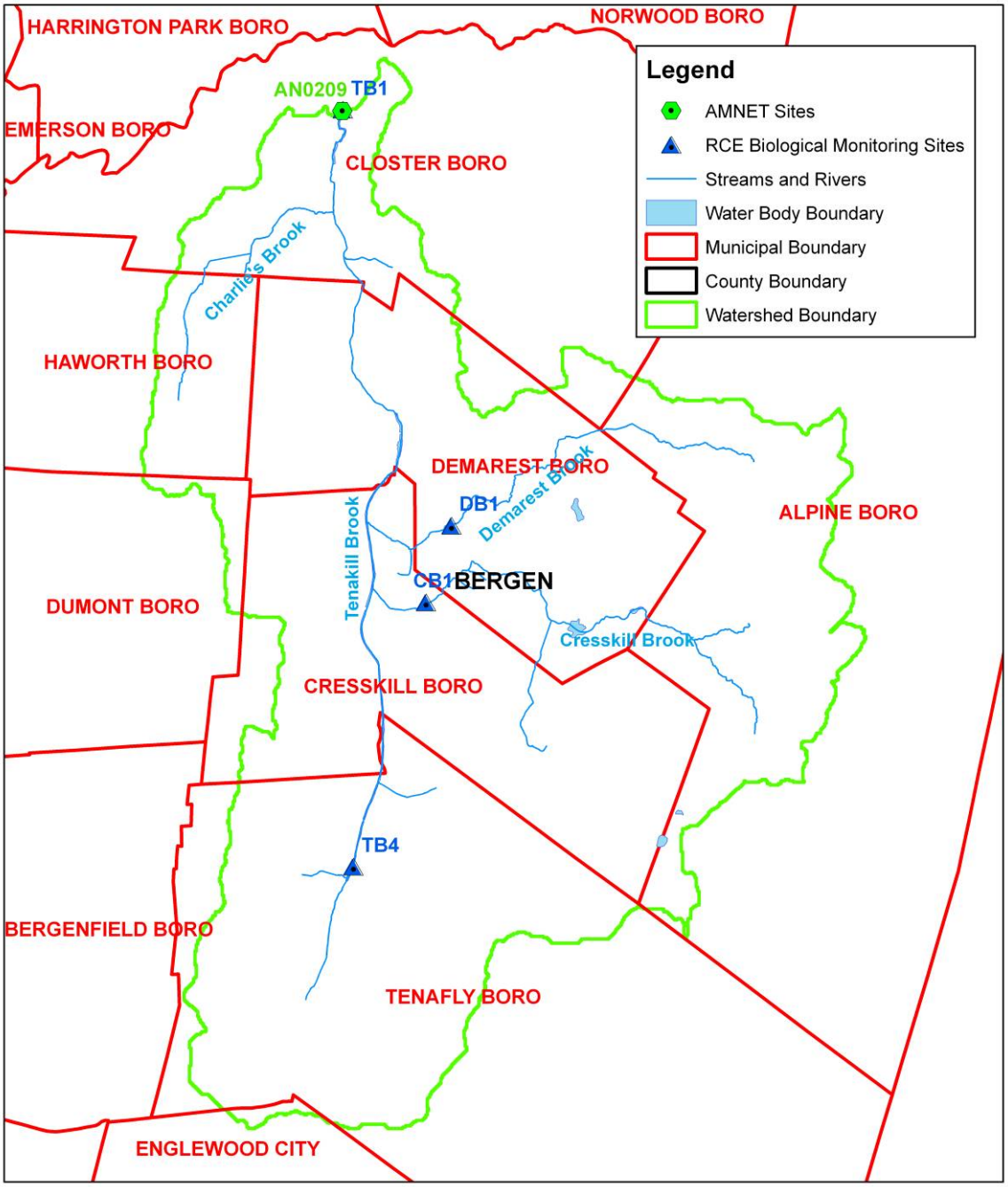


Figure 4: Tenakill Brook Watershed with NJDEP and RCE biological monitoring stations.

Stream Visual Assessment Protocol (SVAP) Data Collected in the Tenakill 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 mean of the elements' 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 track down in the Tenakill 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 Tenakill Brook Watershed

The visual assessment process in the Tenakill Brook Watershed began in March 2006. 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 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 also developed an application to fill out SVAP data on a hand held ArcPad™ unit, which was used for this project. The Tenakill 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 four reaches were scored for Manure Presence out of the 50 reaches assessed; these locations are shown in Figure 5.

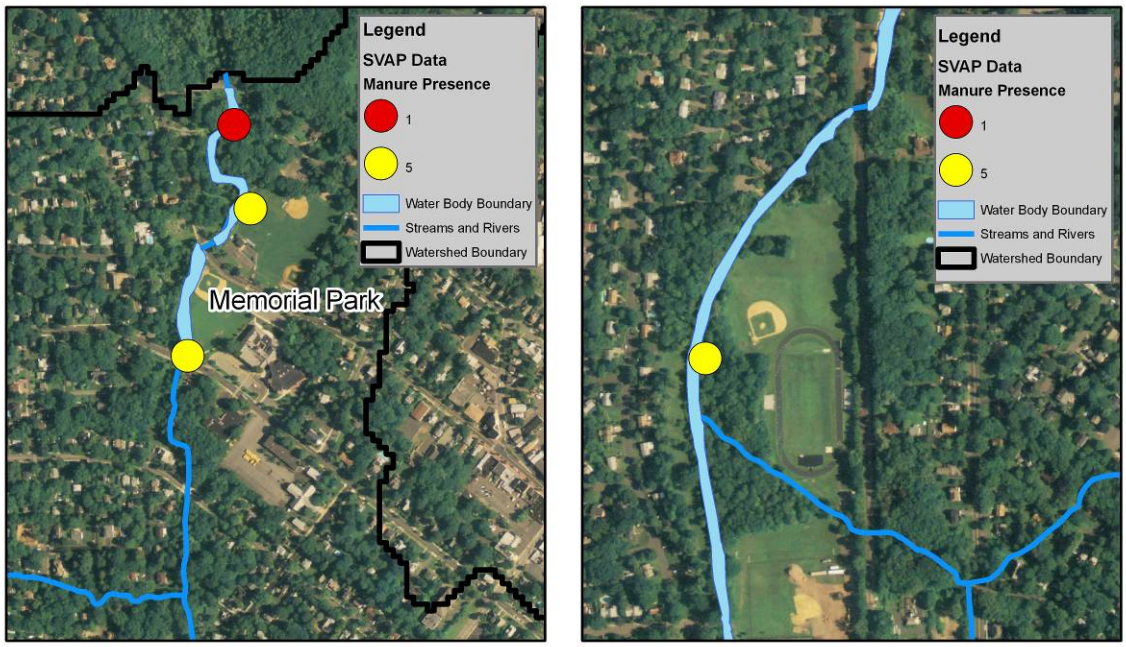


Figure 5: Manure Presence scores in the Tenakill Brook Watershed: Closter Borough (Left) and Cresskill Borough (Right).

SVAP Data

Fifty stream reaches were evaluated in the Tenakill Brook Watershed (Figure 6). Assessed reaches range from 24 feet to 600 feet, approximately. The average overall SVAP score was 4.9, a "poor" score. The range of mean scores for each of the assessed reaches ranged from 2.2 to 7.0 (Table 2) Riffles were present at only five locations and received an average score of "poor" indicating that riffles were on average more than 40% embedded, possibly due to silting of the streams. Barriers to fish movement was the highest scoring element (average of 7.0), and pools were the lowest scoring element (average score of 2.2). The mix of pools and riffles within a stream is a very important ecological concept. The pool-riffle-pool dynamic in a stream is important not only for habitat and ecological reasons, but it controls stream morphology and plays a role in the amount of sediment load carried by the stream. No assessed stream reach received a score of "good" or "excellent," and only half of the reaches were rated as "fair" (24 out of 50; Table 2).

Using the SVAP Data

SVAP scores will be evaluated as individual assessment elements and combined assessment elements. The SVAP results will be compared to land use and water quality monitoring results. The scores, information on pipes, ditches, and remediation notes will be used to identify sources of pollution and potential opportunities for improved management.

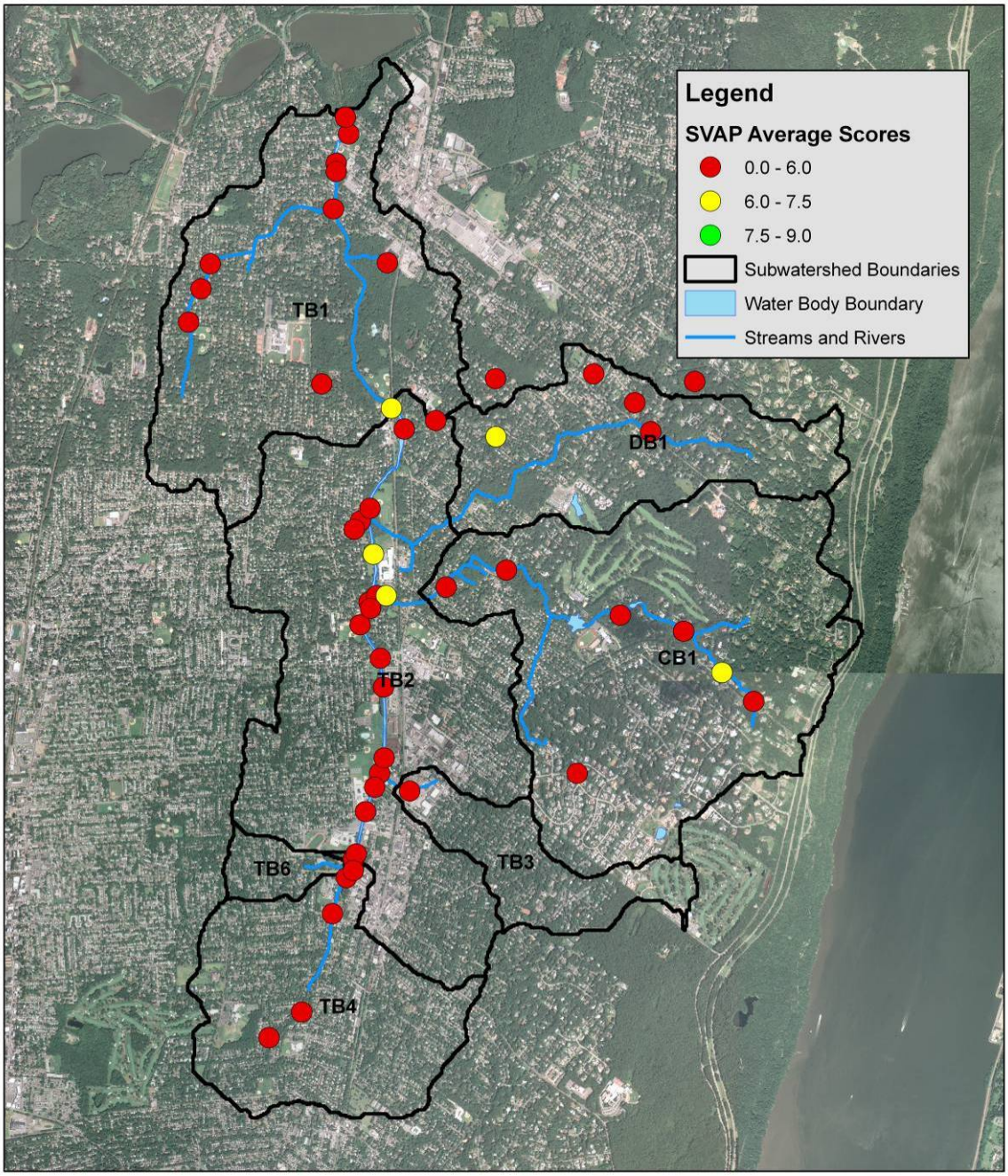


Figure 6: Stream visual assessment results for the Tenakill Brook Watershed.

Table 2: SVAP assessment elements and scores.

Subwatershed	Date	Reference Location	Hydrologic Alteration	Channel Condition	Riparian Zone Left Bank	Riparian Zone Right Bank	Bank Stability Left Bank	Bank Stability Right Bank	Water Appearance	Nutrient Enrichment	Riffle Embeddedness	Barriers to Fish Movement	Instream Fish Cover	Pools	Invertebrate Habitat	Canopy Cover	Manure Presence	Overall Site Average
CB1	6/25/2007	Stream between the dead ends of South St.	n/a	3.0	3.0	7.0	3.0	5.0	9.0	7.0	n/a	5.0	5.0	1.0	n/a	9.0	n/a	5.2
CB1	6/25/2007	Stream under Graham St. and near intersection with	n/a	7.0	8.0	10.0	3.0	3.0	8.0	8.0	n/a	8.0	3.0	1.0	n/a	10.0	n/a	6.3
CB1	6/25/2007	Stream under Anderson/County bridge.	n/a	1.0	6.0	8.0	2.0	2.0	7.0	7.0	n/a	1.0	3.0	3.0	n/a	9.0	n/a	4.5
CB1	6/25/2007	Stream under Church St. and close to intersection	n/a	7.0	9.0	9.0	7.0	8.0	8.0	7.0	n/a	7.0	3.0	2.0	n/a	10.0	n/a	7.0
CB1	6/25/2007	Near Duckpond and Hillside Ave.	n/a	3.0	5.0	5.0	6.0	6.0	8.0	7.0	n/a	6.0	3.0	1.0	n/a	8.0	n/a	5.3
CB1	6/25/2007	Located by Duckpond and Deerhill road.	n/a	7.0	5.0	3.0	6.0	5.0	7.0	7.0	n/a	1.0	3.0	5.0	n/a	6.0	n/a	5.0
CB1	6/25/2007	Stream running alongside Duckpond Rd (after 2nd po	5.0	10.0	10.0	10.0	3.0	3.0	8.0	7.0	n/a	3.0	3.0	2.0	n/a	8.0	n/a	6.0
DB1		Bridge over Warren Lane	1.0	1.0	2.0	0.0	1.0	0.0	7.0	7.0	1.0	1.0	2.0	1.0	n/a	5.0	n/a	2.2
DB1		End of Lake Road, left from walking path.	9.0	10.0	10.0	0.0	3.0	0.0	8.0	7.0	5.0	8.0	5.0	4.0	n/a	7.0	n/a	5.8
DB1	6/12/2007	School & Swim Club off Grove St	5.0	6.0	3.0	5.0	3.0	3.0	3.0	6.0	1.0	10.0	3.0	2.0	n/a	7.0	n/a	4.4
DB1	6/20/2007	Stream going over Pine Terrace (between Anderson A	4.0	6.0	3.0	3.0	4.0	4.0	7.0	7.0	n/a	5.0	5.0	7.0	n/a	6.0	n/a	5.1
DB1	4/3/2007	memorial park near cedar lane	n/a	6.0	1.0	1.0	3.0	1.0	4.0	5.0	n/a	9.0	4.0	5.0	n/a	1.0	1.0	3.4
DB1	6/20/2007	Bridge over Warren Lane	1.0	1.0	2.0	2.0	1.0	1.0	7.0	7.0	1.0	1.0	2.0	1.0	n/a	5.0	n/a	2.5
DB1	6/20/2007	Stream going under Berkery Road via pipe.	3.0	3.0	5.0	5.0	6.0	1.0	7.0	8.0	n/a	8.0	5.0	7.0	n/a	8.0	n/a	5.5
DB1	6/20/2007	Stream going under Litchfield Way.	3.0	3.0	5.0	5.0	1.0	2.0	7.0	8.0	n/a	4.0	1.0	1.0	n/a	10.0	n/a	4.2
TB1	6/12/2007	Intersection of Tenafly & Riveredge Rds	7.0	5.0	6.0	2.0	7.0	4.0	7.0	7.0	n/a	9.0	3.0	1.0	n/a	1.0	n/a	4.9
TB1	4/3/2007	Memorial Park on Harrington Avenue	na	7.0	1.0	1.0	5.0	3.0	3.0	2.0	n/a	9.0	5.0	1.0	n/a	3.0	5.0	3.8
TB1	4/3/2007	north of high street, closter	6.0	5.0	2.0	1.0	4.0	6.0	7.0	6.0	n/a	9.0	3.0	2.0	n/a	7.0	5.0	4.8
TB1	4/3/2007	south of high street crossing	6.0	5.0	3.0	2.0	3.0	4.0	7.0	7.0	n/a	9.0	4.0	3.0	n/a	3.0	n/a	4.7
TB1	6/20/2007	Stream over Central Ave.	5.0	5.0	3.0	1.0	7.0	7.0	8.0	1.0	n/a	8.0	3.0	1.0	n/a	4.0	n/a	4.4
TB1	6/28/2007	Between Chestnut and Beacon streets.	n/a	7.0	7.0	8.0	6.0	7.0	8.0	7.0	n/a	6.0	3.0	1.0	n/a	7.0	n/a	6.1
TB1	6/28/2007	Bemd of Pleasant Ln.	n/a	6.0	4.0	2.0	4.0	6.0	8.0	7.0	n/a	7.0	3.0	1.0	n/a	7.0	n/a	5.0
TB1	6/28/2007	End of Oak St.	n/a	1.0	1.0	1.0	4.0	4.0	8.0	5.0	n/a	1.0	3.0	3.0	n/a	1.0	n/a	2.9
TB1	6/28/2007	Stream near Brooks street.	n/a	5.0	3.0	1.0	5.0	1.0	8.0	7.0	n/a	6.0	5.0	3.0	n/a	7.0	n/a	4.6
TB1	7/9/2007	Behind A&P on Demarest Ave.	n/a	7.0	10.0	10.0	6.0	6.0	7.0	6.0	n/a	8.0	5.0	1.0	n/a	7.0	n/a	6.6
TB2	6/15/2007	Intersection of Merritt Ct and Columbus	5.0	9.0	1.0	1.0	5.0	5.0	8.0	9.0	n/a	8.0	3.0	1.0	n/a	3.0	n/a	4.8
TB2	6/15/2007	Just south Tenakill Swim Club	5.0	8.0	9.0	9.0	5.0	5.0	9.0	8.0	n/a	1.0	1.0	1.0	n/a	1.0	n/a	5.2
TB2	6/15/2007	Cresskill Firehouse Madison Ave	5.0	8.0	3.0	3.0	3.0	3.0	4.0	6.0	n/a	10.0	3.0	1.0	n/a	7.0	n/a	4.7
TB2	6/15/2007	Just South of the end of Tenakill Road	5.0	8.0	9.0	7.0	4.0	4.0	3.0	5.0	n/a	10.0	3.0	1.0	n/a	3.0	n/a	5.2
TB2	6/15/2007	Upstream of Grant Ave	5.0	3.0	4.0	2.0	2.0	8.0	7.0	7.0	n/a	10.0	2.0	0.0	n/a	4.0	n/a	4.5
TB2		School & Swim Club off Grove St	5.0	6.0	3.0	0.0	3.0	0.0	3.0	6.0	1.0	10.0	3.0	2.0	n/a	7.0	n/a	3.8
TB2	6/12/2007	Tenafly Rd along Park & Middle School	7.0	4.0	3.0	5.0	4.0	4.0	4.0	6.0	n/a	10.0	1.0	1.0	n/a	6.0	n/a	4.6
TB2	6/12/2007	Between ball park and swim club off Grove St	6.0	6.0	3.0	3.0	7.0	7.0	3.0	5.0	n/a	10.0	2.0	1.0	n/a	1.0	n/a	4.5
TB2	6/12/2007	Magnolia & 3rd St	5.0	7.0	9.0	5.0	5.0	7.0	2.0	4.0	n/a	10.0	3.0	1.0	n/a	4.0	n/a	5.2
TB2	6/20/2007	End of Old Stable Road	7.0	7.0	4.0	3.0	3.0	3.0	8.0	9.0	n/a	10.0	3.0	1.0	n/a	7.0	n/a	5.4
TB2	6/20/2007	Bridge on Meadow Street	5.0	7.0	1.0	1.0	1.0	1.0	10.0	10.0	n/a	8.0	1.0	1.0	n/a	4.0	n/a	4.2
TB2	6/25/2007	Bridge on Delmar Ave.	n/a	2.0	4.0	4.0	2.0	3.0	8.0	8.0	n/a	6.0	3.0	1.0	n/a	5.0	n/a	4.2
TB2	6/25/2007	Stream near Cresskill HS and Lincoln Dr.	n/a	7.0	3.0	8.0	3.0	4.0	7.0	8.0	n/a	10.0	5.0	7.0	n/a	7.0	n/a	6.3
TB2	6/28/2007	Stream (Tenakill Brook) near Wakelee Field	n/a	6.0	7.0	4.0	7.0	3.0	5.0	5.0	n/a	7.0	8.0	7.0	n/a	10.0	n/a	6.3
TB2	6/28/2007	Stream running under Hardenburgh Ave. bridge	n/a	1.0	1.0	1.0	8.0	8.0	6.0	3.0	n/a	8.0	4.0	1.0	n/a	1.0	n/a	3.8
TB2	6/28/2007	Stream by Deacon Pl.	n/a	8.0	9.0	5.0	7.0	4.0	4.0	3.0	n/a	8.0	3.0	7.0	n/a	3.0	5.0	5.5
TB2	6/28/2007	End of Messine Dr.	n/a	8.0	5.0	5.0	4.0	4.0	5.0	6.0	n/a	9.0	6.0	7.0	n/a	7.0	n/a	6.0
TB2	6/28/2007	Stream going under Grant Ave. bridge. Also close	n/a	6.0	3.0	7.0	4.0	4.0	7.0	4.0	n/a	5.0	4.0	3.0	n/a	7.0	n/a	4.9
TB3	7/9/2007	Piermont by Hudson near Commerce Bank	n/a	3.0	6.0	7.0	3.0	4.0	6.0	7.0	n/a	8.0	3.0	1.0	n/a	7.0	n/a	5.0
TB4	5/7/2007	Intersection of Hamilton Place and Palmer Ave	3.0	3.0	1.0	4.0	2.0	8.0	9.0	9.0	n/a	8.0	1.0	1.0	n/a	9.0	n/a	4.8
TB4	5/7/2007	Intersection of Benjamin Road and Louise Lane	1.0	3.0	1.0	1.0	9.0	9.0	9.0	9.0	n/a	8.0	1.0	1.0	n/a	9.0	n/a	5.1
TB4	5/7/2007	Bridge on Clinton ave	9.0	8.0	10.0	8.0	2.0	2.0	9.0	9.0	n/a	8.0	2.0	1.0	n/a	7.0	n/a	6.3
TB4	5/7/2007	Just upstream of Riveredge Road	9.0	8.0	9.0	8.0	3.0	3.0	8.0	9.0	n/a	8.0	1.0	1.0	n/a	2.0	n/a	5.8
TB4	5/7/2007	Parrellel to the tennis courts in Roosevelt Park	3.0	2.0	1.0	8.0	6.0	2.0	9.0	9.0	n/a	8.0	1.0	1.0	n/a	1.0	n/a	4.3
TB4	7/9/2007	Roosevelt Commons by Riveredge and Tenafly	n/a	3.0	7.0	7.0	7.0	7.0	1.0	1.0	n/a	1.0	3.0	1.0	n/a	7.0	n/a	4.1
Legend				Good = assessment score > 7														
				Fair = assessment score of 5-7														
				Poor = assessment score < 5														
Descriptions of each indicator are available in the U. S. Department of Agriculture Stream Visual Assessment Protocols (USDA, 1998)																		

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 22, 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 across transects at each sampling station. Using this information, flow (Q) was calculated for each event where access to the stream was deemed safe. Surface water quality samples were collected and analyzed by two separate laboratories. The Bergen County Utility Authority conducted analyses for TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, Total Kjeldahl Nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), and fecal coliform. Garden State Laboratories conducted analyses 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 22, 2007 through October 24, 2007. During these events, samples were collected and then analyzed for TP, 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 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* samples were collected during these events. Dates and types of monitoring events are given in Table 3.

Table 3: Water quality monitoring events.

Date	Weather	Regular Monitoring for all Parameters	Bacteria Only Monitoring
5/22/2007	Dry	X	
5/29/2007	Dry	X	
6/5/2007	Wet	X	
6/12/2007	Dry		X
6/19/2007	Dry	X	
6/26/2007	Dry		X
6/27/2007	Wet		X
7/3/2007	Dry	X	
7/10/2007	Dry		X
7/17/2007	Dry	X	
7/24/2007	Wet		X
7/31/2007	Dry		X
8/7/2007	Dry	X	
8/14/2007	Dry		X
8/16/2007	Dry		X
8/21/2007	Wet	X	
8/28/2007	Dry		X
9/11/2007	Wet	X	
9/25/2007	Dry	X	
10/9/2007	Wet	X	
10/24/2007	Dry	X	

Storm events were supposed to be collected as part of this effort. Due to uncooperative weather patterns during the six months of monitoring, no storm samples were collected that would meet the requirements of the state-approved QAPP overseeing this monitoring task. Fortunately, samples were collected under both dry and wet conditions in the watershed, which will 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 model equations were used. HYSEP is a computer-simulation program developed by the USGS

to split the hydrograph to separate baseflow from storm-flow conditions (Sloto and Crouse, 1996). Normally, the equations in 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 Tenakill Brook Watershed. Instead, USGS monitoring station 01377500, Pascack Brook at Westwood, which is 1.8 miles from the USGS station on the Tenakill Brook, was chosen. This surface water body also discharges to the Oradell Reservoir, and the drainage areas share many similarities. The equations were generated to determine baseflow and storm-related flow for the Pascack Brook from January 1, 2006 through March 31, 2008. A 10% error bar was also applied to the baseflow since these data are collected in a watershed other than the Tenakill 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 six water quality monitoring stations were regularly collected over the six-month sampling time frame. These six stations are depicted in Figure 7. Three stations were located on the mainstem Tenakill Brook, and three stations were located on tributaries to the Tenakill Brook. These stations are identified in Table 4. Beginning on July 17, 2007, an additional station was monitored. This adaptive monitoring station was added to the water quality testing to aid the pathogen source track down process. This station is identified as TB6 (Figure 7). Water quality data are presented in Appendices C and D.

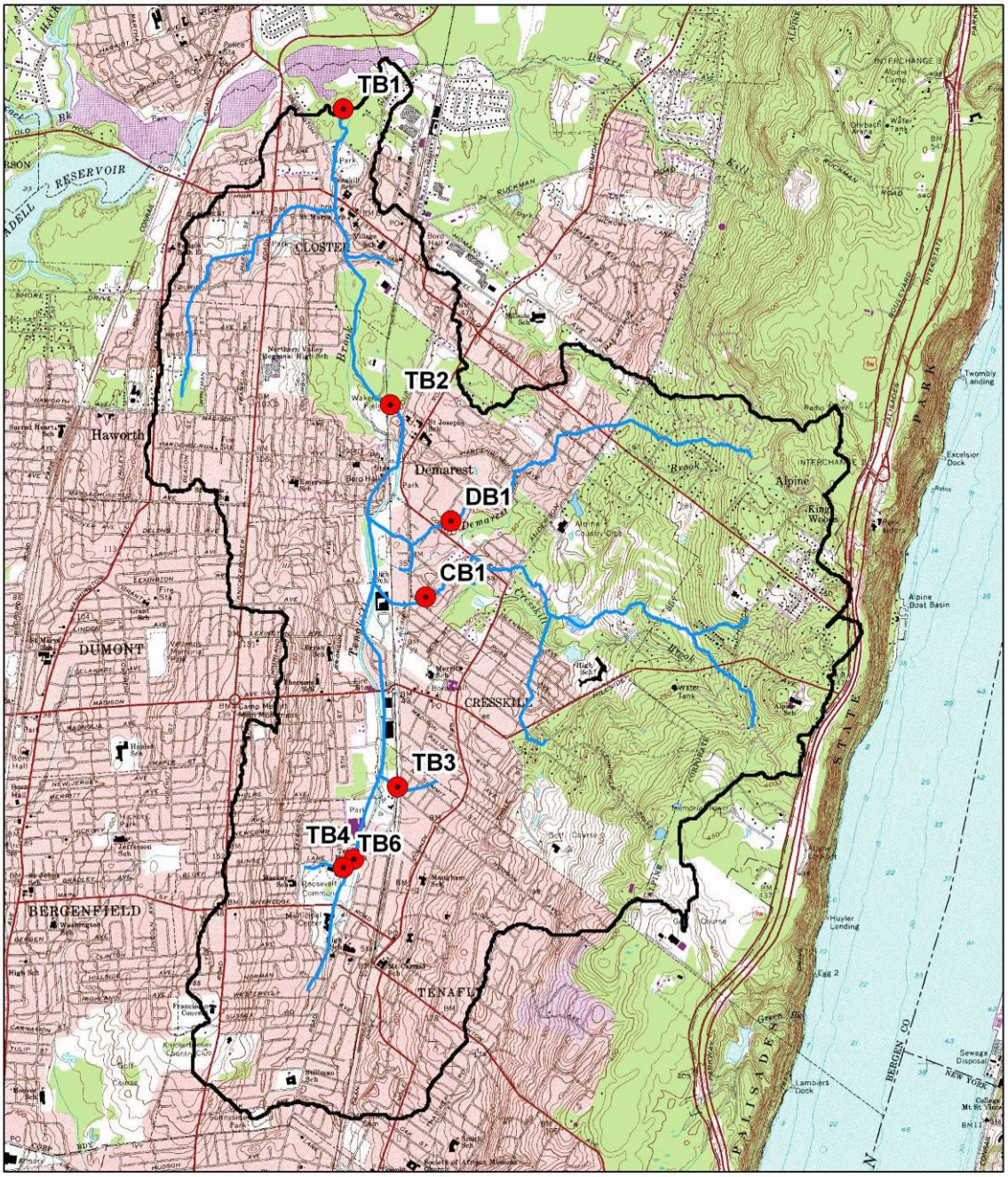


Figure 7: Water quality monitoring stations in the Tenakill Brook Watershed.

Table 4: Water quality monitoring location IDs and descriptions.

Site ID	Site Description
TB1	Tenakill Brook at USGS 01378387 at Cedar Lane, Closter (also AN0209)
TB2	Tenakill Brook at Wakelee Field, Demarest
DB1	Demarest Brook at Maple Avenue, Demarest
CB1	Cresskill Brook at Morningside Avenue, Cresskill
TB3	Unnamed Tributary to the Tenakill Brook at Grove Street, Tenafly
TB4	Tenakill Brook at Tenafly Road, Tenafly
TB6	Unnamed Tributary to the Tenakill Brook below Roosevelt Common Pond, Tenafly

Data Results and Comparison to Water Quality Standards

To evaluate the health of the Tenakill Brook at all the stations, the monitoring results were compared to the designated water quality standards. Water quality standards are developed according to a waterbody's designated uses. The Tenakill 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 describes 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, 2011). Furthermore, the Tenakill Brook is a Category One antidegradation waterbody due to its discharge to the Oradell Reservoir, which is a potable water supply. The applicable water quality standards for this project are detailed in Table 5. As per the NJDEP water quality standards, the phosphorus standard is different for streams (0.1 mg/L) than in lakes (0.05 mg/L) (Table 5). The lake standard

also applies to the tributary discharging to the lake at the point where it enters such bodies of water. Therefore, TB1 is being held to the more stringent standard since this point represents the location where the Tenakill Brook enters the Oradell Reservoir (Table 5).

Table 5: Water quality standards according to N.J.A.C. 7:9B (NJDEP, 2011).

Substance	Surface Water Classification	Criteria
pH (S.U.)	FW2	6.5-8.5
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.
Suspended Solids (mg/L)	FW2-NT	Non-filterable residue/suspended solids shall not exceed 40.
Bacterial Quality (counts/100 mL): Fecal Coliform – former criterion for Bacterial Quality	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.
Bacterial Quality (counts/100 mL): *E. coli*	FW2	Shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL.

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods advises that if the frequency of water quality results exceed the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2004). NJDEP has further stated that a minimum of eight samples collected quarterly over a two-year period are required to confirm the quality of waters (NJDEP, 2004). Therefore, if a waterbody has a minimum of eight samples collected quarterly over a two-year period and samples exceed the water quality criteria for a certain parameter twice, the waterbody is considered "impaired" for that parameter. By applying this rule to the Tenakill Brook Watershed water quality data, it is possible to identify which stations are impaired for each parameter that has been identified as a concern for this project (i.e., pH, TP, *E. coli* and fecal coliform). The number of samples exceeding these standards is given in Table 6. Due to low pH values recorded in the field, pH has also been identified as a potential water quality concern in some regions of the watershed.

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 the count of *E. coli* bacteria. Since the TMDL established by the State of New Jersey refers to fecal coliform, both fecal coliform and *E. coli* were measured.

Table 6: Number of samples that exceed water quality standards for the Tenakill Brook Watershed.

Station	Selected Monitoring Parameters			
	TP	**Fecal coliform***	***E. coli*****	**pH**
TB1	12 out of 12	19 out of 20	20 out of 20	1 out of 19
TB2	6 out of 12	17 out of 19	20 out of 20	4 out of 19
DB1	2 out of 12	19 out of 20	19 out of 20	1 out of 19
CB1	2 out of 12	17 out of 20	19 out of 20	1 out of 19
TB3	4 out of 12	20 out of 20	20 out of 20	3 out of 19
TB4	2 out of 12	20 out of 20	20 out of 20	3 out of 19
TB6	n/a	10 out of 10	7 out of 7	1 out of 10

**Number of samples higher than 400 col/100ml*
*** Number of samples higher than 235 col/100ml*

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

MST Data in the Tenakill Brook Watershed

Microbial source tracking (MST) techniques have recently been developed that 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

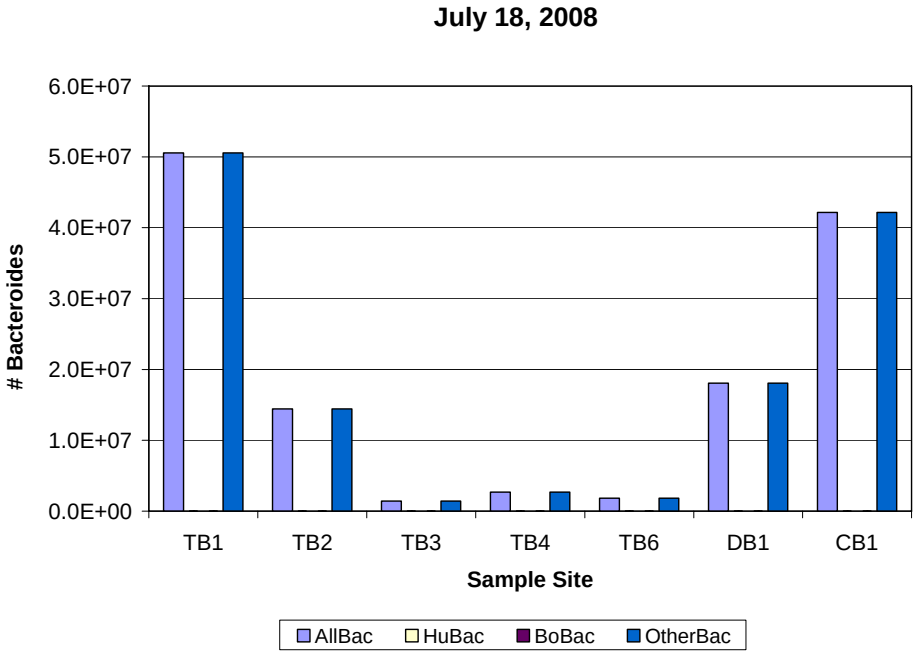
Samples were collected on two dates (July 18, 2008 and August 27, 2008) in sterile bottles at all seven water quality monitoring sites (Figure 7). A 100 mL aliquot of each sample was filtered aseptically onto a membrane filter and held at 4˚C until processing. DNA was extracted from total filtered biomass using a DNeasy® tissue kit (Qiagen, 2004). 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 ηm and 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. All other procedures that were followed are outlined by Layton *et al.* (2006).

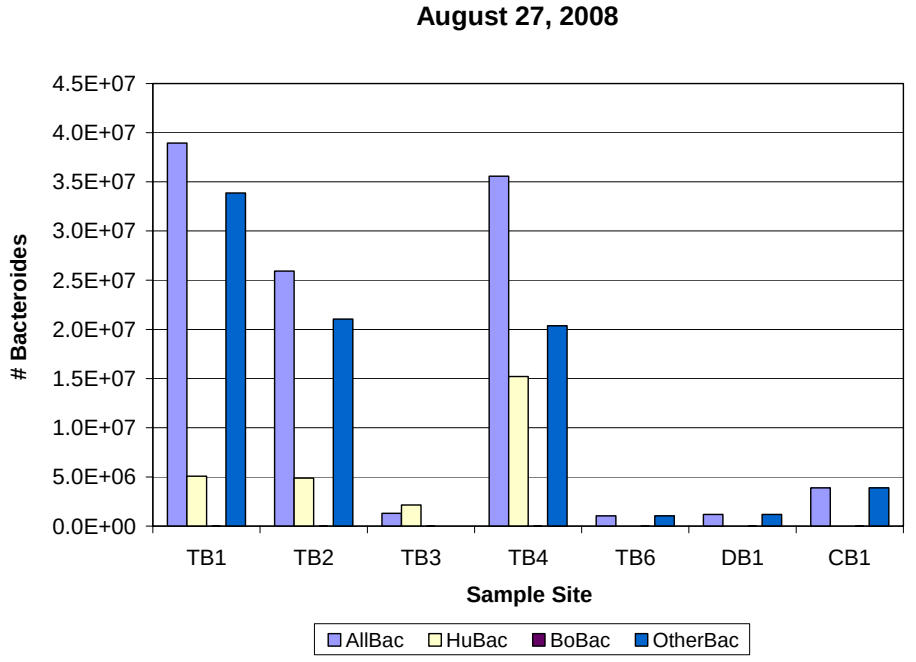
Results of MST

The Tenakill Brook Watershed is a highly-urbanized watershed, with no agriculture within its boundaries (Figure 1). The MST confirmed this with no detections of agriculturally-derived bovine *Bacteroides* (BoBac) in any sample (Figures 8A-8B). *Bacteroides* from human-related sources (HuBac) could be readily detected at five stations on August 27, 2008 (Figure 8B), but none were detected during the July 18, 2008 sampling event. Station TB4 had the highest levels of human-related *Bacteroides* (HuBac) in August 2008 (Figure 8B).

The numbers of *Bacteroides* present in individual samples was also compared to the other indicators of water quality including fecal coliform. Despite the lack of obvious correlations between total *Bacteroides* and fecal coliform, or any of the other water quality measurements, MST provides useful data in regard to the sources and extent of fecal contamination in the watershed. These data show the highly variable nature of all of the water quality measures used.



(A)



(B)

Figure 8: MST data showing the numbers of *Bacteroides* detected on July 18, 2008 (A) and August 27, 2008 (B).

Source Identification

While it is difficult to pinpoint sources of pollution based upon two sampling events, sources could be estimated by the frequency of detection of specific markers at particular stations over these two summer events (Figures 8A-8B). Due to the presence of HuBac detected at many of the sites, potential sources could include failing septic and/or sewer systems or improperly treated human waste as potential sources of fecal contamination.

Data Summary

The data show a variety of water quality concerns in the Tenakill Brook Watershed. The AMNET macroinvertebrate results show severe impairment in the first two monitoring results and moderate impairment in the last monitoring results to the biological communities within the watershed (Table 1). The severe impairment results were seen again in the biological monitoring conducted by Marion McClary (Appendix A). The biological community may be impacted by environmental stressors or degraded habitat. Habitat conditions assessed by both NJDEP through AMNET and Marion McClary (Fairleigh Dickinson University) show suboptimal conditions in areas within the watershed (Table 1; Appendix A). 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 "poor" (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 community seen in the watershed.

While the biological monitoring and SVAP assessments shed light on watershed quality, water monitoring provides possible reasons for this quality. Results indicate that TP, fecal coliform and *E. coli* concentrations, and pH levels are in violation of water quality criteria established by the NJDEP (Table 6; Appendix C). All seven monitoring locations were in violation of TP and bacterial (fecal coliform and *E. coli*) water quality more than twice during the monitoring conducted in 2007 (Table 6).

Tracking of bacterial sources within the watershed indicate a human contribution to bacterial contamination detected in the watershed. Water quality data will be combined with land use data analysis to determine potential sources of pollutants.

A full analysis of data will be conducted and presented in the *Tenakill Brook Watershed Restoration and Protection Plan*.

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Appendix A: Tenakill Brook Benthic Data Report & Species List, Marion McClary, Jr., Ph.D., Fairleigh Dickinson University.

Tenakill Brook Benthic Data Report

Prepared by:

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for

Rutgers Cooperative Extension Water Resources Program
as part of
RP07-001 Tenakill Brook Watershed
Restoration and Protection Plan

June 2008

Biological Monitoring Materials and Methods

Upon arrival at the sampling location, the end of a tape measure was placed and held below any road or bridge crossing that was present and stretched 100 meters upstream to minimize the effect of the road or bridge on stream velocity, depth, and overall habitat quality as per the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. At this location, 100 meters upstream of the road or bridge crossing, the tape measure was again placed and held and stretched 100 meters upstream to include a 100 meter reach that was representative of the characteristics of the stream (the study area). Other road or bridge crossings were avoided. If this was not possible, the tape measure was placed and held below this road or bridge crossing and the aforementioned procedure was repeated until road and bridge crossing could be avoided. There were no major tributaries discharging to the stream in the study area as suggested by the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. The tape measure was left in the study area for sampling.

Before sampling the physical/chemical field sheet (Chapter 5; Appendix A-1, Form 1 of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition) was completed to document the site description, weather conditions, and land use. After sampling this information was reviewed for accuracy and completeness.

The straight-away portions of the sampling reach were photographed with a digital camera starting downstream and ending upstream to include in-stream attributes

(e.g. riffles, falls, fallen trees, pools, bends, etc.) and important structures, plants, and attributes of the bank and near stream areas. If the sampling reach had curves, the "straight-away portions of each curve" were photographed. This means more photographs were taken of sampling reaches that had more curves because each "straight-away segment of the curve" received a photograph, and fewer photographs were taken of sampling reaches that had less curves.

Two sampling procedures were used. One procedure was used depending upon if the habitat was a single habitat or a multihabitat. Habitats that had a very slow current or were greater than 1 ft deep, and lacked riffles were considered to be multihabitats and a multihabitat approach was used for them. Habitats that were 1 ft deep or less and had riffles and runs were considered single habitats. The second procedure was used for all habitats whether they were single or multihabitats. For single habitats with riffles and runs, all riffle and run areas within the 100-m reach were candidates for sampling macroinvertebrates. A composite sample was taken from individual sampling spots in the riffle and runs representing different velocities.

Field Sampling Procedures for Single Habitat

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (A) was done along the bank on the right. The second replicate (B) was done along the bank on the left. The third replicate (C) was done in the middle of the channel. For sampling, a surber sampler (0.3 m x 0.3 m with a mesh size of 500 μ) was placed horizontally on cobble substrate and 2 or 3 kicks (use of the toe or heel of the boot to dislodge the upper layer of cobble or gravel and to

scrape the underlying bed) were done at various velocities in the riffle or series or riffles. Larger substrate particles were picked up and rubbed by hand to remove attached organisms. The net on the vertical section of the frame captured the dislodged organisms from the sampling area.

The kicks collected from three different locations in the cobble substrate were composited to obtain a single homogenous sample for each replicate. After each kick, the collected material was washed by running clean stream water through the net 2 to 3 times until the water was clear. Large debris was removed after rinsing and inspecting for organisms. Any organisms found were placed into a sample container.

The sample in the net was transferred to a sample container and enough 95 percent ethanol was added to cover the sample. Forceps were used to remove organisms from the net. A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

Observations of aquatic flora and fauna were documented and qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling were made.

Habitat assessment (Appendix A-1, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was performed after sampling was completed by walking the reach.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, all nets, pans, and etc. that came in contact with a sample was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The equipment was examined again prior to use at the next sampling site.

Field Sampling Procedures for Multihabitat

Different types of habitat were sampled in approximate proportion to their representation of surface area of the total macroinvertebrate habitat in the reach. For example, if snags comprised 50% of the habitat in a reach and riffles comprised 20%, then 10 kicks were done in snag material and 4 kicks were done in riffle areas. The remainder of the kicks (6) would be done in any remaining habitat type. Habitat types contributing less than 5% of the stable habitat in the stream were not sampled. In this case, the remaining kicks were allocated proportionately among the predominate

substrates. The number of kicks done in each habitat was recorded on the field data sheet.

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (A) was done along the bank on the right. The second replicate (B) was done along the bank on the left. The third replicate (C) was done in the middle of the channel. A total of 20 kicks were done over the length of the reach. A kick was a stationary sampling accomplished by positioning a D-frame dip net (0.3 m width and 0.3 m height and shaped as a "D" with a mesh size of 500 μ) and disturbing the substrate for a distance of 0.5 m upstream of the net.

Kicks collected from the multiple habitats were composited to obtain a single homogenous sample for each replicate. After every 3 kicks or more if necessary, the collected material was washed by running clean stream water through the net two to three times. Large debris was removed after rinsing and inspecting for organisms. Any organisms found were placed into a sample container.

The sample in the net was transferred to a sample container and enough 95 percent ethanol was added to cover the sample. Forceps were used to remove organisms from the net. A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable

Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

Observations of aquatic flora and fauna were documented and qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling were made.

Habitat assessment (Appendix A-1, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was performed after sampling was completed by walking the reach.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, all nets, pans, and etc. that came in contact with a sample was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The equipment was examined again prior to use at the next sampling site.

Coarse Particulate Organic Matter (CPOM) Sampling Procedures

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (D) was done along the bank on the right. The second replicate (E) was done along the bank on the left. The third replicate (F) was done in the middle of the channel. Three grab type samples were collected for each replicate. These samples were sorted in the field, composited (i.e., the contents from the three grab samples from each site was combined into a single container) for each replicate, and preserved in 80% ethanol for later subsampling, identification and enumeration.

A composite collection of a variety of CPOM forms (e.g., leaves, needles, twigs, bark, or fragments of these) was collected for each replicate. The material was sampled in depositional areas, such as pools and along snags and undercut banks. The CPOM sample was processed using a U.S. Standard No. 30 sieve, and added to the composite of the replicate grab samples for each site.

A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, the sieve was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The sieve was examined again prior to use at the next sampling site.

Laboratory Processing For Macroinvertebrate Samples

All samples were dated and recorded in the "Sample Log" notebook or on sample log form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition in the laboratory. All information from the sample container label was included on the sample log sheet. All samples were sorted in a single laboratory to enhance quality control.

The identity and number of organisms were recorded on the Laboratory Bench Sheet (Appendix A-3, Form 3) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The life stage of the organisms, the taxonomist's initials and the Taxonomic Certainty Rating (TCR) was recorded as a measure of confidence.

The back of the bench sheet was used to explain certain TCR ratings or condition of organisms. Other comments were included to provide additional insights for data interpretation.

A 100-organism subsample of the benthic macroinvertebrate composite sample from each sampling site was to be taken into the laboratory according to the methods outlined in the Rapid Bioassessment Protocol used by the NJDEP Bureau of Freshwater and Biological Monitoring. With the exception of chironomids and oligochaetes, benthic macroinvertebrates were to be identified to genus. Chironomids were to be identified to subfamily as a minimum, and oligochaetes were to be identified to family as a minimum.

Each individual organism was to be assigned a number and 100 numbers were to be randomly selected out of a hat. The organisms assigned to these numbers were to be the randomly selected sub-sample. Taxa richness (total families) was to be determined by totaling each different family represented in the sub-sample. The EPT (*Ephemeroptera*, *Plecoptera*, and *Trichoptera* orders; mayflies, stoneflies, and caddisflies) Index was to be determined by adding each individual EPT family in the sub-sample. Percent dominance was to be determined by the family that has the greatest number of individuals in the sub-sample. Percent EPT was be determined by adding the total number of individuals found in all EPT families in the sub-sample. A Modified Family Biotic Index (FBI) was to be determined by $FBI = \Sigma\, x_i\, t_i / n$ where x_i = number of individuals within a family, t_i = tolerance value of a family (in appendix B, Tables C-1 and C-2 of the NJDEP guide), and n = total number of organisms within the sub-sample

(100). Taxa richness, EPT Index, percent dominance, percent EPT, and FBI were to be assigned a biometric score of 0, 3, or 6 (in Table 1 of the NJDEP guide) and totaled. A score of 24-30 means Tenakill Brook watershed is not impaired, 9-21 means it is moderately impaired, and 0-6 means it is severely impaired. A good or bad land assessment moves a score between a range up or down.

The measurement of physicochemical parameters was also conducted concurrent with the benthic macroinvertebrate sampling. These parameters, pH, temperature, dissolved oxygen, and total dissolved solids (TDS) were conducted by Rutgers University.

For archiving samples, specimen vials, (grouped by station and date), were placed in jars with a small amount of denatured 70% ethanol and tightly capped. The ethanol levels in these jars was examined periodically and replenished as needed. A stick-on label was placed on the outside of the jar indicating sample identifier and date.

Biological Monitoring Results and Discussion

Physical characterization/water quality

The Tenakill Brook watershed is composed of variety of different streams. Site TB1 of Tenakill Brook is slow moving and lacks riffles (Table 1). Demarest Brook, a tributary of Tenakill Brook, moves faster than TB1 and has riffles but also has erosion and a lot of deposition (Table 2). Cresskill Brook, another tributary of Tenakill Brook that was sampled during a rain event, may move faster than Demarest Brook and has riffles but does not have as much erosion and deposition as Demarest Brook (Table 3). It is possible that its faster flow was due to the rain event on the day of sampling. TB4 of

Tenakill Brook is slow moving and lacks riffles much like TB1. It differs from TB1 because of its smaller size and lack of curves (Table 4). Tables 1-4 also include information about the stream such as weather conditions during sampling, watershed features, riparian vegetation, instream features, large woody debris, aquatic vegetation, water quality, and sediment and substrate characteristics. The photographs of each station are immediately after the table. The table indicates the number of pages that contain the photographs.

Table 1. Physical characterization/water quality field data sheet for TB1.

Stream Name: Tenakill Brook	
Station #: TB1	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 8/28/07 Time: 9:30 am
Weather conditions:	25% cloud cover in the past 24 hours, heavy rain in the last 7 days, air temperature: 24 ^{o} C
Site location/photographs	See the next 7 pages
Watershed features	Predominant surrounding land use: park, no evidence of local watershed NPS pollution, moderate evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees and shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 5 m, stream depth: 1 m, canopy cover: partly shaded, 100% run, not channelized, no dam present
Large woody debris	LWD: 1 m^2
Aquatic vegetation	Rooted emergent was the dominant type, 50% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, turbid to slightly turbid
Sediment/substrate	No odors, no oils, no deposits,
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 10%
Boulder: 0%	
Cobble: 5%	Muck-Mud: 0%
Gravel: 0%	
Sand: 5%	Marl: 0%
Silt: 45%	
Clay: 45%	

Table 2. Physical characterization/water quality field data sheet for DB1.

Stream Name: Demarest Brook	
Station #: DB1	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 8/28/07 Time: 2:30 pm
Weather conditions:	25% cloud cover in the past 24 hours, heavy rain in the last 7 days, air temperature: 24 ^{o} C
Site location/photographs	See the next 6 pages
Watershed features	Predominant surrounding land use: park, no evidence of local watershed NPS pollution, heavy evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees and shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 1-2 m, stream depth: < 0.3 m, canopy cover: shaded, 30% riffle, 30% pool, 30% run, channelized, no dam present
Large woody debris	LWD: 0 m^2
Aquatic vegetation	0% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, slightly turbid to clear
Sediment/substrate	No odors, no oils, some trash
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 75%
Boulder: 0%	
Cobble: 20%	Muck-Mud: 0%
Gravel: 20%	
Sand: 20%	Marl: 0%
Silt: 20%	
Clay: 20%	

Table 3. Physical characterization/water quality field data sheet for CB1.

Stream Name: Cresskill Brook	
Station #: CB1	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 9/11/07 Time: 12:30 am
Weather conditions:	100% rain, no heavy rain in the last 7 days, air temperature: 72 ^{o} F
Site location/photographs	See the next 4 pages
Watershed features	Predominant surrounding land use: forest, no evidence of local watershed NPS pollution, no evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees are the dominant type
Instream features	Estimated reach length: 100 m, width: 5 m, stream depth: < 0.3 m, canopy cover: partially open, 30% riffle, 30% pool, 30% run, channelized, no dam present
Large woody debris	LWD: 0 m^2
Aquatic vegetation	0% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, slightly turbid to clear
Sediment/substrate	No odors, no oils, no deposits
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 75%
Boulder: 0%	
Cobble: 20%	Muck-Mud: 0%
Gravel: 20%	
Sand: 20%	Marl: 0%
Silt: 20%	
Clay: 20%	

Table 4. Physical characterization/water quality field data sheet for TB4.

Stream Name: Tenakill Brook	
Station #: TB4	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 9/11/07 Time: 3:00 pm
Weather conditions:	100% cloud cover, no heavy rain in the last 7 days, air temperature: 75 ^{o} F
Site location/photographs	See the next 4 pages
Watershed features	Predominant surrounding land use: commercial, no evidence of local watershed NPS pollution, no evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees and shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 2 m, stream depth: < 0.3 m, canopy cover: partly shaded, 100% run, channelized, no dam present
Large woody debris	LWD: 0 m^2
Aquatic vegetation	Rooted emergent (30%), rooted submergent (30%) and rooted floating (30%) were dominant, 100% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, turbid
Sediment/substrate	No odors, no oils, trash
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 60%
Boulder: 0%	
Cobble: 0%	Muck-Mud: 0%
Gravel: 0%	
Sand: 0%	Marl: 0%
Silt: 50%	
Clay: 50%	

Benthic Macroinvertebrates

Because station TB1 of Tenakill Brook was deep, slow moving, and lacked riffles (see Table 1), a D frame dip net was used to collect macroinvertebrates. An average of 2 (common) were collected from TB1 using this technique compared to an average of 1 (rare) that was collected by grab samples (Table 5). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which found for each of the following taxa (Isopoda, Amphipoda, Zygoptera, and Chironomidae) (Table 5).

Because Demarest Brook was shallow and had riffles (see Table 2), a surber was used to collect macroinvertebrates. An average of 1 (rare) was collected from Demarest Brook using this technique compared to an average of 0.3 (absent/not observed) that was collected by grab samples (Table 6). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Trichoptera (Table 6).

Because Cresskill Brook also was shallow and had riffles (see Table 3), a surber was used to collect macroinvertebrates. An average of 2 (common) was collected from Cresskill Brook using this technique compared to an average of 1 (rare) that was collected by grab samples (Table 7). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Trichoptera (Table 7).

Because station TB4 of Tenakill Brook was shallow and lacked riffles (see Table 4), a dip was used to collect macroinvertebrates. An average of 1 (rare) was collected from TB4 using this technique and grab samples (Table 8). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Amphipoda (Table 8).

Table 5. Benthic macroinvertebrate field data sheet for TB1.

Stream Name: Tenakill Brook								
Station #: TB1								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				10s				50vb
Sample collection: d = d frame, s = surber, g = grab	d	d	d		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	3	2	2	2.3	1	2	1	1.3
Fish	0	0	0	0	0	0	0	0.3
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	1	1	0	0.7	1	0	0	0.3
Amphipoda	1	2	1	1.3	1	0	1	0.7
Decapoda	0	0	0	0	0	0	0	0
Gastropoda	0	1	0	0.3	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	1	1	0	0.7	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	2	1	0	1	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	1	0	1	0.7	0	2	0	0.7
Ephemeroptera	1	0	0	0.3	0	0	0	0
Trichoptera	0	0	0	0	0	0	0	0
Other (Nematocera)	0	0	0	0	0	0	0	0

Table 6. Benthic macroinvertebrate field data sheet for DB1.

Stream Name: Demarest Brook								
Station #: DB1								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				20s				0vb
Sample collection: d = d frame, s = surber, g = grab	s	s	s		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	1	1	1	1	0	1	0	0.3
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	1	0	0.3	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0
Ephemeroptera	0	0	0	0	0	0	0	0
Trichoptera	1	0	1	0.7	0	0	0	0
Other (Nematocera)	0	1	0	0.3	0	1	0	0.3

Table 7. Benthic macroinvertebrate field data sheet for CB1.

Stream Name: Cresskill Brook								
Station #: CB1								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				20s				0vb
Sample collection: d = d frame, s = surber, g = grab	s	s	s		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton								
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes								
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	2	2	2	2	1	1	2	1.3
Fish								
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Amphipoda	0	1	0	0.3	0	0	0	0
Decapoda	0	0	0	0	1	0	0	0.3
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	0	0	0	0	0	1	0	0.3
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	1	0.3
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	1	0.3
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0
Ephemeroptera	0	0	1	0.3	0	0	0	0
Trichoptera	2	2	1	1.7	0	1	2	1
Other (Nematocera)	0	0	0	0	0	0	0	0

Table 8. Benthic macroinvertebrate field data sheet for TB4.

Stream Name: Tenakill Brook								
Station #: TB4								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				20s				100 Vb
Sample collection: d = d frame, s = surber, g = grab	d	d	d		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	2	2	0	1.3	0	1	1	0.7
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	1	0	0.3	0	0	1	0.3
Amphipoda	2	1	0	1	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	1	0	0.3	0	0	1	0.3
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	1	0	0.3
Ephemeroptera	1	0	0	0.3	0	0	0	0
Trichoptera	0	0	0	0	0	0	0	0
Other (Nematocera)	0	0	0	0	0	1	0	0.3

Habitat assessment

Station TB1 of Tenakill Brook is suboptimal for epifaunal substrate/available cover, poor for embeddedness, poor for velocity/depth regime, optimal for sediment deposition and optimal for channel flow status for an overall score of suboptimal (Table 9).

Demarest Brook is suboptimal for epifaunal substrate/available cover, optimal for embeddedness, marginal for velocity/depth regime, poor for sediment deposition and marginal for channel flow status for an overall score of suboptimal/marginal (Table 10).

Cresskill Brook is optimal for epifaunal substrate/available cover, optimal for embeddedness, marginal for velocity/depth regime, optimal for sediment deposition and suboptimal for channel flow status for an overall score of optimal (Table 11).

Station TB4 of Tenakill Brook is suboptimal for epifaunal substrate/available cover, poor for embeddedness, marginal for velocity/depth regime, optimal for sediment deposition and optimal for channel flow status for an overall score of suboptimal (Table 12).

Cresskill Brook having an overall score of optimal may be the reason why it was the only water body, other than TB1, to have a macroinvertebrate collection average of 2 (the number of macroinvertebrates collected is common) (Table 7). When considering the type of macroinvertebrates present, all water bodies, including Cresskill Brook, have a collection average of 1 (the number in the different types of macroinvertebrates is rare). This suggests a lack of diversity. TB1 has a macroinvertebrate collection average of 2 (common) because although the number in the different types of macroinvertebrates is rare, it has more different types of macroinvertebrates. This suggests more diversity.

Table 9. Habitat assessment field data sheet for TB1.

Stream Name: Tenakill Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 11	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. 1
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep). 0
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed. 20	Water fills >75% of the available channel; or <25% of channel substrate is exposed	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Table 10. Habitat assessment field data sheet for DB1.

Stream Name: Demarest Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 15	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space. 19	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low). 9	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition. 5
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed	Water fills >75% of the available channel; or <25% of channel substrate is exposed	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed. 8	Very little water in channel and mostly present as standing pools.

Table 11. Habitat assessment field data sheet for CB1.

Stream Name: Cresskill Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient). 16	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space. 20	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low). 10	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 19	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed	Water fills >75% of the available channel; or <25% of channel substrate is exposed. 15	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Table 12. Habitat assessment field data sheet for TB4.

Stream Name: Tenakill Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 12	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. 0
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low). 6	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed. 20	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Benthic Macroinvertebrates

At station TB1 of Tenakill Brook, the Gammaridae averaged 3 individuals followed by the Elmidae with 2, and the Asellidae, the Coenagrionidae, and the Chironomidae with 1 (Table 13).

At Demarest Brook, the Hydropsychidae averaged 1 individual followed by the Tipulidae with 0.3 (Table 14).

At Cresskill Brook, the Hydropsychidae averaged 2 individuals followed by the Baetidae with 1 (Table 15).

At station TB4 of Tenakill Brook, the Gammaridae averaged 2 individuals followed by the Asellidae, the Elmidae, the Simuliidae, the Chironomidae and the Tipulidae with 0.3 (Table 16).

Due to the inability of obtaining a 100-organism subsample, even if combining replicates A-C with D-F which could not be done because different techniques were used in replicates A-C and D-F, taxa richness, EPT Index, percent dominance, percent EPT, and FBI were not calculated for a score. This suggests that the Tenakill Brook watershed should receive the most severe level of biological impairment.

Table 13. Benthic macroinvertebrate field data sheet for TB1.

Stream Name: Tenakill Brook								
Station #: TB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae	2	1	0	1	1	0	0	0.3
# of Amphipoda, Gammaridae	3	4	3	3.3	1	0	1	0.7
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera, mayfly	1	0	0	0.3	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae	4	1	0	1.7	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda, Physidae	0	1	0	0.3	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Zygoptera, Coenagrionidae	1	2	0	1	0	0	0	0
# of Other, Nematocera, Chironomidae	1	0	2	1	0	4	0	1.3

Table 14. Benthic macroinvertebrate field data sheet for DB1.

Stream Name: Demarest Brook								
Station #: DB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae	2	0	2	1.3	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera	0	0	0	0	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Nematocera, Tipulidae	0	1	0	0.3	0	1	0	0.3

Table 15. Benthic macroinvertebrate field data sheet for CB1.

Stream Name: Cresskill Brook								
Station #: CB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda, Gammaridae	0	1	0	0.3	0	0	0	0
# of Decapoda, Cambaridae	0	0	0	0	2	0	0	0.7
# of Ephemeroptera, Baetidae	0	0	2	0.7	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae	5	0	2	2.3	0	1	5	2
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae	0	0	0	0	0	0	1	0.3
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Zygoptera, Coenagrionidae	0	0	0	0	0	1	0	0.3
Simuliidae	0	0	0	0	0	0	1	0.3

Table 16. Benthic macroinvertebrate field data sheet for TB4.

Stream Name: Tenakill Brook								
Station #: TB4								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae	0	1	0	0.3	0	0	1	0.3
# of Amphipoda, Gammaridae	4	3	0	2.3	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera, Baetidae	1	0	0	0.3	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae	0	1	0	0.3	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Simuliidae	0	1	0	0.3	0	0	1	0.3
Nematocera, Chironomidae	0	0	0	0	0	1	0	0.3
Nematocera, Tipulidae	0	0	0	0	0	1	0	0.3

References

NWCC Technical Note 99-1, Stream Visual Assessment Protocol, December 1998. 2 pgs.

Peckarsky, B.L., Fraissinet, P.R., Penton, M.A., and Conklin, Jr., D.J. 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press. Ithaca, N.Y. 442 pgs.

Rawlyk, W. 1998. The Common Benthic Macroinvertebrates of New Jersey Streams: A Field Guide to Family Level Identification. William Rawlyk. 101 pgs.

USEPA 1997. Volunteer Monitoring Guide for Macroinvertebrate Sampling and Data Analysis: New Jersey Impairment Score (NJIS) Bioassessment.

USEPA Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers (EPA 841-B-99-002 Nov. 1999).

Tenakill Brook Benthic Species List

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for

Rutgers Cooperative Extension Water Resources Program
as part of
RP07-001 Tenakill Brook Watershed
Restoration and Protection Plan

June 2009

Table 1. Benthic macroinvertebrate field data sheet for TB1.

Stream Name: Tenakill Brook								
Station #: TB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae, *Caecidotea* sp.	2	1	0	1	1	0	0	0.3
# of Amphipoda, Gammaridae,	3	4	3	3.3	1	0	1	0.7
Gammarus fasciatus								
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera, *Siphlonurus quebecensis*	1	0	0	0.3	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae, *Dubiraphia* sp.	4	1	0	1.7	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda, Physidae, *Physa* sp.	0	1	0	0.3	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Zygoptera, Coenagrionidae,	1	2	0	1	0	0	0	0
Argia sp.								
# of Other, Nematocera, Chironomidae,	1	0	2	1	0	4	0	1.3
Axarus sp.								

Table 2. Benthic macroinvertebrate field data sheet for DB1.

Stream Name: Demarest Brook								
Station #: DB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae,	2	0	2	1.3	0	0	0	0
Hydropsyche sp.								
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera	0	0	0	0	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Nematocera, Tipulidae,	0	1	0	0.3	0	1	0	0.3
Antocha sp.								

Table 3. Benthic macroinvertebrate field data sheet for CB1.

Stream Name: Cresskill Brook								
Station #: CB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda, Gammaridae,	0	1	0	0.3	0	0	0	0
Gammarus fasciatus								
# of Decapoda, Cambaridae,	0	0	0	0	2	0	0	0.7
Orconectes virilis								
# of Ephemeroptera, Baetidae,	0	0	2	0.7	0	0	0	0
Callibaetis sp.								
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae,	5	0	2	2.3	0	1	5	2
Hydropsyche								
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae, *Dubiraphia* sp.	0	0	0	0	0	0	1	0.3
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Zygoptera, Coenagrionidae,	0	0	0	0	0	1	0	0.3
Argia sp.								
Simuliidae, *Simulium* sp.	0	0	0	0	0	0	1	0.3

Table 4. Benthic macroinvertebrate field data sheet for TB4.

Stream Name: Tenakill Brook								
Station #: TB4								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae, *Caecidotea* sp.	0	1	0	0.3	0	0	1	0.3
# of Amphipoda, Gammaridae,	4	3	0	2.3	0	0	0	0
Gammarus fasciatus								
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera, Baetidae, *Callibaetis* sp.	1	0	0	0.3	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Elmidae, *Dubiraphia* sp.	0	1	0	0.3	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Simuliidae, *Simulium* sp.	0	1	0	0.3	0	0	1	0.3
Nematocera, Chironomidae, *Axarus* sp.	0	0	0	0	0	1	0	0.3
Nematocera, Tipulidae, *Antocha* sp.	0	0	0	0	0	1	0	0.3

References

NWCC Technical Note 99-1, Stream Visual Assessment Protocol, December 1998. 2 pgs.

Peckarsky, B.L., Fraissinet, P.R., Penton, M.A., and Conklin, Jr., D.J. 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press. Ithaca, N.Y. 442 pgs.

Rawlyk, W. 1998. The Common Benthic Macroinvertebrates of New Jersey Streams: A Field Guide to Family Level Identification. William Rawlyk. 101 pgs.

Appendix B: Quality Assurance Project Plan, Tenakill Brook Watershed Restoration Plan, Rutgers Cooperative Extension Water Resources Program, January 8, 2007

QUALITY ASSURANCE PROJECT PLAN

TENAKILL BROOK WATERSHED RESTORATION PLAN

Rutgers Cooperative Extension Water Resources Program

January 8, 2007

QUALITY ASSURANCE PROJECT PLAN

TENAKILL BROOK WATERSHED RESTORATION PLAN

Rutgers Cooperative Extension Water Resources Program

Applicant/
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Signature Date

1. Project Name: Tenakill Brook
Watershed Restoration Plan

Requested By: David McPartland
New Jersey Department of Environmental Protection

2. This project has been initiated by the New Jersey Department of Environmental Protection to collect data needed to prepare a comprehensive watershed restoration plan for the Tenakill Brook.

3. Date Project Requested: January 2007

4. Date Project Initiated: May 2007

5. Project Officer: Christopher C. Obropta, Ph.D., P.E.
Rutgers Cooperative Extension Water Resources Program

6. QA Officer: Lisa Galloway Evrard
Rutgers Cooperative Extension Water Resources Program

7. Project Description:

A. Objective and Scope

The proposed watershed study area is the Tenakill Brook Watershed of Watershed Management Area 5 (WMA 5). The Tenakill Brook Watershed, Hydrologic Unit Code 02030103170040, is approximately nine square miles in size. Based upon numerous monitoring sources; including the New Jersey Department of Environmental Protection (NJDEP) Ambient Biomonitoring Network (AMNET) program and the NJDEP USGS water quality monitoring network, water quality impairments exist in the Tenakill Brook Watershed. According to the *New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report*, the Tenakill Brook maintains the following listings:

- 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 and arsenic.

Based on the TMDL prepared for the Tenakill Brook at Cedar Lane in Closter, USGS 01378387, a 96% reduction in fecal coliform load is needed for 10.2 miles of stream. Aquatic life will also need to be addressed through the TMDL process. Furthermore, United Water stream data indicate that total phosphorus is exceeding state criteria in this watershed.

In 2004, the Tenakill Brook was recognized as a *priority stream segment* by the NJDEP, which resulted in funds being provided to collect additional water quality data from the Tenakill Brook. This data collection effort is primarily focused on fecal coliform, so that additional data may aid in the identification of fecal coliform sources for the TMDL. Due to the already established partnership between Bergen County, WMA 5 Committees, and the Rutgers

Cooperative Extension Water Resources Program, the Watershed Restoration Plan will build upon the ongoing work to identify fecal coliform sources. Furthermore, the priority stream segment work will yield a Tenakill Brook Restoration Plan that includes data gathering and GIS development. In saving costs, the project partners will make use of the information that is already being gathered to begin the Watershed Restoration Planning process.

B. Data Usage

The data collected in accordance with this Quality Assurance Project Plan (QAPP) will help describe both dry weather and wet weather water quality conditions. These data will provide the information needed to identify and quantify sources of pollution so that appropriate management practices can be implemented to minimize these sources.

C. Monitoring Network Design and Rationale

Sampling Locations:

The proposed sampling locations are shown in Attachment A. Seven sampling stations have been proposed throughout the watershed as follows:

Tenakill Brook Proposed Water Quality Stations

Station ID	Station Name	Northing	Easting
CC1	Charlie's Creek at Brook St, Closter	779,397	638,818
CB1	Cresskill Brook at Delmar Ave, Cresskill	770,072	641,412
DB1	Demarest Brook at County Rd, Demarest	772,015	642,062
TB1	Tenakill Brook at Harrington Ave, Closter	781,077	639,118
TB2	Tenakill Brook at UWNJ Gaging Station, Demarest	773,931	640,594
TB3	Tenakill Brook at Grove St Parking Lot, Tenafly	765,462	640,012
TB4	Tenakill Brook at Tenafly Rd, Tenafly	763,271	639,299

A WAAS-enable Garmin Rino 120 GPS (global positioning system) unit will be used to locate and identify the sampling locations. Sampling locations will be marked with stakes and surveying tape.

Temporal and Spatial Aspects:

Biweekly Surface Water Sampling

Surface water quality samples will be collected from all sampling locations twice a month, independent of weather, from May through October 2007 (12 events). Three additional surface water quality samples will be collected from all sampling locations in June, July, and August 2007 for fecal coliform analyses (nine additional sampling events). These nine additional sampling events will be independent of precipitation and will allow for a total of five fecal coliform analyses at all sampling locations within a 30 day period during the warmer summer months. All scheduling is subject to the natural occurrence of appropriate stream flow conditions (i.e., non-flooding conditions). Surface water sampling will be conducted so that the samples are representative of the cross section of the stream. A single grab sample will be

collected at all locations where the stream width is six feet or less. At stream locations with a width greater than six feet, three subsurface grab samples will be collected at equidistant points across the stream. These grab samples then will be composited in a larger volume container from which the desired volume will be transferred to the sample bottles. A dedicated large volume container will be assigned to each sample location. Prior to each sampling event, the large volume containers will be decontaminated using the following procedures in accordance with the NJDEP 2005 Field Sampling Procedures Manual: 1) laboratory grade glassware detergent plus tap water wash, 2) generous tap water rinse, 3) distilled/deionized water rinse, 4) 10% nitric acid rinse, 5) distilled/deionized water rinse.

Wet Weather Surface Water Sampling

Three wet weather sampling events, at a minimum, will be conducted between May and October 2007 at each station. The wet weather samples for this plan will be in addition to the 12 biweekly surface water sampling events described above. Collection of stormwater samples will begin at the onset of the storm (i.e., a storm predicted to produce a minimum of ½ inch of precipitation), and an attempt will be made to span the course of the event. By using this method of sampling, the samples should accurately reflect loading for the entire event. A priority will be to acquire first flush samples. Flow will be measured along with concentrations to quantify loading for selected parameters. A minimum of four additional samples will be obtained between the onset of the storm and the time when the flow reaches the pre-storm level, unless impractical, at each station during each storm event. At each station, the samples obtained for the entire event will be flow-weight composited to provide one sample from each station, with the exception of fecal coliform, which will require analysis of each individual grab sample. Rainfall data will be collected from a rain gauge that will be installed in the watershed.

Biological Sampling

Samples of the benthic macroinvertebrate community will be collected in accordance with the Rapid Bioassessment Protocol (RBP) procedure used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-002 Nov. 1999). A multihabitat sampling approach, concentrating on the most productive habitat of the stream plus coarse particulate organic matter (CPOM) or leaf litter, will be used. Benthic macroinvertebrates will be collected from four locations (i.e., CB1, DB1, TB1, TB4) once in either early summer or late summer as described in Attachment B.

Basis for Sampling Locations:

Surface water quality sampling will be conducted to assess the loading inputs of nutrients, total suspended solids and bacteria to the Tenakill Brook, as well as the movement of nutrients, total suspended solids and bacteria from basin to basin to identify and quantify the sources of pollution under dry weather and wet weather conditions. Biological sampling will be conducted so that the benthic macroinvertebrate community can be better characterized, compared, and evaluated for biological integrity.

D. Monitoring Parameters

Surface water quality sample collection will be conducted by the Rutgers Cooperative Extension Water Resources Program (RCE WRP). Stream width, stream depth, and stream

velocity will be measured in accordance with the methods outlined in Attachment C by the RCE WRP. *In situ* measurements of pH, temperature, and dissolved oxygen will be conducted by the Rutgers EcoComplex Laboratory (NJDEP Certified Laboratory #03019). Collected samples will be analyzed for fecal coliform, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, and total suspended solids by New Jersey Analytical Laboratories (NJDEP Certified Laboratory #11005). Once the Rutgers EcoComplex Laboratory obtains certification for these parameters, the analyses will be conducted under NJDEP Certified Laboratory #03019. NJDEP will be notified of this change when it occurs.

Biological sampling will include benthic macroinvertebrate grab/jab type sampling, along with the collection of CPOM. Physicochemical measurements will include *in situ* pH, temperature, dissolved oxygen, stream width, stream depth, and stream velocity. Benthic macroinvertebrate sampling and identification will be conducted by the RCE WRP in accordance with the Rapid Bioassessment Protocol (RBP) procedure used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-002 Nov. 1999). The RCE WRP will make stream width, stream depth, and stream velocity determinations in accordance with the procedures specified in Attachment C. *In situ* measurements of pH, temperature, and dissolved oxygen will be conducted by the Rutgers EcoComplex Laboratory (NJDEP Certified Laboratory #03019).

E. Parameter Table

Measurements of the sampled parameters will be performed in accordance with Table 1A – List of Approved Biological Methods and Table 1B – List of Approved Inorganic Test Procedures (40 CFR Part 136.3) of Attachment D. Sample containers, preservation techniques, and holding times will be in accordance with Table II (40 CFR Part 136.3) of Attachment E. New Jersey Analytical Laboratories will provide appropriate containers for all analyses. Any deviations from the test procedures and/or preservation methods and holding times will be reported to the NJDEP Office of Quality Assurance and will be noted in the final report from the laboratory.

8. Schedule:*

Task	Date
Submit QAPP	January 2007
Conduct biweekly surface water sampling	May – October 2007
Conduct wet weather surface water sampling	May - October 2007
Conduct biological sampling	Early Summer or Late Summer 2007
Submit data and summary report to NJDEP	January 2008

* All scheduling is subject to the natural occurrence of appropriate stream flow conditions (i.e., non-flooding conditions).

9. Project Organization and Responsibility:

Laboratory Operations:	(QA Director) (Lab Director) (NJDEP Representative)	George Latham Allen Thomas Marc Ferko
Sampling Operations:	(QA Officer) (NJDEP Representative)	Lisa Galloway Evrard Marc Ferko
Data Processing/ Data Quality Review:	(QA Officer) (NJDEP Representative)	Lisa Galloway Evrard David McPartland Michele Bakacs
Overall QA:	(QA Officer)	Lisa Galloway Evrard
Overall Coordination:	(Project Officer)	Christopher C. Obropta

10. Organizational Chart:

Overall Coordination: Christopher C. Obropta (RCE WRP) Overall QA: Lisa Galloway Evrard (RCE WRP)
Data Quality Review/Data Processing: Lisa Galloway Evrard (RCE WRP) David McPartland (NJDEP) Michele Bakacs (NJDEP)
Sampling QC/Sampling Operations: Lisa Galloway Evrard (RCE WRP) Marc Ferko (NJDEP)
Laboratory QC/Laboratory Director: George Latham, Quality Assurance Director, (New Jersey Analytical Laboratories) Allen Thomas, Laboratory Director, (New Jersey Analytical Laboratories) Marc Ferko (NJDEP)

11. Sampling Procedures:

All sampling procedures will be in conformance with the NJDEP 2005 Field Sampling Procedures Manual, any applicable USEPA guidance, or with prior written approval. In addition, instrumentation used for the collection of field data will be properly calibrated, in conformance with the manufacturer's instructions and the NJDEP Field Sampling Procedures Manual.

12. Chain of Custody Procedures:

Chain of Custody procedures will be followed for all samples collected for this monitoring program. A sample chain of custody form is provided in Attachment F. A sample is in someone's "custody" if 1) it is in one's actual physical possession, 2) it is in one's view, after being in one's physical possession, 3) it is in one's physical possession and then locked up so that no one can tamper with it, and 4) it is kept in a secured area, restricted to authorized personnel only.

13. Calibration Procedures and Preventative Maintenance:

Calibration and preventative maintenance of laboratory and field equipment will be in accordance with the manufacturer's instructions, NJDEP Field Sampling Procedures Manual, NJAC 7:18 and 40 CFR Part 136.

14. Documentation, Data Reduction, and Reporting:

The QA Officer, for a minimum of five years, will keep all data on file, and all applicable data will be included in the summary report to NJDEP.

15. Quality Assurance and Quality Control:

NJAC 7:18 and 40 CFR Part 136 will be followed for all quality assurance and quality control (QA/QC) practices, including detection limits, quantitation limits, precision, and accuracy. Tables of parameter detection limits, quantitation limits, accuracy, and precision applicable to this study are provided in Attachment G. New Jersey Analytical Laboratories and Rutgers Cooperative Extension will perform data validation.

With regard to the benthic macroinvertebrate samples, at a minimum 10% of the samples will be sent to another laboratory (to be determined) to confirm the identifications done by the Rutgers Cooperative Extension Water Resources Program.

16. Performance and Systems Audits:

All NJDEP certified laboratories participate biannually in USEPA's Performance Evaluation (PE) Studies for each category of certification. Laboratories are required to pass each of these PE studies to maintain certification. The NJDEP Office of Quality Assurance conducts a performance audit of each laboratory that is certified. The NJDEP

Office of Quality Assurance also periodically conducts on-site technical systems audits of each certified laboratory. The findings of these audits, together with the USEPA PE results, are used to update each laboratory's certification status.

The NJDEP Office of Quality Assurance periodically conducts field audits of project sampling operations. The Office of Quality Assurance will be contacted during the project to schedule a possible field audit.

17. Corrective Action:

All NJDEP certified laboratories must have a written corrective action procedure which they adhere to in the event that calibration standards, performance evaluation results, blanks, duplicates, spikes, etc. are out of the acceptable range or control limits. If the acceptable results cannot be obtained for the above-mentioned QA/QC samples during any given day, sample analysis must be repeated for that day with the acceptable QA/QC results. NJDEP will be notified if there are any deviations from the approved work plan.

18. Reports:

The summary report will include at a minimum an Introduction, Purpose and Scope, Results and Discussion, Conclusions and Recommendations, and an appendix with data tables.

ATTACHMENT A

Sampling Locations
Tenakill Brook Watershed

ATTACHMENT B

Biological Sampling Procedures and Analysis

Biological Sampling Procedures and Analysis

These sampling and data analysis procedures are in accordance with the Rapid Bioassessment Protocol procedures used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-02 Nov. 1999).

Sampling Procedures:

Samples will be collected using a multi-habitat sampling approach, concentrating on the most productive habitat of the stream (i.e., the riffle/run areas), plus coarse particulate organic matter (CPOM) or leaf litter. This sampling method minimizes habitat or substrate variation between sampling sites, and includes all likely functional feeding groups of macroinvertebrates in the stream. Three grab type samples will be collected at each sampling site. These samples will be sorted in the field, composited (i.e., the contents from the three grab samples from each site will be combined into a single container), and preserved in 80% ethanol for later subsampling, identification and enumeration.

A composite collection of a variety of CPOM forms (e.g., leaves, needles, twigs, bark, or fragments of these) will be collected. It is difficult to quantify the amount of CPOM to be collected in terms of weight or volume, given the variability of its composition. Collection of several handfuls of material is usually adequate, and the material is typically found in depositional areas, such as in pools and along snags and undercut banks. The CPOM sample will be processed using a U.S. Standard No. 30 sieve, and added to the composite of the grab samples for each site.

A 100-organism subsample of the benthic macroinvertebrate composite sample from each sampling site will be taken in the laboratory according to the methods outlined in the Rapid Bioassessment Protocol used by the NJDEP Bureau of Freshwater and Biological Monitoring. With the exception of chironomids and oligochaetes, benthic macroinvertebrates will be identified to genus. Chironomids will be identified to subfamily as a minimum, and oligochaetes will be identified to family as a minimum.

A habitat assessment will be conducted concurrent with the benthic macroinvertebrate sampling in accordance with the methods used by the NJDEP Bureau of Freshwater and Biological Monitoring. The measurement of physicochemical parameters will also be conducted concurrent with the benthic macroinvertebrate sampling. Surface water sampling for the measurement of pH, temperature, and dissolved oxygen will be conducted on a representative cross section of the steam. At least four subsurface grab samples will be collected across an established transect. These grab samples will be composited, and an appropriate volume will be transferred to sample bottles for in situ measurement of pH, temperature, and dissolved oxygen. Stream width, stream depth, and stream velocity will be measured in accordance with the methods outlined in Attachment C.

Biological Sampling Procedures and Analysis (continued)

Data Analysis:

The NJDEP Bureau of Freshwater and Biological Monitoring uses several community measures of biometrics adapted from the Rapid Bioassessment Protocols to evaluate the biological condition of sampling sites within the Ambient Biomonitoring Network in New Jersey. These community measures include taxa richness, EPT index, %EPT, %CDF, and Modified Family Biotic Index. 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 has been established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired, and is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams.

If the above metrics are not utilized, or if different metrics or indices are used, these changes will be discussed with NJDEP for approval. For example, to determine the similarity among the sampling sites with respect to species composition, the Percentage Similarity Index may be calculated for all pair wise comparisons of the sampling sites. Also, the benthic macroinvertebrates may be separated into the four broad functional feeding groups to evaluate community structure. In addition, the Shannon diversity index may be calculated to evaluate community structure. In addition, the findings from the habitat assessment will be used to interpret survey results and identify obvious constraints on the attainable biological potential of the site.

The final report will include a characterization of the aquatic biota, in particular the benthic macroinvertebrate community.

ATTACHMENT C

Stream Flow Measurement Procedure

Stream Flow Measurement Procedure

Stream width, depth, velocity, and flow determinations will be made in conformance with the following procedures:

1. A measuring tape is extended across the stream, from bank to bank, perpendicular to flow. Meter calibration is checked.

2. Using a Marsh-McBirney, Inc. Model 2000 Flo-Mate Portable Water Flow meter, velocity and depth measurements are made at points along the tape. Normally depth is measured using a rod calibrated in tenths of a foot. In shallow streams, a yardstick may be used to measure depth. Velocities are measured at approximately 0.6 depth (from the surface) where depths are less than 2.5 feet and at 0.2 and 0.8 depth (from the surface) in areas where the depth exceeds 2.5 feet.

3. The stream cross section is divided into segments with depth and velocity measurements made at equal intervals along the cross section. The number of measurements will vary with site conditions and uniformity of stream cross section. Each cross section is divided into equal parts depending upon the total width and uniformity of the section. At a minimum, velocities are taken at quarter points for very narrow sections. In general, velocity and depth measurements are taken every one to five feet. A minimum of ten velocity locations is used whenever possible. The velocity is determined by direct readout from the Marsh-McBirney meter set for 5 second velocity averaging.

4. Using the field data collected, total flow, average velocity, and average depth can be computed. Individual partial cross-sectional areas are computed for each depth and velocity measurement. The mean velocity of flow in each partial area is computed and multiplied by the partial cross-sectional area to produce an incremental flow. Incremental flows are summed to calculate the total flow. The average velocity for the stream can be computed by dividing the total flow by the sum of the partial cross-sectional areas. The average depth for the stream can be computed by dividing the sum of the partial cross-sectional areas by the total width of the stream. The accuracy of this method depends upon a number of factors, which include the uniformity of the steam bottom, total width, and the uniformity of the velocity profile.

ATTACHMENT D

Table 1A – List of Approved Biological Methods
&
Table 1B – List of Approved Inorganic Test Procedures
40 CFR Part 136.3
July 1, 2005

TABLE IA—LIST OF APPROVED BIOLOGICAL METHODS

Parameter and units	Method[1]	EPA	Standard methods 18th, 19th, 20th Ed.	ASTM	AOAC	USGS	Other
Bacteria:							
1. Coliform (fecal), number per 100 mL.	Most Probable Number (MPN), 5 tube 3 dilution, or	p. 132[3]	9221C E[4]				
	Membrane filter (MF)[2], single step.	p. 124[3]	9222D[4]			B–0050–85[5]	
2. Coliform (fecal) in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 132[3]	9221C E[4]				
	MF, single step[6]	p. 124[3]	9222D[4]				
3. Coliform (total), number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2], single step or two step	p. 108[3]	9222B[4]			B–0025–85[5]	
4. Coliform (total), in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2] with enrichment	p. 111[3]	9222(B+B.5c)[4]				
5. *E. coli*, number per 100 mL[20].	MPN[7,9,15], multiple tube,		9221B.1/9221F[4,12,14]				
	multiple tube/multiple well,		9223B[4,13]		991.15[11]		Colilert[Φ13,17] Colilert-18[Φ13,16,17]
	MF[2,6,7,8,9] two step, or		9222B/9222G[4,19]				
	single step	1103.1[20] 1603[21] 1604[22]	9213D[4]	D5392–93[10]			
							mColiBlue 24[18]
6. Fecal streptococci, number per 100 mL.	MPN, 5 tube, 3 dilution,	p. 139[3]	9230B[4], 9230C[4]				
	MF[2], or	p. 136[3]			B–0055–85[5]		
	Plate count	p. 143[4]					
7. Enterococci, number per 100 mL.	MPN[7,9] multiple tube		9230B[4]				
	multiple tube/multiple well			D6503–99[10]			Enterolert[Φ13,23]
	MF[2,6,7,8,9] two step	1106.1[24]	9230C[4]	D5259–92[10]			
	single step, or	1600[25]					
	Plate count	p. 143[3]					
Protozoa:							
8. *Cryptosporidium*[26]	Filtration/IMS/FA	1622[26] 1623[27]					
9. *Giardia*[20]	Filtration/IMS/FA	1623[27]					
Aquatic Toxicity:							
10. Toxicity, acute, fresh water organisms, LC50, percent effluent	*Ceriodaphnia dubia* acute	2002.0[29]					

	Sea urchin, *Arbacia punctulata*, fertilization.	1008.0[31]					

Notes to Table IA:

[1] The method must be specified when results are reported.

[2] A 0.45 µm membrane filter (MF) or other pore size certified by the manufacturer to fully retain organisms to be cultivated and to be free of extractables which could interfere with their growth.

[3] USEPA. 1978. Microbiological Methods for Monitoring the Environment, Water, and Wastes. Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/8–78/017.

[4] APHA. 1998, 1995, 1992. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. 20th, 19th, and 18th Editions. Amer. Publ. Hlth. Assoc., Washington, D.C.

[5] USGS. 1989. U.S. Geological Survey Techniques of Water-Resource Investigations, Book 5, Laboratory Analysis, Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples, U.S. Geological Survey, U.S. Department of Interior, Reston, Virginia.

[6] Because the MF technique usually yields low and variable recovery from chlorinated wastewaters, the Most Probable Number method will be required to resolve any controversies.

[7] Tests must be conducted to provide organism enumeration (density). Select the appropriate configuration of tubes/filtrations and dilutions/volumes to account for the quality, character, consistency, and anticipated organism density of the water sample.

[8] When the MF method has not been used previously to test ambient waters with high turbidity, large number of noncoliform bacteria, or samples that may contain organisms stressed by chlorine, a parallel test should be conducted with a multiple-tube technique to demonstrate applicability and comparability of results.

[9] To assess the comparability of results obtained with individual methods, it is suggested that side-by-side tests be conducted across seasons of the year with the water samples routinely tested in accordance with the most current Standard Methods for the Examination of Water and Wastewater or EPA alternate test procedure (ATP) guidelines.

[10] ASTM. 2000, 1999, 1996, Annual Book of ASTM Standards—Water and Environmental Technology. Section 11.02. American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[11] AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. Association of Official Analytical Chemists International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417.

[12] The multiple-tube fermentation test is used in 9221B.1. Lactose broth may be used in lieu of lauryl tryptose broth (LTB), if at least 25 parallel tests are conducted between this broth and LTB using the water samples normally tested, and this comparison demonstrates that the false-positive rate and false-negative rate for total coliform using lactose broth is less than 10 percent. No requirement exists to run the completed phase on 10 percent of all total coliform-positive tubes on a seasonal basis.

[13] These tests are collectively known as defined enzyme substrate tests, where, for example, a substrate is used to detect the enzyme β–glucuronidase produced by *E. coli*.

[14] After prior enrichment in a presumptive medium for total coliform using 9221B.1, all presumptive tubes or bottles showing any amount of gas, growth or acidity within 48 h ± 3 h of incubation shall be submitted to 9221F. Commercially available EC-MUG media or EC media supplemented in the laboratory with 50 µg/mL of MUG may be used.

[15] Samples shall be enumerated by the multiple-tube or multiple-well procedure. Using multiple-tube procedures, employ an appropriate tube and dilution configuration of the sample as needed and report the Most Probable Number (MPN). Samples tested with Colilert® may be enumerated with the multiple-well procedures, Quanti-Tray® or Quanti-Tray® 2000, and the MPN calculated from the table provided by the manufacturer.

[16] Colilert-18® is an optimized formulation of the Colilert® for the determination of total coliforms and *E. coli* that provides results within 18 h of incubation at 35 °C rather than the 24 h required for the Colilert® test and is recommended for marine water samples.

[17] Descriptions of the Colilert®, Colilert-18®, Quanti-Tray®, and Quanti-Tray®/2000 may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[18] A description of the mColiBlue24® test, Total Coliforms and *E. coli*, is available from Hach Company, 100 Dayton Ave., Ames, IA 50010.

[19] Subject total coliform positive samples determined by 9222B or other membrane filter procedure to 9222G using NA-MUG media.

[20] USEPA. 2002. Method 1103.1: *Escherichia coli* (*E. coli*) In Water By Membrane Filtration Using membrane-Thermotolerant *Escherichia coli* Agar (mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–020.

[21] USEPA. 2002. Method 1603: *Escherichia coli* (*E. coli*) In Water By Membrane Filtration Using Modified membrane-Thermotolerant *Escherichia coli* Agar (modified mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–023.

[22] Preparation and use of MI agar with a standard membrane filter procedure is set forth in the article, Brenner *et al.* 1993. "New Medium for the Simultaneous Detection of Total Coliform and *Escherichia coli* in Water." Appl. Environ. Microbiol. 59:3534–3544 and in USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli* (*E. coli*) in Water by Membrane Filtration by Using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA 821–R–02–024.

[23] A description of the Enterolert® test may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[24] USEPA. 2002. Method 1106.1: Enterococci In Water By Membrane Filtration Using membrane-Enterococcus-Esculin Iron Agar (mE-EIA). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–02–021.

[25] USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–821–R–02–022.

[26] Method 1622 uses filtration, concentration, immunomagnetic separation of oocysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the detection of *Cryptosporidium*. USEPA. 2001. Method 1622: Cryptosporidium in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–026.

[27] Method 1623 uses filtration, concentration, immunomagnetic separation of oocysts and cysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the simultaneous detection of *Cryptosporidium* and *Giardia* oocysts and cysts. USEPA. 2001. Method 1623. Cryptosporidium and Giardia in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–025.

[28] Recommended for enumeration of target organism in ambient water only.

[29] USEPA. October 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fifth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/012.
[30] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Fourth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/013.
[31] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. Third Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/014.

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES

Parameter, units and method	Reference (method number or page)				
	EPA[1,33]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
1. Acidity, as $CaCO_3$, mg/L:					
Electrometric endpoint or phenolphthalein endpoint.	305.1	2310 B(4a) [18th, 19th, 20th].	D1067–92	I–1020–85 I–2030–85	
2. Alkalinity, as $CaCO_3$, mg/L:					
Electrometric of Colorimetric titration to pH 4.5, manual or automatic.	310.1 310.2.	2320 B [18th, 19th, 20th]	D1067–92	I–1030–85 I–2030–85	973.43[3]
3. Aluminium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	202.1	3111 D [18th, 19th]		I–3051–85	
AA furnace	202.2	3113 B [18th, 19th]			
Inductively Coupled Plasma/Atomic Emission Spectrometry (ICP/AES)[36].	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
Direct Current Plasma (DCP)[36].			D4190–94		Note 34.
Colorimetric (Eriochrome cyanine R).		3500–Al B [20th] and 3500–Al D [18th, 19th].			
4. Ammonia (as N), mg/L:					
Manual, distillation (at pH 9.5)[6] followed by:	350.2	4500–NH_3 B [18th, 19th, 20th].			973.49[3]
Nesslerization	350.2	4500–NH_3 C [18th]	D1426–98(A)	I–3520–85	973.49[3]
Titration	350.2	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
Electrode	350.3	4500–NH_3 D or E [19th, 20th] and 4500–NH_3 F or G [18th].	D1426–98(B).		
Automated phenate, or	350.1	4500–NH_3 G [19th, 20th] and 4500–NH_3 H [18th].		I–4523–85	
Automated electrode					Note 7.
5. Antimony-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	204.1	3111 B [18th, 19th]			
AA furnace	204.2	3113 B [18th, 19th]			
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]			
6. Arsenic-Total[4] mg/L:					

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Titrimetric (EDTA), or Ca plus Mg as their carbonates, by inductively coupled plasma or AA direct aspiration (See Parameters 13 and 33).	130.2	2340 B or C [18th, 19th, 20th].	D1126–86(92)	I–1338–85	973.52B[3]
28. Hydrogen ion (pH), pH units:					
Electrometric measurement, or:	150.1	4500–H^+ B [18th, 19th, 20th]	D1293–84 (90)(A or B)	I–1586–85	973.41[3]
Automated electrode				I–2587–85	Note 21.
29. Indium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration or	235.1	3111 B [18th, 19th]			
AA furnace	235.2				
30. Iron—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	236.1	3111 B or C [18th, 19th]	D1068–96(A or B)	I–3381–85	974.27[3]
AA furnace	236.2	3113 B [18th, 19th]	D1068–96(C)		
ICP/AES[36]	200.7[3]	3120 B [18th, 19th, 20th]		I–4471–97[30]	
DCP[36] or			D4190–94		Note 34.
Colorimetric (Phenanthroline).		3500–Fe B [20th] and 3500–Fe D [18th, 19th].	D1068–96(D)		Note 22.
31. Kjeldahl Nitrogen—Total, (as N), mg/L:					
Digestion and distillation followed by.	351.3	4500–N_{org} B or C and 4500–NH_3 B [18th, 19th, 20th].	D3590–89(A)		
Titration	351.3		D3590–89(A)		973.48[3]
Nesslerization	351.3	4500–NH_3 C [18th]	D3590–89(A)		
Electrode	351.3	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
Automated phenate colorimetric	351.1			I–4551–78[8]	
Semi-automated block digestor colorimetric.	351.2		D3590–89(B)	I–4515–91[45].	
Manual or block digestor potentiometric.	351.4		D3590–89(A)		
Block digester, followed by Auto distillation and Titration, or:					Note 39.
Nesslerization, or					Note 40.
Flow injection gas diffusion					Note 41.
32. Lead—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	239.1	3111 B or C [18th, 19th]	D3559–96(A or B)	I–3399–85	974.27[3]

AA furnace	239.2	3113 B [18th, 19th]	D3559–96(D)	I–4403–89[51]	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[16]			D4190–94		Note 34.
Voltametry[11] or			D3559–96(C)		
Colorimetric (Dithizone)		3500–Pb B [20th] and 3500–Pb D [18th, 19th].			
33. Magnesium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	242.1	3111 B [18th, 19th]	D511–93(B)	I–3447–85	974.27[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP or					Note 34.
Gravimetric		3500–Mg D [18th, 19th]			
34. Manganese-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	243.1	3111 B [18th, 19th]	D858–95(A or B)	I–3454–85	974.27[3]
AA furnace	243.2	3113 B [18th, 19th]	D858–95(C)		
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36], or			D4190–94		Note 34.
Colorimetric (Persulfate), or		3500–Mn B [20th] and 3500–Mn D [18th, 19th].			920.203[3]
(Periodate)					Note 23.
35. Mercury—Total,[4] mg/L:					
Cold vapor, manual or	245.1	3112 B [18th, 19th]	D3223–91	I–3462–85	977.22[3]
Automated	245.2				
Oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry (ng/L).	1631E[43]				
36. Molybdenum—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration	246.1	3111 D [18th, 19th]		I–3490–85.	
AA furnace	246.2	3113 B [18th, 19th]		I–3492–96[47]	
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP					Note 34.
37. Nickel—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	249.1	3111 B or C [18th, 19th]	D1886–90(A or B)	I–3499–85.	
AA furnace	249.2	3113 B [18th, 19th]	D1886–90(C)	I–4503–89[51]	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36], or			D4190–94		Note 34.
Colorimetric (heptoxime)		3500–Ni D [17th].			
38. Nitrate (as N), mg/L:					
Colorimetric (Brucine sulfate), or Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40).	352.1				973.50,[3] 419D,[17] p. 28[9]
39. Nitrate-nitrite (as N), mg/L:					
Cadmium reduction, Manual or.	353.3	4500–NO_3 E [18th, 19th, 20th].	D3867–99(B).		

* Nitrate (as N), mg/L, Ion Chromatography EPA 300.00

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,33]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Automated, or	353.2	4500–NO_3 F [18th, 19th, 20th].	D3867–99(A)	I–4545–85.	
Automated hydrazine	353.1	4500–NO_3 H [18th, 19th, 20th].			
40. Nitrite (as N), mg/L; Spectrophotometric:					
Manual or	354.1	4500–NO_2 B [18th, 19th, 20th].			Note 25.
Automated (Diazotization)				I–4540–85.	
41. Oil and grease—Total recoverable, mg/L:					
Gravimetric (extraction)	413.1	5520B [18th, 19th, 20th][38].			
Oil and grease and nonpolar material, mg/L: Hexane extractable material (HEM): n-Hexane extraction and gravimetry.	1664A[42]	5520B [18th, 19th, 20th][38].			
Silica gel treated HEM (SGT-HEM): Silica gel treatment and gravimetry.	1664A[42].				
42. Organic carbon—Total (TOC), mg/L:					
Combustion or oxidation	415.1	5310 B, C, or D [18th, 19th, 20th].	D2579–93 (A or B)		973.47,[3] p. 14[24]
43. Organic nitrogen (as N), mg/L: Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4).					
44. Orthophosphate (as P), mg/L; Ascorbic acid method:					
Automated, or	365.1	4500–P F [18th, 19th, 20th]		I–4601–85	973.56[3]
Manual single reagent	365.2	4500–P E [18th, 19th, 20th]	D515–88(A)		973.55[3]
Manual two reagent	365.3.				
45. Osmium—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration, or	252.1	3111 D [18th, 19th].			
AA furnace	252.2.				
46. Oxygen, dissolved, mg/L:					
Winkler (Azide modification), or.	360.2	4500–O C [18th, 19th, 20th]	D888–92(A)	I–1575–78[6]	973.45B[3]
Electrode	360.1	4500–O G [18th, 19th, 20th]	D888–92(B)	I–1576–78[6].	

* Nitrite (as N), mg/L, Ion Chromatography EPA 300.00

47. Palladium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	253.1	3111 B [18th, 19th]			p. S27[10]
AA furnace	253.2				p. S28[10]
DCP					Note 34.
48. Phenols, mg/L:					
Manual distillation[26]	420.1				Note 27.
Followed by:					
Colorimetric (4AAP) manual, or:	420.1				Note 27.
Automated[19]	420.2.				
49. Phosphorus (elemental), mg/L:					
Gas-liquid chromatography					Note 28.
50. Phosphorus—Total, mg/L:					
Persulfate digestion followed by.	365.2	4500–P B, 5 [18th, 19th, 20th]			973.55[3]
Manual or	365.2 or 365.3	4500–P E [18th, 19th, 20th]	D515–88(A)		
Automated ascorbic acid reduction.	365.1	4500–P F [18th, 19th, 20th]		I–4600–85	973.56[3]
Semi-automated block digestor.	365.4		D515–88(B)	I–4610–91[40]	
51. Platinum—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	255.1	3111 B [18th, 19th]			
AA furnace	255.2.				
DCP					Note 34.
52. Potassium—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	258.1	3111 B [18th, 19th]		I–3630–85	973.53[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
Flame photometric, or		3500–K B [20th] and 3500–K D [18th, 19th].			
Colorimetric					317 B[17]
53. Residue—Total, mg/L:					
Gravimetric, 103–105°	160.3	2540 B [18th, 19th, 20th]		I–3750–85.	
54. Residue—filterable, mg/L:					
Gravimetric, 180°	160.1	2540 C [18th, 19th, 20th]		I–1750–85.	
55. Residue—nonfilterable (TSS), mg/L:					
Gravimetric, 103–105° post washing of residue.	160.2	2540 D [18th, 19th, 20th]		I–3765–85.	
56. Residue—settleable, mg/L:					
Volumetric, (Imhoff cone), or gravimetric.	160.5	2540 F [18th, 19th, 20th].			
57. Residue—Volatile, mg/L:					
Gravimetric, 550°	160.4			I–3753–85.	
58. Rhodium-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	265.1	3111 B [18th, 19th].			

Colorimetric (methylene blue)	376.2	4500–S ^{2}D [18th, 19th, 20th].			
67. Sulfite (as SO_3), mg/L:					
Titrimetric (iodine-iodate)	377.1	4500–SO_3 ^{2}B [18th, 19th, 20th].			
68. Surfactants, mg/L:					
Colorimetric (methylene blue)	425.1	5540 C [18th, 19th, 20th]	D2330–88.		
69. Temperature, °C:					
Thermometric	170.1	2550 B [18th, 19th, 20th].			Note 32.
70. Thallium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	279.1	3111 B [18th, 19th]			
AA furnace	279.2.				
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
71. Tin—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	282.1	3111 B [18th, 19th]		I–3850–78[8]	
AA furnace, or	282.2	3113 B [18th, 19th].			
ICP/AES	200.7[5].				
72. Titanium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	283.1	3111 D [18th, 19th].			
AA furnace	283.2.				
DCP					Note 34.
73. Turbidity, NTU:					
Nephelometric	180.1	2130 B [18th, 19th, 20th]	D1889–94(A)	I–3860–85.	
74. Vanadium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	286.1	3111 D [18th, 19th].			
AA furnace	286.2		D3373–93.		
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP, or			D4190–94		Note 34.
Colorimetric (Gallic Acid)		3500–V B [20th] and 3500–V D [18th, 19th].			
75. Zinc—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	289.1	3111 B or C [18th, 19th]	D1691–95(A or B)	I–3900–85	974.27,[3] p. 37[9]
AA furnace	289.2.				
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP,[36] or			D4190–94		Note 34.
Colorimetric (Dithizone) or		3500–Zn E [18th, 19th].			
(Zincon)		3500–Zn B [20th] and 3500–Zn F [18th, 19th].			Note 33.

Table 1B Notes:

[1] "Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, Environmental Monitoring Systems Laboratory—Cincinnati (EMSL-CI), EPA–600/4–79–020, Revised March 1983 and 1979 where applicable.

[2] Fishman, M.J., *et al.* "Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments, "U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO, Revised 1989, unless otherwise stated.

[3] "Official Methods of Analysis of the Association of Official Analytical Chemists," methods manual, 15th ed. (1990).

[4] For the determination of total metals the sample is not filtered before processing. A digestion procedure is required to solubilize suspended material and to destroy possible organic-metal complexes. Two digestion procedures are given in "Methods for Chemical Analysis of Water and Wastes, 1979 and 1983". One (Section 4.1.3), is a vigorous digestion using nitric acid. A less vigorous digestion using nitric and hydrochloric acids (Section 4.1.4) is preferred; however, the analyst should be cautioned that this mild digestion may not suffice for all samples types. Particularly, if a colorimetric procedure is to be employed, it is necessary to ensure that all organo-metallic bonds be broken so that the metal is in a reactive state. In those situations, the vigorous digestion is to be preferred making certain that at no time does the sample go to dryness. Samples containing large amounts of organic materials may also benefit by this vigorous digestion, however, vigorous digestion with concentrated nitric acid will convert antimony and tin to insoluble oxides and render them unavailable for analysis. Use of ICP/AES as well as determinations for certain elements such as antimony, arsenic, the noble metals, mercury, selenium, silver, tin, and titanium require a modified sample digestion procedure and in all cases the method write-up should be consulted for specific instructions and/or cautions.

NOTE TO TABLE 1B NOTE 4: If the digestion procedure for direct aspiration AA included in one of the other approved references is different than the above, the EPA procedure must be used. Dissolved metals are defined as those constituents which will pass through a 0.45 micron membrane filter. Following filtration of the sample, the referenced procedure for total metals must be followed. Sample digestion of the filtrate for dissolved metals (or digestion of the original sample solution for total metals) may be omitted for AA (direct aspiration or graphite furnace) and ICP analyses, provided the sample solution to be analyzed meets the following criteria:

a. has a low COD (<20)

b. is visibly transparent with a turbidity measurement of 1 NTU or less

c. is colorless with no perceptible odor; and

d. is of one liquid phase and free of particulate or suspended matter following acidification.

[5] The full text of Method 200.7, "Inductively Coupled Plasma Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes," is given at Appendix C of this Part 136.

[6] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies.

[7] Ammonia, Automated Electrode Method, Industrial Method Number 379–75 WE, dated February 19, 1976, Bran & Luebbe (Technicon) Auto Analyzer II, Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[8] The approved method is that cited in "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments", USGS TWRI, Book 5, Chapter A1 (1979).

[9] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 25 West 43rd Street, New York, NY 10036.

[10] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency", Supplement to the Fifteenth Edition of Standard Methods for the Examination of Water and Wastewater (1981).

[11] The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

[12] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test method which measures "total BOD". The addition of the nitrification inhibitor is not a procedural option, but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required can the permittee report data using a nitrification inhibitor.

[13] OIC Chemical Oxygen Demand Method, Oceanography International Corporation, 1978, 512 West Loop, PO Box 2980, College Station, TX 77840.

[14] Chemical Oxygen Demand, Method 8000, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[15] The back titration method will be used to resolve controversy.

[16] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97–70, 1977, Orion Research Incorporated, 840 Memorial Drive, Cambridge, MA 02138. The calibration graph for the Orion residual chlorine method must be derived using a reagent blank and three standard solutions, containing 0.2, 1.0, and 5.0 mL 0.00281 N potassium iodate/100 mL solution, respectively.

[17] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976.

[18] National Council of the Paper Industry for Air and Stream Improvement, Inc. Technical Bulletin 253, December 1971.

[19] Copper, Biocinchoinate Method, Method 8506, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[20] After the manual distillation is completed, the autoanalyzer manifolds in EPA Methods 335.3 (cyanide) or 420.2 (phenols) are simplified by connecting the re-sample line directly to the sampler. When using the manifold setup shown in Method 335.3, the buffer 6.2 should be replaced with the buffer 7.6 found in Method 335.2.

[21] Hydrogen ion (pH) Automated Electrode Method, Industrial Method Number 378–75WA, October 1976, Bran & Luebbe (Technicon) Autoanalyzer II, Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[22] Iron, 1,10-Phenanthroline Method, Method 8008, 1980, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[23] Manganese, Periodate Oxidation Method, Method 8034, Hach Handbook of Wastewater Analysis, 1979, pages 2–113 and 2–117, Hach Chemical Company, Loveland, CO 80537.

[24] Wershaw, R.L., *et al*, "Methods for Analysis of Organic Substances in Water," Techniques of Water-Resources Investigation of the U.S. Geological Survey, Book 5, Chapter A3, (1972 Revised 1987) p. 14.

[25] Nitrogen, Nitrite, Method 8507, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[26] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[27] The approved method is cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition. The colorimetric reaction is conducted at a pH of 10.0±0.2. The approved methods are given on pp 576–81 of the 14th Edition: Method 510A for distillation, Method 510B for the manual colorimetric procedure, or Method 510C for the manual spectrometric procedure.

[28] R.F. Addison and R.G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," Journal of Chromatography, Vol. 47, No. 3, pp. 421–426, 1970.

[29] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to pH of 12. Therefore, for levels of silver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[30] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 15th Edition.

[31] EPA Methods 335.2 and 335.3 require the NaOH absorber solution final concentration to be adjusted to 0.25 N before colorimetric determination of total cyanide.
[32] Stevens, H.H., Ficke, J.F., and Smoot, G.F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation," Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1, 1975.
[33] Zinc, Zincon Method, Method 8009, Hach Handbook of Water Analysis, 1979, pages 2–231 and 2–333, Hach Chemical Company, Loveland, CO 80537.
[34] "Direct Current Plasma (DCP) Optical Emission Spectrometric Method for Trace Elemental Analysis of Water and Wastes, Method AES0029," 1986—Revised 1991, Thermo Jarrell Ash Corporation, 27 Forge Parkway, Franklin, MA 02038.
[35] Precision and recovery statements for the atomic absorption direct aspiration and graphite furnace methods, and for the spectrophotometric SDDC method for arsenic are provided in Appendix D of this part titled, "Precision and Recovery Statements for Methods for Measuring Metals".
[36] "Closed Vessel Microwave Digestion of Wastewater Samples for Determination of Metals", CEM Corporation, PO Box 200, Matthews, NC 28106–0200, April 16, 1992. Available from the CEM Corporation.
[37] When determining boron and silica, only plastic, PTFE, or quartz laboratory ware may be used from start until completion of analysis.
[38] Only use Trichlorotrifluorethane (1,1,2-trichloro-1,2,2-trifluoroethane; CFC–113) extraction solvent when determining Total Recoverable Oil and Grease (analogous to EPA Method 413.1). Only use *n*-hexane extraction solvent when determining Hexane Extractable Material (analogous to EPA Method 1664A). Use of other extraction solvents is strictly prohibited.
[39] Nitrogen, Total Kjeldahl, Method PAI-DK01 (Block Digestion, Steam Distillation, Titrimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.
[40] Nitrogen, Total Kjeldahl, Method PAI-DK02 (Block Digestion, Steam Distillation, Colorimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.
[41] Nitrogen, Total Kjeldahl, Method PAI-DK03 (Block Digestion, Automated FIA Gas Diffusion), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.
[42] Method 1664, Revision A "n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry" EPA–821–R–98–002, February 1999. Available at NTIS, PB–121949, U.S. Department of Commerce, 5285 Port Royal, Springfield, Virginia 22161.
[43] USEPA. 2002. Method 1631, Revision E, "Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry." September 2002. Office of Water, U.S. Environmental Protection Agency (EPA–821–R–02–019). The application of clean techniques described in EPA's draft Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels (EPA–821–R–96–011) are recommended to preclude contamination at low-level, trace metal determinations.
[44] Available Cyanide, Method OIA–1677 (Available Cyanide by Flow Injection, Ligand Exchange, and Amperometry). ALPKEM, A Division of OI Analytical, PO Box 9010, College Station, TX 77842–9010.
[45] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Ammonia Plus Organic Nitrogen by a Kjeldahl Digestion Method", Open File Report (OFR) 00–170.
[46] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Chromium in Water by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 93–449.
[47] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Molybdenum by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 97–198.
[48] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Total Phosphorus by Kjeldahl Digestion Method and an Automated Colorimetric Finish That Includes Dialysis" Open File Report (OFR) 92–146.
[49] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Arsenic and Selenium in Water and Sediment by Graphite Furnace-Atomic Absorption Spectrometry" Open File Report (OFR) 98–639.
[50] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Elements in Whole-water Digests Using Inductively Coupled Plasma-Optical Emission Spectrometry and Inductively Coupled Plasma-Mass Spectrometry", Open File Report (OFR) 98–165.
[51] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Inorganic and Organic Constituents in Water and Fluvial Sediment", Open File Report (OFR) 93–125.

TABLE IC—LIST OF APPROVED TEST PROCEDURES FOR NON-PESTICIDE ORGANIC COMPOUNDS

Parameter[1]	EPA method number[2,7]			Other approved methods		
	GC	GC/MS	HPLC	*Standard Methods* [Edition(s)]	ASTM	Other
1. Acenaphthene	610	625, 1625B	610	6440 B [18th, 19th, 20th].	D4657–92	Note 9, p.27.
2. Acenaphthylene	610	625, 1625B	610	6440 B, 6410 B [18th, 19th, 20th].	D4657–92	Note 9, p.27.
3. Acrolein	603	624[4], 1624B				
4. Acrylonitrile	603	624[4], 1624B				
5. Anthracene	610	625, 1625B	610	6410 B, 6440 B [18th, 19th, 20th]	D4657–92	Note 9, p. 27.

ATTACHMENT E

Table II - Required Containers, Preservation Techniques, and Holding Times
40 CFR Part 136.3
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3544. Available from the American Society for Microbiology, 1752 N Street NW., Washington, DC 20036. Table IA, Note 22.

(58) USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli (E. coli)* in Water by Membrane Filtration using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA 821–R–02–024. Available from NTIS, PB2003–100129. Table IA, Note 22.

(59) USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA–821–R–02–022. Available from NTIS, PB2003–100127. Table IA, Note 25.

(60) USEPA. 2001. Method 1622: *Cryptosporidium* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–026.

Available from NTIS, PB2002–108709. Table IA, Note 26.

(61) USEPA. 2001. Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–025. Available from NTIS, PB2002–108710. Table IA, Note 27.

(62) AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. AOAC International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417. Table IA, Note 11.

(c) Under certain circumstances the Regional Administrator or the Director in the Region or State where the discharge will occur may determine for a particular discharge that additional parameters or pollutants must be reported. Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator, or the Director upon the recommendation of the Director of the Environmental Monitoring Systems Laboratory—Cincinnati.

(d) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring Systems Laboratory—Cincinnati, additional alternate test procedures for nationwide use.

(e) Sample preservation procedures, container materials, and maximum allowable holding times for parameters cited in Tables IA, IB, IC, ID, and IE are prescribed in Table II. Any person may apply for a variance from the prescribed preservation techniques, container materials, and maximum holding times applicable to samples taken from a specific discharge. Applications for variances may be made by letters to the Regional Administrator in the Region in which the discharge will occur. Sufficient data should be provided to assure such variance does not adversely affect the integrity of the sample. Such data will be forwarded, by the Regional Administrator, to the Director of the Environmental Monitoring Systems Laboratory—Cincinnati, Ohio for technical review and recommendations for action on the variance application. Upon receipt of the recommendations from the Director of the Environmental Monitoring Systems Laboratory, the Regional Administrator may grant a variance applicable to the specific charge to the applicant. A decision to approve or deny a variance will be made within 90 days of receipt of the application by the Regional Administrator.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IA—Bacteria Tests:			
1–5 Coliform, total, fecal, and *E. coli*	PP, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$.	6 hours.
6 Fecal *streptococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
7 *Enterococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
Table IA—Protozoa Tests:			
8 *Cryptosporidium*	LDPE	0–8 °C	96 hours.[17]
9 *Giardia*	LDPE	0–8 °C	96 hours.[17]
Table IA—Aquatic Toxicity Tests:			
6–10 Toxicity, acute and chronic	P,G	Cool, 4 °C[16]	36 hours.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IB—Inorganic Tests:			
1. Acidity	P, G	Cool, 4°C	14 days.
2. Alkalinity	P, G	do	Do.
4. Ammonia	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
9. Biochemical oxygen demand	P, G	Cool, 4°C	48 hours.
10. Boron	P, PFTE, or Quartz.	HNO_3 TO pH<2	6 months.
11. Bromide	P, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, G	Cool, 4°C	48 hours.
15. Chemical oxygen demand	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
16. Chloride	P, G	None required	Do.
17. Chlorine, total residual	P, G	do	Analyze immediately.
21. Color	P, G	Cool, 4°C	48 hours.
23–24. Cyanide, total and amenable to chlorination.	P, G	Cool, 4°C, NaOH to pH>12, 0.6g ascorbic acid[9]	14 days[6]
25. Fluoride	P	None required	28 days.
27. Hardness	P, G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months.
28. Hydrogen ion (pH)	P, G	None required	Analyze immediately.
31, 43. Kjeldahl and organic nitrogen	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
Metals:[7]			
18. Chromium VI[7]	P, G	Cool, 4 °C	24 hours.
35. Mercury[17]	P, G	HNO_3 to pH<2	28 days.
3, 5–8, 12,13, 19, 20, 22, 26, 29, 30, 32–34, 36, 37, 45, 47, 51, 52, 58–60, 62, 63, 70–72, 74, 75. Metals except boron, chromium VI and mercury[7].	P, G	do	6 months.
38. Nitrate	P, G	Cool, 4°C	48 hours.
39. Nitrate-nitrite	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
40. Nitrite	P, G	Cool, 4°C	48 hours.
41. Oil and grease	G	Cool to 4°C, HCl or H_2SO_4 to pH<2	28 days.
42. Organic Carbon	P, G	Cool to 4 °C HC1 or H_2SO4 or H_3PO4, to pH<2.	28 days.
44. Orthophosphate	P, G	Filter immediately, Cool, 4°C	48 hours.
46. Oxygen, Dissolved Probe	G Bottle and top.	None required	Analyze immediately.
47. Winkler	do	Fix on site and store in dark	8 hours.
48. Phenols	G only	Cool, 4°C, H_2SO_4 to pH<2	28 days.
49. Phosphorus (elemental)	G	Cool, 4°C	48 hours.
50. Phosphorus, total	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
53. Residue, total	P, G	Cool, 4°C	7 days.
54. Residue, Filterable	P, G	do	7 days.
55. Residue, Nonfilterable (TSS)	P, G	do	7 days.
56. Residue, Settleable	P, G	do	48 hours.
57. Residue, volatile	P, G	do	7 days.
61. Silica	P, PFTE, or Quartz.	Cool, 4 °C	28 days.
64. Specific conductance	P, G	do	Do.
65. Sulfate	P, G	do	Do.
66. Sulfide	P, G	Cool, 4°C add zinc acetate plus sodium hydroxide to pH>9.	7 days.
67. Sulfite	P, G	None required	Analyze immediately.
68. Surfactants	P ,G	Cool, 4°C	48 hours.
69. Temperature	P, G	None required	Analyze.
73. Turbidity	P, G	Cool, 4°C	48 hours.
Table IC—Organic Tests[8]			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, Teflon-lined septum.	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5].	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] HCl to pH2[9].	Do.
3, 4. Acrolein and acrylonitrile	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] adjust pH to 4–5[10]	Do.
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols[11].	G, Teflon-lined cap.	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction.
7, 38. Benzidines[11]	do	do	7 days until extraction[13]
14, 17, 48, 50–52. Phthalate esters[11]	do	Cool, 4 °C	7 days until extraction; 40 days after extraction.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
82–84. Nitrosamines[11,14]	....do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark.	Do.
88–94. PCBs[11]	....do	Cool, 4 °C	Do.
54, 55, 75, 79. Nitroaromatics and isophorone[11].	....do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark.	Do.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons[11].	....do	....do	Do.
15, 16, 21, 31, 87. Haloethers[11]	....do	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	Do.
29, 35–37, 63–65, 73, 107. Chlorinated hydrocarbons[11].	....do	Cool, 4 °C	Do.
60–62, 66–72, 85, 86, 95–97, 102, 103. CDDs/CDFs[11].			
aqueous: field and lab preservation.	G	Cool, 0–4 °C, pH<9, 0.008% $Na_2S_2O_3$[5].	1 year.
Solids, mixed phase, and tissue: field preservation.	....do	Cool, <4 °C	7 days.
Solids, mixed phase, and tissue: lab preservation.	....do	Freeze, < 10 °C	1 year.
Table ID—Pesticides Tests:			
1–70. Pesticides[11]	....do	Cool, 4°C, pH 5–9[15]	Do.
Table IE—Radiological Tests:			
1–5. Alpha, beta and radium	P, G	HNO_3 to pH<2	6 months.

Table II Notes

[1] Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

[2] Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.

[3] When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See § 136.3(e) for details. The term "analyze immediately" usually means within 15 minutes or less of sample collection.

[5] Should only be used in the presence of residual chlorine.

[6] Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

[7] Samples should be filtered immediately on-site before adding preservative for dissolved metals.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] Sample receiving no pH adjustment must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4C temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature can not be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

[17] Samples collected for the determination of trace level mercury (100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. Samples collected for dissolved trace level mercury should be filtered in the laboratory. However, if circumstances prevent overnight shipment, samples should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. Samples that have been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

ATTACHMENT F

Sample Chain of Custody Form

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NJ ANALYTICAL LABS 6897373052

05/09/2005 09:50

New Jersey Analytical Laboratories

Chain Of Custody
Commercial

Client Information

Client Name & Address:

page _____ of _____

Phone: Fax:

Notes

Sampled by: (Print/Sign)

Lab ID No.	Sample ID/Location	Date Sampled	Time Sampled	Total No. Containers	Bottle Volume	Matrix	HCl	Sterile	H2SO4	HNO_3	Unpreserved	Other	Analysis					Notes

Relinquished by Sampler 1	Date: Time:	Received by: 1	Date: Time:
Relinquished by: 2	Date: Time:	Received by: 2	Date: Time:
Relinquished by: 3	Date: Time:	Received by: 3	Date: Time:

New Jersey Analytical Laboratories, LLC
1590 Reed Road, Suite 101B Tel: 609-737-3477
Pennington, NJ 08534 Fax: 609-737-3052

Cooler Temp

Received for Laboratory by:

ATTACHMENT G

Tables of Parameter Detection Limits, Accuracy, and Precision

Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision

Parameter:	Dissolved Ortho-Phosphate (as P)	Total Phosphorus (as P)	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite-Nitrogen	Total Kjeldahl Nitrogen	Total Suspended Solids	Fecal Coliform
Referenced Methodology – (NJDEP Certified Methodology)	EPA 365.2	EPA 365.2	EPA 350.3	EPA 300.0	EPA 300.0	EPA 351.3	EPA 160.2	Standard Methods 9222D
Method Detection Limit (ppm)-Calculated	0.0029	0.0060	0.004	0.034	0.031	0.048	NA	<10
Instrument Detection Limit (ppm)	NA	NA	NA	0.034	0.031	NA	NA	NA
Project Detection Limit (ppm)	0.0024	0.016	0.008	0.02	0.04	0.047	NA	<10
Quantitation Limit (ppm)	0.01	0.02	0.05	0.04	0.04	0.05	0.5	NA
Accuracy (mean % recovery)	106.9	108.6	94.9	97.5	98.2	96.9	NA	NA
Precision-% (mean – RPD)	2.18	2.80	4.31	3.01	3.46	5.98	8.61	17.34
Accuracy Protocol (% recovery for LCL/UCL)	83.8/ 130.0	91.3/ 126.0	62.6/ 127.2	92.2/ 102.8	80.1/ 116.3	67.1/ 126.7	NA	NA
Precision Protocol-% (maximum RPD)	8.10	10.13	10.63	5.03	6.74	9.28	28.03	24.82

RPD – Relative % Difference; NA – Not Applicable

Laboratory: New Jersey Analytical Laboratories, LLC - (NJDEP #11005)

Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision (continued)

Parameter:	pH (SU)	Temperature (°C)	Dissolved Oxygen (mg/L)
Referenced Methodology – (NJDEP Certified Methodology)	Standard Methods 4500-H^+ B	Standard Methods 2550 B	Standard Methods 4500-O G
Method Detection Limit (ppm)	NA	NA	NA
Instrument Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 – 20 mg/L
Project Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 - 20 mg/L
Quantitation Limit (ppm)	NA	NA	NA
Accuracy (mean % recovery)	NA	NA	NA
Precision (mean – RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l
Accuracy Protocol (% recovery for LCL/UCL)	NA	NA	NA
Precision Protocol (maximum RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l

RPD – Relative % Difference; NA – Not Applicable

Laboratory: Rutgers EcoComplex Laboratory (NJDEP #03019)

Appendix C: Tabulated Water Quality Monitoring Data

Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/2007	TB1	16.51	7.16	6.3	16.0	607	410	3.20	0.50	0.40	1.60	5.70	0.03	0.13	7.00
5/29/2007	TB1	9.91	7.28	6.5	17.0	540	500	0.50	0.50	0.40	1.70	3.10	0.02	0.06	7.00
6/5/2007	TB1	16.02	6.58	5.5	17.4	20,000	4,100	0.50	0.50	0.40	1.10	2.50	0.06	0.12	6.00
6/12/2007	TB1	4.74	7.34	6.6	18.9	3,500	500	Bacteria Only							
6/19/2007	TB1	9.62	7.64	7.2	19.1	3,000	2,000	0.50	0.50	0.40	1.60	3.00	0.04	0.09	19.00
6/26/2007	TB1	6.83	7.35	6.8	20.4	900	520	Bacteria Only							
6/27/07	TB1	6.34	n/a	5.5	22.7	520	1,500								
7/3/07	TB1	16.53	6.68	6.9	16.3	613	530	0.50	0.50	0.40	1.60	4.60	0.04	0.06	2.00
7/10/07	TB1	6.91	7.00	6.7	18.1	n/a	480	Bacteria Only							
7/17/07	TB1	5.84	7.58	6.8	20.6	533	470	0.50	0.50	0.40	1.40	2.80	0.04	0.08	4.00
7/24/07	TB1	16.52	6.33	7.1	18.2	9,000	7,200	Bacteria Only							
7/31/07	TB1	9.53	7.28	6.8	21.3	880	610								
8/7/07	TB1	5.91	7.10	6.6	22.0	700	520	0.50	0.50	0.40	1.40	n/a	0.03	0.08	2.00
8/14/07	TB1	6.14	7.00	7.1	19.3	1,090	580	Bacteria Only							
8/16/07	TB1	9.04	n/a	n/a	n/a	720	590								
8/21/07	TB1	17.46	7.93	8.3	16.7	6,000	5,600	0.50	0.50	0.40	1.40	4.20	0.03	0.15	14.00
8/28/07	TB1	2.19	6.93	6.7	20.0	780	600	Bacteria Only							
9/11/07	TB1	10.67	6.93	6.2	22.5	60,000	80,000	0.50	0.50	0.40	1.30	2.70	0.08	0.27	27.00
9/25/07	TB1	3.63	6.66	5.1	16.0	1,020	710	0.50	0.50	0.40	1.50	2.90	0.01	0.10	2.00
10/9/07	TB1	5.94	6.89	5.2	20.6	300	n/a	0.50	0.50	0.40	1.30	2.70	0.04	0.07	7.00
10/24/07	TB1	2.67	6.82	5.5	17.2	410	390	0.69	0.13	0.02	1.29	2.13	0.05	0.07	1.00
n		21	19	20	20	20	20	12	12	12	12	12	12	12	12
min		2.19	6.33	5.1	16.0	300	390	0.50	0.13	0.02	1.10	2.13	0.01	0.06	1.00
mean*		9.00	7.08	6.5	19.0	1,447	1,079	0.74	0.47	0.37	1.43	3.30	0.04	0.11	8.17
max		17.46	7.93	8.3	22.7	60,000	80,000	3.20	0.50	0.40	1.70	5.70	0.08	0.27	27.00
st. dev.		4.91	0.40	0.8	2.2	13,627	17,665	0.78	0.11	0.11	0.17	1.07	0.02	0.06	7.96

*For Fecal coliform and *E. coli* , geometric means were calculated.

Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/07	TB2	12.54	7.22	8.4	15.6	627	410	3.10	0.50	0.40	1.60	5.60	0.03	0.09	2.00
5/29/07	TB2	7.96	6.91	5.3	n/a	700	510	0.50	0.50	0.40	1.60	3.00	0.02	0.07	5.00
6/5/07	TB2	18.16	6.47	5.3	18.5	14,000	3,800	0.50	0.50	0.40	1.10	2.50	0.06	0.16	6.00
6/12/07	TB2	3.38	7.33	5.6	19.7	1,200	690	Bacteria Only							
6/19/07	TB2	6.70	7.33	6.1	20.1	1,000	500	0.50	0.50	0.40	1.40	2.80	0.03	0.08	15.00
6/26/07	TB2	5.78	7.17	5.6	20.7	680	410	Bacteria Only							
6/27/07	TB2	7.72	n/a	5.6	22.5	2,200	680								
7/3/07	TB2	1.56	6.28	4.7	17.0	380	370	1.20	0.50	0.40	1.40	4.90	0.03	0.06	4.00
7/10/07	TB2	5.31	6.81	4.8	18.1	n/a	240	Bacteria Only							
7/17/07	TB2	4.05	7.27	5.0	20.8	333	340	0.50	0.50	0.40	1.10	2.50	0.04	0.10	5.00
7/24/07	TB2	13.14	6.25	7.6	18.4	7,000	2,300	Bacteria Only							
7/31/07	TB2	4.92	7.17	5.7	21.8	587	420								
8/7/07	TB2	5.37	6.9	5.6	22.4	1,160	560	0.50	0.50	0.40	1.20	2.60	0.03	0.08	2.00
8/14/07	TB2	8.92	6.9	5.8	20.1	2,700	660	Bacteria Only							
8/16/07	TB2	16.17	n/a	n/a	n/a	820	720								
8/21/07	TB2	42.46	7.36	7.9	16.7	32,000	13,000	0.50	0.50	0.40	1.30	4.00	0.03	0.12	14.00
8/28/07	TB2	4.96	6.7	6.2	20.5	1,000	590	Bacteria Only							
9/11/07	TB2	21.32	6.15	3.8	22.5	60,000	80,000	1.70	0.50	0.40	1.30	3.90	0.09	0.16	6.00
9/25/07	TB2	4.44	7.28	3.7	16.0	2,900	2,400	0.50	0.50	0.40	1.40	2.80	0.01	0.11	12.00
10/9/07	TB2	4.51	6.85	4.4	20.5	2,600	n/a	0.50	0.50	0.40	1.20	2.60	0.03	0.22	72.00
10/24/07	TB2	2.77	6.53	4.5	17.3	n/a	800	0.75	0.23	0.03	1.10	2.10	0.04	0.09	6.00
n		21	19	20	19	19	20	12	12	12	12	12	12	12	12
min		1.56	6.15	3.7	15.6	333	240	0.50	0.23	0.03	1.10	2.10	0.01	0.06	2.00
mean*		9.63	6.89	5.6	19.4	1,908	982	0.90	0.48	0.37	1.31	3.28	0.04	0.11	12.42
max		42.46	7.36	8.4	22.5	60,000	80,000	3.10	0.50	0.40	1.60	5.60	0.09	0.22	72.00
st. dev.		9.21	0.40	1.2	2.2	14,885	17,771	0.79	0.08	0.11	0.18	1.09	0.02	0.05	19.26

*For Fecal coliform and *E. coli* , geometric means were calculated.

Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/07	DB1	3.63	7.44	10.0	14.9	230	110	2.00	0.50	0.40	1.80	4.70	0.03	0.06	2.00
5/29/07	DB1	1.02	7.35	8.8	15.2	780	440	0.50	0.50	0.40	2.10	3.50	0.02	0.07	116.00
6/5/07	DB1	2.93	6.67	7.8	18.0	5,900	2,500	0.50	0.50	0.40	1.40	2.80	0.06	0.08	2.00
6/12/07	DB1	0.45	7.55	8.4	16.3	740	1,200	Bacteria Only							
6/19/07	DB1	0.78	7.68	8.4	16.2	1,040	680	0.50	0.50	0.40	2.00	3.40	0.04	0.04	7.00
6/26/07	DB1	0.82	7.57	8.3	18.1	1,040	780	Bacteria Only							
6/27/07	DB1	0.54		8.3	18.6	467	640								
7/3/07	DB1	0.61	6.28	7.1	15.0	800	820	0.50	0.50	0.40	2.10	5.60	0.03	0.06	6.00
7/10/07	DB1	0.55	6.96	8.3	14.0		560	Bacteria Only							
7/17/07	DB1	0.65	7.61	8.6	17.5	706	2,000	0.50	0.50	0.40	1.90	3.30	0.03	0.06	5.00
7/24/07	DB1	1.92	6.51	8.2	17.4	3,900	4,800	Bacteria Only							
7/31/07	DB1	0.68	7.1	9.1	18.5	1,180	700								
8/7/07	DB1	0.57	7.2	8.9	19.3	1,640	1,700	0.50	0.50	0.40	1.80	3.20	0.09	0.05	2.00
8/14/07	DB1	0.68	7.2	8.3	16.4	2,800	2,300	Bacteria Only							
8/16/07	DB1	0.51				640	660								
8/21/07	DB1	7.11	7.33	9.0	16.0	23,000	6,600	0.50	0.50	0.40	1.00	3.40	0.04	0.12	20.00
8/28/07	DB1	0.54	6.92	8.2	17.9	2,600	3,100	Bacteria Only							
9/11/07	DB1	3.57	6.67	7.4	24.6	60,000	58,000	0.50	0.50	0.40	0.91	2.31	0.08	0.20	45.00
9/25/07	DB1	0.34	7.27	n/a	n/a	5,800	4,300	0.50	0.50	0.40	2.00	3.40	0.01	0.05	2.00
10/9/07	DB1	0.45	6.9	6.2	18.3	21,000		0.50	0.50	0.40	2.00	3.40	0.03	0.06	4.00
10/24/07	DB1	0.37	6.65	6.0	16.5	4,700	4,200	0.25	0.03	0.01	1.85	2.14	0.03	0.04	5.00
n		21	19	19	19	20	20	12	12	12	12	12	12	12	12
min		0.34	6.28	6.0	14.0	230	110	0.25	0.03	0.01	0.91	2.14	0.01	0.04	2.00
mean*		1.37	7.10	8.2	17.3	2,186	1,571	0.60	0.46	0.37	1.74	3.43	0.04	0.07	18.00
max		7.11	7.68	10.0	24.6	60,000	58,000	2.00	0.50	0.40	2.10	5.60	0.09	0.20	116.00
st. dev.		1.67	0.41	1.0	2.3	14,019	12,645	0.45	0.14	0.11	0.41	0.94	0.02	0.05	33.25

*For Fecal coliform and *E. coli* , geometric means were calculated.

Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/07	CB1	1.50	7.37	10.3	14.8	210	110	1.90	0.50	0.40	2.00	4.80	0.02	0.04	2.00
5/29/07	CB1	2.47	6.91	6.9	17.2	900	350	0.50	0.50	0.40	2.20	3.60	0.02	0.04	6.00
6/5/07	CB1	5.90	7	5.7	18.4	6,000	2,400	0.50	0.50	0.40	1.40	2.80	0.07	0.10	6.00
6/12/07	CB1	0.87	7.63	7.4	18.7	640	430	Bacteria Only							
6/19/07	CB1	1.87	7.59	7.8	19.2	640	470	0.50	0.50	0.40	1.90	3.30	0.03	0.04	11.00
6/26/07	CB1	1.66	7.42	8.2	20.6	760	660	Bacteria Only							
6/27/07	CB1	1.87		7.7	21.7	660	780								
7/3/07	CB1	1.04	6.45	6.3	16.9	553	520	0.50	0.50	0.40	1.70	4.80	0.03	0.09	21.00
7/10/07	CB1	1.29	7.18	7.4	17.2		2,200	Bacteria Only							
7/17/07	CB1	1.41	7.57	8.2	19.8	763	1,800	0.50	0.50	0.40	1.50	2.90	0.03	0.06	2.00
7/24/07	CB1	4.04	6.63	8.5	18.0	3,400	2,000	Bacteria Only							
7/31/07	CB1	2.32	7.45	8.8	20.9	900	780								
8/7/07	CB1	1.56	7.1	8.3	22.2	1,100	740	0.50	0.50	0.40	1.40	2.80	0.05	0.05	2.00
8/14/07	CB1	2.63	7.2	8.0	18.8	720	800	Bacteria Only							
8/16/07	CB1	6.00				1,100	700								
8/21/07	CB1	16.08	7.04	9.8	16.8	13,000	7,000	0.50	0.50	0.40	1.20	3.80	0.03	0.11	13.00
8/28/07	CB1	1.38	6.61	5.7	20.3	2,900	1,500	Bacteria Only							
9/11/07	CB1	5.78	6.84	7.5	23.7	60,000	38,000	0.50	0.50	0.40	1.30	2.70	0.04	0.07	10.00
9/25/07	CB1	1.28	6.55	6.3	15.9	353	400	2.40	0.50	0.40	1.80	5.10	0.01	0.08	2.00
10/9/07	CB1	0.75	7.17	5.9	20.0	1,040		2.40	0.50	0.40	1.70	5.00	0.02	0.04	10.00
10/24/07	CB1	1.26	7.92	n/a	17.0	340	270	0.25	0.09	0.01	1.80	2.14	0.03	0.03	3.00
n		21	19	19	20	20	20	12	12	12	12	12	12	12	12
min		0.75	6.45	5.7	14.8	210	110	0.25	0.09	0.01	1.20	2.14	0.01	0.03	2.00
mean*		3.00	7.14	7.6	18.9	1,240	971	0.91	0.47	0.37	1.66	3.65	0.03	0.06	7.33
max		16.08	7.92	10.3	23.7	60,000	38,000	2.40	0.50	0.40	2.20	5.10	0.07	0.11	21.00
st. dev.		3.42	0.41	1.3	2.3	13,324	8,353	0.81	0.12	0.11	0.30	1.04	0.02	0.03	5.90

*For Fecal coliform and *E. coli* , geometric means were calculated.

Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/07	TB3	0.90	7.41	9.4	18.2	467	400	2.50	0.50	0.40	2.10	5.50	0.02	0.05	85.00
5/29/07	TB3	0.20	7.16	6.8	16.8	800	530	0.50	0.50	0.40	2.40	3.80	0.02	0.03	6.00
6/5/07	TB3	1.06	6.82	5.9	19.3	4,900	1,300	0.50	0.50	0.40	2.90	4.30	0.06	0.13	59.00
6/12/07	TB3	0.25	7.52	7.2	17.4	800	620	Bacteria Only							
6/19/07	TB3	0.33	7.38	7.8	18.8	5,000	4,200	0.50	0.50	0.40	2.10	3.50	0.03	0.04	11.00
6/26/07	TB3	0.10	7.18	6.8	20.8	840	490	Bacteria Only							
6/27/07	TB3	0.18		6.3	20.6	6,000	16,000								
7/3/07	TB3	0.29	6.25	7.0	17.5	920	590	0.50	0.50	0.40	2.20	5.80	0.02	0.03	7.00
7/10/07	TB3	0.09	6.75	7.4	15.4		4,800	Bacteria Only							
7/17/07	TB3	0.33	7.31	7.8	19.6	440	390	0.50	0.50	0.40	2.50	3.90	0.02	0.03	2.00
7/24/07	TB3	0.55	6.86	7.3	19.1	3,100	2,000	Bacteria Only							
7/31/07	TB3	0.45	7.33	8.0	20.1	4,800	380								
8/7/07	TB3	0.36	6.7	7.2	21.1	11,000	4,600	0.50	0.50	0.40	1.80	3.20	0.02	0.04	2.00
8/14/07	TB3	0.58	7.4	7.2	19.1	580	380	Bacteria Only							
8/16/07	TB3	0.24				600	290								
8/21/07	TB3	6.44	6.96	10.1	16.6	60,000	30,000	0.50	0.50	0.40	0.44	2.28	0.05	0.15	20.00
8/28/07	TB3	0.17	6.73	5.4	19.6	2,400	2,100	Bacteria Only							
9/11/07	TB3	0.53	6.26	7.1	23.3	60,000	47,000	1.10	0.50	0.40	1.40	3.40	0.07	0.14	17.00
9/25/07	TB3	0.13	3.88	5.0	16.9	24,000	33,000	0.50	0.50	0.40	2.20	3.60	0.01	0.14	26.00
10/9/07	TB3	0.05	7.06	4.9	18.5	17,000		0.50	0.50	0.40	1.90	3.30	0.02	0.04	6.00
10/24/07	TB3	-0.05	7.59	n/a	16.5	4,100	2,100	0.59	0.18	0.02	2.12	2.90	0.03	0.04	3.00
n		21	19	19	20	20	20	12	12	12	12	12	12	12	12
min		-0.05	3.88	4.9	15.4	440	290	0.50	0.18	0.02	0.44	2.28	0.01	0.03	2.00
mean*		0.63	6.87	7.1	18.8	3,195	1,926	0.72	0.47	0.37	2.00	3.79	0.03	0.07	20.33
max		6.44	7.59	10.1	23.3	60,000	47,000	2.50	0.50	0.40	2.90	5.80	0.07	0.15	85.00
st. dev.		1.36	0.82	1.3	1.9	18,024	13,357	0.59	0.09	0.11	0.62	1.01	0.02	0.05	25.88

*For Fecal coliform and *E. coli* , geometric means were calculated.

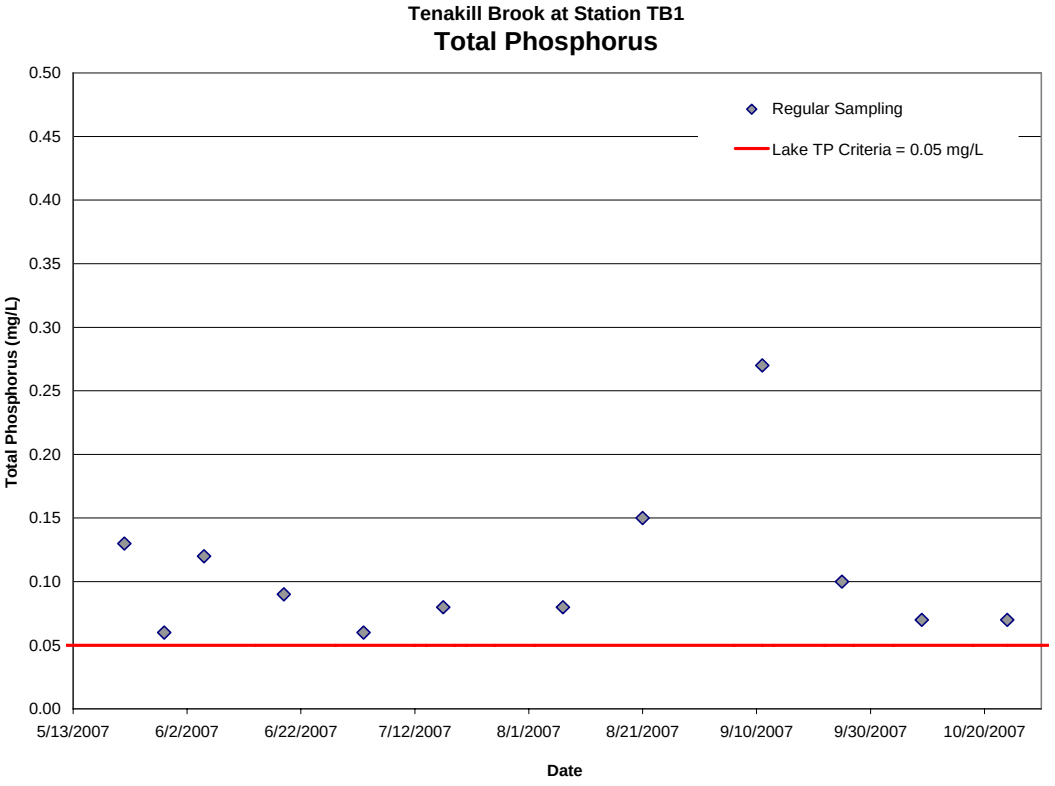
Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
5/22/07	TB4	1.50	6.98	5.5	19.7	920	2,100	3.80	0.05	0.03	2.75	6.63	0.01	0.06	3.70
5/29/07	TB4	1.22	7.12	5.3	18.4	2,000	710	0.50	0.05	0.10	0.25	0.90	0.03	0.27	23.50
6/5/07	TB4	1.38	6.68	4.7	20.4	6,000	3,300	0.50	0.15	0.04	4.67	5.36	0.02	0.06	10.70
6/12/07	TB4	0.78	7.52	6.9	18.8	4,500	1,700								
6/19/07	TB4	0.91	7.27	6.7	20.0	6,000	1,600				Bacteria Only				
6/26/07	TB4	1.14	7.23	6.0	23.5	1,180	2,700								
6/27/07	TB4	0.99		6.1	21.9	960	3,600	0.50	0.14	0.03	1.71	2.38	0.02	0.03	5.30
7/3/07	TB4	1.61	6.4	5.5	18.6	840	2,300				Bacteria Only				
7/10/07	TB4	0.85	6.89	5.9	15.5		2,500	0.50	0.05	0.10	2.44	3.09	0.01	0.03	4.00
7/17/07	TB4	1.09	7.47	7.4	19.3	673	1,600								
7/24/07	TB4	0.98	6.83	6.5	18.9	3,400	2,600				Bacteria Only				
7/31/07	TB4	1.74	7.33	8.1	19.9	1,160	900	0.50	0.05	0.01	0.69	1.25	0.03	0.81	10.00
8/7/07	TB4	1.07	7.1	7.4	21.0	4,600	1,700								
8/14/07	TB4	1.38	7.5	7.0	18.3	2,180	740				Bacteria Only				
8/16/07	TB4	1.87				2,100	410	0.50	0.05	0.10	2.57	3.22	0.03	0.07	4.70
8/21/07	TB4	16.04	6.34	9.8		37,000	18,000			Storm Event		1.57		0.06	9.45
8/28/07	TB4	0.64	7.03	6.1	18.9	2,200	780				Bacteria Only				
9/11/07	TB4	1.87	6.1	6.1	21.8	60,000	78,000	0.50	0.11	0.10	2.59	3.30	0.01	0.02	3.30
9/25/07	TB4	0.15	7.04	5.1	18.4	1,000	750	0.50	0.05	0.00	2.02	2.57	0.01	0.02	4.00
10/9/07	TB4	1.08	7.02	8.0	18.2	1,900		0.50	0.05	0.00	2.02	1.45		0.07	10.78
10/24/07	TB4	-0.96	7.6	n/a	16.0	4,000	3,200	0.92	0.23	0.10	1.57	2.84	0.01	0.05	3.70
n		21	19	19	19	20	20	12	12	12	12	12	12	12	12
min		-0.96	6.10	4.7	15.5	673	410	0.50	0.05	0.00	0.25	0.90	0.01	0.02	3.30
mean*		1.78	7.02	6.5	19.3	2,745	2,133	1.03	0.10	0.05	2.27	3.08	0.01	0.08	8.64
max		16.04	7.60	9.8	23.5	60,000	78,000	3.80	0.23	0.10	4.67	6.63	0.03	0.27	23.50
st. dev.		3.33	0.42	1.2	1.9	14,728	17,247	1.23	0.07	0.05	1.34	1.99	0.01	0.08	6.86

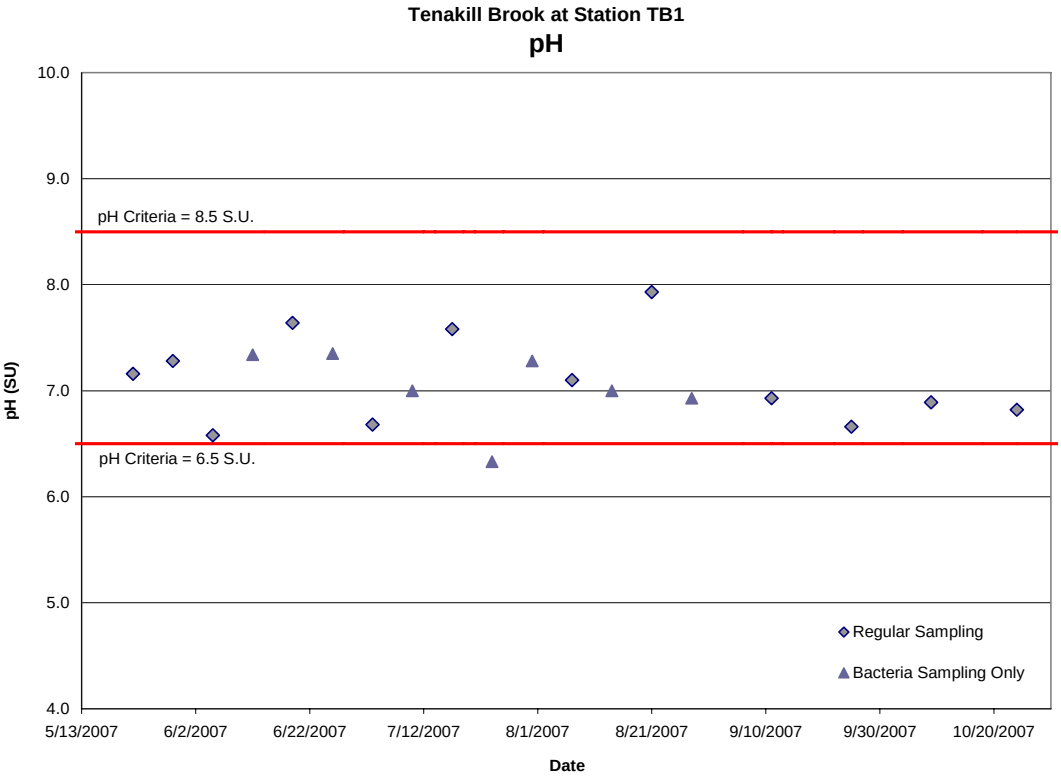
*For Fecal coliform and *E. coli* , geometric means were calculated.

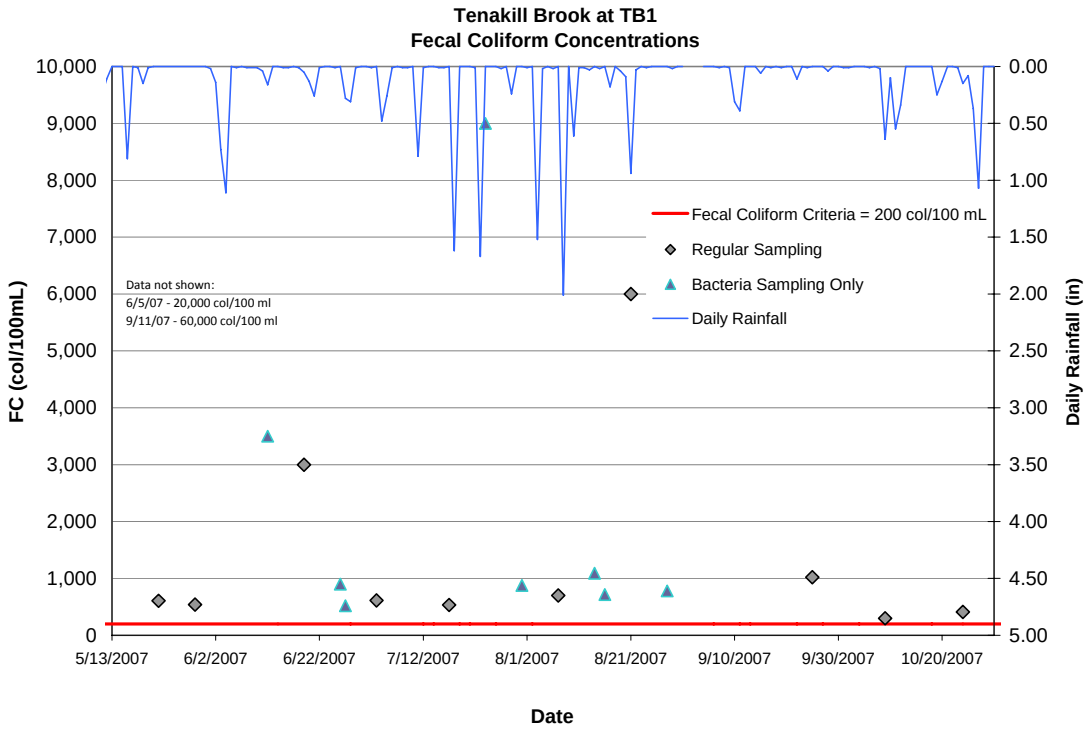
Date	Station ID	Flow Rate (Q)	pH	Dissolved Oxygen	Temp.	Fecal Coliform	*E. coli*	Total Kjeldahl Nitrogen	Ammonia Nitrogen as N	Nitrite-N	Nitrate-N	TN	Ortho Phosphate Dissolved	Total Phosphorus	TSS
		cfs	*S.U.*	*mg/L*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*
7/17/07	TB6	0.70	6.85	6.9	28.4	800		Bacteria Only							
7/24/07	TB6	0.65	6.64	7.1	27.4	3,300	2,400								
7/31/07	TB6	1.81	6.65	8.4	22.2	3,400	3,600								
8/7/07	TB6	1.85	6.37	8.1	22.3	11,000	14,000								
8/14/07	TB6	0.95	6.73	8.5	22.2	13,000	4,800								
8/16/07	TB6	0.89	6.56	8.8	21.2	19,000	16,000								
8/21/07	TB6	1.45	6.74	9.8	19.7	11,000	6,300								
8/28/07	TB6	0.83	6.74	9.5	18.7	60,000									
9/11/07	TB6	0.98	6.68	7.0	22.9	60,000									
9/25/07	TB6	0.95	6.62	7.4	23.1	3,000	1,900								
n		10	10	10	10	10	7								
min		0.65	6.37	6.9	18.7	800	1,900								
mean*		1.10	6.66	8.1	22.8	8,835	5,259								
max		1.85	6.85	9.8	28.4	60,000	16,000								
st. dev.		0.44	0.13	1.0	3.0	22,608	5,687								

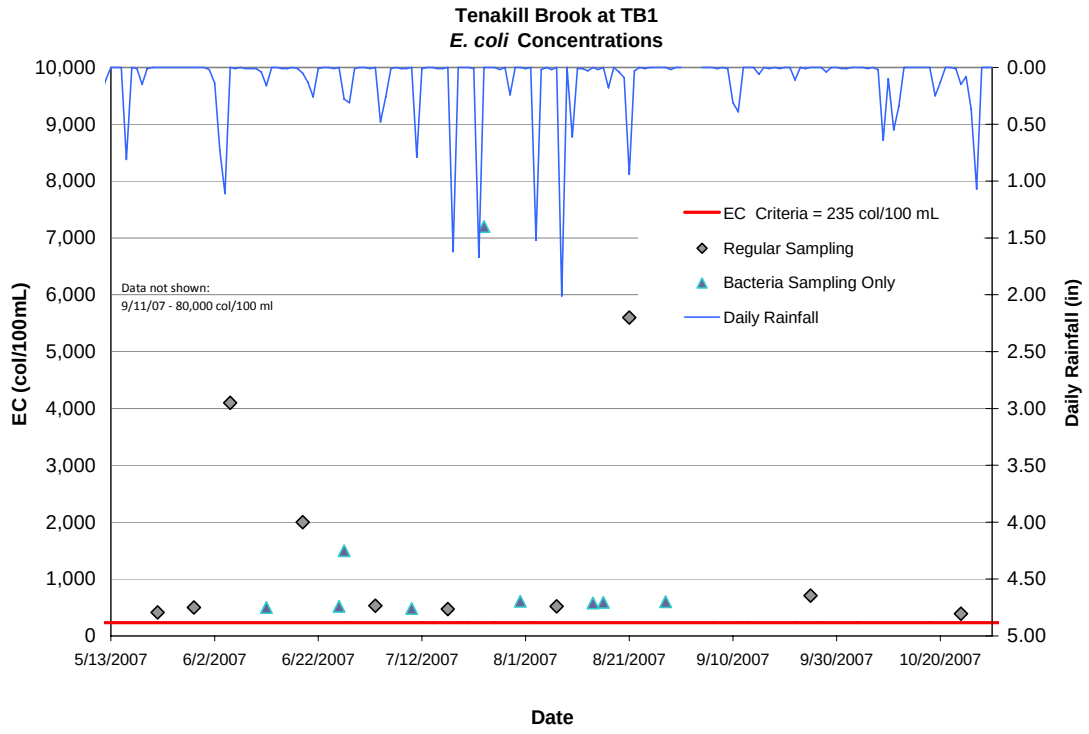
*For Fecal coliform and *E. coli* , geometric means were calculated.

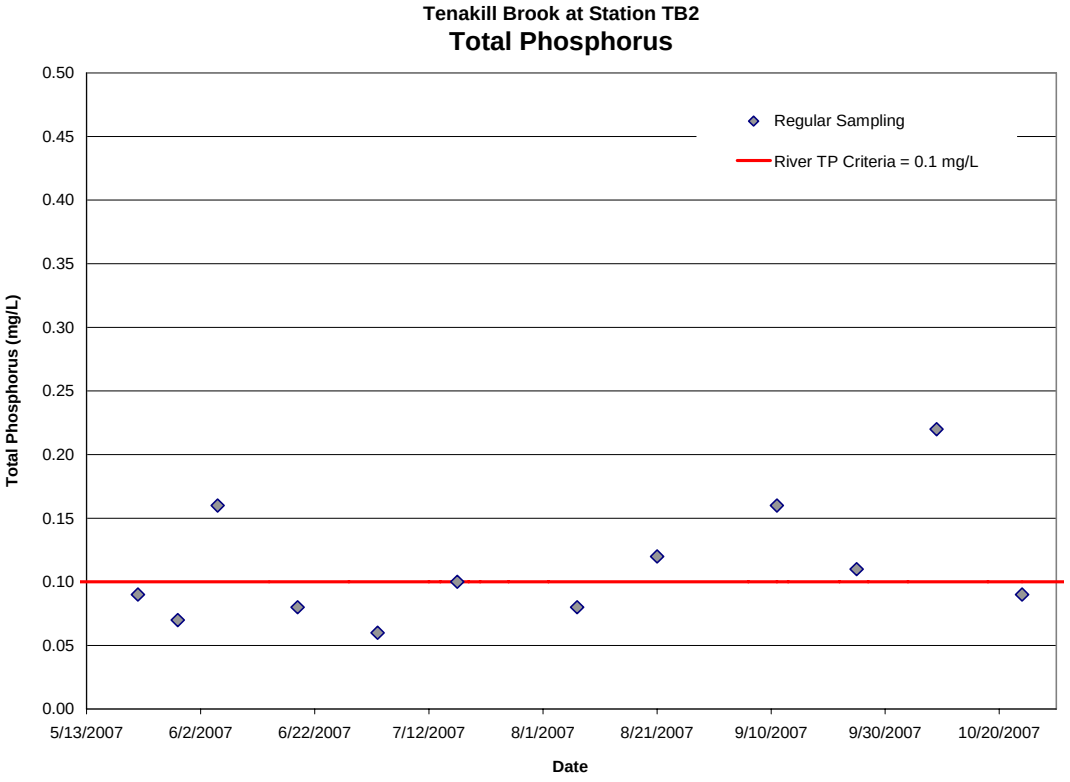
Appendix D: Presentation of Graphed Instream Water Quality Data

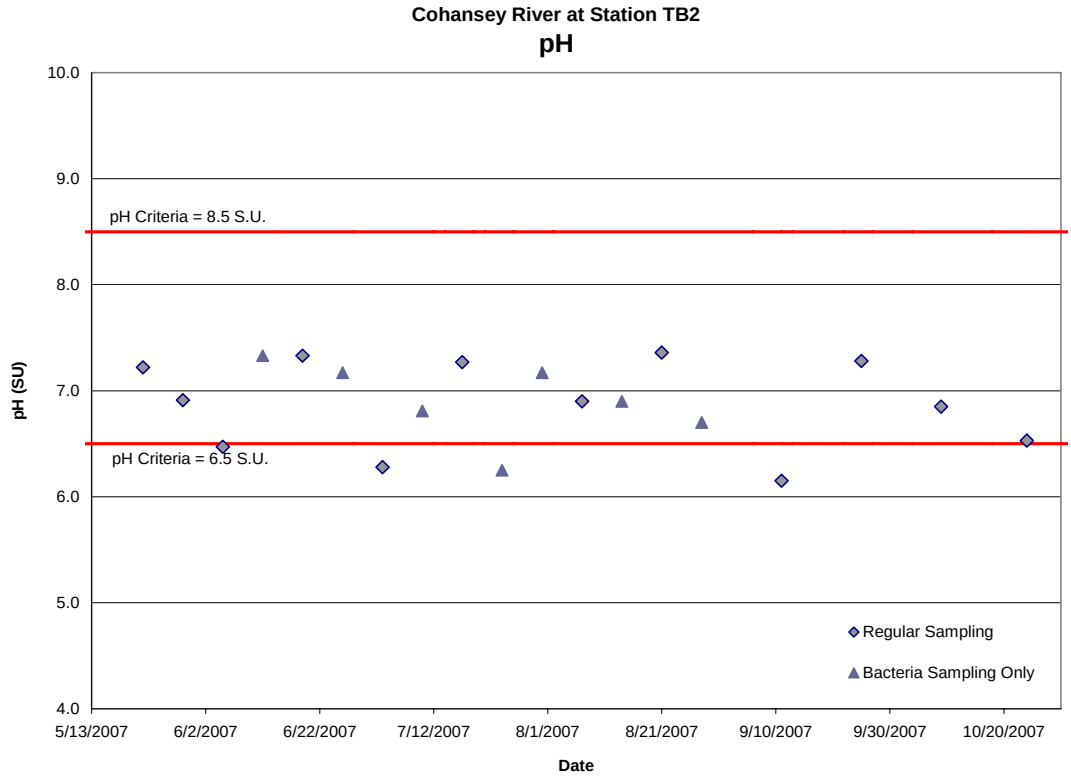

Tenakill Brook at Station TB1
Total Phosphorus
Regular Sampling
Lake TP Criteria = 0.05 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

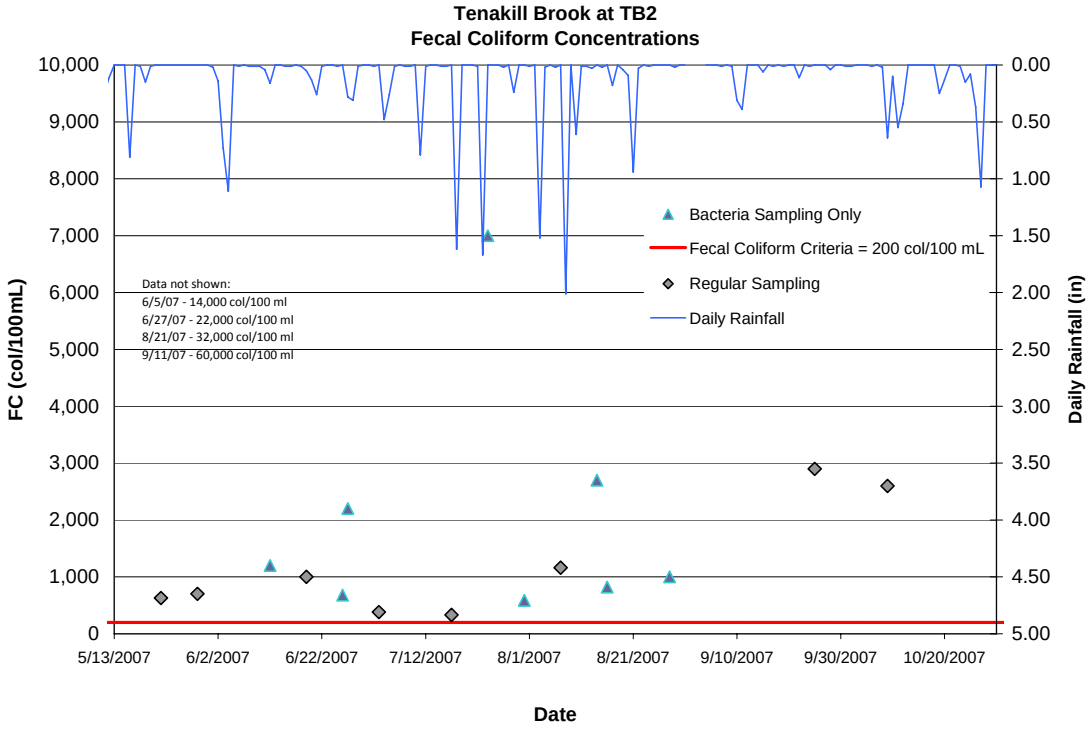

Tenakill Brook at Station TB1
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

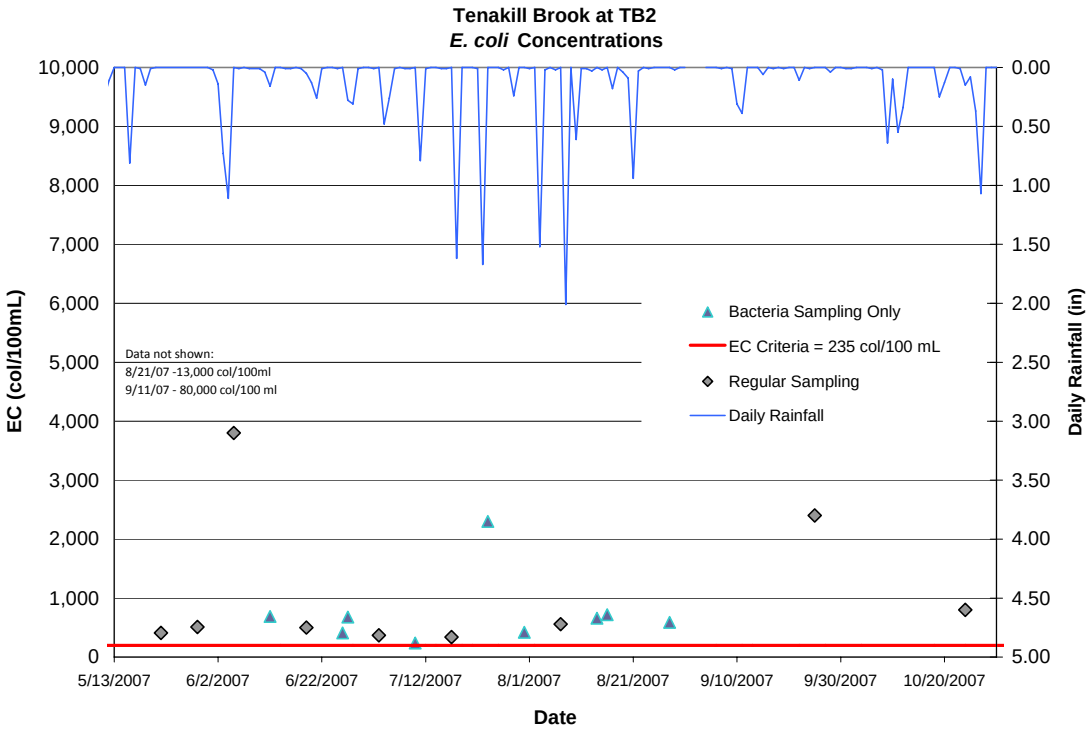

Tenakill Brook at TB1
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
Data not shown:
6/5/07 - 20,000 col/100 ml
9/11/07 - 60,000 col/100 ml
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

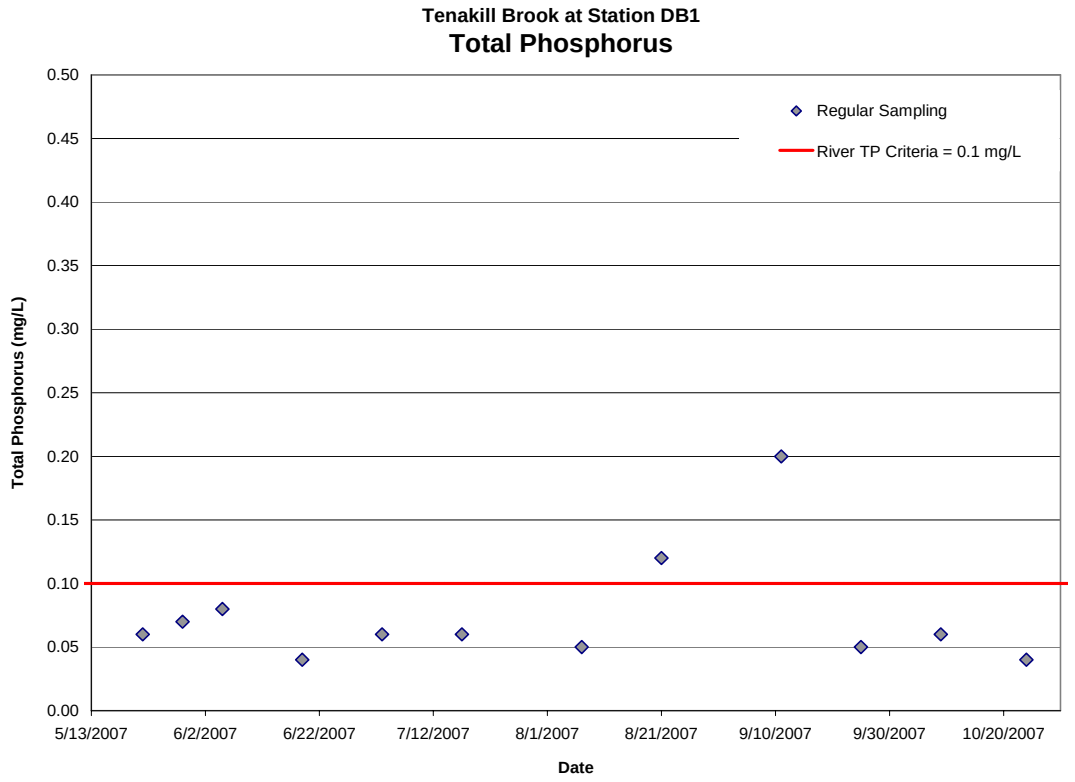

Tenakill Brook at TB1
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
EC Criteria = 235 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
Data not shown:
9/11/07 - 80,000 col/100 ml
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

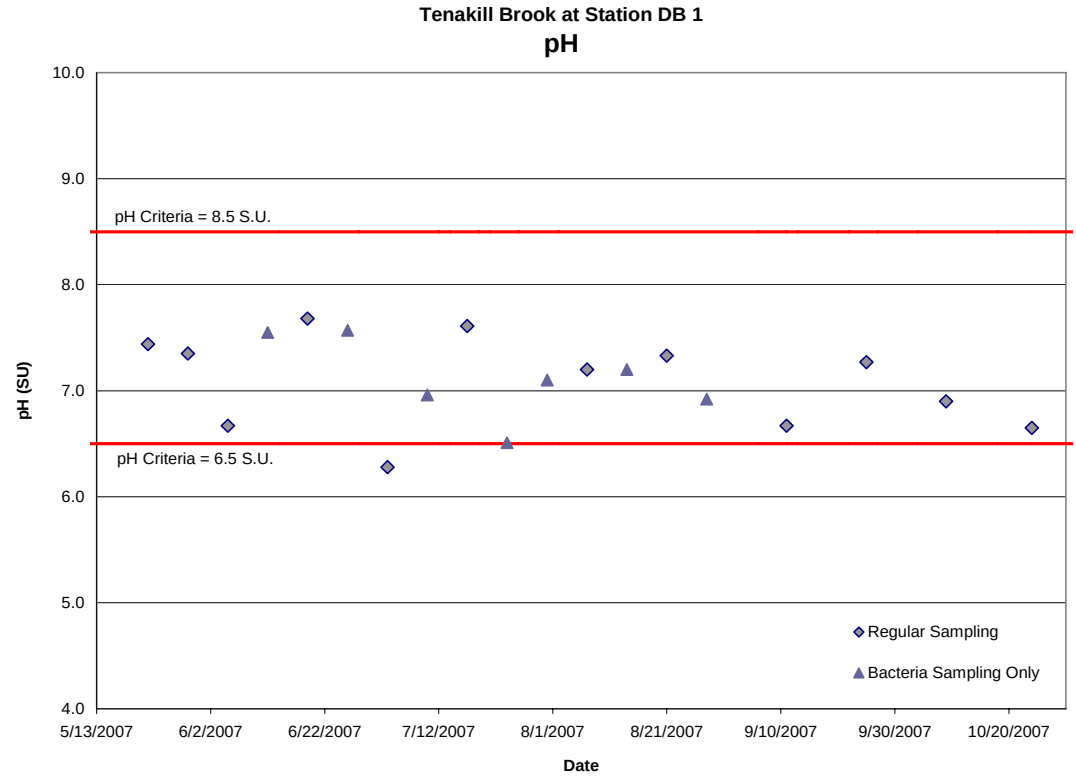

Tenakill Brook at Station TB2
Total Phosphorus
Regular Sampling
River TP Criteria = 0.1 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

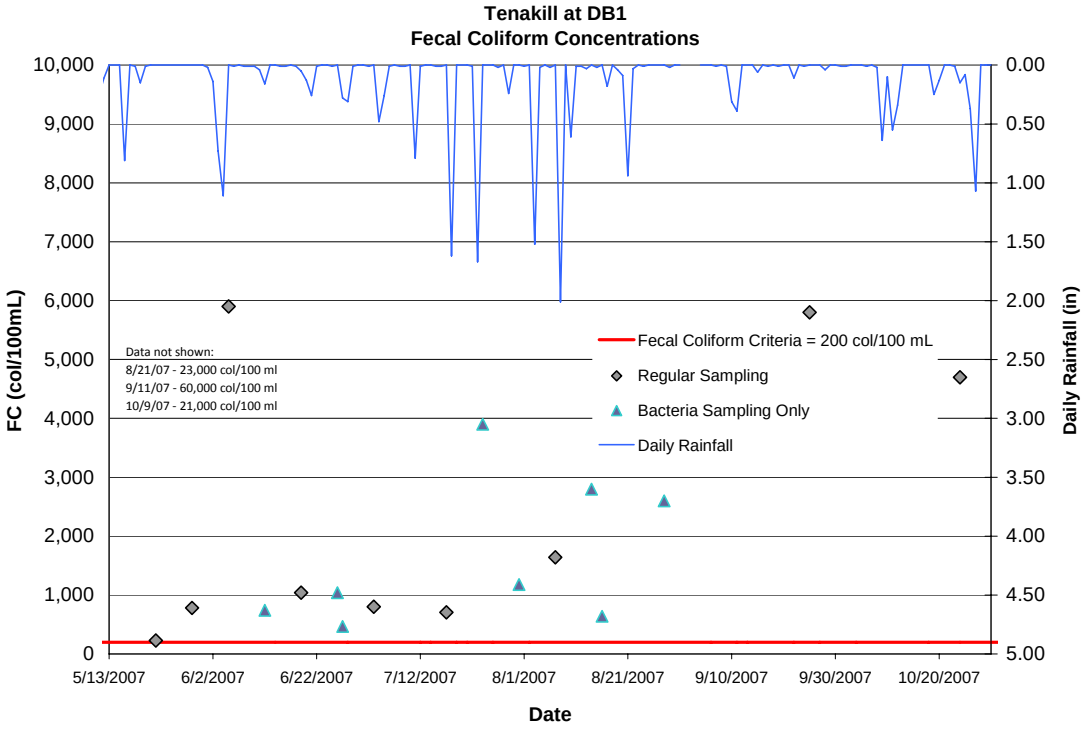

Cohansey River at Station TB2
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

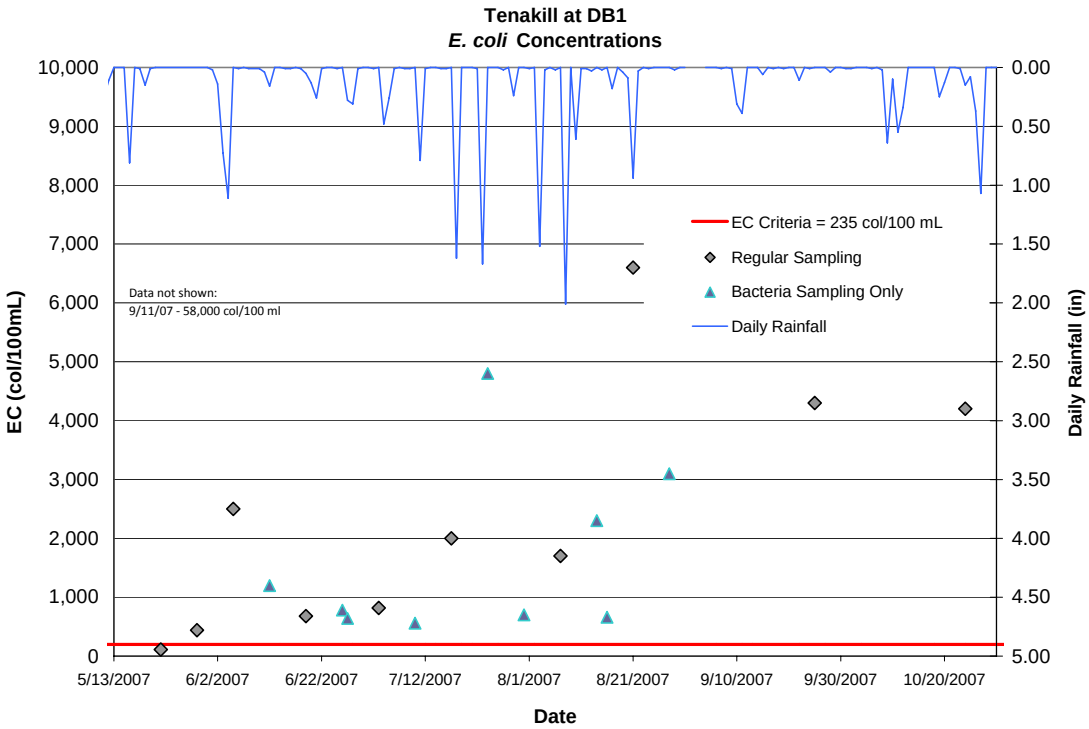

Tenakill Brook at TB2
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Bacteria Sampling Only
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Daily Rainfall
Data not shown:
6/5/07 - 14,000 col/100 ml
6/27/07 - 22,000 col/100 ml
8/21/07 - 32,000 col/100 ml
9/11/07 - 60,000 col/100 ml
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

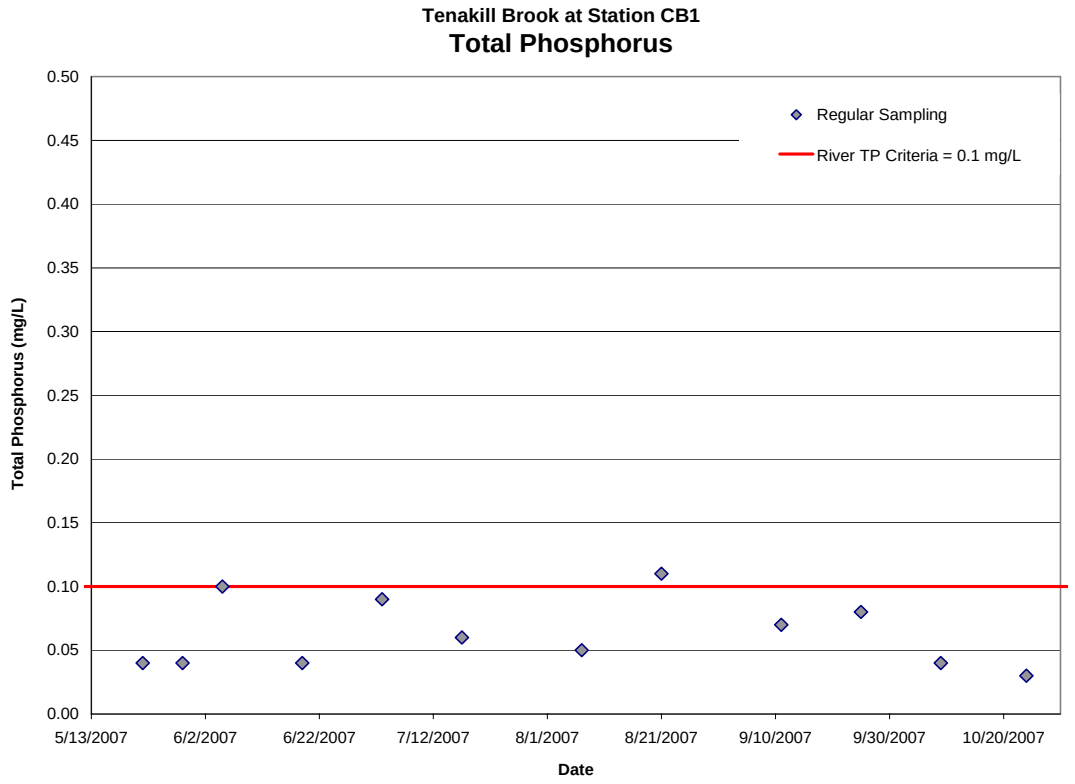

Tenakill Brook at TB2
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
Bacteria Sampling Only
EC Criteria = 235 col/100 mL
Regular Sampling
Daily Rainfall
Data not shown:
8/21/07 -13,000 col/100ml
9/11/07 - 80,000 col/100 ml
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

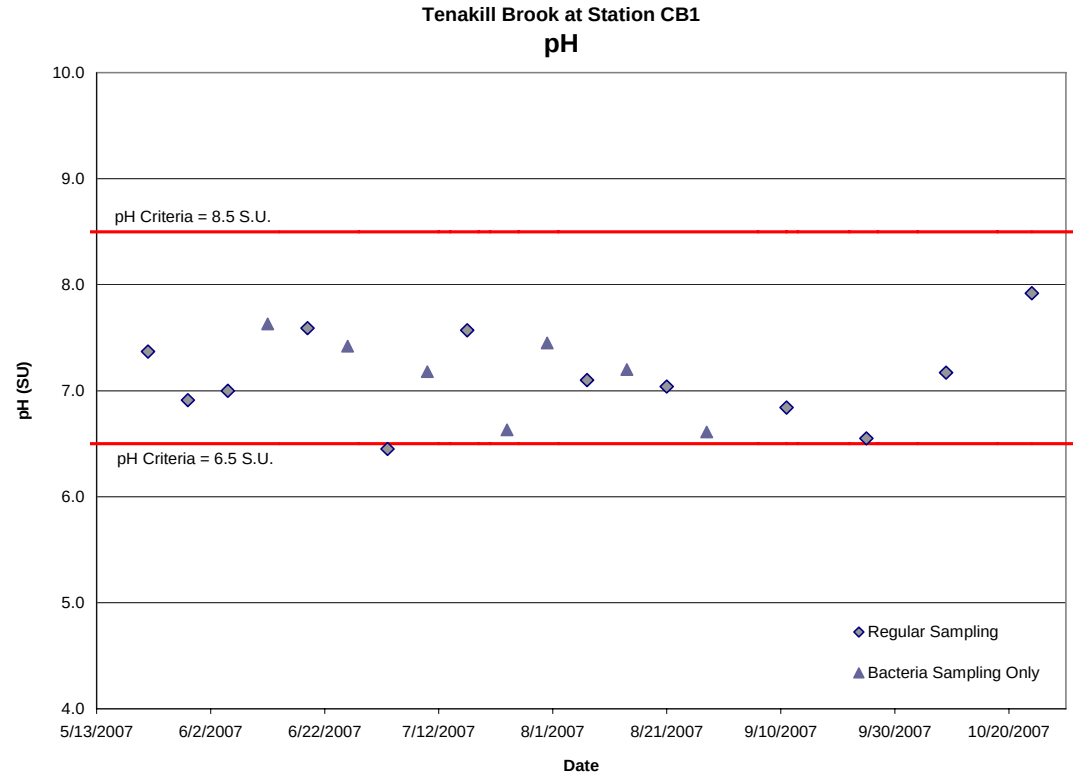

Tenakill Brook at Station DB1
Total Phosphorus
Regular Sampling
River TP Criteria = 0.1 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

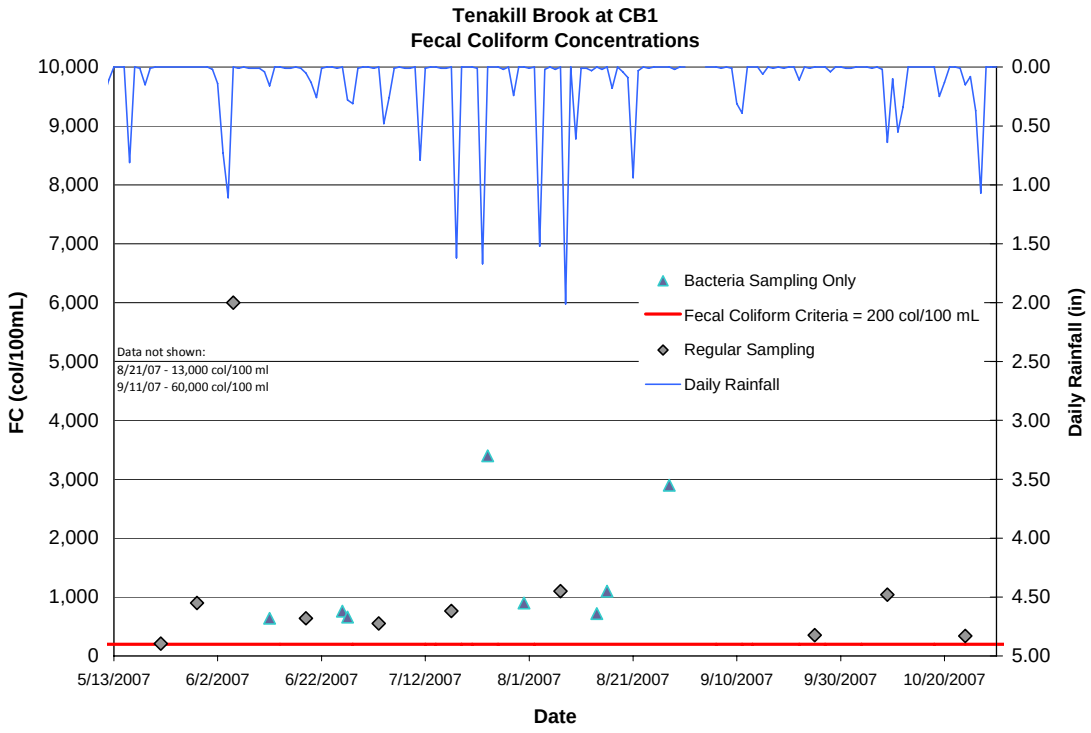

Tenakill Brook at Station DB 1
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

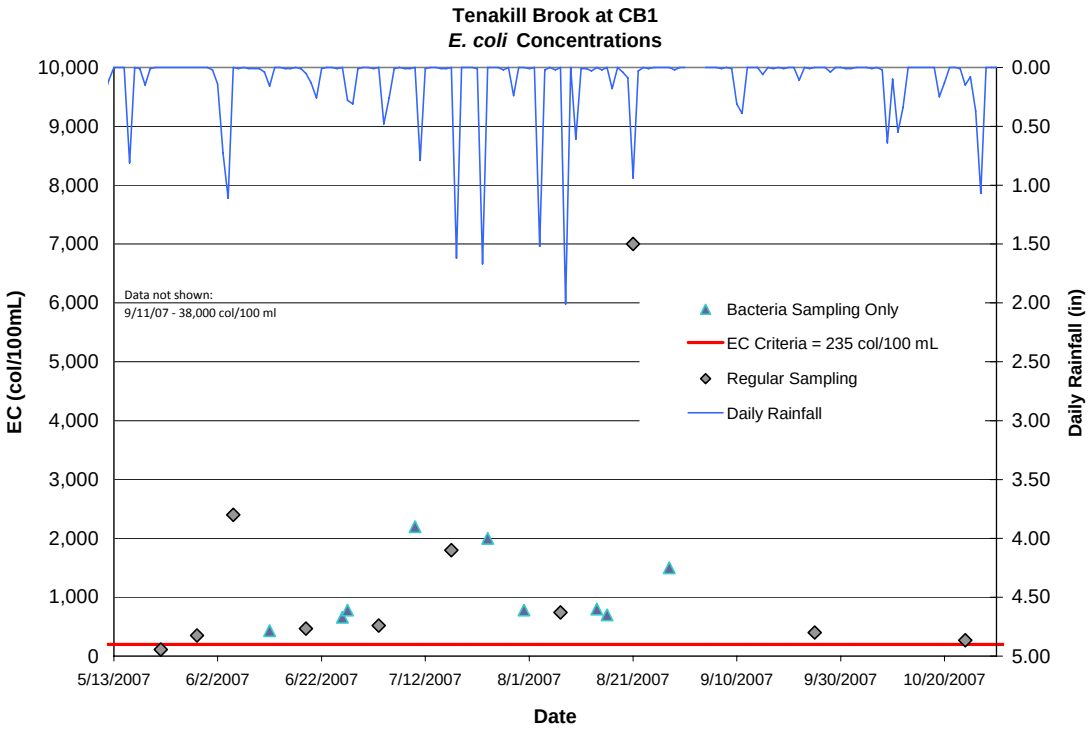

Tenakill at DB1
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
8/21/07 - 23,000 col/100 ml
9/11/07 - 60,000 col/100 ml
10/9/07 - 21,000 col/100 ml
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

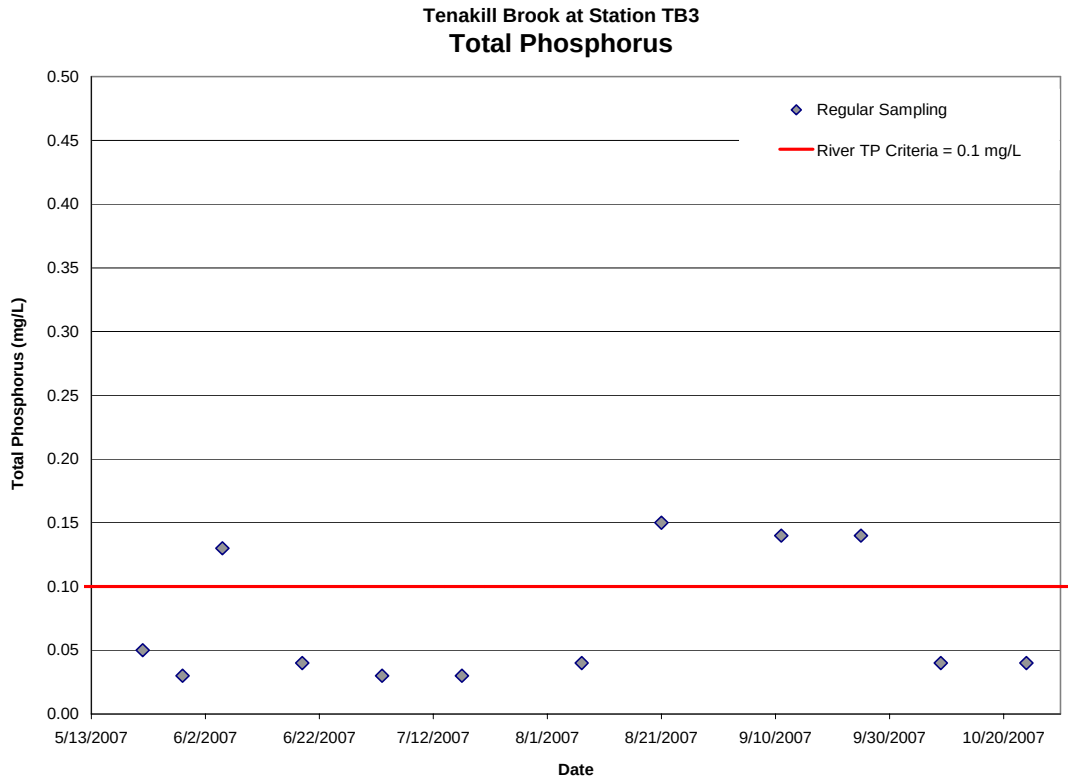

Tenakill at DB1
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
9/11/07 - 58,000 col/100 ml
EC Criteria = 235 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

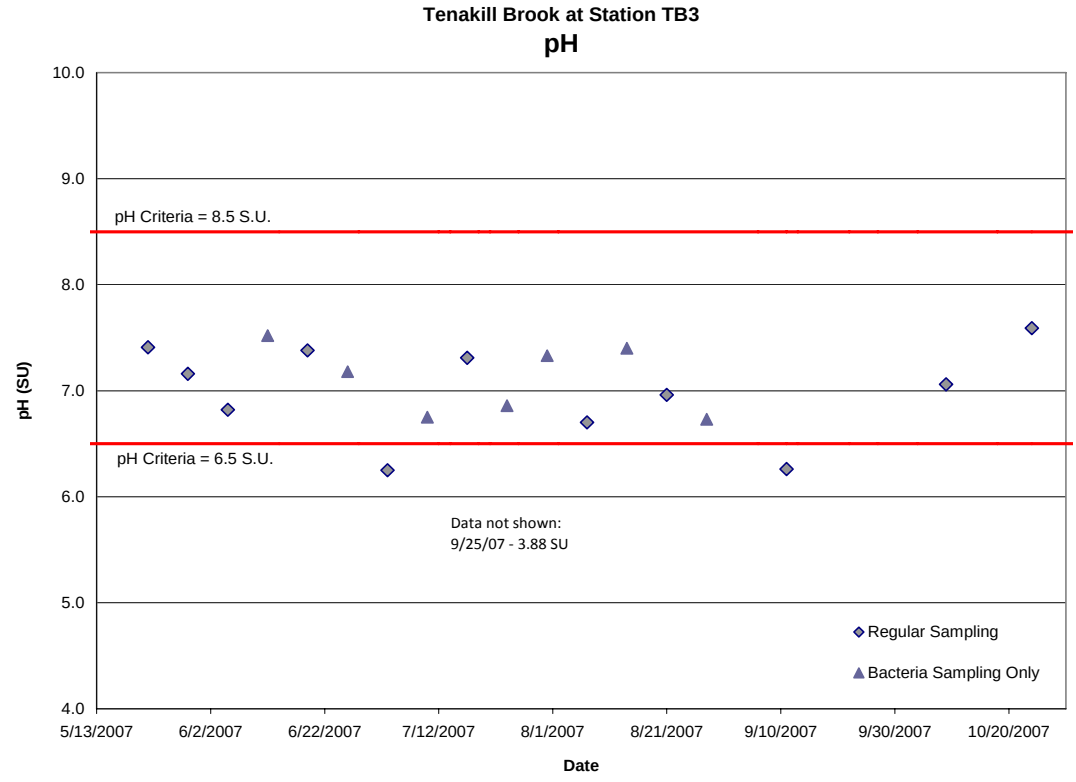

Tenakill Brook at Station CB1
Total Phosphorus
Regular Sampling
River TP Criteria = 0.1 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

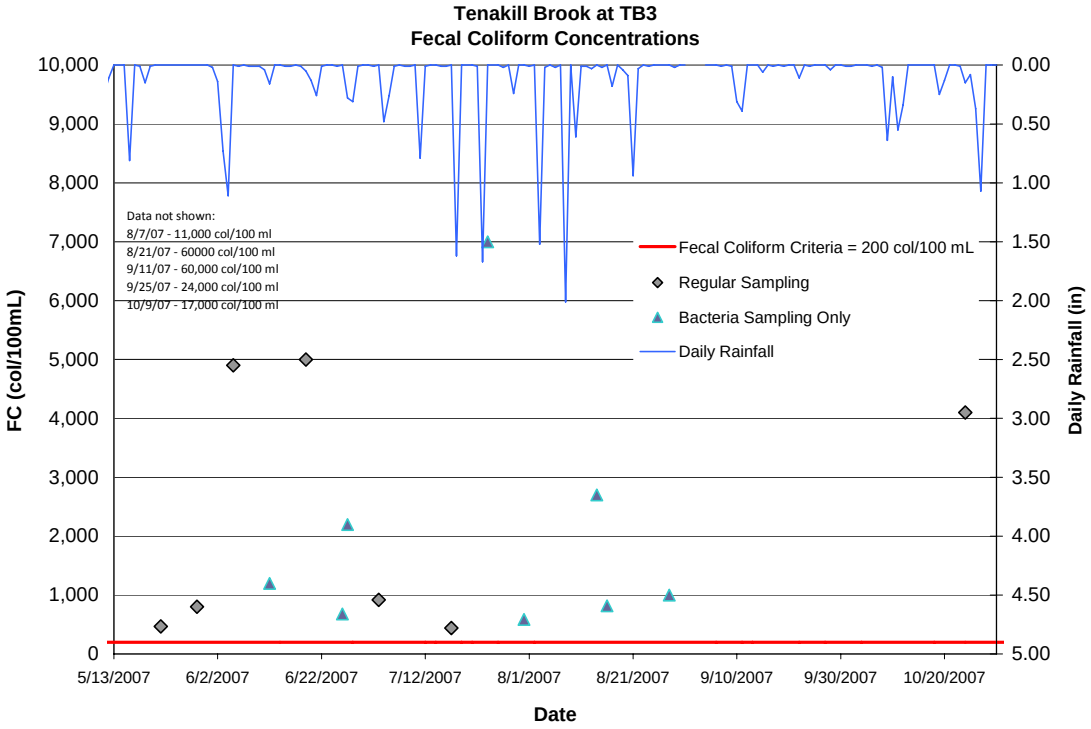

Tenakill Brook at Station CB1
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

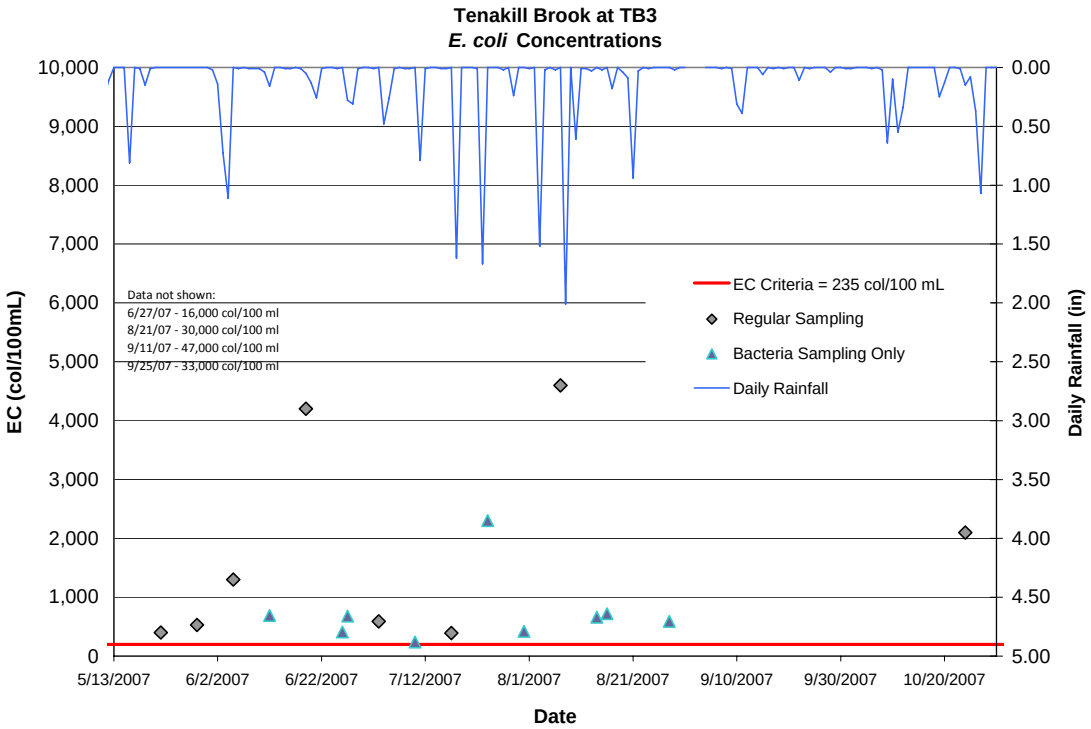

Tenakill Brook at CB1
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
8/21/07 - 13,000 col/100 ml
9/11/07 - 60,000 col/100 ml
Bacteria Sampling Only
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

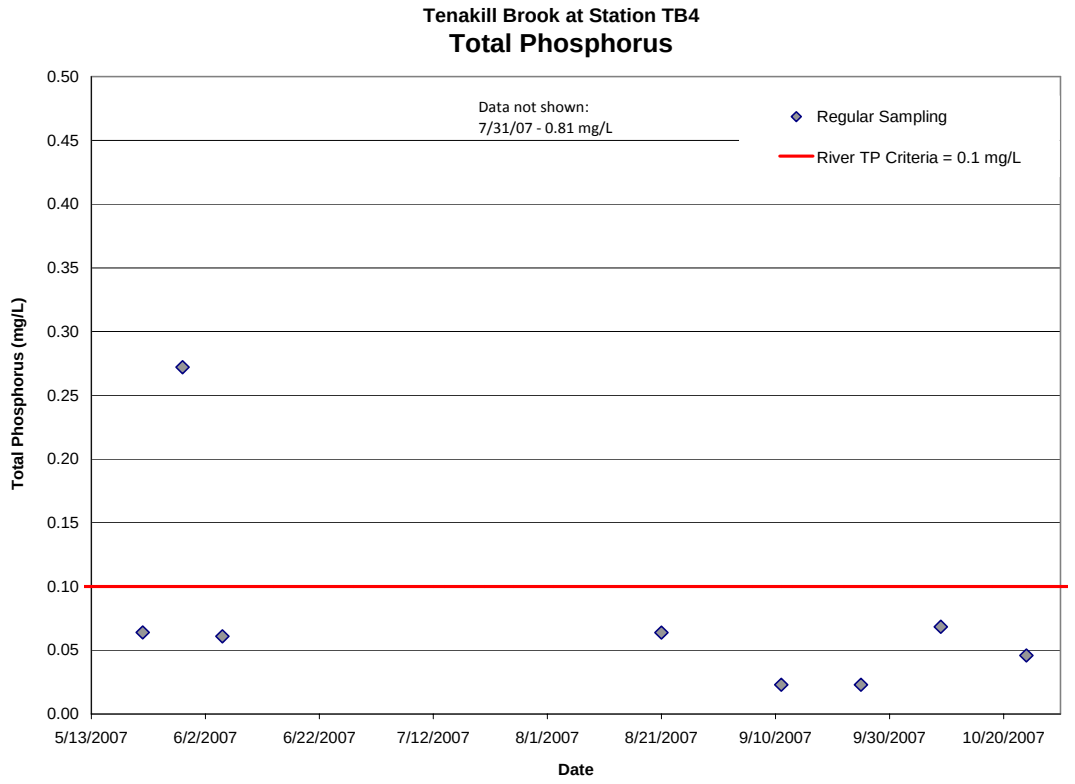

Tenakill Brook at CB1
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
9/11/07 - 38,000 col/100 ml
Bacteria Sampling Only
EC Criteria = 235 col/100 mL
Regular Sampling
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

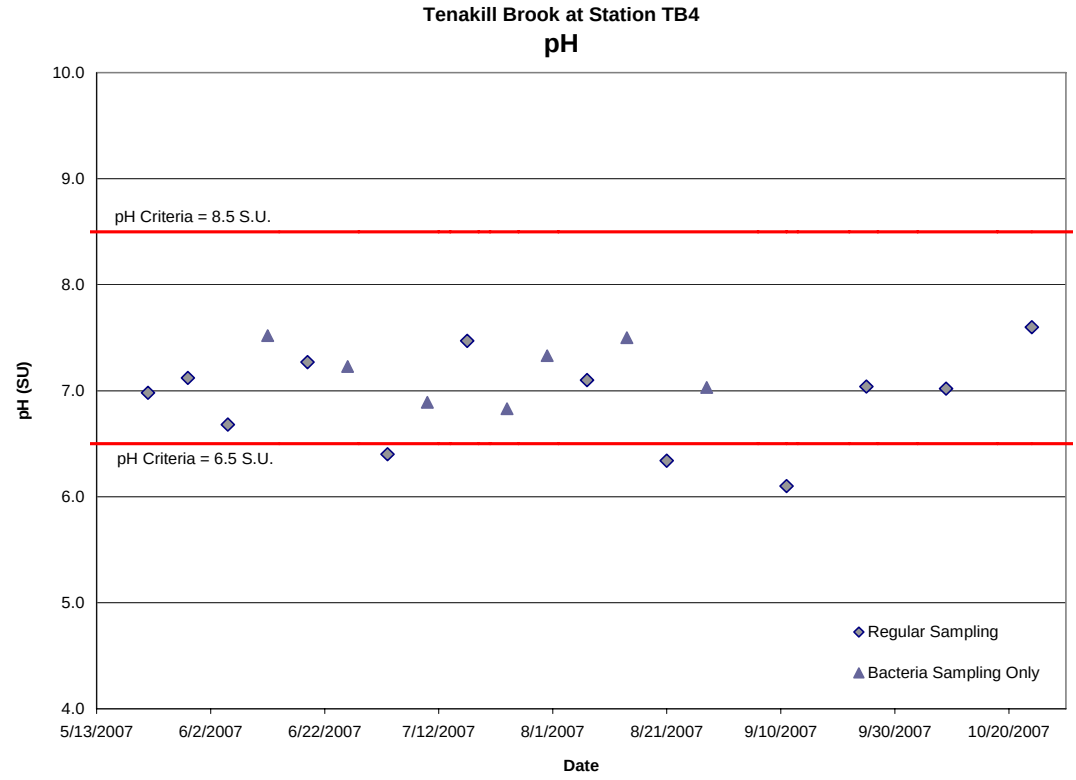

Tenakill Brook at Station TB3
Total Phosphorus
Regular Sampling
River TP Criteria = 0.1 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

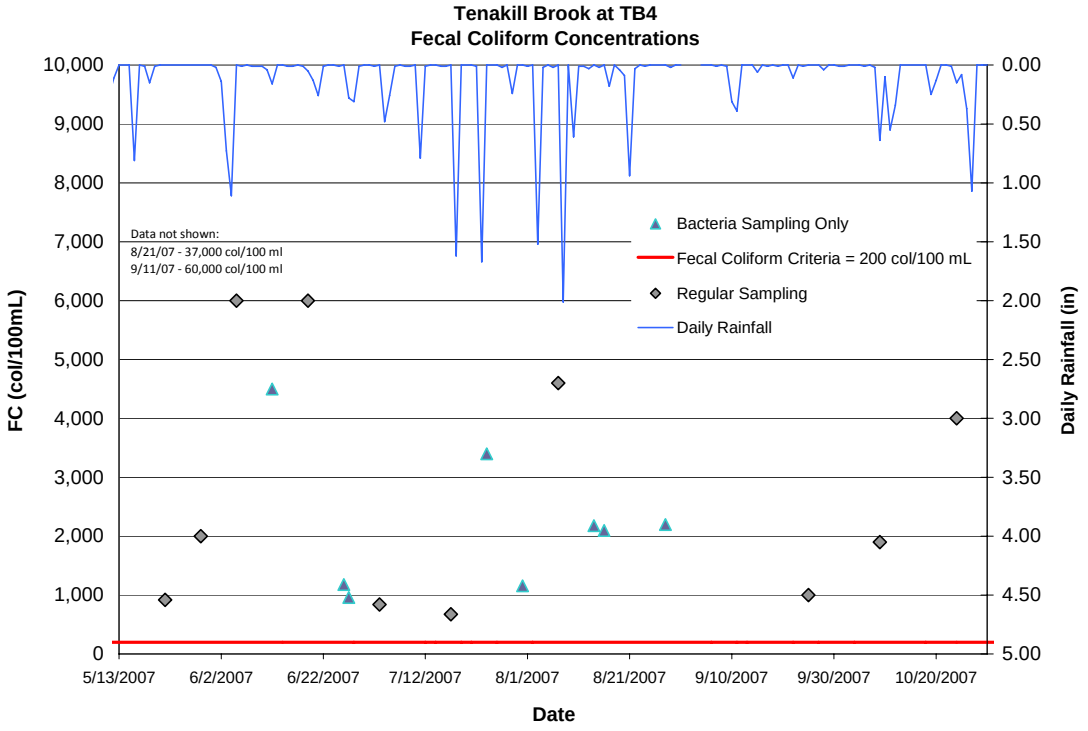

Tenakill Brook at Station TB3
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Data not shown:
9/25/07 - 3.88 SU
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

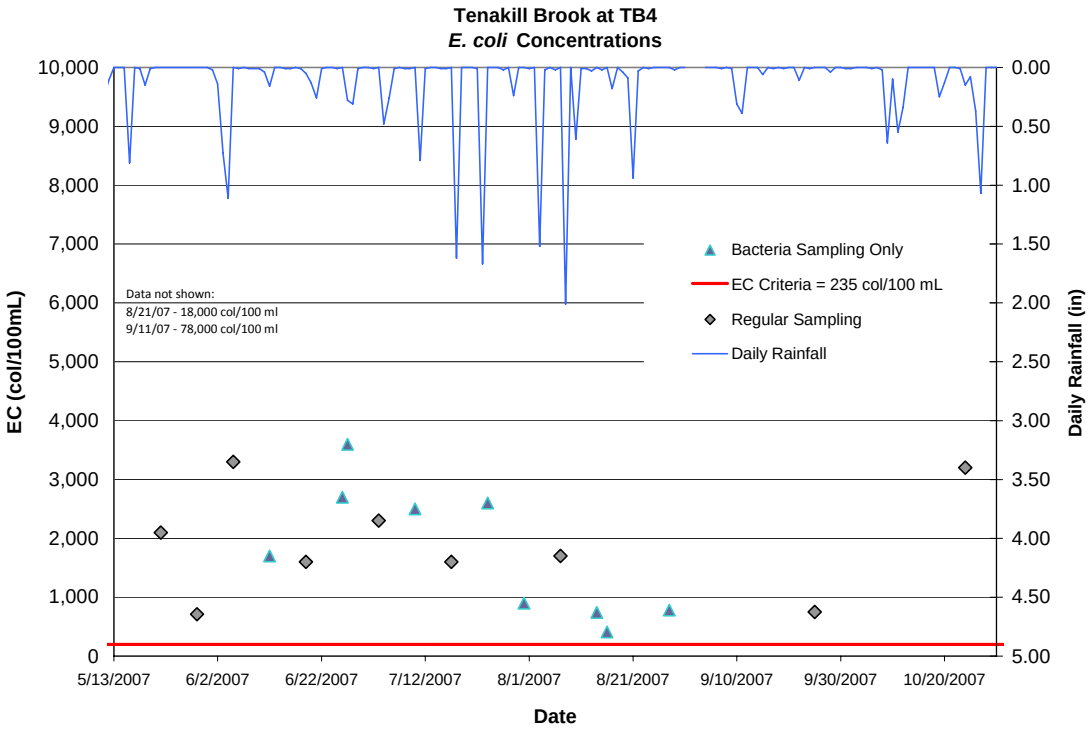

Tenakill Brook at TB3
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
8/7/07 - 11,000 col/100 ml
8/21/07 - 60000 col/100 ml
9/11/07 - 60,000 col/100 ml
9/25/07 - 24,000 col/100 ml
10/9/07 - 17,000 col/100 ml
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

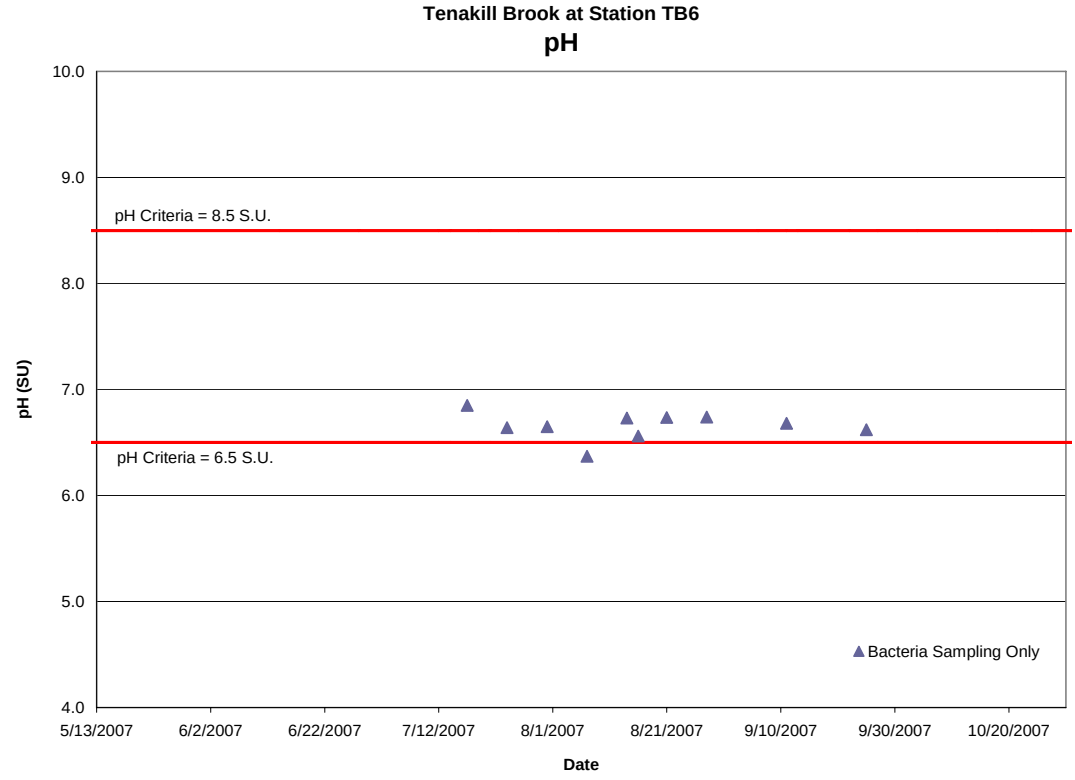

Tenakill Brook at TB3
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
6/27/07 - 16,000 col/100 ml
8/21/07 - 30,000 col/100 ml
9/11/07 - 47,000 col/100 ml
9/25/07 - 33,000 col/100 ml
EC Criteria = 235 col/100 mL
Regular Sampling
Bacteria Sampling Only
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007

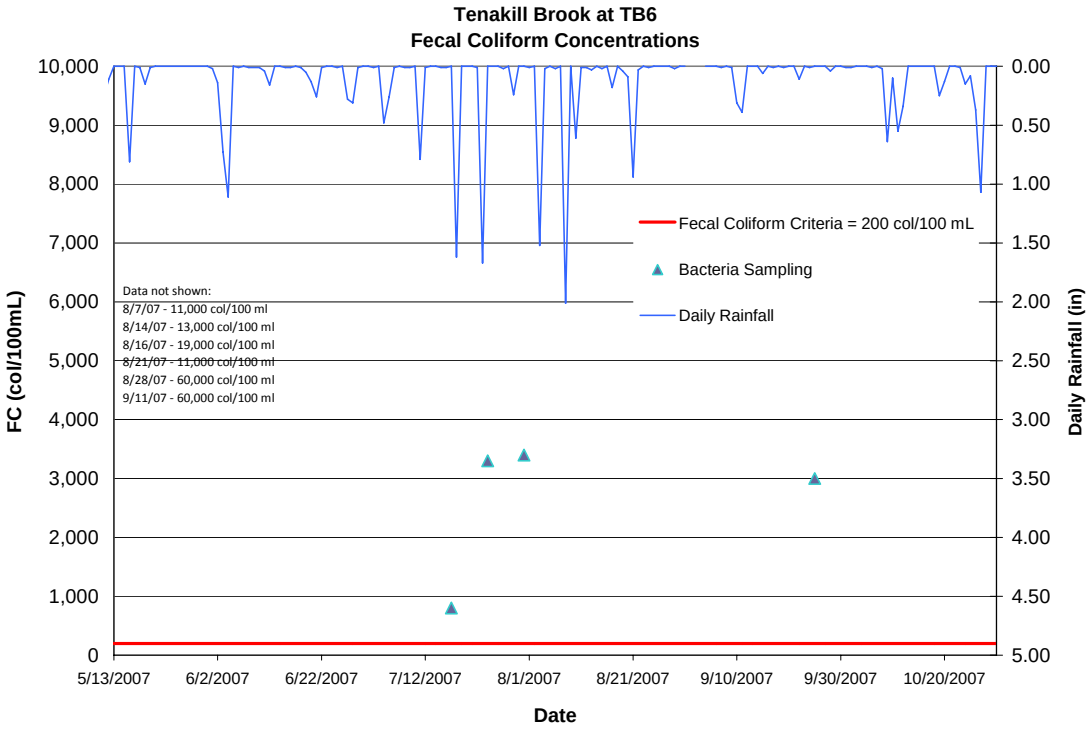

Tenakill Brook at Station TB4
Total Phosphorus
Data not shown:
7/31/07 - 0.81 mg/L
Regular Sampling
River TP Criteria = 0.1 mg/L
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date

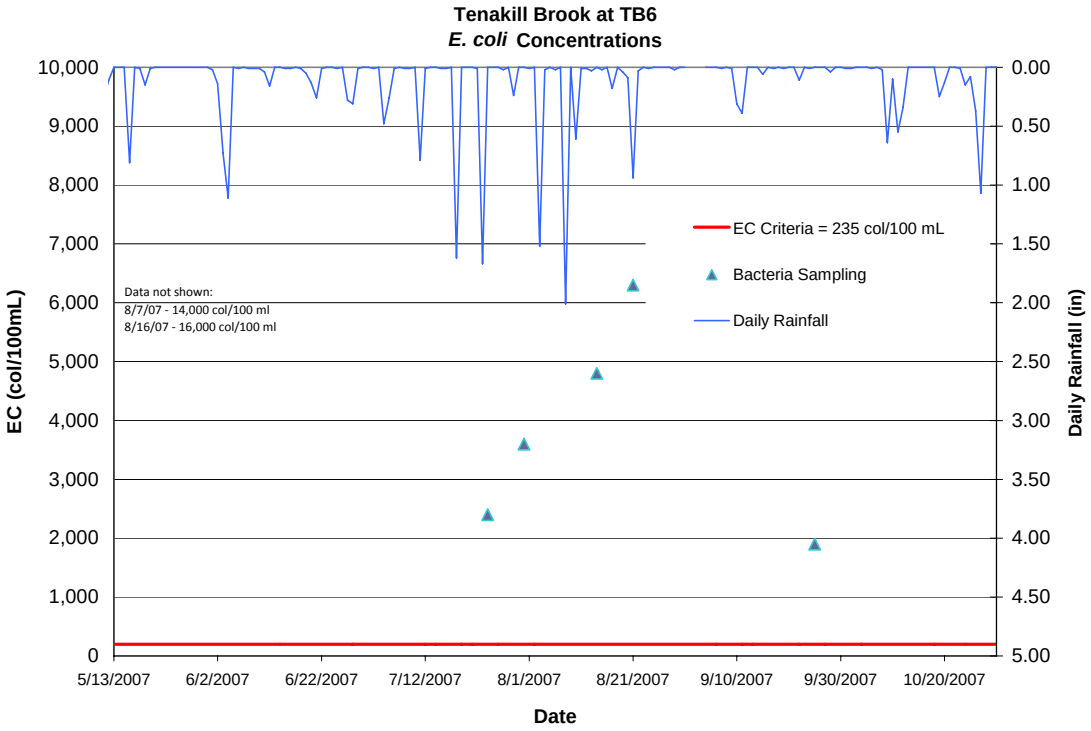

Tenakill Brook at Station TB4
pH
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Regular Sampling
Bacteria Sampling Only
pH (SU)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date


Tenakill Brook at TB4
Fecal Coliform Concentrations
FC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
8/21/07 - 37,000 col/100 ml
9/11/07 - 60,000 col/100 ml
Bacteria Sampling Only
Fecal Coliform Criteria = 200 col/100 mL
Regular Sampling
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007


Tenakill Brook at TB4
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
Data not shown:
8/21/07 - 18,000 col/100 ml
9/11/07 - 78,000 col/100 ml
Bacteria Sampling Only
EC Criteria = 235 col/100 mL
Regular Sampling
Daily Rainfall
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007


Tenakill Brook at Station TB6
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
pH (SU)
pH Criteria = 8.5 S.U.
pH Criteria = 6.5 S.U.
Bacteria Sampling Only
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date


Tenakill Brook at TB6
Fecal Coliform Concentrations
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
FC (col/100mL)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Daily Rainfall (in)
Fecal Coliform Criteria = 200 col/100 mL
Bacteria Sampling
Daily Rainfall
Data not shown:
8/7/07 - 11,000 col/100 ml
8/14/07 - 13,000 col/100 ml
8/16/07 - 19,000 col/100 ml
8/21/07 - 11,000 col/100 ml
8/28/07 - 60,000 col/100 ml
9/11/07 - 60,000 col/100 ml
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
Date


Tenakill Brook at TB6
E. coli Concentrations
EC (col/100mL)
Daily Rainfall (in)
Date
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5/13/2007
6/2/2007
6/22/2007
7/12/2007
8/1/2007
8/21/2007
9/10/2007
9/30/2007
10/20/2007
EC Criteria = 235 col/100 mL
Bacteria Sampling
Daily Rainfall
Data not shown:
8/7/07 - 14,000 col/100 ml
8/16/07 - 16,000 col/100 ml