
Fecal Coliform Source Tracking and TMDL Implementation Recommendations



Prepared for the

Mulhockaway Creek Stormwater Management and Watershed Restoration Plan

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319(h) Nonpoint Source Pollution Control Program

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Executive Summary

In 2003, the NJDEP issued a Fecal Coliform Total Maximum Daily Load (TMDL) for 48 streams in the Raritan Basin Watershed. One of the streams is the Mulhockaway Creek, located in Bethlehem and Union Townships in Hunterdon County, and is tributary to the Spruce Run Reservoir, a major water supply reservoir. The TMDL serves as a surface water quality management plan and identifies load reductions and long-term management strategies for the stream to meet water quality standards. Water quality standards are used to assess the condition of a water body and its ability to be used for certain purposes. Fecal Coliform is used as an indicator for the level of bacterial and pathogenic contamination in the stream and whether or not it is suitable for primary contact recreation (e.g. swimming). In October 2006, NJDEP switched indicator bacteria and the water quality standard from fecal coliform to *Escherichia coli* (E. Coli); however, NJDEP still intends to implement the fecal coliform TMDLs since streams are likely to exceed the E. Coli standard if fecal coliform standards were exceeded.

According to the TMDL, the sources were reported as deer and geese since the watershed land use is primarily forest and agriculture. The long-term management strategy recommended for the Mulhockaway Creek is source track down. Additional management measures included a fecal coliform survey, prioritization of EQIP funds for agricultural best management practices (BMPs), goose management programs, and the Phase II stormwater program.

For the Phase II stormwater management program, a watershed-based stormwater management plan was developed for the Mulhockaway Creek. As part of this program, the fecal coliform source track down survey was performed for NJDEP. The survey included additional fecal coliform monitoring in more locations within the watershed, a remote sensing analysis of aerial photography, and preliminary identification and field verification of potential sources.

This report details the source tracking activities and data analysis, identifies locations of potential sources, recommends possible management measures and proposes a phased implementation strategy with intermediate milestones. The work and recommendations are summarized in this executive summary. Additional background and detailed information is available in the main body of the report, while the overall characterization of the watershed is found in the *Mulhockaway Creek Stormwater Management and Watershed Restoration Plan*. This report is a companion document to the Plan.

Sources and Root Causes

In the 2003 TMDL, NJDEP theorized that fecal coliform sources were primarily related to agriculture and wildlife, particularly deer and geese. This presumption is appropriate given the rural/suburban character of the watershed. However, project committee members also suspected sanitary sources, particularly septic systems. The additional fecal coliform track down sampling, recommended in the TMDL and conducted for this project, was limited to analysis of fecal coliform (FC) and fecal enterococci (a subset of

fecal streptococci - FS). Both bacteria were enumerated to develop the FC/FS ratio, which can be used to differentiate between human and animal sources. The FC/FS ratio method was used prior to the development of more sophisticated source tracking analyses, such as coliphage, DNA analyses and multiple antibiotic resistance (MAR). Although not always robust because bacteria survival is not predictable, the FC/FS ratio is useful as an inexpensive preliminary indicator of source type.

Based on the additional sampling, data analyses, remote sensing and field surveys, deer and geese are likely sources of contamination, considering their abundance, but so are sanitary wastewater and agricultural operations. Pattenburg,¹ one of the more densely populated areas in the watershed, contains older housing stock rumored to have failing septic systems and possibly cesspools. The sampling locations in the vicinity of Pattenburg indicated potential human contamination based on the FC/FS ratio. In addition, an inventory of stormwater infrastructure conducted for the stormwater management plan indicated that approximately 15 outfalls in the Main Street area are suspected of illicit sanitary connections because malodorous dry weather flows were present. Tank effluent, absorption field laterals or hydraulic connections² are the likely sources rather than direct connection to waste sources since other related materials, such as toilet paper, were not observed. Animals from several agricultural operations had direct access to the stream or the riparian buffer was poor. Manure storage and application at a few farms is also a likely contributor. Geese are prevalent within the watershed and are present in the vicinity of every open water body, specifically in-line³ ponds.

Load Reductions

The data collected for this project as well as the historic data indicate that the fecal coliform concentrations⁴ are typically on the order of 10^3 col/100 ml. Larger concentrations on the order of 10^4 were observed, but only during storm events (for the project) or prior to 1989. Of the non storm event project samples, approximately 90 percent met a surrogate secondary contact recreation standard of 700 col/ 100 ml. Although this standard is for the Delaware River and SE2 waters, the Mulhockaway Creek is likely suitable for secondary contact recreation (e.g. boating, fishing), except during storm events. In addition, the physical attributes of the Creek, particularly its shallow depth, exclude immersion and thus primary contact recreation. Swimming during storm events is unsafe due to the high velocity of the streamflow.

The required load reduction reported in the TMDL is 91 percent for the Mulhockaway Creek. An actual bacterial load in counts/day was not specified for either existing conditions nor was the assimilative capacity of the stream. Load allocations were not assigned by type of non-point source. The diffuse nature of the sources and the growth

¹ A locale in Union Township

² The Department of Health for the State of New York demonstrated through dye testing that an E. Coli outbreak in 1999 at a fairground was due to a hydraulic connections between a septic system and a well.

³ In-line ponds are those that are located in the stream channel and all streamflow is routed through the pond.

⁴ Bacteria concentrations are often reported in scientific notation to indicate the order of magnitude of the measurement. Comparing the order of magnitude of the data is more appropriate since bacteria concentrations have the tendency to have a lognormal distribution.

and expiration of bacteria makes calculation of an actual load and load reductions difficult. No data were available about wildlife or livestock populations nor was information readily available about failing septic systems or cesspools. Without such information, attributing relative bacterial loading contributions would be a guess at best.

Rather than invest time and funds researching information to calculate and allocate loads, the focus of this project was to identify potential sources, rather than quantify their impacts. Nonpoint source pollution can be direct/concentrated (sanitary, agricultural) or dispersed (wildlife) throughout the watershed. For concentrated sources, management measures are more likely to produce results since they can be readily identified and targeted for action. Of the 53 potential sources identified, twenty locations were identified as having poor manure management, animals with access to the stream, and/or inadequate riparian buffer with animals near the stream. Potential sanitary sources were identified in eight locations.

Management Measures

Management measures are recommended for each of the potential sources located in the watershed. The measures fall into six categories: agricultural best management practices, septic system/cesspool management, sanitary illicit connection detection and removal, microbial source tracking, wildlife management programs and public education. The first three types of management actions relate primarily to minimizing or eliminating the impact of more concentrated sources of nonpoint source pollution. The latter three types are the most likely means to assess and handle the more diffuse sources. Each class of management measure is discussed in both this report and in the TMDL. Typical management measures are proposed for the 53 locations identified for the project. They are not detailed because limited information was available to develop specific actions at each site and collection of such data was outside of the project scope.

Measureable Milestones

The goal of the TMDL and implementation of the management measures is to meet the designated use of primary contact recreation as determined by the fecal coliform standard. Since the NJDEP has changed its standard, the goal is to meet the new standard for E. Coli. Since nonpoint source management measures to reduce E. Coli are identical to those for fecal coliform, the ultimate goal is to meet the E. Coli water quality standard and attain use for primary contact recreation.

One intermediate milestone could be established in addition to meeting the primary contact recreation standard. The secondary contact recreation standard could be an intermediate goal for the implementation of management measures. Since funding for implementation is limited, reducing the bacterial load to the secondary contact recreation standard will likely protect the majority of persons using the stream. Primary contact recreation is limited in the stream because there are few if any pools where a person might swim. Reductions in load will result from the management measures for more

concentrated sources, such as sanitary illicit connections, failing septic systems, excluding animals from streams and better manure management. Sanitary illicit connections and failing septic systems mean the presence of sanitary wastes and these problems should be addressed regardless of the TMDL.⁵ Excluding animals from the streams and better manure management have been shown to reduce the bacterial and nutrient loads to affected streams.

Once management measures for concentrated sources have been implemented, NJDEP should determine if the primary contact recreation standard is met. If it is not, implementation of additional management measures should move forward. However, before doing so, NJDEP should employ microbial source tracking (MST) to determine if the problem is manageable or not and to focus resources. For instance, if the contamination is related to deer, a community deer management program may already be in place to manage the deer herd, and thus, bacterial contamination from them.

Implementation

Schedule

A priority schedule has been suggested for implementing management measures in subwatersheds with higher concentrations. The priority recommendations are for concentrated locations of sources and include animal exclusion and manure management at two sites, manure management at one site, septic system and cesspool evaluations and sanitary illicit connection⁶ detections in Pattenburg and goose management at two locations. Because the sources are more obvious at these locations than others, management measures at these locations should reduce the bacterial loading on the stream.

Technical Assistance and Funding

The management measures identified through this project are preliminary in nature and require some additional site investigations and assessment to determine a detailed best management practices or size facilities. For priority recommendations, the best management practices include improvement or reestablishment of riparian buffers on pastureland, manure management, excluding animals from the stream and a sanitary survey. The most likely sources of technical assistance and funding would be the North Jersey Resource Conservation and Development Council (NJ RC&D) and Natural Resource Conservation Service (NRCS) through the United States Department of Agriculture Environmental Quality Incentives Program (EQIP), the Conservation Reserve Enhancement Program (CREP) and associated New Jersey Cost-Share Farm Programs.⁷ These programs are described in the TMDL.

⁵ One best management practice for stormwater systems is to remove illicit connections from the storm sewer system. However, Bethlehem and Union Townships are Tier B municipalities.

⁶ These are suspected not confirmed.

⁷ <http://www.extension.iastate.edu/agdm/livestock/html/b1-75.html>

EPA has a guidance manual on performing sanitary surveys. NJDEP staff, AmeriCorps Watershed Ambassadors or State and/or County health officials can conduct these assessments. Development of a septic system/onsite wastewater management plan could be supported either by 604b wastewater planning funds or 319(h) non point source program funds as implementation of this recommended management measure. The individual homeowners are responsible for disconnecting illegal sanitary connections to the ditches, storm sewers or streams or for repairing and replacing failing septic systems and cesspools. If multiple systems are failing as a result of the hydrogeology or density of the area, the NJ Environmental Infrastructure Trust could be a funding source if a local wastewater treatment facility is required.

Criteria and Monitoring Program

NJDEP currently has an ambient water quality monitoring program in place, which will at least assess the bacteria levels of the Mulhockaway Creek at the USGS Gauge (01396660). Data are collected in the summer using the “5 samples in 30 days” protocol. As implementation of projects start, NJDEP may want to monitor the subwatersheds where the recommendations are being implemented such that the improvement in water quality can be directly attributable to the management action. The criteria to be met are the fecal coliform standard for secondary contact recreation, as an intermediate goal, and the E. Coli standard for primary contact recreation. Since the potential sources are dispersed throughout the watershed, it may be useful to assess whether or not the contamination is wildlife related and determine the associated contribution to the exceedence of the standard(s).

Education

Many education programs are underway in the watershed. Through the Spruce Run Initiative, a septic system education program was developed to educate homeowners about the proper maintenance of septic systems and how to detect problems. The North Jersey Resource Conservation and Development Council (NJ RC&D) and the South Branch Watershed Association are implementing the “River Friendly” programs, which educate property owners about land management practices beneficial to water resources. NJ RC&D also arranges technical assistance to farmers through the United States Department of Agriculture’s Natural Resource Conservation Service (NRCS). The NJDEP’s Phase II Municipal Stormwater Management Permits require the townships to produce and distribute education materials about stormwater management and can also be used to educate residents and landowners about nonpoint source pollution and management.

Introduction

The Mulhockaway Creek is located in Hunterdon County, New Jersey in the communities of Bethlehem and Union Townships. The Creek drains the western portion of the Spruce Run Reservoir watershed, a major water supply facility for the State. The Clean Water Act requires each State to designate appropriate uses for each water body and determine if the water body meets those uses. The Mulhockaway Creek does not meet its designated use as suitable for primary contact recreation because fecal coliform concentrations exceed the surface water quality standard. As a result, in 2003, the New Jersey Department of Environmental Protection (NJDEP) developed a Total Maximum Daily Load (TMDL) for the Creek.

Background

A TMDL determines a load or concentration of a pollutant that a stream can receive and what amount of reduction is needed from sources in the watershed so that the stream will meet water quality standards and its designated uses. The required reduction of the fecal coliform load is estimated to be approximately 91 percent of the current load. The TMDL recognized that the Mulhockaway Creek has no known point sources of fecal coliform and that all contamination was likely from non-point sources, particularly deer and geese. One recommendation for implementation of the TMDL included a more extensive fecal coliform monitoring program to prioritize sub-watershed areas for implementation efforts and funds.

Fecal Coliform concentrations are used as an indicator of pathogen contamination of the water. Bacterial contamination usually results from discharges of sanitary sewage⁸ or exposed animal⁹ wastes. For the TMDL, NJDEP used a two-part water quality standard to assess bacterial contamination. "Fecal coliform levels shall not exceed a geometric average of 200/100 ml nor should more than 10 percent of the total samples taken during any 30-day period exceed 400/100 ml."¹⁰ Bacteria concentrations are lognormally distributed, varying by orders of magnitude. Geometric means are used to quantify and compare the central tendency among groups of lognormally distributed data.

Since the initiation of this project NJDEP has changed their indicator bacteria to *Escherichia coli* (E. Coli). "E. Coli levels shall not exceed a geometric mean of 126/100 ml or a single sample maximum of 235/100 ml." Since both E. coli and fecal coliform are indicators of bacterial contamination, results using either indicator can be expected to be similar and have been shown to be similar¹¹. The E. Coli standard is specified for assessing the suitability of waters for primary contact recreation. Although the standard

⁸ Direct, illicit/illegal connections to the storm sewers, leaking sanitary sewers and failing septic systems.

⁹ Wildlife, pets, livestock, manure.

¹⁰ N.J.A.C 7:9-1.14(c); FW2 waters; August 2004.

¹¹ U.S. Environmental Protection Agency. 1986. Ambient Water Quality Criteria for Bacteria – 1986. U.S. Environmental Protection Agency, Washington, DC. EPA440/5-84-002, January 1986. NJDEP used the fecal coliform standard recommended by EPA. While EPA recommended the fecal coliform standard, they strongly encouraged the transition to E. Coli or enterococci for fresh waters.

has changed, NJDEP decided to proceed with the implementation of the fecal coliform TMDLs, since water bodies exceeding standards for fecal coliform would likely exceed standards for E. Coli. NJDEP specifies no water quality standard for secondary contact recreation for FW2 waters. However, NJDEP does specify a secondary contact standard of 700 col/ 100 ml for saline waters. In addition, the Delaware River secondary contact recreation standard is 770 col/ 100 ml.

As part of the *Mulhockaway Creek Stormwater Management and Watershed Restoration Plan*, fecal coliform track down monitoring was conducted to support NJDEP's TMDL implementation efforts. TRC Omni Environmental¹² was contracted to coordinate and perform the water quality sampling program. This document summarizes the additional monitoring and other associated activities for the development of Fecal Coliform TMDL Implementation Recommendations. Detailed information about the sampling program can be found in the Quality Assurance Project Plan, which is reproduced in Appendix A. The Quality Assurance Project Plan (QAPP) contains photographs of all the sampling locations. A detailed summary of the sampling program and results is located in Appendix B. While useful for track-down activities, samples were collected solely for the purpose of identifying subwatersheds more likely to have violations of the fecal coliform water quality standards and should not be used for regulatory purposes.

Watershed Description

The Mulhockaway Creek watershed comprises 15 square miles of the western portion of the Spruce Run Reservoir watershed and is within NJDEP's Watershed Management Area 8 (WMA 8): North and South Branch Raritan Rivers. Figure 1 presents the watershed, streams and geography of the study area. The Mulhockaway Creek is comprised of several unnamed tributaries which join just upstream of the reservoir. For this project, these streams were named based on roads in their sub watersheds for association and discussion purposes. Of the 31.3 stream miles, 18.1 miles are first order, 11.2 miles are second order and two miles are third order or greater.¹³

The watershed is located within the contact zone between the Piedmont Plain and Highlands physiographic provinces and is mostly designated Highlands Preservation Area. The remainder of the watershed, consisting of the I-78 corridor between Exits 11 and 12, is in Highlands Planning Area. The headwater areas tend to be steep, becoming less so within approximately one mile of the Reservoir. The soils in the watershed are primarily described as well-drained and approximately half of the watershed is covered by highly-erodible soils.

NJDEP land use/cover data from 2002 show that the Mulhockaway Creek watershed is predominantly forested (47 percent), with smaller portions of urban (23 percent), agriculture (17 percent), and wetlands (11 percent). The remainder of the area (2 percent) is classified as barren or water surfaces. Forested and wetland areas are primarily

¹² Now two firms: TRC Solutions and Omni Environmental

¹³ Based upon NJDEP 1995/1997 Watershed Mapping. The NJDEP's 2002 Hydrography does not include stream order as an attribute.

described as deciduous in nature. The majority of the forested cover is classified as having crown closure greater than 50 percent. More than 84 percent of the wetlands are deciduous wooded wetlands. Of the total urban area (2,220 acres), more than 72 percent (1,602 acres) is classified as rural residential¹⁴, 3.8 percent (84 acres) is low to medium density residential¹⁵. Commercial, industrial, major roadways and built-up land¹⁶ comprise 19 percent (420 acres) of the urban lands. More than 90 percent of the agricultural lands are characterized as pasture and cropland. Land use/cover is presented in Figure 2.

Historic Data

As part of the Cooperative Monitoring Program conducted by the USGS and NJDEP, Fecal coliform data have been collected at the streamflow gauge (USGS 01396660, Mulhockaway at Van Syckel, NJ) since 1976. Prior to 2000, data were collected sporadically, but more than once per year through 1998. Commencing in 2002, data were collected in accordance with 5 samples per 30 days to evaluate the concentrations in relation to water quality standards. All data are presented in Appendix C. Figure 3 presents the monthly median fecal coliform concentrations for the period of record. Figure 4 demonstrates the annual trend in concentrations and the associated variability. Except in 1976, 1980, and 1986-1988, the maximum annual concentrations were less than 6000 col/ 100 ml. For data collected in the year 2000 and after, geometric means were used for comparison to the standard. Only 5 samples were taken annually so evaluation of the 90 percent passing of the single sample criterion did not seem appropriate. The geometric means of the data met the standard between 2001 and 2003, but exceeded the standard in 2000, 2004 and 2005. In 2005, NJDEP performed some additional sampling at 4 locations in the watershed, upstream of the USGS gauge. Geometric means at all but one location exceeded the water quality standard. These data are compared with the project data later in the *Track Down Monitoring Results* section of this report.

NJDEP/USGS also collected Total Suspended Solids (TSS) data from October 1976 – August 2005. Samples were collected under ambient conditions and during flows that ranged from 1.8 cfs (exceeded 99 percent of the time) and 105 cfs (flows exceeded only 20 percent of the time). TSS concentrations were less than 10 mg/l for all but 4 samples, three of which occurred at flows larger than 40 cfs. The data indicate that for flows below 40 cfs, the TSS concentrations are notably low.

¹⁴ Land use code 1140

¹⁵ Land use codes 1130 and 1120, respectively.

¹⁶ Land use codes 1200, 1300, 1410, and 1700, respectively.

Track Down Monitoring

The goal of the monitoring program was to collect fecal coliform data at 10 locations under various flow conditions to determine when contamination was an issue, where contamination was more likely, or which subwatersheds contribute significantly more load than others. Sampling locations were selected to isolate portions of the watershed to identify likely source areas contributing bacteria to the Creek. The sampling locations are presented on Figure 5. Table 1 contains information about the monitoring sites and why they were chosen. Locations MC1, MC2, MC6 and MC10 are all located on the main stem of the Mulhockaway Creek, while the others segregate tributaries.

Sampling was conducted between August and October 2007 during low flow conditions, ambient conditions and during storm events. Ambient conditions represent the mean flow condition and storm events represent high flow conditions. The frequency and reasons for sampling during different conditions are as follows:

- Ambient events were sampled twice per month, independent of weather conditions and over a range of seasonal and flow conditions, for a total of 6 events. Since ambient samples are collected regardless of the flow condition, 4 of the 6 events sampled occurred during low flow conditions. The purpose of ambient condition sampling is to gather general baseline information for the Creek.
- Low-flow conditions were sampled 3 times, twice in August and once in September. Low-flow conditions were defined by the flow measured at USGS station 01396660, Mulhockaway Creek and Van Syckel. A low-flow event occurs when the streamflow is less than the flow that is exceeded 70% of the time (d70), which is 7.9 cfs. In addition, low-flow events must be preceded by at least 72 hours with no more than 0.1 inches of rain. The purpose of sampling during low-flow events is to determine water quality conditions when little or no surface runoff is flowing in the stream. The majority of the water in the stream should consist of base flow, and water quality impacts will be primarily be from ground water or sanitary illicit discharges. Spikes in bacteria concentrations during low-flow events would potentially indicate failing septic systems and cesspools, sanitary illicit connections, or poor management of areas with domestic animals.
- Storm events (wet weather) were sampled in September and October. Three grab samples were collected at each location for each event. The first sample was collected at the beginning of the storm (when approximately 0.1 inch of precipitation has been observed). The remaining two samples were collected during the storm to characterize the water quality over the hydrograph. Storm water events were performed for storms predicted to deliver at least 0.5 inches of rain that were preceded by at least 72 hours with no more than 0.1 inches of rain. Storm event sampling is used to determine the water quality impacts of stormwater runoff. Figures 6 and 7 present the storm event hydrographs and when samples were collected during each event.

Table 1. Monitoring Location Descriptions

ID	Location	Description
MC1	Mulhockaway Creek, Route 614 in Pattenburg	Headwaters upstream of Pattenburg; mixed land uses
MC2	Mulhockaway Creek, northern crossing on Baptist Church Road	Loading from Pattenburg (more concentrated development)
MC3	Unnamed tributary to Mulhockaway Creek on Baptist Church Road immediately north of Lehigh Valley railroad tracks	Livestock operations and low density residential development
MC4	Unnamed tributary to Mulhockaway Creek, north of Route 78 on Route 173 west of Perryville	Livestock operations; pumped sewage main; and low density residential
MC5	Unnamed tributary to Mulhockaway Creek, south of Route 78 on Frontage Road in Perryville	Livestock operations; school on-site wastewater treatment plant; pumped sewage main; and low density residential
MC6	Mulhockaway Creek at southern crossing on Van Syckel's Corner Road, west of Route 635	Route 78 and livestock in immediate vicinity of sampling location
MC7	Crossing of unnamed tributary to Mulhockaway Creek on Van Syckel's Corner Road, west of Route 635	Steeply sloped; undeveloped forest; downstream low-density residential
MC8	Crossing of unnamed tributary to Mulhockaway Creek on Van Syckel's Corner Road, west of Route 635	Steeply sloped; undeveloped forest; downstream low-density residential
MC9	Crossing of unnamed tributary to Mulhockaway Creek on Van Syckel's Corner Road, east of Route 635	Steeply sloped; undeveloped forest; downstream low-density residential; not upstream of MC10
MC10	Mulhockaway Creek at bridge crossing on Route 635	Accumulator site; comparison with historical water quality

All samples were analyzed for fecal coliform, enterococci (a subset of fecal streptococci) and total suspended solids. Both bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals, and enter water bodies from human and animal waste. The ratio of the fecal coliform to fecal streptococci (FC/FS) varies for different animals. Ratios greater than 4.0 indicate human sources, while ratios less than 0.8 indicate animal sources. Ratios between 0.8 and 4.0 are considered inconclusive, or indicate contamination from both human and animal species. Because the survival rates of these organisms vary in different environments (flow, temperature), this ratio is not always reliable, but can be useful as a preliminary indicator of bacteria sources.

Samples were analyzed for Total Suspended Solids (TSS) to determine if a relationship between fecal coliform and TSS could be established. Fecal Coliform and E. Coli attach to suspended particles, which settle from the water column. Both can survive and proliferate in bottom sediments and can live for extended periods of time because the bacteria are sheltered from harmful stimuli such as sunlight and temperature. Thus, resuspension is a potential source of contamination due to the higher velocities experienced by the stream during storm events.

Results

Fecal Coliform

Bacteria concentrations are lognormally distributed, often varying by orders of magnitude. Accepted statistical practice is to use geometric means to quantify and compare the central tendency among groups of lognormally distributed data. For the calculation of geometric means at each site, the fecal coliform concentrations were grouped as follows: ambient conditions, low-flow conditions, dry weather (combined ambient and low-flow conditions), 5 samples in nearly 30 days (non-storm, 8/3-9/11 and 8/7-9/20), storm event (1 and 2), and all storm samples. These results were compared against 200 colonies per 100 ml. Individual sample results were also compared against the single sample maximums of 400 col per 100ml and 700 col per 100 ml.

A total of 149 samples were collected at 10 locations: 59 ambient conditions (6 events), 30 during low-flow conditions (3 events), and 60 storm/wet weather (2 events, 3 samples per event). Of the ambient samples, 4 were also collected under low flow conditions. Tables 2 through 4 present and summarize the data collected. The fecal coliform concentrations and statistical summaries (geometric means) are located in Table 2. Table 3 presents the rankings of concentrations at sites, by event and statistic. The fecal coliform/fecal streptococcus ratios (FC/FS) are interpreted within Table 4 and discussion below. Detailed data by event are located in Appendix D.

Concentrations were typically low with orders of magnitude less than 10^3 for all but one sample, which occurred during wet weather sampling. Of all of the 149 samples collected, 69 exceeded the single sample criterion, 49 of which occurred during the 2 storm events sampled. Of the 89 dry weather samples (ambient and low flow), 69 (77

percent) were less than the single sample water quality criterion, 22 of the 30 (73 percent) low-flow and 47 of the 59 (80 percent) ambient condition samples. During dry weather 90 percent (80 of 89) of samples met the presumed secondary contact recreation standard¹⁷, while only 28 percent (17 of 60) of wet weather samples did. Figure 8 demonstrates that concentrations differ by an order of magnitude between dry and wet weather events.

The greatest concentration was 17,000 col/100 ml (at MC3) with the next highest concentration of 8,900 col/100 ml (at MC5), both samples collected during the first storm event (9/14-15/2006). Of the 11 wet weather samples that met the single sample criterion, 8 were collected during the first round of the second event. The geometric mean of the wet weather samples, summarized by individual event and combined, exceeded the geometric mean criterion at all sites. MC5 had largest geometric means for wet weather conditions. MC4 also ranked high for storm geometric means.

Ambient and low flow samples, which represent dry weather, were combined to evaluate conformance with the criteria. At 4 sites (MC3, MC4, MC8, MC9), the single sample criterion was not exceeded for any of the dry weather events. The geometric means exceeded the criterion at MC1, MC5, MC6, with the latter two usually producing the higher concentrations. For just low flow events, MC7 and MC10 also exceeded the geometric mean criterion, although MC1 did not. Considering 5 samples (ambient and low flow only) in nearly 30 days (8/9 – 9/11; 39 days) the geometric mean criterion was also exceeded at MC4. MC6 had highly ranked geometric means for dry weather conditions, as did MC5. The lowest ranked geometric means (all less than the criterion) for dry weather conditions occurred at MC2, MC3, MC8, and MC9.

¹⁷ An example standard. New Jersey has no standard for secondary contact recreation for FW2 waters.

Table 2. Source Tracking Fecal Coliform Monitoring Data and Statistical Summaries

Event	Date	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10
Ambient1	8/3/2006	1400	100	28	260	3500	2900	510	310	120	
Ambient2	8/15/2006	290	220	44	260	260	440	340	190	280	900
Ambient3	9/20/2006	680	200	200	60	120	920	120	160	120	60
Ambient4	9/29/2006	540	320	340	330	450	540	210	260	160	760
Ambient5	10/16/2006	40	40	30	40	370	60	50	60	20	60
Ambient6	10/25/2006	32	32	16	4	4	4	4	12	4	24
LowFlow1	8/7/2006	120	180	76	280	800	1800	200	330	110	600
LowFlow2	8/21/2006	610	530	85	50	1100	470	1200	110	35	170
LowFlow3	9/11/2006	58	36	32	360	320	240	120	64	290	180
Storm1R1	9/14/2006	5000	1600	4200	4100	8900	2600	2300	2900	360	2000
Storm1R2	9/14/2006	880	920	480	1300	1400	1900	420	240	560	1300
Storm1R3	9/15/2006	6600	4600	17000	6200	7000	3100	3900	6200	4700	3900
Storm2R1	10/17/2006	30	40	150	760	1600	50	220	200	30	60
Storm2R2	10/17/2006	4400	5600	3500	2200	5600	3900	2800	5000	3400	2800
Storm2R3	10/18/2006	2400	2400	860	2500	700	3800	170	1500	580	1100
Statistical Summaries (Geometric Means)	Ambient	240	110	59	77	204	231	98	110	61	143
	Low	162	151	59	171	655	588	307	132	104	264
	Dry	210	122	59	101	301	315	143	117	73	180
	8/3-9/11	286	123	57	210	489	873	219	182	167	276
	8/7-9/20	242	172	71	151	388	607	259	148	130	251
	Storm 1	3074	1892	3248	3209	4435	2483	1556	1628	982	2164
	Storm 2	682	813	767	1611	1844	905	471	1145	390	570
All storm	1448	1240	1579	2274	2860	1499	856	1365	619	1110	
Maximums	Dry	1400	530	340	360	3500	2900	1200	330	290	900
	Storm	6600	5600	17000	6200	8900	3900	3900	6200	4700	3900
NOTES:											
	Exceeds the single sample Criterion of 400 col/100 ml for primary contact recreation										
	Exceeds the single sample Criterion of 700 col/100 ml for secondary contact recreation										
	240 Exceeds the geometric mean criterion of 200 col/100 ml for primary contact recreation										

Table 3. Ranking of Source Tracking Fecal Coliform Monitoring Results and Statistical Summaries

Event	Date	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10
Ambient1	8/3/2006	3	8	9	6	1	2	4	5	7	
Ambient2	8/15/2006	4	8	10	6	6	2	3	9	5	1
Ambient3	9/20/2006	2	3	3	9	6	1	6	5	6	9
Ambient4	9/29/2006	2	7	5	6	4	2	9	8	10	1
Ambient5	10/16/2006	6	6	9	6	1	2	5	2	10	2
Ambient6	10/25/2006	1	1	4	6	6	6	6	5	6	3
LowFlow1	8/7/2006	8	7	10	5	2	1	6	4	9	3
LowFlow2	8/21/2006	3	4	8	9	2	5	1	7	10	6
LowFlow3	9/11/2006	8	9	10	1	2	4	6	7	3	5
Storm1R1	9/14/2006	2	9	3	4	1	6	7	5	10	8
Storm1R2	9/14/2006	6	5	8	3	2	1	9	10	7	3
Storm1R3	9/15/2006	3	7	1	4	2	10	8	4	6	8
Storm2R1	10/17/2006	9	8	5	2	1	7	3	4	9	6
Storm2R2	10/17/2006	4	1	6	10	1	5	8	3	7	8
Storm2R3	10/18/2006	3	3	7	2	8	1	10	5	9	6
Statistical Summaries (Geometric Means)	Ambient	1	5	10	8	3	2	7	6	9	4
	Low	6	7	10	5	1	2	3	8	9	4
	Dry	3	6	10	8	2	1	5	7	9	4
	8/3-9/11	3	9	10	6	2	1	5	7	8	4
	8/7-9/20	5	6	10	7	2	1	3	8	9	4
	Storm 1	4	7	2	3	1	5	9	8	10	6
	Storm 2	7	5	6	2	1	4	9	3	10	8
All storm	5	7	3	2	1	4	9	6	10	8	
Maximums	Dry	3	6	8	7	1	2	4	9	10	5
	Storm	3	6	1	4.5	2	9	9	4.5	7	9
NOTES:		Highest Concentration for Event or Largest Geometric Mean									
		Second Highest Concentration for Event or Largest Geometric Mean									
		Third Highest Concentration for Event or Largest Geometric Mean									

Table 4. Fecal Coliform/Fecal Streptococci Ratios

Type	Date/Site	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	MC9	MC10
Ambient 1	8/3/2006	E				E	E	E			
Ambient 2	8/15/2006						E				E
Ambient 3	9/20/2006	E					E				
Ambient 4	9/29/2006	E				E	E				E
Ambient 5	10/16/2006										
Ambient 6	10/25/2006										
Low Flow 1	8/7/2006					E	E				E
Low Flow 2	8/21/2006	E	E			E	E	E			
Low Flow 3	9/11/2006										
Storm 1 Rour	9/14/2006	E	E	E	E	E	E	E	E		E
Storm 1 Rour	9/14/2006	E	E	E	E	E	E	E		E	E
Storm 1 Rour	9/14/2006	E	E	E	E	E	E	E	E	E	E
Storm 2 Rour	10/17/2006				E	E					
Storm 2 Rour	10/17/2006	E	E	E	E	E	E	E	E	E	E
Storm 2 Rour	10/17/2006	E	E	E	E	E	E		E	E	E
Human				Animal				E	Fecal Coliform exceeded 400 col/100ml		
Indeterminate High				Indeterminate Low							

Spatial comparison of the results yielded some unanticipated observations. The samples at two (MC6, MC10) of three downstream sites did not have the highest concentrations during either dry or storm events, although MC6 did produce highly ranked geometric means for dry weather. MC6 is just upstream of the confluence of the Mulhockaway Mainstem with five of the branches and MC10 is downstream of the confluence of all streams but the MC9 branch. More than 43 percent of the watershed drains to MC6 and approximately 80 percent drains to MC10 (accumulated drainage area). Potential sources are concentrated near MC6, but the larger contributing watershed area may be diluting the bacteria concentrations and the reach between MC6 and MC10 is forested, which may reduce temperature, a growth stimuli. The two largest concentrations for dry weather occurred at MC5 and MC6. MC5 is located in the mid to upper portion of its subwatershed and nothing specifically stands out about the watershed, which would make higher concentrations seem likely. For wet weather, MC3 and MC5 produced the largest stormwater concentrations. MC3 is a tributary stream to the upper reach of the Mulhockaway Creek. Nothing particular is noteworthy of MC3 except that it had the smallest geometric means for all dry weather combinations of data and its tributary watershed has the largest amount of forest per stream mile in the 300 foot buffer area.

The FC/FS ratio analysis produced ambiguous results. For ambient and low flow conditions, a loose interpretation of the results implies potential animal contamination at 5 sites (MC3, MC4, MC5, MC7, MC8), indeterminate contamination at 2 sites (MC2, MC10), and potential human contamination at 3 sites (MC1, MC6, and MC9). FC/FS ratios indicate mostly indeterminate contamination during storm events. The first storm event indicates a first flush and then a later flush during hydrograph recession, which may imply septic system failures. Sample collection times and streamflow during the storm event were presented in Figures 6 and 7 for Storm 1 and Storm 2, respectively. The second storm event shows reductions in concentrations at all but one site, from peak to recession flows. However, since the watershed has no concentrated human sources (sanitary sewers), the high stormwater concentrations may be indicative of natural sources given characteristic steep slopes and large amounts of forested land cover.

In 2005, NJDEP sampled four additional sites in the watershed. Three of the samples were at locations similar to the project locations MC2, MC7 and MC8. The other was downstream from the confluence of the branches monitored at MC4 and MC5. Their results were similar for those of the project, except at MC7, where the NJDEP measured significantly larger fecal coliform concentrations. However, given the lack of concentrated sources in the MC7 watershed, this result seems anomalous.

Total Suspended Solids

Project samples were also analyzed for Total Suspended Solids (TSS) concentrations. During low and ambient flow conditions, TSS concentrations did not exceed the surface water quality standard of 25 mg/l for FW2-TP waters and were not greater than 12 mg/l. However, during the first storm event, TSS concentrations at MC1 exceeded the standard during the first round and at both MC2 and MC3 during the third round. All locations but MC1 exceeded the TSS standard during the second round of the third event. Figures 9-12 present the TSS concentrations summarized by event type. Figures 13 and 14 show the

relationship between TSS and fecal coliform. MC2 and MC3 fecal concentrations appeared to correspond to TSS, but more samples would be needed to confirm that conclusion.

Remote Sensing Analyses

A remote sensing analysis, using GIS, was conducted to establish potential sources of bacterial contamination for further inspection through windshield surveys. A first step was to evaluate possible relationships between land use/cover and likely bacteria concentrations. Available GIS data for the watershed area above each sampling location were compared with the sampling data to determine watershed commonalities yielding similar concentrations. The analyses were performed for the watersheds above the sampling locations (cumulative¹⁸ monitoring sheds) and within a 300 ft buffer of the stream within the monitoring shed. GIS information evaluated included:

- Land use/Land Cover¹⁹ – acres, percentage, acres/stream mile
 - Agriculture
 - Forest
 - Urban – Residential
 - Urban – All other
- Number of Catch Basins and Outfalls²⁰
- Housing Units²¹
 - Within buffer
 - Within buffer/stream mile
- Soil Drainage Condition²²

The data were evaluated for trends to determine if the different characteristics of the monitoring shed were reflected in the statistical summaries of fecal coliform concentrations. The summaries were geometric mean of low flow samples, geometric mean of ambient condition samples, geometric means of low flow and ambient condition samples, and maximum observed stormwater concentration. Since only 10 locations were sampled, the results are somewhat limited because one or two unusual conditions can bias a statistical relationship.

Land Use/Cover

Fecal coliform concentrations did not correlate well with land use except for the percentage of agricultural area within the 300-ft buffer. A regression analysis of the relationships between the percent agricultural land use in the 300-ft buffer for ambient and ambient and low flow conditions and the acres of agricultural use per stream mile versus ambient flow conditions produced r-squared values of approximately 0.7, which

¹⁸ For example, all land use above a monitoring location, not just within the delineated subwatershed.

¹⁹ NJDEP, 2002

²⁰ HCSCD, 2006

²¹ Unpublished, NJWSA, 2007

²² NRCS SSURGO, 1999

implies that 70 percent of the variation in fecal coliform concentration might be attributable to agricultural land use. Figure 15 presents these comparisons. Relationships of residential, other urban and forested land uses versus fecal coliform concentration summaries were not as strong. These results are presented in Appendix E.

Soil Drainage

Soil drainage condition was hypothesized to affect fecal coliform concentrations as a predictor of the mobility of the fecal coliform in the environment. However, the soils were very consistent within the watershed and did not vary in relation to the fecal coliform concentrations. Thus, soil drainage condition was a poor predictor of fecal coliform contamination for this watershed.

Catch Basins and Outfalls

The number of outfalls and catch basins in both the buffer and the watershed were evaluated to determine if the stormwater system might be a large source of bacterial contamination from wastes washed into or directly connected to the stormwater conveyance system (ditch, swale, stream, etc.). Storm sewers provide a good environment for bacterial growth, especially if water is continually present, either through sanitary illicit connections, ground water infiltration, blockages or lack of slope (stagnation). Illicit connections can include sump pumps, roof drains, cooling tower discharges, pool drains and sanitary discharges improperly routed to the storm sewer (rather than a sanitary sewer or septic system). However, the number of catch basins and outfalls, in either the monitoring shed or the 300-ft buffer or per stream mile, did not reflect the level of fecal contamination.

Housing Proximity

The number of houses within the 300-ft buffer and within the 300-ft buffer per stream mile were used as a surrogate for septic systems proximate to the stream. While inspection of the plotted data implies a slight increasing trend with the number of houses per stream mile, the relationship only accounts for approximately 40 percent of variability during dry weather or low flows. If MC6 were considered an outlier, the relationship would describe roughly 80 percent of the variability; however, the small samples size would preclude doing so. Neither the fecal coliform data for MC6 nor its watershed data indicate anything particularly different about MC6 except the sampling location is immediately downstream from horse pasture, with minimal stream buffer, geese, and poorly managed manure.

Watershed Surveys

Visual inspection of aerial photos and confirmation by windshield survey were used to identify potential sources of fecal coliform contamination. The surveys concentrated on sources that were primarily close to the stream and those that could be seen from the road. Since the Mulhockaway Creek runs through mostly private property, access to

many locations was limited. While the problem is anticipated to be entirely nonpoint source in nature, agricultural and indirect human sources are also possible. The aerial photographs were examined for the following in the vicinity of the streams:

- Goose habitat such as ponds and open fields;
- Agricultural operations involving animals; and
- Houses in close proximity to the stream.

Upon inspection of the aerial photographs and field surveys, 53 sites were identified as potential concentrated sources. As much of the property in the Mulhockaway Creek is private and inaccessible, many of the areas could not be evaluated in detail; thus, some of the recommendations are for further investigation. Remedial actions primarily involve fencing animals from stream and adding appropriate buffers, examination and remediation of waste management practices and goose management.

Stormwater Inventory

As part of the Mulhockaway Creek Stormwater Management and Watershed Restoration Plan, the Hunterdon County Soil Conservation District (HCSCD) inventoried the stormwater infrastructure located in the watershed, including swales, ditches, detention basins, catch basins, outfall pipes, dams, culverts, best management practices and areas of concern. A detailed description and summary of the inventory is located in the Stormwater Management and Watershed Restoration Plan. For outfall pipes, where the collected runoff enters the stream, HCSCD noted whether or not there was a potential illicit connection. Evidence of illicit connections included presence of dry weather flow, cyclic or intermittent flow (for example, sump pumps), suds and odor. Septic-like odor indicates the potential presence of an illegal sanitary connection, infiltration of septic wastewater into the storm sewer system (pipes, swales or ditches), or possibly stagnant water. Of 450 outfall pipes identified, 42 had strong evidence of an illicit connection and another 60 pipes were suspected illicit connections. Septic odors were noted in the vicinity of Pattenburg.²³ The inventory also identified locations where livestock had access to the stream and/or manure was mismanaged.

Summary of Source Tracking

A field survey of potential source locations was conducted in April 2007. Except for those located on public property, only potential sources visible from roads could be evaluated. Because most possible sources were on private property further investigation into the sources will be required. Additional confirmatory investigations of potential sources are outside of the scope of this project and the Authority does not have right-of-trespass to do them.

²³ Personal communication with Christopher Testa of Hunterdon County Soil Conservation District, April 2007.

Potential Sources

The majority of the sources are related to either wildlife, particularly geese and deer, and livestock. The watershed contains in-line ponds, many of which are not buffered by vegetation and are surrounded by open fields. These conditions create the type of habitat preferable to geese. In April 2007, however, geese were not observed in excessive quantities. In 1999, Hunterdon County Board of Agriculture concluded that an over abundant deer population was resulting in severe damage to agricultural crops.²⁴ Within the County, the reported deer harvest has declined by 27percent between a peak of 14,700 in 1999 to a low of 10,700 in 2006.²⁵ While not specifically identified, the overabundance of deer may be a source of bacterial contamination. Livestock were observed on some small farms. None of the farms appear to be large operations, but on some, animals are not separated from the stream and where they are the riparian buffer is tended to be poor.

Failing septic systems, cesspools and sanitary illicit connections are suspected in locations as being another source of bacterial contamination. Several houses are located in close proximity to the stream in a few concentrated locations. In these areas the lots tend to be smaller and the homes tend to be older, implicating improperly sited or failing (due to age) septic systems and cesspools.²⁶ Some septic systems may also be hydraulically connected to the stream. A hydraulically connected system would be one where the septic system laterals were located in soils more transmissive than required to remove bacteria or other contaminants from the septic tank effluent. For example, the Department of Health for the State of New York demonstrated through dye testing that an E. Coli outbreak in 1999 at a fairground was due to a hydraulic connections between a septic system and a well.²⁷

An inventory of stormwater outfalls to the stream indicated that approximately 25 percent discharged into the stream during dry weather. However, not all illicit connections contribute to bacterial contamination. Other potential sources of human fecal coliform contamination include a small on-site wastewater treatment plant, servicing two schools (recently upgraded and expanded), a community onsite wastewater treatment facility, which discharges to groundwater, and a sanitary wastewater force main, which conveys wastewater from an office park to a treatment plant located and discharging outside of the watershed.

The source track down work is summarized by location below. Figure 16 presents the potential sources identified for this project. Table 5 briefly describes the suspect problems and potential remedial activities.

²⁴ Governor's Report on Deer Management in New Jersey, 1999, Department of Environmental Management, Division of Fish Game and Wildlife in consultation with the Department of Agriculture.

²⁵ http://www.state.nj.us/dep/fgw/pdf/deer_harv_county95-06.pdf

²⁶ Personal communication with Debra W. Vaccarella, REHS, Senior Environmental Health Specialist, Hunterdon County Department of Health. Given the age and lot size of housing in Pattenburg, the existence and continued use of cesspools is likely. In addition, the area is poorly drained with a high water table and stagnant stream reaches.

²⁷ <http://www.health.state.ny.us/press/releases/2000/ecoli.htm>

MC1: Headwaters of Mulhockaway Mainstem

The possible sources in this watershed include wildlife, human (septic systems, cesspools and sanitary illicit connections) and agriculture. The Pattenburg Quarry is an informal sanctuary for wildlife and contains the headwaters of this stream. Water has filled excavated areas, creating ponds. An in-line pond²⁸ surrounded by a large area of open space is of concern for potential goose habitat. Large fields were fertilized with manure, which might create a short-term seasonal problem if the field buffer is inadequate. The FC/FS ratio for five of the samples indicated potential human contamination. A higher density residential area is located near the sampling location and one house is less than 40 feet from the stream on a quarter acre lot. This location was selected to represent water quality entering Pattenburg, upstream of the higher density residential area. However, a few houses with either cesspools or septic systems are in the immediate vicinity of the sampling location may have biased the sampling results.

MC2: Mulhockaway Mainstem

The stream is mostly buffered by forested area, except mid-watershed, near the confluence with the stream above MC1. A large (24 inch diameter) stormwater outfall pipe drains Route 614 and outlets to the creek just below MC1. Pattenburg is located mid-watershed where the lots along Main Street average 0.4 acres. Illicit connections are suspected at 15 outfall locations in the watershed and three of those are within approximately 300 feet of the sampling site. However, solids and other wastes normally associated with sanitary wastewater were not, so the likelihood is infiltration of septic system effluent or a hydraulic connection with cesspools. One farm is located along the stream with a narrow buffer (less than 50 feet, approximately) and sheep and geese were observed in the adjacent pasture.

MC3: Baptist Church Branch

The stream is well buffered by forest (150-300 ft) along the eastern branch and headwater areas. The riparian buffer is poor along the western branch. An in-line pond on the western branch may be habitat for geese, but is located on private property. There is a small farm where animals were not fenced from the stream. Other agricultural operations also abut the streams, but livestock access to the stream, if any, could not be determined. Sources are most likely wildlife and probably deer.

MC4: Driftway Branch

In the headwaters, residential development is nearby although the stream is buffered by forest. The stream is mostly inaccessible, except in Hoffman Park. At least nine in-line ponds are located within the Park. Geese were observed in the largest pond, but evidence of a large goose population (excrement) was not present in significant quantity. The open fields and proximate water bodies would provide ideal habitat for geese. The detention basin in the Perryville Office Park is home to several geese and discharges to the stream

²⁸ Inaccessible. Located on private property.

upstream of the sampling location. Sanitary wastes from the Office Park are transported through a force main under the creek to the Clinton Sewer Department, outside of the Mulhockaway Watershed. The pumping station for the force main is also upstream of the sampling location.

MC5: Mechlin Comer Branch

A small farm is located adjacent to the stream and downstream of the Old Farm Road Riparian Buffer Restoration.²⁹ Livestock have direct access to the stream. A detention basin for Country Acres is tributary to the stream in the headwater areas. The basin is overgrown and deer are known to congregate there. The homes in Country Acres were constructed approximately 30 years ago, the approximate design life of a septic system³⁰. The Clinton Sewer Department force main, which runs under the Driftway Branch, also runs under this branch. The Union Township School onsite wastewater treatment plant discharges to the creek upstream of the sampling location. Inspection of the available discharge monitoring data for the plant indicates that a maximum grab effluent sample had a concentration greater than 600 col/100 ml in June of 2005. However, the maximum observed in 2006, also June, was 170 col/100 ml. The plant was recently refurbished in the fall of 2006. The maximum observed monthly geometric mean concentration through September 2007 was 120 col/100 ml in June.

MC6: Mulhockaway Mainstem Downstream

Streamflow from half of the Mulhockaway Creek watershed passes through MC6. Within the monitoring watershed between MC2 and MC3, the drainage from Interstate 78 is collected and discharged to the creek. The northern tributary has a large forested buffer, but the headwaters are located in a small residential area. Another development, located on the ridge of the subwatershed, Village Square, uses a discharge to ground water onsite wastewater treatment plant, an unlikely source of fecal coliform.³¹ Most of the suspect sources in MC6 are in the downstream portion of the monitoring shed and are related to livestock. A large equestrian farm is located around the stream. The horses do not have direct access to the stream, but the fences have little to no vegetated buffer adjacent to them. Geese have also been observed congregating in the fields. A large manure pile was located within 150 feet of the stream and approximately 200 feet from the sampling location. The manure is stored on a concrete pad, but the pad is not surrounded by a berm. A small poultry farm, which sells eggs, is also located in the vicinity of the sampling location. Poultry manure, unmanaged, was stored on the lawn of the property in April of 2007.

MC7: Fox Farm Branch

The headwaters of the stream are buffered by forest. About mid-watershed, there is a small cluster of houses on small lots. One house is less than 20 feet from the stream, has limited open space for a septic system and may have a cesspool. Ponds, partially bordered by open fields and which may or may not be hydraulically connected to the

²⁹ Project conducted under the EPA Targeted Watershed Grant for the Raritan Basin.

³⁰ www.sustainability.uconn.edu/homewater/01-septic.html

³¹ NJDEP does not require analysis of fecal coliform for discharges to groundwater.

stream are also located nearby. These ponds may be habitat for geese. Horse pasture is prevalent in the downstream area as well as open lawn areas where geese gather. A small duck pond is located just downstream of the sampling location.

MC8: Norton Church Branch

The stream flows through some rural residential development in its headwaters and then becomes buffered by forest, mid-watershed. A small headwater pond is buffered by vegetation and residents have not observed geese in the pond. Manure was for sale along Charlestown Road and livestock was observed, but it could not be determined how close the animals were to the stream or how well the stream was buffered. The aerials indicate little to no buffer. Geese gather in a field near the sampling location. A dog kennel is located just upstream of the sampling location. The dog runs are approximately 300 feet from the stream.

MC9: Charlestown Branch

Except in the downstream area, the stream is buffered by forest. There are headwater and on-line ponds, which were inaccessible. Livestock on one small farm with a headwater pond had direct access to the pond and stream. Livestock included sheep and poultry. Also along the stream was a small private kennel or breeder. The cages were above the stream, but below the roadbed, on a steep slope. In the lower watershed, the stream flows through some smaller lot residential development, but only a few are less than 2 acres. Adjacent to the sampling location is a mounded septic system.

MC10: Mulhockaway Main Stem

This location receives the flow from all of the other monitoring sheds except MC9 and is located at the USGS streamflow gauge (01396660). Between MC10 and the most immediate upstream stations (MC6, MC7, MC8), the watershed is mostly forested except for the portions below MC4 and MC5, where drainage from Route 78 and some commercial areas enter the stream. Downstream of the commercial and highway area, the stream is buffered by forest. The Hunterdon Hills Playhouse is located in this area downstream of MC4. On the playhouse property, there is a large pond where geese gather, but it does not appear to have an outlet to the stream.

Implementation

The fecal coliform concentrations are low but still cause the Mulhockaway Creek to fail its designated use for primary recreation. Although the stream is tributary to the Spruce Run Reservoir, the bathing beach does not encounter problems meeting the water quality standard and has few, if any, beach closures. While stream access is limited, a popular unofficial trout fishing area is located just upstream of the Reservoir. Except during wet weather, the stream meets the secondary contact recreation standard 90 percent of the time. Although a few sources stand out as good locations to target implementation efforts, much of the fecal coliform contamination is likely from dispersed nonpoint sources throughout the watershed, some of which is likely related to wildlife.

Recommended Remedial and Management Measures

For the watersheds associated with each monitoring location, implementation measures to target and reduce the fecal coliform contamination have been identified. The subwatersheds have been ranked high, medium, and low as a means to focus implementation efforts in areas where concentrations are greater or sources are more obvious. Table 6 presents the recommendations in each subwatershed and the priority of each watershed for implementation. The management measures fall into 6 categories, outlined and explained below:

- Agricultural management and assistance programs to reduce nonpoint sources of pollution;
- Wildlife management programs for deer and geese;
- Septic system and cesspool maintenance, rehabilitation and/or replacement;
- Sanitary illicit connection detection and removal; and
- Microbial Source Tracking to differentiate human, domesticated animal and wildlife including methods to differentiate species;
- Education Programs

Location	Measures
5e	Fence animals from stream and improve approximately 500 feet of riparian buffer. Manure management. Engage landowner/tenant in “River Friendly” Farm Program. Assess Country Acres septic systems, density and maintenance status.
6a, 6b, 6c, 6d, 7c	Improve approximately 700 feet riparian buffer. Manure management. Engage landowner/tenant in “River Friendly” Farm Program.
1b/1d	Conduct sanitary survey of Pattenburg and vicinity and near older housing developments. Find illicit connections and redirect. Evaluate for failing septic systems and remedy as necessary.
4a-j, 4k	Establish buffer around ponds to deter geese. Engage business park in “River Friendly” Program.
See also: Watershed wide recommendations in the <i>Mulhockaway Creek Stormwater Management and Watershed Restoration Plan</i> : Comprehensive Agricultural Management Program and Sanitary Survey.	

Agricultural Management Programs

Agricultural Management Programs are discussed in some detail in the TMDL and consist of cost-sharing programs to aid in the design and implementation of conservation management plans and best management practices. The USDA Farm Services Agency provides most of the funding and the Natural Resources Conservation Service provides assistance to landowners to develop resource management plans. The Environmental Quality Incentive Program (EQIP), the Conservation Reserve Program (CRP), and NJ’s Conservation Reserve and Enhancement Program (CREP) can provide assistance to

farmers related to vegetated filter and buffer strips and animal waste management facilities. A detailed discussion of these programs is included in the TMDL and is thus not included herein. Farms been preserved through the Garden State Preservation Trust Fund (GSPTF) are also eligible for cost-share assistance through the New Jersey's Department of Agriculture.

Some of the agricultural operations in the watershed may not qualify for these programs. However, another avenue to remedial actions on farms maybe the River Friendly Farm program. This program was developed by the NRCS and is based on River Friendly programs (Resident, Business, Golf Course) established by the Stony Brook Millstone Watershed Association. Through the EPA Targeted Watershed Grant Program, the River Friendly Program is being implemented in the Spruce Run Reservoir Watershed (ending September 2007). The intent of the program is to educate agricultural operations about actions they can take to protect water resources through certification. For River Friendly Farm certifications, a site visit is conducted with the farm manager to determine best management practices, which would make the farm or agricultural operation "River Friendly." Upon implementation of the management practices developed through the site visit, the farmer is recognized for protecting and enhancing water bodies.³² After completion of the EPA Targeted Watershed Grant Program, NJWSA will evaluate the results to determine its potential for continuance using other funding sources.

Wildlife Management Programs

Wildlife Management Programs may be the only recourse for contamination by wildlife. The TMDL noted that the likely sources of fecal coliform contamination were deer and large goose populations in ponds. The watershed provides adequate, if not ideal, habitat for deer. Approximately 47 percent of the watershed is forested and 17 percent agriculture, and most of the urban area is rural residential or low density residential. NJDEP's Clinton Wildlife Management Area - East, more than 1,950 acres, is partially contained in the Mulhockaway Creek watershed and is public land open for hunting. Deer harvest data indicate that in the last 5 years, between 2,100 and 2,600 are harvested each year in Deer Management Zone 7, which contains the Mulhockaway Creek watershed. According to the Governor's Report on Deer Management (1999) the short-term goal of the state's program is to reduce the herd by approximately 23 percent, but estimate that the heard must be reduced by 40 percent per year to remain stable. A program to reduce the deer herd may reduce fecal coliform from natural sources, but also has additional benefits such as protection of vegetation.

Geese are a major source of fecal coliform contamination throughout the state and within this watershed. Geese tend to flock around open water, especially open water with groomed banks including farm ponds and retention basins. As of 1986, NJDEP inventoried more than 80 ponds³³ in the watershed. Geese also congregate on large manicured lawns and open fields. Goose management programs are relatively easy to implement and can be as simple as a dog that chases them away or allowing vegetation to grow up around ponds and water bodies. In addition, ordinances could be enacted to

³² For more information: http://www.nj.nrcs.usda.gov/programs/glci/RFF_fact_sheet.pdf

³³ NJDEP Open Water Areas, New Jersey 1986. Publication date: Nov. 1, 1998.

prohibit the feeding of waterfowl on public lands. NJDEP and the Townships will need to convince individual landowners to implement goose management programs. The River Friendly Business program may create opportunities to address geese issues with several businesses in the watershed.

Septic System and Cesspool Maintenance and Replacement

Septic system and cesspool³⁴ maintenance and replacement may be required to reduce the impact that failing septic systems or hydraulically connected cesspools may have on water quality. The sampling indicated, but did not conclude that septic systems provided a large contribution to the impairment. Accordingly, a sanitary survey³⁵ is recommended to confirm the impairment from septic systems and/or cesspools. The sanitary survey will provide valuable data to the Townships and will be useful in preparing a septic system management plan and mandatory maintenance program, both required by the proposed Water Quality Management Planning rules. The Hunterdon County or State Departments of Health should be enlisted to locate cesspools, evaluate the septic systems of properties in close proximity to the stream and to identify areas with poor soils for septic systems, high concentrations of older systems and/or replacements, where failures have occurred. Through the Spruce Run Initiative, a septic system education program was developed and implemented for both Bethlehem and Union Townships. Educational materials³⁶ were developed to inform homeowners of the proper uses of septic systems, maintenance requirements, protection of absorption fields and symptoms of problems. Townships should occasionally resend these materials to residents. Clusters of failing septic systems pose a threat to public health and may need to be replaced with a community wastewater treatment system. The Hunterdon County Department of Health could be a resource to the Townships to continually assess conditions within their community.

Sanitary Illicit Connection Detection and Removal

Sanitary illicit Connection Detection and Removal can be initiated through a sanitary survey. No sanitary sewers are located in the watershed, except for one force main, so a survey would likely find four types of possible connections if present in the watershed:

- sanitary wastes piped directly to the stream (also known as wildcat or rogue sewers);
- sanitary wastes piped into a storm sewer or ditch;
- septic systems or cesspools located too close to a ditch or storm sewer (circumventing treatment in the soil) or located on inappropriate soils, and
- disposal of pet and other domesticated animal wastes in ditches or close to stream channels.

In addition, septic system laterals or cesspools may be directly or hydraulically connected to the storm system. Rogue sewers would most likely be located in areas with older

³⁴ <http://www.cet.nau.edu/Projects/WDP/resources/treatmentsyst/Cesspool.htm>.

³⁵ <http://www.epa.gov/safewater/mdbp/pdf/sansurv/sansurv.pdf>

³⁶ For more information, see <http://www.raritanbasin.org/Education/SepticSystembrochure.pdf> and <http://www.raritanbasin.org/Education/SepticSystemPosterfinalver11X17.pdf>

homes and not in newer developments. Stream connections and improper disposal of pet and domesticated animal wastes are found through stream surveys, such as those performed by the AmeriCorps Watershed Ambassadors. Connections to storm sewers and ditches are usually located through the observation of dry weather flows after a significant period of dry weather and then back tracking to the source. Testing for optical brighteners is another method to determine if dry weather flows contain human wastes. Laundry detergent contains dyes to make cotton clothes look whiter and brighter. These chemicals are not harmful, but they indicate the presence of laundry effluent, which may be a sign of discharges of untreated or inadequately treated wastewater, including that from failing septic systems, to the stream. Many inexpensive methods for testing for optical brighteners have been developed for implementation by volunteers, who could aid in further track down activities. Solutions will involve installation, maintenance, repair or replacement of septic systems, replacement of cesspools, and/or connection to a small community wastewater treatment facility.

Microbial source tracking

Microbial source tracking methods are used to determine the type of source upon which to focus remedial efforts. Sophisticated methods range from the differentiation of human and non-human sources (coliphage), differentiation among human, domesticated animal and wildlife (Multiple Antibiotic Resistance) and species identification (DNA based analyses, such as PCR and QPCR). This testing is recommended for areas with both high concentrations and no obvious source or multiple diverse sources.

At this time, microbial source tracking is not recommended. Investigating the 53 sites and implementing the appropriate actions may be sufficient to achieve the desired reduction required by the Fecal Coliform TMDL. However, these methods are useful to persuade landowners to implement mitigation measures, if they do not believe the problem stems from activities on the property. If the Mulhockaway Creek continues to violate water quality standards after implementation of the recommendations in this plan, microbial source tracking would be useful to determine if there is a significant, yet non-obvious, source or if the problem is related to background conditions, such as wildlife, particularly deer.

Education Programs

The Spruce Run Initiative (SRI) is a cooperative arrangement among the Authority and five municipalities, including Bethlehem and Union Townships. The goal of the partnership is the coordinated implementation of activities that benefit water quality in, and draining to, the Spruce Run Reservoir. Projects are documented on the website³⁷ and include coordinated purchase of open space and preservation of land in concentrated areas, a watershed model, a highway corridor study, septic system maintenance education, among others. The participating municipalities are committed to continuing the successes of the SRI. As such, educational programs related to the TMDL implementation can be coordinated through the Initiative. In addition, since the sources are all nonpoint in nature, the educational component of the stormwater regulations also

³⁷ <http://www.njwsa.org/WPU/sri.htm>

provides a vehicle for the Townships to promote awareness and understanding of the importance of implementing these recommendations. North Jersey Resource Conservation and Development Council (NJ RC&D) is an organization facilitates the wise use and protection of natural resources and is sponsored by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). The NJ RC&D and NRCS provide technical assistance to farmers and others to address issues related to water quality and water resource protection. The River Friendly Farm program is managed by NJ RC&D and will be an important vehicle for educating agricultural landowners about best management practices, which will help reduce bacterial contamination of the stream from their property.

Goals

The goal of implementing the management measures identified herein is to ensure that the Mulhockaway Creek achieves the surface water quality standards and is safe for primary contact recreation. However, the diffuse nature of the sources and few concentrated point sources may mean that the stream is exceeding criteria based on natural conditions. Considering this, we recommend that NJDEP establish three milestones for implementation, and phase the implementation to achieve these results. The milestones, which follow an adaptive management strategy, are as follows:

1. Meet a presumed secondary contact recreation standard of 700 col/100 ml through implementation of the recommendations in Table 6. Since the stream is only wadeable and not swimmable, meeting the secondary contact recreation standard will likely protect the majority of persons using the stream. While this is not an established standard for FW2 waters in New Jersey, it is used for the Delaware River, which forms one of the State's boundaries. Only 10 of 89 dry weather samples exceeded this criterion and all that failed were only one order of magnitude greater (highest concentration 3500 col/100ml). Focus should be placed on the more concentrated sources.
2. Determine the nature of contamination. Once obvious or direct sources of contamination are remedied, managing the more diffuse sources will be difficult. Through the use of microbial source tracking techniques, the nature of the contamination should be determined. Implementation measures that target the sources of similar character to the results should be given priority for implementation. For instance, if the contamination is found to be human based, the implementation focus should be on management measures for septic systems and/or sanitary illicit connections. If the load, after meeting the first milestone, is clearly natural (wildlife), it may be prudent maintain efforts implemented to meet the first milestone.
3. Meet the single sample criterion of 400 col/100 ml for Fecal Coliform or the criteria for E. Coli³⁸. If the contamination is not natural, NJDEP should continue to implement the management measures from this document and any identified by others or through fieldwork.

³⁸ E. Coli levels shall not exceed a geometric mean of 126/100 ml or a single sample maximum of 235/100 ml for primary contact recreation.

Recommendations

According to the TMDL, the required load reduction for fecal coliform is 91 percent and a specific loading (counts/year) was not reported. The rural residential nature of the watershed, nonpoint source nature of the loading and lack of information available about failing septic systems or animal counts on individual properties make it difficult to attribute portions of fecal coliform load to the potential sources identified. However, not all of the nonpoint source pollution is diffuse and some concentrated or direct nonpoint sources are located within the watershed. To begin the implementation process to achieve the first goal of meeting the secondary contact water quality standard, sites with direct concentrated nonpoint sources have been targeted for management measures and will require cooperation from individual landowners and assistance from North Jersey RC&D.

Table 6 summarizes the management measures that should be pursued first to address the fecal coliform impairment. These locations were chosen because the potential for contamination was confined to a small area and is likely to contribute a significant load. For the 15 sampling events, 11 of the concentrations from MC5 were either the first or second largest. The highest dry weather flow concentration (3500 col/100 ml) was also observed here. At site 5e, animals have direct access to the stream and there is no buffer. In addition to cows, geese were observed congregating in the stream. At MC6, concentrations of bacteria ranked among the top 2 for 8 of the 15 events. The dry weather geometric mean was greatest at this site. The proximity of manure from both horses (site 6b) and poultry (site 6a) seem a likely source of bacterial contamination of the stream. The animals are fenced away from the stream, but the riparian buffer is sparse in locations. At MC1, the concentrations are not particularly large or small, but the FC/FS ratio implies the potential for human contamination. Pattenburg, partially located in MC1, is rumored to have failing septic systems and possibly cesspools. Stormwater outfalls along Rte 614 and Main Street were noted as potentially having illicit connections evidenced by odor and dry weather flow. The second largest geometric mean for wet weather was for samples from MC4. The many ponds in Hoffman Park may be attractive to geese. The large open lawn and wet detention basin at the Perryville Office Park is known to have resident geese.

Summary

Based on water quality data, aerial inspections and fieldwork confirmations, more than 53 sites were identified as potential sources of fecal coliform in the watershed. The sources are likely concentrations of geese congregating on open fields and in on-line ponds, related to livestock (either animals in the streams or manure mismanagement) or sanitary wastewater from failing septic systems or illicit connections. While some of the sources contribute directly to the bacterial contamination of the stream, many are dispersed throughout the watersheds. For the dispersed sources, implementation of measures will be difficult because many landowners will need to be involved.

Since fecal coliform and other bacteria occur naturally in the environment and can even flourish in bottom sediments, reasonable assurances that any management measure or combination of management measures will be successful are difficult to guarantee. Phasing implementation of management measures and seeking the intermediate goal of secondary contact recreation is appropriate because the likely sources in the watershed are scattered and the physical configuration of the stream is not conducive to swimming. Pursuing nonpoint source management measures at the most likely concentrated sources should be initiated. The sanitary survey can be conducted by NJDEP, possibly through the AmeriCorps Watershed Ambassador Program, by the State Department of Health or the Hunterdon County Department of Health. NJDEP can work with the Board of Agriculture and NJ RC&D to identify cost-effective opportunities for manure management, fencing and installation of riparian buffers.

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