Musconetcong River Watershed Protection Plan: Hampton to Bloomsbury

North Jersey Resource Conservation and Development

Prepared for:
New Jersey Department of Environmental Protection
Division of Policy Implementation and Watershed Restoration
Funded by Section 319(h) Grant RP06-073

Prepared by:
North Jersey Resource Conservation and Development (RC&D) Area Inc
Clinton, New Jersey
October 2012

In fulfillment of the requirement of the Clean Water Act 319(h) Grant "Watershed Restoration and Protection Plan for the Musconetcong Watershed- Hampton to Bloomsbury" which was funded and approved by the Division of Policy Implementation and Watershed Restoration, formerly the Division of Watershed Management, at the New Jersey Department of Environmental Protection (Grant Contract #RP06-073).

Table of Contents

1.0 Acknowledgements 10
2.0 Executive Summary 12
2.1 Background 12
2.2 Sources and Root Causes 13
2.2.1 Pathogens 13
2.2.2 Nutrients 14
2.2.3 Sediment 14
2.2.4 Temperature 14
2.3 Required Load Reductions 14
2.4 Management Measures 15
2.4.1 Management Measures to Reduce Pathogenic Loads 15
2.4.2 Management Measures to Reduce Nutrient Loads 16
2.4.3 Management Measures to Reduce Sediment Loads 17
2.4.4 Management Measures to Restore Watershed Hydrology 18
2.5 Recommended Projects 19
2.6 Implementation Schedule 21
2.7 Measurable Milestones 23
2.8 Technical Assistance and Funding 25
2.9 Criteria and Monitoring Program 26
2.10 Education 27
3.0 Project Background, Purpose and Partnership 28
3.1 Introduction 28
3.2 Purpose of the Plan 29
3.3 Partnership 29
4.0 Watershed Description 32
4.1 Geography and Topography 32
4.2 Demographics 33
4.3 Climate 33
4.4 Hydrology 34
4.5 Geology 34
4.6 Soils 35
4.7 Groundwater Recharge and Stream Hydrology 36
4.8 Land Use and Land Cover 37
4.9 Critical Environmental Areas 38
4.9.1 Hydric Soils 38
4.9.2 Wetlands 39
4.9.3 Floodplains 40
4.10 Open Space Preservation and Protected Areas 40
4.11 Ecological Resources 42
4.11.1 Wildlife and Wildlife Habitat 42
4.11.2. Fisheries 43
4.11.3 Fish Consumption Advisories 46
4.11.4 Typical Vegetation & Rare Plant Species / Undesirables 47
5.0. Physical Condition 49
5.1 Erosion 49

5.2 Hydromodification 49
5.3 Riparian Areas 49
5.4 Stream Visual Assessment Protocol (SVAP) 51
6.0 Surface Water Quality 53
6.1 Designated Uses and Impairments 53
6.1.1 Designated Uses 53
6.1.2 Impairments 53
6.2 Monitoring Stations 56
6.2.1 Monitoring Program May 2007 - October 2007 56
6.2.2 Monitoring Program for August 2008 56
6.2.3 Monitoring Program for May 2009 56
6.3 Summary of Water Quality Data - Results and Trend Analyses 61
6.3.1 Monitoring Program May 2007 - October 2007 61
6.3.2 Monitoring Program for August 2008 71
6.3.3 Monitoring Program for May 2009 74
6.3.4 Temperature Monitoring Program for Summer 2010 76
6.3.5 Microbial Source Tracking 79
6.3.6 Biological Monitoring 83
6.4 Point and Nonpoint Source Loadings 85
6.4.1 Point Sources 85
6.4.2 Nonpoint Sources 86
6.4.3 Estimated Loading Targets and Priorities 86
7.0 Municipal Regulations and Resources 92
7.1 Stormwater Management Regulations 92
7.2 Highlands Act/Highlands Regional Master Plan 93
7.3 Stream Buffers 94
7.4 Agriculture 94
7.5 Steep Slopes 94
7.6 Septic Systems 94
7.7 NJ Wild and Scenic Rivers 95
8.0 Restoration Strategies and Protection Projects 96
8.1 Watershed Wide Restoration Projects and Best Management Strategies 96
8.1.1 Stormwater Best Management Practices 96
8.1.2 Specific Restoration Projects 117
Project Name: #4 Illicit Connection 127
8.2 Project Prioritization 157
9.0 Next Steps 164
9.1 Milestones and Implementation Strategies 164
9.1.1 Milestones and Implementation in the First Two Years 164
9.1.2 Milestones and Implementation Plan in the First Five Years 165
9.1.3 Milestones and Implementation Plan in the First Ten Years 166
9.2 Additional Watershed Protection Efforts and Previous Projects 167
9.3 Monitoring and Evaluation 169
9.3.1 BMP Documentation Database 169
9.3.2 Water Quality Monitoring 170
9.3.3 Biological Monitoring 170

9.3.4 Stream Visual Assessment 170
10.0 Summary 171
10.1 Nine Elements of a Watershed Plan 172

List of Tables

Table 2.1 – Associated HUC 14's within project boundary
Table 2.2 – Recommended BMP projects for the Musconetcong River Watershed
Table 2.3 – Priority ranks for all BMP projects in the Musconetcong River Watershed
Table 2.4 – Implementation targets for the recommended BMP projects in the Musconetcong River Watershed
Table 2.5 – BMP implementation schedule in the Musconetcong River Watershed
Table 2.6 – Potential sources of funding for implementation of BMP projects
Table 4.1 – Musconetcong Subwatershed Municipalities
Table 4.2 – 2010 Census Population Estimates
Table 4.3 – Area of distribution of groundwater recharge in the Musconetcong River Watershed
Table 4.4 – Musconetcong River Watershed Land Use Classifications
Table 4.5 – Land Use Cover Comparison
Table 4.6 – The types and areas of wetlands in the Musconetcong River Watershed
Table 4.7 – Number of Preserved Farms per Municipality of the Project Area
Table 4.8 – List of endangered species and their habitat priority in the Musconetcong River Watershed
Table 4.9 – Potential Impaired sites for the Musconetcong River Watershed
Table 4.10 – Fish species observed in the Musconetcong River at Route 632
Table 4.11 – Fish species observed in the Musconetcong River at New Hampton Road
Table 6.1 – Applicable Surface Water Quality Criteria – N.J.A.C.7:9B (*Last Amended: April 4, 2011 43 N.J.R. 833(a)*)
Table 6.2 – Description of and basis for water quality monitoring locations within the Musconetcong River Watershed, 2007 monitoring program
Table 6.3 – Additional monitoring locations for August 2008 bacteria monitoring
Table 6.4 – Additional monitoring locations for May 2009 bacteria monitoring
Table 6.5 – Summary of temporal and spatial aspects of surface water quality monitoring program for the Musconetcong River Watershed, 2007 monitoring program
Table 6.6 – Percentage of samples from the biweekly and additional bacteria sampling that exceeded surface water quality criteria (SWQC)
Table 6.7 – Results of August 2008 bacteria monitoring
Table 6.8 – Results of bacteria monitoring conducted during three storm events during the summer of 2008
Table 6.9 – Results of May 2009 bacteria monitoring
Table 6.10 – Presence (+) and absence (-) of human and bovine *Bacteroides* within the Musconetcong River Watershed during three wet weather sampling events in 2008

Table 6.11 – Presence (+) and absence (-) of human and bovine *Bacteroides* within the Musconetcong River Watershed in May 2009
Table 6.12 – Annual Loading Rates for Individual Subwatersheds
Table 6.13 – Annual Loading Rates Normalized to Area for Individual Subwatersheds
Table 6.14 – Summation of Rankings for Loadings and Area-Normalized Loadings
Table 6.15 – Priority Watersheds by Surface Water Quality Parameter
Table 8.1 – Water quality effects, costs and cost-effectiveness of agricultural BMPs in the Musconetcong River Watershed
Table 8.2 – Water quality effects, costs and cost-effectiveness of stormwater BMPs in Musconetcong River Watershed
Table 8.3 – Cost of three major BMPs for reducing pathogenic loads in the Musconetcong River Watershed
Table 8.4 – Priority ranks for all BMP projects in the Musconetcong River Watershed
Table 9.1 – Implementation goals, expected pollutant load reductions and implementation costs of BMP projects for the Musconetcong River Watershed in the first two years
Table 9.2 – Implementation goals, expected pollutant load reductions and implementation costs of BMP projects in the Musconetcong River watershed in the first five years
Table 9.3 – Implementation goals, expected pollutant load reductions and implementation costs of BMP projects within the Musconetcong River watershed in ten years
Table 9.4 – Additional Watershed Protection Efforts and Projects TU working along Musky river: across from Hampton borough Park in Warren County to Shurts Road

List of Maps (Appendix B)

Map 1 – Musconetcong River Watershed Project Area
Map 2 – Transportation Network within Musconetcong River Watershed Project Area
Map 3 – 2000 Census population within Project Area
Map 4 – Musconetcong River Watershed Project Area Topography
Map 5 – Musconetcong River Watershed Project Area Available Soils
Map 6 – Musconetcong River Watershed Project Area Bedrock
Map 7 – Musconetcong River Watershed Project Area Groundwater Recharge
Map 8 – Musconetcong River Watershed Project Area Wetland Designations
Map 9 – Land Use in the Musconetcong River Watershed Project Area
Map 10 – Preserved Farmland and Open Space within the Project Area
Map 11 – Musconetcong River Watershed Project Area Roads and Streams
Map 12 – Musconetcong River Watershed Project Area FEMA 100-Year Flood Zone
Map 13 – NJDEP Landscape data: Wetland habitat in Musconetcong Project Area
Map 14 – NJDEP Landscape data: Forest habitat in Musconetcong Project Area
Map 15 – NJDEP Landscape data: Grassland habitat in Musconetcong Project Area
Map 16 – Musconetcong River Watershed Project Area Known Contaminated Sites

List of Figures

Figure 6.1 – Musconetcong River Watershed monitoring locations May 2007 – September 2010
Figure 6.2 – Increasing percent agriculture land us by subwatershed
Figure 6.3 – Relation of median value of temperature to percent agriculture land use within the Musconetcong River Watershed
Figure 6.4 – Relation of median value of E. coli to percent agriculture land use within the Musconetcong River Watershed
Figure 6.5 – Relation of median value of fecal coliform to percent agriculture land use within the Musconetcong River Watershed
Figure 6.6 – Increase percent forest land use by subwatershed
Figure 6.7 – Relation of median value of temperature to percent forest land use within the Musconetcong River Watershed
Figure 6.8 – Relation of median value of E. coli to percent forest land use within the Musconetcong River Watershed
Figure 6.9 – Relation of median value of fecal coliform to percent forest land use within the Musconetcong River Watershed
Figure 6.10 – Increasing percent urban land use by subwatershed
Figure 6.11 – Relation of median value of temperature to percent urban land use within the Musconetcong River Watershed
Figure 6.12 – Relation of median value of E. coli to percent urban land use within the Musconetcong River Watershed
Figure 6.13 – Relation of median value of fecal coliform to percent urban land use within the Musconetcong River Watershed
Figure 6.14 – Land cover and urban land distribution for the Musconetcong River Watershed
Figure 6.15 – Daily Maximum temperatures, June 22 to September 26, 2010
Figure 6.16 – Rolling 7-day average of daily maximum temperatures, June 22 to September 26, 2010
Figure 8.1 – Typical profile of a vegetative buffer
Figure 8.2 – Home Rain Garden
Figure 8.3 – Road Rain Garden
Figure 8.4 – Aerial photo of a detention basin in Franklin Township
Figure 8.5 – Map of Detention Basins within the Musconetcong River Watershed
Figure 8.6 – Photo of Existing Roadside Drainage Swale
Figure 8.7 – Locations of potential roadside ditch retrofits
Figure 8.8 – Potential Cover Crop project
Figure 8.9 – Location of potential stream buffer extension, livestock exclusion fencing, cattle stream crossing and alternate watering sources
Figure 8.10 – Location of potential detention basin retrofit
Figure 8.11 – Location of potential illicit connection
Figure 8.12 – Location of manure pile located on stormwater outlet
Figure 8.13 – Location for potential roadside ditch retrofit on Asbury West-Portal road
Figure 8.14 – Location for potential roadside ditch improvements on Turkey Hill road
Figure 8.15 – Location for potential vegetative buffer project

Figure 8.16 – Location for potential roadside ditch improvements on Butler road
Figure 8.17 – Location for potential road rain garden project
Figure 8.18 – Location for potential stream corridor restoration

List of Acronyms

AMNET – Ambient Biomonitoring Network
AU – Animal Units
AWEP – Agricultural Water Enhancement Program
BBN – Bring Back the Natives
BFEs – Base Flood Elevations
BMPs – Best Management Practices
CCPI – Cooperative Conservation Partnership Initiative
CEM – Channel Evolution Model
CR – County Routes
CREP – Conservation Reserve Enhancement Program
DO – Dissolved Oxygen
DPW – Department of Public Works
E. coli – Escheria coli
EI – Erodibility Index
EPA – U.S. Environmental Protection Agency
EPT – Ephemeroptera, Plecoptera, Trichoptera
EQIP – Environmental Quality Incentive Program
FEMA – Federal Emergency Management Agency
FOTG – Field Office Technical Guide
FSA – Farm Service Agency
FW – Freshwater
GPS – Global Positioning System
HCSCD – Hunterdon County Soil Conservation District
HRU – Hydrologic Response Unit
HSAs – Hydrologically Sensitive Areas
ICM – Integrated Crop Management
MOS – Margin of Safety
MUSYM - Map Unit Symbol
MWA- Musconetcong Watershed Association
NASS – National Agricultural Statistics Service
NEMO – Nonpoint Education for Municipal Officials
NJDA – New Jersey Department of Agriculture
NJDEP – New Jersey Department of Environmental Protection
NJGS – New Jersey Geological Survey
NJIS – New Jersey Impairment Score
NJIT – New Jersey Institute of Technology
NJPDES – New Jersey Pollution Discharge Elimination System
NJWSA – New Jersey Water Supply Authority
NPS – Nonpoint Source Pollution
NRCS – Natural Resources Conservation Service

NT – Non-Trout
OSDSs – On-site Sewage Disposal Systems
PIG – Planning Incentive Grant
PCR – Polymerase Chain Reaction
NJRC&D – North Jersey Resource Conservation and Development Council
RCE – Rutgers Cooperative Extension
ROW – Right of Way
RTMUA – Raritan Township Municipal Utilities Authority
SADC – State Agriculture Development Committee
SSA – Sewer Service Area
SSURGO – Soil Survey Geographic
STEPL – Spreadsheet Tool for Estimating Pollutant Load
SVAP – Stream Visual Assessment Protocol
SWAT – Soil and Water Assessment Tool
SWQC – Surface Water Quality Criteria
TMDL – Total Maximum Daily Loads
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids
USDA – U.S. Department of Agriculture
USGS – U.S. Geological Survey
VAPP – Visual Assessment Project Plan
VSA – Variable Source Area
WHIP – Wildlife Habitat Incentive Program

List of Appendices

Appendix A - Rutgers University, Water Resources Program: Water Quality Analysis, Data Loading Calculations, Stream Visual Assessment Protocols (SVAPs)
Appendix B – Created Maps
Appendix C - Bernie Beatty Farm Stream Crossing and Spring Development

1.0 Acknowledgements

Funding for this project was provided by the Division of Policy Implementation and Watershed Restoration, formerly the Division of Watershed Management, at the New Jersey Department of Environmental Protection (NJDEP) through the Clean Water Act's Section 319(h) program (Grant Contract #RP06-073). Additional in-kind contributions to the project are provided by Rutgers Cooperative Extension Water Resources Program and the volunteers from Bethlehem Township. The following individuals from the respective agencies contributed to the completion of the project:

New Jersey Department of Environmental Protection
Nick Zripko, Project Manager: Overall grant administration, project guidance and communication with various Divisions at NJDEP

North Jersey Resource Conservation and Development (RC&D) Area Inc.
Grace Messinger, Executive Director, former Watershed Specialist: Project Manager, SVAP data collection and entry, Plan Document co-author
Nathan Charron, Watershed Specialist: Plan Document co-author, GIS data support, Watershed Assessment and Characterization
Patrick Natale, Agricultural Outreach Specialist: Agricultural practices and BMPs; GIS data support

Rutgers Cooperative Extension Water Resource Program
Christopher C. Obropta, Ph.D., P.E., Associate Extension Specialist and Associate Professor: Water quality monitoring and stormwater best management practices (BMPs) and the primary author of the stormwater BMP report
Lisa Galloway Evrard, Senior Program Coordinator: Water quality monitoring and assessment and primary author of the Water quality monitoring report
Jeremiah Bergstrom, Senior Program Coordinator: Stormwater BMP assessment
Sean Walsh, former Program Associate: Stormwater BMP assessment
Katie Buckley Giacalone, former Program Associate: Stream Visual Assessment Protocol (SVAP) training and primary author of report

Musconetcong Watershed Association
Beth Styler Barry, Executive Director: SVAP, primary author of Municipal Regulations and Resources, Watershed Assessment and Characterization

Natural Resource Conservation Service
Christine Hall, former North Jersey RC&D Coordinator: Agricultural practices and BMPs

Bethlehem Township (Hunterdon County)
Eric Sween, Appointed Municipal Representative

Franklin Township (Warren County)
Beth Styler Barry, Appointed Municipal Representative

Hampton Borough (Hunterdon County)
Robert Sheridan, Appointed Municipal Representative

AmeriCorps, Watershed Ambassador Program (through New Jersey Department of Environmental Protection)
Service Years 2006 to 2011: SVAP Data Collection and Watershed Assessment

SVAP Volunteers
Bethlehem Township: Cinny MacGonagle, Tom Koven, Joyce Koch, Eric Sween

2.0 Executive Summary

2.1 Background

The Musconetcong River drains a 157.6 square mile watershed and is a major tributary of the Delaware River. The Musconetcong creates a boundary throughout its length by first dividing Morris and Sussex counties as well as Warren and Hunterdon counties. In December of 2006 the Musconetcong Wild and Scenic Rivers Act was signed into law. This legislation designates portions of the Musconetcong River as a part of the larger National Wild and Scenic Rivers System. Of the twenty-six municipalities that fall within the watershed fourteen of them are eligible for Wild and Scenic designation. (Musconetcong Advisory Committee, 2003)

In 2004 a group of water resource professionals from various agencies including North Jersey Resource Conservation and Development (NJRCD), Rutgers Cooperative Extension (RCE) and the Musconetcong Watershed Association (MWA) were assembled to discuss what systematic approach should be taken to address water quality concerns within the Musconetcong River watershed. A proposal for developing the Musconetcong River Watershed Protection Plan was developed after a series of discussions between the lead agency (NJRCD) and its collaborators and submitted to the Clean Water Act Section 319(h) program administered by the New Jersey Department of Environmental Protection (NJDEP). In 2005, NJDEP awarded NJRCD and its collaborators the grant (Contract #RP06-073) to develop the Musconetcong River Watershed Protection Plan. NJRCD was also the lead effort in creating a restoration plan that would begin to address fecal coliform impairments for the NJDEP Priority Waters Initiative in 2004.

The plan will detail the management measures needed to achieve the necessary reduction in bacteria and attain water quality standards for total phosphorus (TP), total suspended solids (TSS), reduce the aquatic life impairments to a non-impaired level, and outline the possibility of restoring the base flow of the Musconetcong River. The plan will focus efforts on a seven mile stretch of the Musconetcong River as well as 19 miles of tributaries (i.e., West Portal Brook, Turkey Hill Brook, and five unnamed tributaries). The total project area covers 19.6 square miles of the watershed, making its way through five municipalities (Hampton Borough, Lebanon, Bethlehem, Washington and Franklin Townships) and two counties (Hunterdon and Warren).

Table 2.1: Associated HUC 14's within the project area

	Waterway Name	HUC 14
1	Musconetcong R (75d 00m to Rt. 31)	02040105160040
2	Musconetcong R (I-78 to 75d 00m)	02040105160050

2.2 Sources and Root Causes

Water quality issues within the Musconetcong River Watershed are the result of land use changes over the years. According to historical data developed and maintained by NJDEP, there have been significant increases in urban land and decreases in agricultural lands over the past two decades. Urban land use went from being 11 percent of the total land area in 1896 to 17 percent in 2007. Agriculture went from being 52 percent to 35 percent in 2007. Forested land also increased from 31 percent in 1986 to 43 percent in 2007. Other land uses were fairly constant with barren land between 0-0.3 percent, water was constant at 0.6 percent and wetlands were between 4-5 percent. Within this watershed, three primary sources of fecal coliform exist: livestock, septic and wildlife. Potential sources for this non-attainment include environmental stressors including: increased water temperature, decreased dissolved oxygen, soil and streambank erosion, stormwater runoff, and decreased water quality from nonpoint source pollution.

Land use changes dramatically alter watershed hydrology. Throughout the past few decades, as urban land increases, the impervious surfaces such as rooftops, driveways, additional roads, and parking lots, increase whereas pervious surfaces, such as traditional agricultural lands decrease. Such land use changes usually decrease infiltration and groundwater recharge and increase surface runoff. Urban and suburban development requires additional roads and stormwater infrastructure, such as drainage pipes and ditches. The latter are designed to convey stormwater away from individual properties as quickly as possible. Tile drainage and swale infrastructure in agricultural lands quickly disperse agricultural runoff from agricultural fields. In general, agricultural and urban development lead to flashy watershed hydrology in which high-velocity flowing runoff reaches the streams quickly resulting in streambank erosion, unstable channel conditions, and further sedimentation of streams and degradation of stream habitat.

2.2.1 Pathogens

Pathogens in waterways are indicated by the presence of fecal coliform and *Escherichia coli* (*E. coli*).. In general both human and animal wastes are sources of these pathogens in waterways. The average counts/100ml for fecal coliform reached 1,332 col/100ml and *E. coli* reached 2,021 org./100ml. These numbers are well above the standards of 235 counts/100ml and 400 counts/100ml for *E. coli* and Fecal Coliform respectively. With all 9 sites having maximum levels above the standards it is clear that the Musconetcong River and its tributaries are impaired for both fecal coliform as well as *E. coli*. As can also be shown by comparing Figure 6.2-6.14 , which shows the land use percentages that flow to specific testing locations, and also show levels of *E. coli* and Fecal coliform respectively although these impairments are not subject to specific land use demographics. There are many different ways of decreasing these levels within a waterway including livestock stream access control and vegetative buffers, which will be discussed later in the document.

2.2.2 Nutrients

Nutrient loads include total nitrogen (TN) and total phosphorus (TP) and these nutrients are a problem in many of the waterways of the United States, including the Musconetcong River Watershed. Nitrogen can be added to a stream or waterway through stormwater runoff; however phosphorus is not readily available for stormwater impacts in the same way because of its bonding to the soil. Within the Musconetcong project area phosphorus was found to be one of the pollutants of concern with some sampling locations coming up as 0.19 mg/L, however the average over the whole project area was 0.05 mg/L, however the standard for phosphorus says that there cannot be any stream with hits of more than 0.1 mg/L Over the course of the testing 4 of 9 sites tested above 0.1 mg/L with 0.11, 0.11, 0.11 and 0.19 mg/L respectively. These nutrients can be reduced in many of the ways including educating the public on the use of fertilizers, the need for soil testing and even buffer or filter strips, all of which are discussed later in the document.

2.2.3 Sediment

Sediment in the water column is measured by total suspended solids (TSS). TSS is added when river banks become compromised or stormwater is allowed to wash over bare soil surfaces. Sediment is not highlighted as one of the impairments for the Musconetcong River; however it is important to consider this potential pollutant in any management strategy. This addition to streams can be decreased by stabilizing streambanks along waterways or decreasing stormwater access to bare soil. Many of the different strategies will be addressed later.

2.2.4 Temperature

High temperature can have adverse affects on a stream corridor including decreased biological biodiversity as well as effects on the water treatment processes. Temperature can be changed within a waterway by many different ways; however the two main reasons for increased temperature are the introduction of effluents and direct exposure to the sun's rays. For a healthy stream the water should remain below 20°C. The median temperature for the Musconetcong River is below this standard at 17.5°C, however there were several instances of temperatures reaching 23°C. The best way to reduce temperature impacts on a stream is to make sure there are not long stretches exposed to direct sunlight as well as spreading out effluent injection sites.

2.3 Required Load Reductions

The NJDEP (2010a) designated the majority of the Musconetcong River and its tributaries as Trout Production (TP) Streams with a few being designated as Trout Maintenance (TM) waters. According to this designation from the New Jersey Surface Water Quality Standards (NJAC 7:9B) amended January 4, 2010 (42 N.J.R. 68a), the previously stated surface water

quality standards are applicable to the pollutants of concern in the Musconetcong River and its tributaries:

- *E. coli* shall not exceed a geometric mean of 126 counts per 100 milliliter (mL) or a single sample maximum of 235 counts per 100 mL;
- Fecal coliform shall not exceed geometric average of 200 counts per 100 mL, nor shall more than 10 percent of the total samples taken during any 30-day period exceed 400 counts per 100 mL;
- TP shall not exceed 0.1 mg/L;
- TSS shall be less than 40 mg/L; and
- TN shall be below 10 mg/L to protect human health.

For all impaired streams throughout the US, the EPA requires the development of a Total Maximum Daily Load (TMDL) for pollutants of concern. A TMDL is a calculation of the maximum amount of a pollutant a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

The NJDEP has adopted and approved a TMDL for fecal coliform in the Musconetcong River; therefore, this parameter has been moved to Sublist 4a. This TMDL requires 93% reductions in nonpoint source fecal coliform loads from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban and agricultural lands. Targets are an annual reduction of approximately 4,000 pounds of total phosphorus (TP), 200 tons of sediment and approximately 56 percent of the fecal coliform loadings.

2.4 Management Measures

There are different management recommendations to reduce the impact of pathogens, nutrients and sediment on a stream corridor and to restore watershed hydrology.

2.4.1 Management Measures to Reduce Pathogenic Loads

The following management measures are recommended to reduce pathogen loads to the streams from various sources including livestock, septic systems and wildlife:

- Animal Manure Management – In addition to the implementation of the Criteria and Standards for Animal Waste Management (N.J.A.C. 2:91) adopted by the New Jersey Department of Agriculture (NJDA) in the watershed, the plan also calls for the operation of five small scale regional manure composting and storage facilities and the development and implementation of manure incorporation technology when applying manure as fertilizer in row-crop and hay production.
- Livestock Access Control – The plan calls for complete exclusion of livestock from the streams and the immediate riparian areas from pasture land with technical assistance and financial funding support. The exclusion of livestock primarily focuses on streams that pass directly through or are currently included in pasture land and shall not apply to temporary stream crossings for livestock.
- Sewer Infrastructure Maintenance in Sewer Service Areas (SSAs) – The plan calls for periodical assessments on the conditions and capacity of all sewer infrastructures in

its service area and planned updates and/or improvement in the sewer infrastructure in the watershed.

- Wildlife Management – The contributions of wildlife to pathogen contamination in the watershed is minor compared to other sources currently. The plan calls for the active participation in various wildlife management programs implemented at the state and county levels and the implementation of various BMP practices to disrupt habitats for deer and geese along the streams.
- Detention Basin Retrofitting – The detention basin captures a large amount of stormwater runoff from medium and low density developed areas where pathogen sources could be present. There is no existing empirical data indicating how much retrofitting detention basins would reduce pathogen loads. However, depending on the final design of the detention basin, a retrofitted basin could function like a bio-retention basin or constructed wetland to assist in the removal of pathogen loads to streams.

2.4.2 Management Measures to Reduce Nutrient Loads

The following management measures are recommended to reduce nutrient loads to streams from various sources discussed above:

- Integrated Crop Nutrient Management – The proper amounts of fertilizers applied to crops should be based on the reasonable crop yield goal and the available nutrients found in the soil as determined by annual soil testing. The soil test-based integrated crop management (ICM) should be offered as technical assistance to farmers located within the watershed.
- Conservation Buffers – Conservation buffers are planned vegetative mixtures of native trees, shrubs and grasses placed in a landscape to influence ecological processes and enhance the ecosystem goods and services including nutrient filtering and uptake. There are many types of conservation buffers such as contour buffer strips, field borders, grassed waterways, filter strips and riparian forest buffers that should be applied within the watershed where appropriate.
- Cover Crop – Cover crops are grasses, legumes, forbs or other herbaceous material established for seasonal cover and other conservation purposes. Cover crops reduce soil erosion, help maintain soil moisture and improve soil nutrients and organic content. Proper use of cover crops also have other benefits including lower farming operation costs, reduced tillage needed, less herbicide and fertilizer use, and better overall soil health. Technical assistance and financial incentives should be provided to incorporate cover crops into any cropping system in fields that are not in use for all or part of the year.
- Manure Management – Cropland should not simply be used as a dumping ground for animal waste. Manure application can be rotated among numerous fields to avoid concentrating manure in a limited area. Manure should be applied just as with any other nutrients, with an ICM plan or nutrient management plan. Manure should be tested for nutrient content and then applied according to crop needs minus soil residual to protect water resources and promote crop growth and soil health.

- Prescribed Grazing – Prescribed grazing is a system that helps agricultural producers to manage grazing and browsing of animals to ensure that there is always adequate ground cover and to ensure proper nutrition for the livestock. A prescribed grazing plan may include a reduction of livestock, rotating livestock more frequently and using temporary fencing to exclude livestock from pastures recovering from frequent grazing activity. Prescribed grazing will help to maintain healthy and productive pastures. Healthy pastures will protect soil from erosion and the resultant phosphorus and fecal runoff. In addition, an actively growing pasture will uptake more nutrients, improve water infiltration and reduce runoff and non point sources (NPS).
- Nutrient Management for Lawn Care – The recently enacted Fertilizer Control Law establishes standards for certain fertilizer applications, requires certification of professional fertilizer applicators, and regulates labeling and sale of certain fertilizers. As with agricultural fertilizer application, lawn fertilizer application should be soil test-based to promote health lawn and reduce nutrient loads to streams at the same time.

2.4.3 Management Measures to Reduce Sediment Loads

The following management measures are recommended to reduce sediment loads to streams from various sources as discussed above:

- Contour Farming – Contour farming uses ridges and furrows formed by tillage, planting and other farming operations to change the direction of runoff from directly down slope to around the hill slope thereby reducing the velocity at which the water travels. This slowing down of surface water runoff reduces the transport of phosphorus and other contaminants while also reducing sediment loads from gully erosion.
- Conservation Buffers – Conservation buffers have multiple water quality benefits and reduce both nutrient as well as sediment loads to a stream. As runoff makes its way through a buffer, the dense vegetation acts as a filter, preventing sediment and sediment-absorbed nutrients, pesticides and pathogens from entering the stream system. Conservation buffers should be installed in proper locations to achieve optimal effectiveness in improving water quality.
- Livestock Access Control – Livestock access control not only reduces pathogen loads to streams, but also eliminates livestock disturbance of the streambank as well as the stream channel. A stable stream bed and streambank results in less sediment being added to the system.
- Cover Crop – Cover crops reduce soil erosion, help maintain soil moisture, and improve soil nutrient and organic content. Technical assistance and financial incentives should be provided to incorporate cover crops into any cropping system in fields that are not in use for all or part of the year.
- Prescribed Grazing – Prescribed grazing will help to maintain healthy and productive pastures. Healthy pastures will protect soil from eroding and adding sediment and nutrients to a stream. In addition an actively growing pasture will uptake nutrients and improve water infiltration.

- Roadside Ditch Retrofitting – The roadside ditches in the watershed are actively eroding therefore they are also actively adding sediment to the stream system. Roadside ditch retrofitting can turn the ditch into bio-retention systems that are very similar to constructed wetlands. These systems can help trap sediment, nutrients and contaminants as the water flows from the roads, through the ditches and into the streams. The vegetation can also slow down the water as it moves through the ditch thereby reducing its velocity and preventing scouring of the channel.
- Streambank Stabilization – Streambank stabilization contributes significantly to TSS in streams. Streambank stabilization can be used as an important measure to reduce streambank erosion, improve water quality, and enhance stream ecology. Although the streambank can be temporarily stabilized through various techniques, permanent stabilization has to be achieved by controlling the amount of velocity of stormwater runoff in the watershed. To stabilize the streambank, any land activity that disturbs the streambank should be prohibited.

2.4.4 Management Measures to Restore Watershed Hydrology

Land use changes and the associated stormwater infrastructure have significantly altered watershed hydrology. Watershed restoration should mitigate the negative impacts of land use changes on watershed hydrology. The following management measures are proposed to restore watershed hydrology and streamflow in the Musconetcong River watershed, in addition to their water quality benefits.

- Bio-retention Systems – Traditional stormwater infrastructure is designed to quickly deliver stormwater from the sources to the streams. Bio-retention systems are BMPs that are designed to retain the stormwater flow and slowly discharge it to the system and/or stream. These systems are designed to treat the retained water to achieve substantial water quality benefits through the biological processes in the plants embedded in the system. These retention basins also give the stormwater a chance to infiltrate, thereby creating groundwater recharge and decreasing the overall stormwater input to the stream. Bio-retention systems should include a series of bio-retention facilities that are maintained under different situation and include rain gardens in residential and commercial properties and along roadsides.
- Conservation Buffers – Conservation buffers provide both water quality benefits as well ecological benefits. Conservation buffers could achieve runoff reduction through evapotranspiration processes by plants and could promote groundwater recharge through multiple biological and hydrological processes.
- Conservation Planning and Ordinances – Land use changes, especially suburban development, substantially alter watershed hydrology and causes many water quality problems in the Musconetcong River Watershed. As suburban sprawl continues within the watershed, conservation planning and ordinances should be reviewed, developed, implemented and enforced to help prevent harmful land use activities and protect the water resources within the watershed.

- Farmland and Open Space Preservation – All municipalities in the watershed have active farmland and open space preservation programs. These programs were originally established as urban sprawl control measures to protect important natural and cultural resources from overdevelopment, to retain the amenities of traditional rural communities and improve environmental quality including water quality. Municipal farmland and open space preservation programs in the watershed should continue to be used and should be expanded to protect critical source areas (CSAs) from intensive land use activities and disturbances and to prevent water resources from being degraded at their sources.

2.5 Recommended Projects

Table 2.2 summarizes the scope and cost of the BMP projects recommended for achieving water quality goals for the watershed. There are eight types of agricultural BMP projects and, four types of stormwater BMP projects. The recommended projects should be applied in various locations in the watershed according to their intended uses. The first column is the specific BMP recommendations. The second column is the total amount of applicable area, length or units for which the BMP could potentially be applied. The third column is the cost per unit while columns five and six specify the total cost of the project as well as the total annual cost recurrence that could be expected for each BMP. The fourth column is the effective lifespan of the BMP once established. The total cost for implementing eight types of agricultural BMP projects is $5.9 million, among which more than half is designated for conservation buffers on agricultural lands. The total cost for all stormwater BMP projects is approximately $4.4 million. The total implementation costs are estimated to be around $10.3 million.

Table 2.2: Recommended BMP Projects for the Musconetcong River Watershed

Types of BMP Project	Applicable Unit	Unit Cost ($/unit)	Life span (years)	Total Cost ($)	Annualized Cost ($/year)
1. Cover Crop	2,528 acres	315	3	796,320	265,440
2. Prescribed Grazing	562 acres	444	5	249,528	49,905
3. Livestock Access Control	15,538 feet	11.54	10	179,308	17,930
4. Contour Farming	1,164 acres	117	3	136,188	45,396
5. Nutrient Management	6,079 acres	117	3	711,243	237,081
6. Conservation Buffers on Agricultural Land	623 acres	6,027	15	3,754,821	250,321
7. Regional Animal Waste Storage and composting Structure	1 units	90,000	10	90,000	9,000
8. Manure Application Incorporation Technology	208 acres	156	1	32,448	32,448
A. Subtotal for Agricultural BMP Projects (1-8)				*5,949,856*	*907,521*
9. Rain Gardens	665 units	4,150	15	2,759,750	183,983
10. Roadside Ditch Retrofitting	50 units	23,500	15	1,175,000	78,333
11. Detention Basin Retrofitting	4 units	29,500	15	118,000	7,866
12. Vegetative Buffers on Developed Land	66,872 feet	4.84	15	323,660	21,577
B. Subtotal for Stormwater BMP Projects (9-12)				*4,376,410*	*291,759*
E. Total (A + B)				*10,326,266*	*1,199,280*

Although all BMP projects are recommended, they differ in terms of their cost and effectiveness in reducing pollutant loads. Table 2.3 summarizes the priority ranks of all BMP projects according to their cost-effectiveness of BMPs in reducing TP, sediments and pathogens in the Musconetcong River Watershed. Cost-effectiveness measures the average reduction in the loading of pollutant achieved by a BMP per dollar spent on implementing that BMP. It equals the annual pollutant load reduction divided by the annual cost of full implementation of the BMP project in the watershed.

Table 2.3: Priority ranks for all BMP projects in the Musconetcong River Watershed

Type of BMP Project	Priority Rank in Reducing		
	TP	Sediment	Pathogen
1. Cover Crop	8	7	
2. Prescribed Grazing	5	6	4
3. Livestock Access Control	1	2	1
4. Contour Farming	4	3	
5. Nutrient Management	2		7
6. Conservation Buffers on Agricultural Land	3	4	8
7. Livestock Waste Storage and Composting Facility	12		2
8. Manure Application Incorporation Technology	11		3
9. Rain Garden	10	9	
10. Road Ditches	9	8	9
11. Detention Basin Retrofitting	7	5	5
12. Vegetative Buffers on Developed Land	6	1	6

Note: A shaded area indicates that the impact of the BMP on the reduction of the pollutant is insignificant.

2.6 Implementation Schedule

Although all twelve types of BMP projects are recommended, it is not necessary to implement all BMPs on all applicable lands or at applicable facilities to achieve pollutant reduction targets for the Musconetcong River Watershed. There are practical limits on implementation of BMP projects at all applicable sites. Natural resource conditions or limitations may restrict the kinds of BMPs that can be implemented on a set piece of land. For various reasons some farmers or landowners may resist the type of implementation recommended for their lands. For example, cover crop is applicable on all 2,528 acres of row-crop fields within the watershed, but it is unrealistic to think that every farmer within the watershed can/should use cover crop on their fields. The required pollutant reduction targets could be achieved by implementing the recommended BMP projects at a fraction of the total area in which they could be implemented. An implementation plan should balance the physical restrictions related to the natural resource conditions, stakeholder's willingness and ability to implement these projects and financial feasibility.

Table 2.4: Implementation targets for the recommended BMP projects in the Musconetcong River Watershed

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
		%	Unit	TP (lbs)	Sed. (tons)	$	%
1	Cover Crop	50	1,264 acres	247	25	398,160	9.9
2	Prescribed Grazing	50	281 acres	120	5	124,764	3.1
3	Livestock Access Control	100	15,538 feet	575	33	179,308	4.5
4	Contour Farming	75	873 acres	240	35	102,141	2.5
5	Nutrient Management	75	4,557 acres	2,073	n/a	533,169	13.2
6	Conservation Buffers in Agricultural Lands	50	311 acres	1,165	79	1,874,397	46.6
7	Livestock Waste Storage and Composting Structure	100	1 units	n/a	n/a	90,000	2.2
8	Manure Application Incorporation Technology	75	156 acres	n/a	n/a	24,336	0.6
9	Rain Garden	5	33 units	n/a	n/a	136,950	3.4
10	Road Ditches	25	12 units	3	n/a	282,000	7.0
11	Detention Basin Retrofitting	100	4 units	28	4	118,000	3.0
12	Vegetative Buffers on Developed Lands	50	33,436 feet	46	24	161,830	4.0
Total				4,497	205	4,025,055	100

The estimation in reduction for TP is on the conservative side for several reasons. First, almost all BMP projects that reduce pathogen loads will also reduce TP loads, and reductions from some of the BMPs are difficult to quantify, thus they have not been included in the calculation. Second, the implementation of the newly enacted Fertilizer Control Law and the municipal low-phosphorus ordinances for lawn care should substantially reduce TP loads from urban lands. Third, targeting the application of BMP projects in the critical pollution source areas should reduce pollutant loads much more than the average reduction rates used in this estimation in Table 2.4. The quantification of pathogen load reduction is a difficult task.

The implementation plan also considers how the BMP projects are implemented in the watershed over space and time. The implementation plan is discussed in terms of a 10-year planning horizon. Table 2.5 presents the implementation schedule in 2, 5 and 10 year increments in terms of percentage of the applicable unit and the application unit for each BMP.

In addition to allocating the BMP projects across different timeframes, another important aspect of the implementation plan is the best place in the watershed to implement the BMP projects. In order to maximize the pollutant load reduction potential, especially during the first few years of implementation, BMP projects should be implemented in high priority areas identified in the project.

Table 2.5: BMP implementation schedule in the Musconetcong River Watershed

Types of BMP Projects		In 2 Years		In 5 Years		In 10 Years	
		%	Unit	%	Unit	%	Unit
1	Cover Crop	10	253	25	632	50	1,264
2	Prescribed Grazing	10	56	25	141	50	281
3	Livestock Access Control	25	3,885	50	7,769	100	15,538
4	Contour Farming	25	291	50	582	75	873
5	Nutrient Management	25	1,520	50	3,040	75	4,557
6	Conservation Buffers in Agricultural Lands	10	62	25	156	50	311
7	Livestock Waste Storage and Composting Structure	0	0	100	1	100	1
8	Manure Application Incorporation Technology	25	52	50	104	75	156
9	Rain Garden	1	7	2.5	17	5	33
10	Road Ditches	5	3	13	7	25	12
11	Detention Basin Retrofitting	25	1	50	2	100	4
12	Vegetative Buffers in Developed Lands	10	6,687	25	16,718	50	33,436

The assumption of a 10-year planning projection does not mean that it will necessarily take 10 years to achieve the required pollutant load reduction targets. Depending on funding availability and stakeholder willingness to act, many of the recommended BMP projects can be implemented at a much faster pace, however on the other side it may take longer than projected for the very same reasons. Attaining the required load reduction targets does not guarantee that the water quality and biological integrity of the streams within the watershed will increase in this set of time. After all, it takes time for reductions in pollutant loads to affect water quality.

2.7 Measurable Milestones

During the first two years after the plan has been adopted, the municipalities within the watershed should:

- Educate the residents, farmers and businesses on the water quality status in the Musconetcong River and how they should be responsible for its stewardship and land management.
- Establish implementation steps for the New Jersey State Rules for improving water quality and/or preventing water quality from continuous deterioration. These rules include, but are not limited to: New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules (N.J.A.C. 7:14A), the Stormwater Management Rules (N.J.A.C. 7:8), the Flood Hazard Area Control Act (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act (N.J.A.C. 7:7A), the Criteria and Standards for Animal Waste Management (N.J.A.C. 2:91) and the Fertilizer and Soil Conditioner Law (N.J.S.A. 4:9-15.1) for commercial and residential lawn care and management.

- Redefine their open space and farmland preservation plan for protecting hydrologically sensitive areas from future development.
- Develop the municipal ordinance for OSDS inspection, maintenance and operation that requires a 3-year certification program.
- Work with federal, state, county governmental agencies, universities, non-governmental and non-profit agencies along with local environmental consulting firms to apply for and secure the neccesary funding and technical assistance to begin implementation of the proposed BMP projects in the watershed.

The implementations of the BMP projects for the first two years as indicated in Table 2.5 below are estimated to cost $932,214 and achieve the following milestones toward the pollutant reduction goals and the attainment of water quality standards:

- Prevent further deterioration in water quality and watershed hydrology;
- Reduce 900 pounds of annual TP load, which is close to 15 percent of the required annual load reduction in TP;
- Reduce 41tons of annual sediment load, which is equivalent to 30 percent of the required annual load reduction in sediment; and
- Reduce 5 percent of the required annual load reduction in pathogens.

Implementation of the BMP projects during the first five years as indicated in Table 2.5 below are estimated to cost $2,196,513 and achieve the following milestones toward the pollutant reduction goals and the attainment of the water quality standards:

- Improvement of water quality and watershed hydrology;
- Reduce 2,249 pounds of annual TP load, which is equivalent to 40 percent of the required annual load reduction in TP;
- Reduce 103 tons of sediment load, which is equivalent to 70 percent of the required annual load reduction in sediment; and
- Reduce 60 percent of the required annual load reduction in pathogens.

The completion of the 10-year implementation of the BMP projects as indicated in Table 2.5 below is estimated to cost $4,025,055 and achieve the following milestones toward the pollutant reduction goals and the attainment of the water quality standards:

- Improvement of water quality and watershed hydrology;
- Reduce 4,497 pounds of annual TP load, which is equivalent to 80 percent of the required annual load reduction in TP;
- Reduce 205 tons of annual sediment load, which exceeds the required annual load reduction in sediment and achieve the attainment of the water quality standards on TSS;
- Achieve the required annual load reduction of 89 percent in annual pathogen loads and attain the water quality standards in pathogens.

2.8 Technical Assistance and Funding

As indicated in Table 2.4, the total cost for achieving implementation targets is about $4,025,055. That cost can be broken down into three components: (1) outreach and technical assistance costs for reaching out to stakeholders and designing BMP implementation plans, as well as obtaining any necessary permits or obeying regulations to install the BMPs; (2) BMP installation costs for related materials, labor, equipment and other items; and (3) BMP maintenance costs during and following BMP installation to ensure proper operation of each BMP. Of the $4,025,055 of implementation costs, $407,132 is for outreach and technical assistance, $3,016,478 is for installation and $601,445 is for maintenance.

Funding available for implementation of the BMPs depends on the type of project and the nature of the costs. NRCS and Farm Service Agency (FSA) support installation of agricultural BMPs through outreach, technical assistance and cost-sharing of installation costs. There are no consistent funding sources for implementing stormwater BMPs.

The funding and technical assistance for the plan are based on the following recommendations. First, all maintenance costs for installed BMPs should be the responsibility of the stakeholders. For example, homeowners should pay for the maintenance costs, i.e. upkeep, watering, for installed rain gardens. Second, a good percent of the outreach, technical assistance and installation costs for agricultural BMPs should be secured through traditional Farm Bill programs, such as the Conservation Reserve Enhancement Program (CREP), Environmental Quality Incentive Program (EQIP) and Wildlife Habitat Incentive Program (WHIP).

Table 2.6: Potential sources of funding for implementation of BMP projects

Types of BMP Projects		Total Cost	Stake-holders share	USDA	Other Sources	
					BMP Inst.	Tec. As.
1	Cover Crop	398,160	0	199,080	188,884	10,196
2	Prescribed Grazing	124,764	0	62,382	44,828	17,554
3	Livestock Access Control	179,308	31,087	74,111	44,578	29,532
4	Contour Farming	102,141	0	51,070	39,416	11,655
5	Nutrient Management	533,169	0	266,584	205,746	60,839
6	Conservation Buffers in Agricultural Lands	1,874,397	388,728	742,833	473,316	269,520
7	Livestock Waste Storage and Composting Structure	90,000	50,000	20,000	20,000	
8	Manure Application Incorporation Technology	24,336	0	12,168	12,168	
9	Rain Garden	136,950	49,500		54,450	33,000
10	Road Ditches	282,000	90,000		156,000	36,000
11	Detention Basin Retrofitting	118,000	30,000		68,000	20,000
12	Vegetative Buffers in Developed Lands	161,830	26,386		109,059	26,375
Total		4,025,055	665,701	1,428,228	1,939,897	514,671

Table 2.6 summarizes the potential sources of funding for implementation of BMP projects. Stakeholders, such as farmers and residents, could pay $665,701 of the total implementation costs. The remaining stakeholder costs are for the time and labor required to install BMPs. USDA could contribute $1,428,228 for agricultural BMPs. An additional $2,454,568 is needed from other sources of which $1,939,897 is for BMP installation and $514,671 is for outreach and technical assistance.

Other sources of funding for BMP projects include:

- NJDEP: Clean Water Act 319(h) Nonpoint Source Pollution Control Grants program
- U.S. Fish and Wildlife Service: Partners for Fish and Wildlife program and Bring Back the Natives
- U.S. EPA: Five Star Restoration Challenge Grants

2.9 Criteria and Monitoring Program

Two criteria can be used to evaluate whether a watershed restoration project was successful. The first criterion relates to changes is land use management practices. This criterion evaluate whether: (1) the proposed BMP projects are implemented into a watershed; (2) stakeholders are more aware of the impacts of their land use and management decisions; and (3) stakeholders continue to practice environmentally friendly BMPs after initial BMP funding ends. The second criterion relates to the outcomes observed in the streams and local riparian

areas. This criterion evaluates success in such categories as whether: (1) water quality and biological conditions in streams improve over time; and (2) stream channels become more stabilized.

Based on these criteria a monitoring program can be used to determine the success of these watershed restoration efforts. Such a program would include, but not be limited to the involvement of the following elements:

- Establish a database to document the BMPs that are implemented in different locations of the watershed and estimate their water quality impacts using quantitative models, such as a Spreadsheet Tool for Estimating Pollutant Load (STEPL) model;
- Continue comprehensive stream flow, water quality and biological monitoring program at the USGS 01457000 Gage Station in the watershed and compare the newly obtained water quality monitoring data to the previous data to determine whether water quality improves;
- Continue long-term biological monitoring in two biological monitoring stations within the watershed to determine long-term changes in biological conditions in the Musconetcong and its adjoining streams; and
- Use volunteer support to periodically conduct visual stream assessment using NJDEP's August 2007 Visual Assessment Protocol Plan (VAPP) to assess physical changes in the streams and their riparian zones.

2.10 Education

The success of any watershed restoration plan depends on the stakeholders' understanding of the water quality problems within the watershed, and their willingness and ability to take action to solve those problems. Education is the key to enhancing stakeholder understanding and interest as well as effecting their ability and willingness to take action. This education can take many different forms, such as public media, formal workshops or active participation in community programs offered by various agencies.
Examples of such programs are:

- River Friendly Programs
- Rain Garden Program
- Sustainable Jersey ™
- Detention Basin Retrofits
- Agriculture Mini-Grant Program
- Soil Testing Program
- Nonprofit Education for Municipal Officials (NEMO)
- Stewardship of Open Space (SOS)
- Greening of Department of Public Works (DPWs)

North Jersey RC&D will also be developing a public education program to try and inform residents of the importance of testing their septic systems for improper functionality. The ultimate goal of education programs is to improve stakeholder awareness and to promote behavior changes that will be beneficial to achieving watershed restoration.

3.0 Project Background, Purpose and Partnership

The development of the Musconetcong River Watershed Restoration Plan is funded by the Federal Clean Water Act Section 319 (h) Program administered through the Division of Policy Implementation and Watershed Restoration, formerly the Division of Watershed Management, at NJDEP. This chapter describes the general background of the planning area, project organizational structure and introduces the purpose of the watershed restoration plan.

3.1 Introduction

In the fall of 2000, NJRC&D Council was selected as the project coordinator for a watershed management initiative in the Upper Delaware Watershed. In partnership with NJDEP and NRCS, the RC&D Council supported the public education and outreach process as well as coordinated the watershed characterization and assessment work that constituted the first phase of the watershed management planning process. Phase one of the watershed management process was completed in 2003.

Through this extensive stakeholder driven management process, the Upper Delaware Watershed Management Project produced technical reports documenting the health of the region's resources. Accomplishments included:

- *Riparian Zones in the Upper Delaware Watershed, April 2002*
- *Water Resource Evaluation System for the Upper Delaware Watershed, August 2002*
- *Estimating Impervious Cover and Its Impact on Water Resources, May 2002*
- *Water Quality in the Upper Delaware Watershed, May 2001*
- *Recreational Resources in the Upper Delaware Watershed, July 2002*
- *Fish and Wildlife in the Upper Delaware Watershed, December 2002*
- *Wetlands in the Upper Delaware Watershed, November 2003*
- *Setting of the Upper Delaware Watershed, November 2001*

In February 2004, the NJDEP, Division of Watershed Management for the Northern Bureau initiated the *Priority Stream Reach Assessment Grant Program*. This grant program was designed to allocate one $25,000 grant to each watershed management area. This funding would finance the development of a more specific subwatershed characterization and assessment report plan.

In the summer of 2003, the Upper Delaware Watershed Technical Advisory Committee (TAC) met to discuss the proposed Fecal Coliform Total Maximum Daily Load (TMDL) that was being proposed for the Upper Delaware Watershed. During this TAC meeting the priority stream reach assessment program was discussed and the group selected the Musconetcong priority area between Hampton Borough and Bloomsbury Borough, Hunterdon County.

At the project onset ten sampling locations were selected for the collection of fecal coliform data. Five (5) sampling sites were chosen along the Musconetcong River mainstem and five (5) sampling sites were chosen from the six (6) tributaries that flow into the Musconetcong

River throughout Warren and Hunterdon Counties in the priority reach. See Appendix B, Map 1.

Based on the work done for the Priority Stream Reach Assessment Grant Program, in 2005, North Jersey RC&D applied for the NJ DEP fiscal year 2006 319(h) Nonpoint Source Pollution Control Grant to develop a more comprehensive Watershed Restoration and Protection Plan for the Musconetcong River and its tributaries as it flows from Hampton Borough to just above Bloomsbury Borough in Hunterdon County.

Through the additional source of funds this project involved more extensive water quality monitoring at an expanded network of sampling locations; it also included obtaining stream visual assessments and completing macroinvertebrate analysis at two locations in the watershed. Additionally through the use of these funds, North Jersey RC&D was able to more intimately work with the five municipalities and local landowners within the watershed to locate the source of pollution impact and to coordinate and implement best management practices to reduce the pollution sources affecting this area.

3.2 Purpose of the Plan

The project designers developed a watershed restoration plan that describes the management measures needed to achieve adequate levels in the reduction of fecal coliform and attain water quality standards for both TP and TSS, reduce aquatic life impairments to a non-impaired status and assess the potential for the restoration of the base flow of the Musconetcong River in the 19.6 square miles of the watershed located within the project area.

3.3 Partnership

The development of the Musconetcong River Watershed Restoration Plan is a multi-disciplinary and multi-agency collaborative effort. The collaborative partner agencies are listed below:

Administrative Agency

New Jersey Department of Environmental Protection: Division of Policy Implementation and Watershed Restoration (NJDEP)

Contact Information: Nick Zripko
P.O. Box 420
Trenton, NJ 08625-0420
(609) 633-2201
http://www.nj.gov/dep/watershedmgt/

Lead Agency

North Jersey Resource Conservation & Development (NJRC&D)

Contact Information: Grace Messinger
Executive Director
P.O. Box 5113
Clinton, NJ 08809-0113
(908)441-9191
http://www.northjerseyrcd.org

Collaborative Agencies

Musconetcong Watershed Association

Contact Information: Beth Barry
Executive Director
P.O. Box 113
Asbury, NJ 08802
(908) 537-7060
http://www.musconetcong.org

Rutgers Cooperative Extension (RCE)

Contact Information: Dr. Christopher C. Obropta, Ph. D., P.E.
Associate Extension Specialist in Water Resources
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
http://www.water.rutgers.edu

The project team was comprised of the representatives from NJDEP, RCE and MWA with NJRC&D as the project lead. Ten tasks were carried out by the project team to develop the plan. Regular project team meetings were held to communicate the progress being made and coordinate the project activities. The planning committee included the project team members as described above, representatives of the townships in the watershed project area, related agency personnel and other stakeholders such as local residents, businesses and farmers in the watershed. Two public planning committee meetings were held during the course of the project. The first planning committee meeting was held on January 30, 2007 to introduce the public to the project, the project team, the methodology being used in the project, and to seek the project volunteers as well as the public inputs on the water quality problems and their solutions in the watershed. The second planning committee meeting was held on April 29, 2008 to communicate the preliminary project results and findings to the general public and seek their inputs on the development of the plan. In place of a third planning committee meeting, the Project Team as lead by North Jersey RC&D presented the updated water quality monitoring data and implementation projects ideas as individual municipal meetings. These meetings were held with the Bethlehem Township Environmental Commission on January 20, 2009; Lebanon Township Environmental Commission on February 1, 2009; Hampton Borough Environmental Commission on February 11, 2009; Washington Township

on March 10, 2009; and with the Franklin Township representatives on March 23, 2009. A final project planning committee meeting was held on May 8, 2012 to present the watershed restoration plan and seek public input to revise and refine it and to identify opportunities for implementing the watershed restoration plan.

4.0 Watershed Description

4.1 Geography and Topography

The Musconetcong River is a tributary to the Delaware River and is classified as one of the five major subwatershed basins in the Upper Delaware Watershed. The Musconetcong River possesses one hundred fifty-six (156) square mile drainage from Hunterdon, Warren, Morris and Sussex Counties. Beginning at the headwaters and traveling to the confluence of the Delaware River, the Musconetcong River is approximately forty-two (42) miles in length. The project area, as identified in Appendix B, Map 1, encompasses seven municipalities located in Hunterdon and Warren Counties. The project area is approximately 12.6% of the entire Musconetcong River Watershed.

The project area runs southwest from Route 31 through Lebanon Township and Hampton Borough, Hunterdon County and crosses into Washington and Franklin Township, Warren County and finally ends in Bethlehem Township, Hunterdon County, prior to the Interstate 78 interchange (see Appendix B, Map 2).

Table 4.1 below references the relative size in acres of the municipalities located within the project area. Alexandria Township and Glen Gardner Borough only constitute 0.1% of the flow into the project area from their respective municipalities; therefore it is not a significant chunk of the overall drainage of the project area. Lebanon Township is a 37.7 square mile area that is located in the northern part of Hunterdon County, New Jersey. Twenty-four percent of the township drains to the Musconetcong River and 0.4% if that flows into the subwatershed project area. The township is historically an agricultural community; however growth has occurred in recent years, creating more impervious cover in the region. Hampton Borough, Hunterdon County is approximately 1.5 square miles and about eighty-nine percent of this borough drains to the Musconetcong River of which eighty-six point nine percent of that flows into the project area. Washington Township, Warren County, is seventeen point nine square miles and approximately eight point nine percent of the township drains into the project area. Franklin Township, Warren County, is twenty-four point two five square miles and approximately thirty-three percent of the township drains into the Musconetcong River project area. The project area ends in Bethlehem Township, Hunterdon County, with this township being twenty-one point eight square miles and fifty-two percent of its drainage flowing to the Musconetcong River of which forty-one point eight percent is within the project area.

Table 4.1 Musconetcong Subwatershed Municipalities

Municipality	County	Total Acres	Acres in Project Area	Percent of Municipality Draining into Project Area
Alexandria Township	Hunterdon	17,713.8	2.3	0.0%
Glen Gardner Borough	Hunterdon	1,002.0	0.9	0.1%
Lebanon Township	Hunterdon	20,410.7	79.5	0.4%
Hampton Borough	Hunterdon	982.8	854.2	86.9%
Washington Township	Warren	11,397.9	1,015.1	8.9%
Franklin Township	Warren	15,300.3	5,047.5	33.0%
Bethlehem Township	Hunterdon	13,279.9	5,547.6	41.8%
Totals	-	80,087.4	12,547.1	15.7%

4.2 Demographics

According to the 2010 census population estimates shown in Table 4.2 below, Lebanon Township has the largest population with Washington Township a close second, however neither one of these townships has a large percentage of their area draining to the project area with point four percent and eight point nine percent respectively. The municipality with the largest population influence in the project area is Hampton Borough; with eighty-six point nine percent draining to the river. These statistics are illustrated in B, Map 3.

Table 4.2: 2010 Census Population Estimates

Municipality	County	Population	% of Municipality Draining to Project Area
Lebanon Township	Hunterdon	6,588	0.4%
Hampton Borough	Hunterdon	1,401	86.9%
Washington Township	Warren	6,461	8.9%
Franklin Township	Warren	3,176	33.0%
Bethlehem Township	Hunterdon	3,979	41.8%
Totals	-	21,605	15.7%

State of New Jersey, Dept of Labor and Workforce Development. www.wnjpin.state.nj.us

4.3 Climate

The climate of the region is humid subtropical, with typical hot and humid summer months and cold winter months. According to weather data collected at the Flemington Weather Station located at 40.56ºN 74.88ºW maintained by the National Climate Center between

1955-2008 the average low temperature for the summer ranges from 55-61 ºF (12.78-16.1ºC). On average, 19 days each summer had air temperatures that exceeded 90 ºF (32.2ºC). It was rare for summer temperatures to exceed 100 ºF (37.78 ºC). The average high temperature during the winter months (December-February) was in the range of 37-41 ºF (2.78-5ºC) and an average low temperature between 19-29 ºF(-7.2- -1.67ºC). For brief time periods the winter temperatures reached low temperatures at 10 ºF (-12.23ºC) and highs of 60 ºF(15.57ºC). Spring and autumn can exhibit wide ranges in temperature variation ranging from chilly to warm, although both seasons are generally milder in temperature and lower in humidity.

Mean annual precipitation throughout the watershed was about 48 inches during the period of 1955-2008. It rained an average of 104 days a year and was uniformly spread throughout the year. Snowfall in the winter season varies from year to year but ranged between 5 and 30 inches during the same time period. For some years nor'easters (a storm that can occur at any time of year normally characterized by a combination of high winds and precipitation) occurred during winter and early spring causing blizzards or flooding. Drought and rain-free periods can last for weeks. Hurricanes and tropical storms, such as Floyd in 1999, are rare.

4.4 Hydrology

Appendix B, Map 4 shows the topography of the Musconetcong River Watershed project area. By utilizing this data along with the data in Map 7, which shows groundwater recharge and can be used to estimate infiltration rates, and Maps 6 and 5, which show bedrock formations and soil types respectively, we can gather an overall picture of the hydrology of the project area.

4.5 Geology

The ridges of these HUC 14 drainage basins are igneous and metamorphic rocks which contain older soils because it is south of the terminal moraine. The soils that make up this section include Gnesis, Annandale, Parker, Edneyville, Califon and Cokesbury. Califon and Cokesbury are the wettest soils in this series, with Cokesbury being the wettest and most poorly drained. A fragipan, the restrictive layer for plant roots and water, is contained in the Annandale, Bartley and Califon series as well. Nassau limitations are that it has shallow depth to bedrock, high rock fragment content, and is associated with rock outcrops.

The New York – New Jersey Highlands is a geological formation composed primarily of Precambrian igneous and metamorphic rock running from the Delaware River near Musconetcong Mountain, northeast through the Skylands Region of New Jersey along the Bearfort Ridge and the Ramapo Mountains, Sterling Forest, Harriman and Bear Mountain State Parks in New York, to the Hudson River at Storm King Mountain. The northern region is also known as the Hudson Highlands and the southern as the New Jersey Highlands. A broader definition would extend the region west to Reading, Pennsylvania, and east to the Housatonic River in Connecticut, encompassing the Reading Prong. (NY-NJ Highlands)

In New Jersey, the region's watershed is protected by the state's own Highlands Water Protection and Planning Act. In addition to preserving water resources, the act supports open

space preservation and the creation of new recreational parks and hiking trails in America's most densely populated state.

4.6 Soils

There are six (6) soil associations identified within the project area. The United States Department of Agriculture, Natural Resources Conservation Service (NRCS) has provided descriptions of each soil association within the county soil surveys. Appendix B, Map 6 shows the locations for the soil series present in the subwatershed study area.

Soil surveys for Hunterdon and Warren Counties were used to obtain the descriptions listed below. The Warren County Soil Survey is in the process of being updated by NRCS and that updated information will be available electronically by the end of 2007.

From the southwestern boundary of Lebanon Township into Hampton Borough, to Bethlehem Township, soils immediately adjacent to the Musconetcong River are comprised of the Rowland-Birdsboro-Raritan association. These soils are found in areas with gentle to nearly level slopes and are well to poorly drained. They are typically associated with floodplains and may be flooded during parts of the year.

The remaining drainage area Hampton to Bethlehem Township, Hunterdon County is underlain by the soils of the Duffield-Washington association and Parker-Edneyville-Califon association. The Duffield-Washington association is found in lower elevations of the Musconetcong Valley and is formed from the underlying limestone and dolomite bedrock. There are solution channels, caverns and sinkholes present. They are generally found in areas of deep, gently sloping to moderately steep areas and are well drained soil; this soil can also be found in some rocky areas. Soils of the Parker-Edneyville-Califon association are found in areas with gentle to steep slopes and are excessively to poorly drained. Cobbles and gravel sized weathered residual rock fragments are often found with these types of soils and in some cases, the gravel fragments comprise more than 20 percent of the soils. The percentage of rock fragments increase with increasing elevation. These soils are typically found from 200 to 1,000’ above sea level. The Parker-Edneyville-Califon soils form a thin layer (less than 6 feet) over the bedrock surface with occasional outcrops of bedrock. The NRCS Soil Survey indicates severe limitations for Rowland-Birdsboro-Raritan and Parker-Edneyville-Califon soil association and they are considered to be unsuitable for septic systems.

In Warren County the eastern parts of Washington and Franklin Townships that lie along the Musconetcong River are comprised of the Washington-Bartley association. These soils are found on nearly level to steep upland areas and are well to moderately well drained. They are underlain by weathered limestone and dolomite bedrock. Solution channels, caverns, and sinkholes are present in these areas. Included in this association are small areas of Nassau soils that are nearly level to steep and somewhat excessively drained. These soils have rock fragment contents that typically exceed 35 percent and are shallow to shale bedrock. They are also commonly associated with areas of rock outcrops comprised of shale bedrock.

The central parts of Washington and Franklin Townships consist of soils of the Annandale-Washington-Califon association. These soils are found on nearly level to steep upland areas

and are well to somewhat poorly drained. They formed from granitic-gneiss till, with areas of Washington being underlain by weathered limestone and dolomite bedrock. Also found in this area are soils of the Edneyville-Parker-Rock outcrop association. These soils are found on nearly level to steep upland areas and are well to somewhat excessively drained. Cobbles and gravel sized weathered residual rock fragments are often found with these types of soils and in some cases, the rock fragment content comprises more than 35 percent of the soils. The rock outcrops found in this association are dominantly granitic-gneiss bedrock.

Direct drainage to river- soils and geology surrounding the river in this section is Jacksonburg Limestone, Kittatinny Supergroup, Hardyston Quarzite- lower ground, generally is the Washington Bartley series, and is depicted in Appendix B, Map 7.

In Warren County in between Jacksonburg Limestone, Kittatinny Supergroup, Hardyston Quarzite is Martinsburg Formation and Jutland Sequence. The tributaries on the Warren County side of the Musconetcong River run through the Nassau soil type, which is made up of shale and is shallow. It is also very porous and water runs through it quickly.

4.7 Groundwater Recharge and Stream Hydrology

Groundwater recharge is defined as the water that infiltrates the ground and reaches the water table regardless of the underlying geology. It supports aquifer recharge, stream base flow and wetlands. NJDEP 1995 land-use/land-cover update and NRCS soil and municipality-based climatic data were combined and used to estimate groundwater recharge in inches per year. Recharge was then ranked by volume (billions of gallons per year) using natural breaks in the percentage of total volume. There are 6 types of state ranks within the Musconetcong River Watershed.

Table 4.3: Area distribution of groundwater recharge in the Musconetcong River Watershed

Groundwater Recharge		Area	
State Rank	Description	Acres	Percent
A	16-23 inches per year	3,350	26.7
B	11-15 inches per year	8,444	67.3
C	8-11 inches per year	0	0
D	1-7 inches per year	101	0.8
L	Hydric soils	238	1.9
W	Wetlands and open water	414	3.3
Total		12,547	100.0

Watershed hydrology characterizes water movement within a watershed in response to storm events. This is based on the type of land use and land cover, which will be dealt with later in the section, and how the water moves over or through these areas. The average annual precipitation in the Musconetcong River watershed is about 48 inches. Estimated annual mean evapotranspiration, groundwater recharge and runoff in the Musconetcong River Watershed are 16-23 inches, 11-15 inches and 1-7inches, respectively. (NJWSA, 2000).

4.8 Land Use and Land Cover

The 2007 Land Use Land Cover dataset is the fourth iteration conducted by the NJDEP to capture the state of the land use and natural land cover statewide in a digital GIS file. The initial land use land cover GIS file was based on aerial photography captured in the spring of 1986. The second iteration of the land use data was based on photography captured in 1995, the third series was based on photography captured in the spring of 2002 and the latest data was based on photography captured in 2007.

As with all previous layers, the 2007 data was produced by visually interpreting color infrared photography. Through this process, photo-interpreters examine each image, and based on their knowledge of photo signatures, classify the image into various land use/ land cover categories. The classifications are converted into a land use/land cover GIS digital file, with each delineated polygon representing a distinct land use/land cover type.

All four land use/land cover data sets contain important land use data used in a wide variety of environmental analyses. Every effort has been made to insure that all land use data sets are as accurate as possible. However LULC data are not intended to substitute for on the ground jurisdictional boundaries. Users of all data sets should refer to the links included below for more information that will help them understand the mapping process and appropriate uses and limitations of the data.

Freshwater wetlands were first mapped under the New Jersey Freshwater Wetlands Mapping Program and were incorporated into the land use land cover datasets. The freshwater wetlands delineations in these data are for screening purposes only and are **not** regulatory. The Land Use Regulatory Program (LURP) of the NJDEP determines the extent and final determination of freshwater wetlands in the State of New Jersey.

Land uses within the Musconetcong River Watershed and the subwatershed study area are shown in Table 4.4 below. Dominate land uses for the Musconetcong River Watershed consist of forest, urban, and agriculture. Land use within the subwatershed study area is dominated by agriculture, forest and urban areas. Agricultural areas are mostly located within the river valleys, and forested areas dominate the land use on the ridgelines on either side of the valleys (see Appendix B, Map 9).

Table 4.4: Musconetcong River Watershed Land Use Classifications

Land Use Land Cover Type	**Entire Musconetcong River Watershed**		**Subwatershed Study Area**	
	Area (Acres)	**%Coverage**	**Area (Acres)**	**% Coverage**
Agriculture	11,596	11.6	4,373	34.9
Barren Land	820	1.0	41	0.3
Forest	55,809	56.0	5,418	43.2
Urban	21,278	21.4	2,118	16.9
Water	4,231	4.3	76	0.6
Wetlands	5,807	5.5	521	4.2
Totals	99,541	100.0	12,547	100.0

NJDEP, Land Use by Watershed Management Areas- 2007, GIS Data Layer.

According to Table 4.5 below, land use/land cover comparison from 1986 to 2007, shows that there has been a decrease in agriculture, and an increase in forest urban land use. It must be noted that the amount of barren land in the area has increased, due in part to residential development that is happening within the watershed. This change in land use/land cover in urban areas is mostly caused by the development of single family homes while the increase in forest cover is most likely the result of old fields being taken out of production and being allowed to succeed to a woodland state.

Table 4.5: Land Use Land Cover Comparison from 1986 to 2007.

Land Use Land Cover (Type)	Acres 1986	Acres 1995/97	Acres 2002	Acres 2007	Change 1986 to 2007 (Acres)
Agriculture	6,531.3	6,161.8	5,579.7	4,372.7	-2,158.6
Barren Land	2.7	51.4	64.2	40.8	+ 38.1
Forest	3,941.7	3,994.2	4,296.1	5,417.6	+ 1,475.9
Urban	1,417.5	1,691.7	1,968.6	2,118.3	+ 700.8
Water	80.9	80.9	80.4	76.4	- 4.5
Wetlands	573.0	567.3	558.2	521.4	- 51.6

NJDEP, Land Use by Watershed Management Areas- 2007, GIS Data Layer.

The 2007 Land use/Land cover polygon shapefiles for New Jersey's Watershed Management Areas have been created by comparing the 2002 color infrared digital imagery from the 2007 imagery, and delineating areas of change. For the 2002 update, several new codes were added to the code list and were kept for the 2007 data. All polygons retain the original 1995 land use code unless it was determined that the new code could be applied retroactively so that change analysis can be done correctly. In addition, an impervious surface (IS) code has been assigned to each polygon for 2002 and 2007 as well as retaining the IS code from 1995.

As stated in this metadata record's use constraints section, NJDEP makes no representations of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied with respect to the digital data layers furnished hereunder. NJDEP assumes no responsibility to maintain them in any manner or form. By downloading this data, the user agrees to the data use constraints listed within this metadata record.

4.9 Critical Environmental Areas

4.9.1 Hydric Soils

NRCS defines a hydric soil as a soil that is formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper soil layer. Hydric soils are commonly associated with wetland areas and are strongly influenced by the presence of water. However, hydric soils and wetlands are not one in the same. To be considered a wetland an area must have hydric soils, wetland adapted vegetation and the presence of water for enough time that soils become anaerobic during the year.

4.9.2 Wetlands

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and types of plant and animal communities found in the soil and on its surface (Cowardin, 1979). For regulatory purposes under the Clean Water Act, the term wetland means "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances, do support, a prevalence of vegetation typically adapted for life in saturated conditions. Wetlands generally include swamps, marshes, bogs and similar areas (EPA Regulations listed at 40 CFR 230.3(t))." Wetlands provide important functions such as filtration of pollutants from stormwater runoff before making their way into groundwater or surface water basins, acting as storage areas for flood waters, protecting streambanks from erosion, providing wildlife habitat and providing recreation opportunities to communities. The major concern related to wetlands in the watershed is losses due to agriculture and urban development. The loss of wetlands significantly alters watershed hydrology and contributes too many of the water quality and quantity problems observed today. You can see the different types of wetlands located within the project area by referring to Map 8 in Appendix B.

NJDEP developed and maintains two types of wetlands information for general planning and regulatory purposes. The first type is delineated wetlands listed in the NJDEP land use/cover change database. These wetlands are primarily located along intermittent stream systems as well as wetlands that have been modified for recreational, agricultural or industrial uses. There are a total of 622 acres of delineated wetlands within the Musconetcong River Watershed based on the NJDEP 2007 land use/cover database. Table 4.6 lists the types of wetlands and their NJDEP class codes and acreages. The dominant types of wetlands in the watershed are deciduous wooded wetlands and agricultural wetlands, which comprise 43.9 and 34.6 percent of the total wetlands in the watershed respectively.

The second type of wetlands is the linear wetlands derived from the freshwater wetlands data developed by the New Jersey Freshwater Wetlands Mapping Program of NJDEP, which fulfills a requirement of the 1987 Freshwater Wetlands Act. This program mapped all freshwater wetland polygons greater than one acre in area and all linear freshwater wetland features greater than 10 feet in width.

Table 4.6: The types and areas of wetlands in the Musconetcong River Watershed, 2007

Types of Wetlands	NJDEP Land Use Class Code	Acres	Percent
Agricultural wetlands (modified)	2140	215	34.6
Deciduous scrub/shrub wetlands	6231	87	14.0
Deciduous wooded wetlands	6210	273	43.9
Disturbed wetlands (modified)	7430	8	1.2
Herbaceous wetlands	6240	33	5.3
Managed wetland	1850	6	1.0
Total		622	100

Sources: NJDEP 2007 land use/cover database

4.9.3 Floodplains

Floodplains are important parts of a river system that are often overlooked. Floodplains allow the water to spill over the banks and flow over the area instead of within the riverbed. This allows the flow of water to come into contact with trees, rocks and other types of debris that can slow the speed and force of the river thereby changing how it interacts with the environment further upstream. Also by allowing the water to flow over the land there will be infiltration which will decrease the overall volume of flow. Many of these areas have been altered or changed throughout history especially in areas where people live within the floodplain. Obviously it is unfeasible to think that we could repair these areas, however it is important to protect the areas that remain and allow flooding where applicable.

4.10 Open Space Preservation and Protected Areas

Hunterdon and Warren Counties participate in the Farmland Preservation Program as well as Open Space preservation within the region. These preserved lands are important to decrease the impact of urban sprawl and secure a green future for generations to come. Table 4.7 below shows that there are at least twenty preserved farms within the subwatershed project area. A look at Appendix B, Map 10 illustrates this point as well as shows the locations of at least eight open space parcels within the project area.

Table 4.7: Number of Preserved Farms per Municipality of Study Area

Municipality	County	# Preserved Farms in Twp	Located In Subwatershed
Lebanon Township	Hunterdon	13	No
Hampton Borough	Hunterdon	0	No
Bethlehem Township	Hunterdon	16	8
Washington Township	Warren	12	6
Franklin Township	Warren	22	6

Reference: Information obtained via Hunterdon Counties Farmland Preservation website and Warren Counties Farmland preservation plan.

Another important preservation program that takes place within the project area is the historic Highlands Water Protection and Planning Act (Highlands Act), which was signed into law (N.J.S.A. 13:20-1 et seq.) on August 10, 2004. The purpose of the Highlands Act is to preserve an essential source of clean and plentiful drinking water for one-half of the State's population, and to protect the State's great diversity of natural resources. The Highlands Region supplies drinking water to over 5.4 million people or approximately 379 million gallons of drinking water daily. In addition to water resources, the northern New Jersey 800,000-acre Highlands Region contains exceptional natural resources such as contiguous forest lands, wetlands, pristine watersheds, and plant and wildlife habitat. The region contains many sites of historic significance and provides abundant recreational opportunities.

The Highlands Act documents the geographical boundary of the Highlands Region in New Jersey and establishes a Highlands Preservation Area (Preservation Area) and a Highlands Planning Area (Planning Area), each of roughly 400,000 acres. Additionally, the Highlands Act required the Department to establish regulations in the Highlands Preservation Area and created a Highlands Water Protection and Planning Council to develop a regional master plan for the entire Highlands Region.

The Highlands Act sets forth requirements for major development projects in the Highlands Preservation Area, to be implemented by the Department. The Department is charged with issuing a "Highlands Preservation Area Approval" to ensure compliance with all of its regulatory programs, including those implemented pursuant to the Freshwater Wetlands Protection Act, the Flood Hazard Area Control Act, the Endangered and Non-Game Species Conservation Act, the Water Supply Management Act, the Water Pollution Control Act, the Realty Improvement Sewerage and Facilities Act (1954), the Water Quality Planning Act, and the Safe Drinking Water Act. In addition, the Highlands Act withdrew approved sewer service area designations in the Highlands Preservation Area where wastewater collection systems were not installed by August 10, 2004 (except where exemptions were specified). On October 6, 2006, the Department amended all applicable area wide Water Quality Management Plans to reflect this withdrawal of sewer service area designations.

On November 1, 2006, the Department readopted the Highlands Water Protection and Planning Act rules at N.J.A.C. 7:38, which implement the enhanced environmental standards

established in the Highlands Act. The rules establish a consolidated Highlands permitting review and approval process for activities constituting major Highland development and establish a standard to prevent the degradation of water quality in consideration of deep aquifer recharge. As a prerequisite for Department permit applications for Highlands Preservation Area development proposals, the Division of Watershed Management makes Highlands Applicability determinations (including project exemption status) and Water Quality Management Plan consistency determinations. These determinations identify regulated activities in the Highlands preservation area, determine exemption status of these activities, and determine if the activities are consistent with the Water Quality Management Plan, to guide the course of permitting for the Department under the Highlands Act. Additional information about the Highlands Act and its implementation is available on the Department's Web site at http://www.nj.gov/dep/highlands/ .

4.11 Ecological Resources

4.11.1 Wildlife and Wildlife Habitat

NJDEP Division of Fish and Wildlife classified the watershed within the group in Watershed Management Area 1. Like the rest of the Watershed Management Area 1 this watershed is dominated by agricultural fields of crops and pastures, which are normally poor habitat for wildlife. The forest in the watershed is highly fragmented and exists primarily in small patches interspersed by development and agriculture. Encroaching development, disturbance, habitat loss, fragmentation and environmental degradation threaten wildlife. Use of pesticides, mowing and other agricultural practices endanger grassland birds and their habitats (NJDEP 2008b).

This region supports two federal endangered and threatened species, six state endangered species, 11 states threatened species and 57 special concern and regional priority wildlife species, in addition to six game species of regional priority and six nongame fish species currently without state or regional status. The bog turtle is a federally threatened species that utilizes many of New Jersey's natural habitats and is on the path to extinction because of habitat degradation and destruction. The red-shouldered hawk, northern harrier, short-eared owl, upland sandpiper, vesper sparrow, green floater and Appalachian grizzled skipper are state endangered species. State threatened wildlife include the barred owl, Cooper's hawk, long-eared owl, osprey, bobolink, grasshopper sparrow, savannah sparrow, wood turtle, long-tailed salamander, tidewater mucket and yellow lampmussel. Special concern wildlife includes cavity-nesters, colonial water birds, forest passerines, freshwater wetland birds, grassland birds, raptors and scrub-shrub birds. Latin names for all these species can be located in the New Jersey Wildlife Action Plan (NJDEP, 2008b).

The Endangered and Nongame Species Program in the Division of Fish & Wildlife through NJDEP has developed the "Critical Habitats" project (also known as the Landscape Project) that identifies critical habitats for endangered and threatened species. Table 4.8 lists those species of concern supported by the Musconetcong River Watershed and the habitat priority ranks from the NJ Landscape Project.

Table 4.8: List of endangered species and their habitat priority in the Musconetcong River Watershed

Habitat Type	Name of Endangered Species	Habitat Priority Rank
Grassland	American Kestrel	2, 3 & 4
	Eastern Box Turtle	2 & 4
	Eastern Meadowlark	2
	Northern Harrier	4
Forest	Cooper's Hawk	3
	Eastern Box Turtle	2
	Forest Core	3
	Great Blue Heron	2
	Wood Turtle	3
Forest wetland	Cooper's Hawk	3
Emergent wetland	Bobolink	3

The habitat priority ranking is based on the conservation status of the species listed as follows: Rank 5 is assigned to patches containing one or more occurrences of at least one wildlife species listed as endangered or threatened on the Federal endangered and threatened species list; Rank 4 is assigned to patches with one or more occurrences of at least on State endangered species; Rank 3 is assigned to patches containing one or more occurrences of at least one State threatened species; Rank 2 is assigned to patches containing one or more occurrences of species considered to be species of special concern; and Rank 1 is assigned to patches that meet habitat-specific suitability requirements, such as minimum size criteria for endangered, threatened or priority wildlife species, but do not intersect with any confirmed occurrences of such species (Niles et al., 2008). Although the Musconetcong River Watershed supports concerned species, it does not provide an ideal habitat for those species since two and three are the most dominant habitat priority rankings.

4.11.2. Fisheries

NJDEP uses the Fisheries Index of Biotic Integrity (FIBI) to assess the attainment of the Clean Water Act goal of "fishable" waters. Data collected to determine the index are also used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. The FIBI24 measures the number of fish species, types of fish species, number of benthic insects, types of benthic insects, and ratios of trout species to piscivores (top carnivores) and proportion of individuals with disease or abnormalities.

In 2005, NJDEP's Bureau of Freshwater and Biological Monitoring determined the FIBI for the Musconetcong River at New Hampton Road at site FIBI005, (just upstream of project stream reach) it was IBI rated as *Good* which means:

- Species richness somewhat below expectation, especially due to the loss of some intolerant species;
- some species present with less than optimal abundances or size distributions;
- trophic structure shows some signs of stress (increasing frequency of generalists and tolerant species)

and the FIBI for the Musconetcong River at Asbury/Bloomsbury Road at site FIBI0061, located within project stream reach river was IBI rated as *Fair* which means. (completed SVAP at location (reference reach for mainstem) in 2007)

- Signs of additional deterioration include fewer species, loss of most intolerant species, highly skewed trophic structure (high frequency of generalists and tolerant species);
- older age classes of trout and/or top carnivores may be rare

The Habitat Score/Rating for FIBI005 was *Optimal* and *Sub-Optimal* for FIBI061. The Habitat Score/Rating includes parameters for Epifaunal Substrate/Available Cover, Embeddedness, Velocity/Depth Regimes, Sediment Deposition, Channel Flow Status, Channel Alteration, Frequency of Riffles (or bends), Bank Stability (left bank and right bank), Bank Vegetative Protection (left bank and right bank), and Riparian Vegetative Zone Width (left bank and right bank).

Habitat assessments are conducted at every sampling site and all information is recorded on field sheets (Barbour et al. 1999). Habitat assessments provide useful information on probable causes of impairment to instream biota when water quality parameters do not indicate a problem. The habitat assessment consists of an evaluation of the following physical features along the 150 meter reach: substrate, channel morphology, stream flow, bank stability, canopy, and stream side cover.

Table 4.9: Potentially Impaired sites for the Musconetcong River Watershed Project Area

FIBI Site	Waterbody	Location	County	Habitat Rating	IBI Rating
FIBI005	Musconetcong River	New Hampton Rd	Hunterdon/Warren Washington Township	Optimal	Good
FIBI061	Musconetcong River	Asbury-Bloomsbury Rd	Warren Franklin Township	Sub-Optimal	Fair

(from NJDEP: FIBI 205 volume 1 report)

Potentially Impaired Sites*: Musconetcong River - FIBI061*

The Musconetcong River site located in Franklin Township was re-sampled in 2005 after the site received a “poor” rating in 2003. Based on the hydrology and sampling difficulty at this site, along with the low species richness and overall fish abundance from the 2003 sample, the determination was made to re-sample using more effective gear.

The barge electrofishing employed on July 12, 2005 was far more effective than the previous year’s sampling method (backpack electrofishing), but the high flows due to the natural hydrology and geology likely reduced sampling efficiency, as the discharge in 2003 and 2005 was 422.5 and 265 cfs, respectively. Benthic species, such as bullheads and madtoms are often missed when sampling in higher flows. The 2005 “fair” rating is not indicative of the

surrounding habitat and is likely slightly underestimating the true biological integrity of the site.

In addition, the inclusion of stocked trout in the DELT anomaly metric has reduced the score slightly. Stocked trout typically have numerous deformities as a result of being raised in concrete hatchery raceways. These deformities in stocked fish may not be indicative of poor water quality, but merely a result of the environment in which they are raised. In addition, several young-of-the-year brown trout were collected in the mainstem Musconetcong River, but likely originated from one of the numerous trout production tributaries in the area, such as West Portal Creek.

Table 4.10: Fish Species Observed in the Musconetcong River at Route 632 (FIBI061)

Common Name	Scientific Name	Abundance	Size Range (inches)
American Eel	*Anguilla rostrata*	125	
Blacknose Dace	*Rhinichthys atratulus*	123	
Tessellated Darter	*Etheostoma olmstedi*	39	
Brown Trout	*Salmo trutta*	13	2.6 - 10.9
Longnose Dace	*Rhinichthys cataractae*	13	
Rainbow Trout*	*Oncorhynchus mykiss*	8	10.2 - 17.4
Brown Trout	*Salmo trutta*	6	10.7 - 12.5
White Sucker	*Catostomus commersoni*	5	
Cutlips Minnow	*Exoglossum maxillingua*	4	
Rock Bass	*Ambloplites rupestris*	3	6.4 - 7.2
Tiger Trout*	*Salmo trutta x Salvelinus fontinalis*	1	6.7 - 6.7
Pumpkinseed	*Lepomis gibbosus*	1	3.1 - 3.1

Source: http://www.state.nj.us/dep/wms/bfbm/download/fibi061-2.pdf
Species listed in order of abundance. Samples collected July 12, 2005.
** indicates stocked fish*

Other Important Findings*: Musconetcong River - FIBI005*

This region of the Musconetcong River is classified as FW2-TM indicating a trout maintenance stream. Although young-of-the-year trout were not collected, a number of wild and stocked trout were collected including 14 wild brown trout, 3 stocked brown trout, and 4 wild brook trout. In addition, several other intolerant species were collected including cutlips minnows (19) and margined madtoms (3) which also indicate good water quality and fish habitat. These results, along with "optimal" habitat scores in Rounds 1 and 2 and a recent "non-impaired" AMNET rating in 2002, makes this stretch of the Musconetcong River a likely candidate for upgrade to Category One antidegradation classification (NJAC 7:9B).

Table 4.11: Fish Species Observed in the Musconetcong River at New Hampton Road (FIBI005)

Common Name	Scientific Name	Abundance	Size Range (inches)
Blacknose Dace	*Rhinichthys atratulus*	281	
American Eel	*Anguilla rostrata*	147	
Tessellated Darter	*Etheostoma olmstedi*	126	
White Sucker	*Catostomus commersoni*	79	
Longnose Dace	*Rhinichthys cataractae*	56	
Cutlips Minnow	*Exoglossum maxillingua*	19	
Brown Trout	*Salmo trutta*	14	4.0 - 7.9
Smallmouth Bass	*Micropterus dolomieu*	9	1.3 - 2.2
Redbreast Sunfish	*Lepomis auritus*	5	4.3 - 5.7
Brook Trout	*Salvelinus fontinalis*	4	4.3 - 5.5
Brown Trout*	*Salmo trutta*	3	10.7 - 11.5
Spottail Shiner	*Notropis hudsonius*	3	
Margined Madtom	*Noturus insignis*	3	
Banded Killifish	*Fundulus diaphanus*	1	
Rock Bass	*Ambloplites rupestris*	1	3.3 - 3.3

Source: http://www.state.nj.us/dep/wms/bfbm/download/fibi005-2.pdf
Species listed in order of abundance. Samples collected July 21, 2005.
** indicates stocked fish*

The observed impacts and potential impacts often appear related to the habitat/water quality and the land use/land cover of the surrounding watershed. Vegetative cover and riparian buffers are important in maintaining natural stream function necessary to sustain a healthy stream community.

4.11.3 Fish Consumption Advisories

A recent NJDEP project analyzed hatchery trout (from state operated and private facilities), wild trout and trout from commercial markets for several contaminants including mercury, PCBs, DDT and its metabolites (DDD & DDE), and chlordane. The overall results show that levels of all contaminants tested in hatchery trout were low and similar to those found in trout from commercial markets. Hatchery raised and wild trout, with the exception of Schooley's Mountain Brook, are within the general fish consumption advisory for state freshwaters of no more than one meal per week for both the general population and high-risk individuals. Wild trout caught from Schooley's Mountain Brook fall within the current general population advisory of no more than one meal per week, and no more than one meal per month for high-risk individuals.

4.11.4 Typical Vegetation & Rare Plant Species / Undesirables

The watershed is made up of many different types of habitat including agricultural, forests, wetlands and urban environments. These types of lands include typical vegetation of the Raritan River Basin and New Jersey Piedmont Plain Regions. Agricultural land is devoted heavily to row crop production including, but not limited to corn, soybeans, wheat, rye, hay and pastures with fescue and various types of cool-season and warm-season grasses. Typical forest species found in the New Jersey Piedmont Plain region are red oak (*Quercus rubra*), white oak (*Quercus alba*) and black oak (*Quercus velutina*). Other less abundant canopy species include hickory (*Carya* spp.), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), tulip tree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), black cherry (*Prunus serotina*), black birch (*Betula lenta*), American elm (*Ulmus americana*) and Green Ash (*Fraxinus Americana*). The understory of the forest is dominated by flowering dogwood (*Cornus florida*) and includes saplings of canopy species. Viburnums (*Viburnum acerifolium, V.prunifolium, V. dentatum*), spicebush (*Lindera benzoin*), American hornbeam (*Carpinus caroIiniana*) and witch hazel (*Hamamelis virginiana*) are major shrub-layer species while two cherry species (*Prunus serotina, P. avium*) are commonly associated with the forest edge (Robichaud and Anderson, 1994).

Historically, agriculture and urban development have been the major threats to the diverse vegetation found in New Jersey's forests and wetlands. In recent years, however, deer, invasive and exotic species have become major threats to the states diverse vegetation as well. Deer have a significant negative impact on the abundance, growth, regeneration and diversity of approximately 700-800 native plant and animal species that utilize similar habitat in New Jersey. In areas having high deer populations, deer consume large amounts of ground cover, shrubs and smaller, younger trees affecting other creatures such as birds, driving these species' populations down to the point of local extinction (New Jersey Audobon Society, 2005). Recent surveys have estimated deer density in Hunterdon County to be over 180 individuals per square mile. This density is greater than the overall US population density of 87 individuals per square mile. The Hunterdon County Board of Agriculture concluded that deer have caused severe damage to agricultural crops and other types of vegetation. Within the county, the reported deer harvest has declined by 27 percent, from a peak of 14,700 in 1999 to 10,700 in 2006.

In the absence of native ground cover, aggressive exotic plants, many of which are introduced for ornamental purposes, begin to take over the forest floor, thereby limiting the ability of native plants and their dependent animal populations to recover or adapt. Invasive exotic plant species out-compete native species when the latter are stressed by deer, climate change, forest fragmentation and pollution. Invasive species of concern within the watershed include:

- Trees:

Norway maple *(Acer platanoides)*
Tree of heaven, Stink tree *(Ailanthus altissima)*
Princess tree, *Paulownia (Paulownia tomentosa)*
Sweet cherry, Bird cherry *(Prunus avium)*
Black locust *(Robinia pseudoacacia)*

- Shrubs*:*

Japanese barberry *(Berberis thunbergii)*
Autumn olive *(Eleagnus umbellata)*
Burning bush winged euonymus *(Euonymus alatus)*
Border privet *(Ligustrum obtusifolium)*
Tartarian honeysuckle *(Lonicera tatarica)*
Multi flora rose *(Rosa multiflora)*
Wineberry *(Rubus phoenicolasius)*
Siebold's viburnum *(Viburnum sieboldii)*

- Vines:

Porcelainberry *(Ampelopsis brevipedunculata)*
Oriental bittersweet, Asiatic bittersweet *(Celastrus orbiculatus)*
English ivy *(Hedera helix)*
Japanese honeysuckle *(Lonicera japonica)*
Grapevine *(Vitis spp.)*
Wisteria *(Wisteria floribunda)*

- Annuals, Biennials, and Perennials*:*

Garlic mustard *(Alliaria petiolata)*
Mugwort *(Artemisia vulgaris)*
Crown vetch *(Coronilla varia)*
Purple loosestrife *(Lythrum salicaria)*
Japanese knotweed, Mexican bamboo *(Fallopia japonica)*
Periwinkle, myrtle, vinca *(Vinca minor)*

- Grasses*:*

Japanese stiltgrass, basket or wire grass *(Microstegium vimineum)*
Hardy bamboo *(Arundinaria, Bambusa,* Dendrocalamus ssp.)
Common reed (*Phragmites australis)*

Vegetation within the Musconetcong River Watershed is visibly impaired by deer brows and invasive species such as multiflora rose (*Rosa multiflora*), barberry (*Berberis thunbergii*) and autumn olive (*Elaegnus umbellate*), which are less paltable to deer. Non-native invasive species suppress regeneration of native vegetation because they can grow without regard to competition or herbivory. Autumn olive and multiflora rose shade the herb layer, limiting growth of lower level vegetation which holds soil in place and prevents erosion. Notable exposure of soil in forests is common within the watershed.

5.0. Physical Condition

Streams and rivers function to convey water from high to low points in the terrain in addition to providing habitat for wildlife and aquatic organisms. The force of gravity pulling the water downhill provides the energy to erode soil and cut stream channels to facilitate the movement of water. A stream's conveyance function is often evaluated by its shape and configuration, also known as its geomorphology. Erosion, the resulting sedimentation and the state of the riparian area are major factors in the watershed affecting the physical condition of the stream as well as its water quality and suitability for aquatic life

5.1 Erosion

Erosion is a natural process by which precipitation moves sediment from one area to another. This process has been increased through the years, however, due to decreased area for infiltration. In a natural setting (as portrayed in Image 5.1) approximately 10% of precipitation becomes runoff, while the presence of impervious cover can increase this amount to as high as 55%. This increase in the volume of water washing over the landscape inevitably increases the rate of erosion.

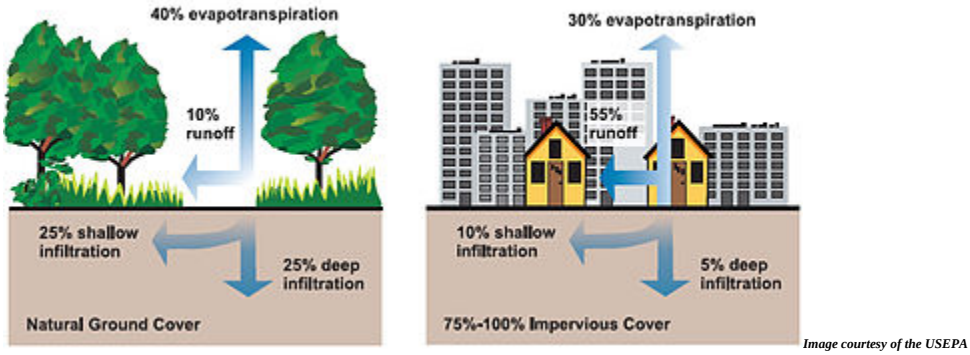

Image courtesy of the USEPA

Figure 5.1- Natural ground cover and impervious cover and their effects on infiltration rates

5.2 Hydromodification

Stream flow normally takes the path of least resistance, and this path can change over time. Therefore the path the water takes can modify or alter the landscape in profound ways. Over time, as erosion and other factors take place, the stream channel can shift to different locations within its flood zone depending on this path of least resistance. Human activities can aid and even speed up this process by altering the stream floodplains and increasing the amount of water that makes it to the stream channel.

5.3 Riparian Areas

Riparian areas are categorized as the transitional zone between an aquatic environment (rivers, streams, lakes or wetlands) and the terrestrial environment, but are more commonly

referred to as the area directly adjacent to a river or stream. Riparian areas are typically more productive and possess higher plant and animal diversity than surrounding upland areas by providing water, food, cover, migration routes and connectors between habitats.

Flood control is often times overlooked as a benefit of riparian buffers. Floods cannot be prevented and are natural occurrences within nature, however due to human disturbances such as development (parking lots, homes, roads, exposed bare soils etc) runoff is increased and storm flows within streams are increased drastically. Poor stormwater runoff management contributes greatly to flashy, high water flood events, however streams that have an intact riparian buffer (with trees) can slow flood flows, resulting in reduced downstream flood peaks.

Riparian areas also provide a means of reducing nonpoint source pollution. Nonpoint source pollution is most simply defined as: pollution that is generally generated as a result of precipitation (rainfall or snowmelt) moving over the land through surface runoff and shallow ground water transferring natural and human-made pollutants into lakes, rivers, wetlands and coastal waters.

The health of the riparian corridor within the study area was assessed using a model that was developed by Hughes and Lathrop (2001). This model, was created for use within two sub-watersheds within the Upper Delaware Watershed. This project attempted to develop an accurate, simple methodology for riparian health in Northwestern New Jersey using readily available data from state and federal governmental agencies. The model has been modified and run for the entire Upper Delaware Watershed (McGinnis, 2001).

The model first defines riparian areas based upon hydrology factors. A riparian area in this model is either: defined as a wetland by NJDEP Freshwater Wetlands maps; has hydric soils as defined by USDA Natural Resources Conservation Service (NRCS) soils maps; or is floodprone as defined by US Geologic Survey (USGS) 100 year floodplain maps. An area is defined as riparian under the model if any one of the three criteria above is found immediately adjacent to a stream. In the original model developed by Hughes and Lathrop, in some areas along streams (steep slopes near first and second order streams for example) there are no flood plains, no hydric soils and no wetlands adjacent to streams in the watershed. The health and condition of the streamside vegetation is still very important in these areas. The McGinnis version of the model created a 40-foot wide strip (the width of one pixel in the database) on each side of any stream without one of the three defining hydrology factors. Every stream will then have at least an 80-foot riparian zone (40 feet on each side of the stream) in which the relative health was characterized. This results in a continuous area that will have all of the streamside vegetation characterized.

The second part of the model assesses the relative health of the defined riparian areas. The health was characterized by examining surface water quality designations from NJDEP, land use/land cover data from NJDEP and threatened and endangered species data from the NJ Division of Fish & Wildlife's "Landscape Project."

5.4 Stream Visual Assessment Protocol (SVAP)

This project did not utilize the Visual Assessment Project Plan (VAPP) August 2007 which was developed by the NJDEP because it was not available at the time the 319 grant contract was finalized. Instead the Project Team used the United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS) Stream Visual Assessment Protocol (SVAP) to gather baseline data for this project. The SVAP is used to score a site based on a set of 15 indicators, including:

• Channel condition: Natural vs. altered channel (e.g., channelization; installation of riprap, dikes or levies; or downcutting or incision).
• Hydrologic alteration: Connectivity to the floodplain (e.g., structures or channel incision that limit the stream's access to the floodplain).
• Riparian zone: Stream's buffer area (e.g., a perfect score requires natural vegetation to extend at least two active channel widths on each side of the stream. A lower score, for instance a 5, is given when natural vegetation extends only half the active channel width on each side of the stream).
• Bank stability: Bank condition (banks are either level with the floodplain and stable or are higher and eroding; banks have exposed roots or slope failures present with the reach).
• Water appearance: Water clarity (clear with visible bottom or cloudy/murky).
• Nutrient enrichment: Presence of algae and/or aquatic macrophytes (A stream with a diverse plant community and clear water scores a 10; a stream with greenish water and an overabundance of algae and/or macrophytes scores a 3).
• Barriers to fish movement: Withdrawals, culverts, dams or diversions both up and downstream of the reach.
• Instream fish cover: Available cover types for fish habitat (e.g., woody debris, riffles, pools, and cobble).
• Pools: Abundance and depth of pools within the reach.
• Invertebrate habitat: Number of cover types available as habitat.
• Canopy cover: Coldwater versus warmwater fisheries. The project area is considered a coldwater fishery, thus a reach that is well shaded would score high, whereas a reach that is minimally shaded would score low.
• Manure presence: Evidence of livestock in or near the stream; it was not scored for any of the project sites.
• Salinity: Non-applicable for the project watershed.
• Riffle embeddedness: Embeddedness of cobble or gravel in sediment.
• Macroinvertebrates observed: Type and diversity of species present. A site with a good diversity of pollution intolerant species received a score of 15, while a site dominated by more pollution tolerant organisms might receive a 6. It should be noted that several of the SVAPs were performed during the fall and winter months, which are not ideal months for the observation of macroinvertebrates.

Once the team chose a segment for assessment, the active channel width was measured. A reach that was 12 times the active channel width was then scored from one to 10 (one to 15 for Macroinvertebrates observed and one to five for manure presence) based on the 15 parameters described above; any parameter that was not applicable to a particular site was not scored. In the project watershed, salinity was determined to be not applicable. The scores for

each parameter were summed and divided by the total number of parameters scored to yield the SVAP score.

The SVAP relies heavily on relative comparison of sites, rather than a rigorous quantitative analysis; it is a screening assessment tool rather than a site-specific monitoring protocol, and therefore is subjective. Each parameter is scored based on the assessor's observations of a particular reach. For this reason, the Project Team ensured consistency of assessors among all of the sites. The SVAP assessors included the North Jersey RC&D Watershed Specialist, the Musconetcong Watershed Association Executive Director, NJDEP AmeriCorps Watershed Ambassador for the Upper Delaware Watershed, Musconetcong Watershed Association and residents of Bethlehem Township Environmental Commission and RCE Water Resources Program staff.

The SVAP provided a great deal of useful information regarding the Musconetcong River and its corresponding tributaries. The shortfall of the protocol is that it fails to provide a mechanism for identifying the cause of identified problems.

6.0 Surface Water Quality

6.1 Designated Uses and Impairments

6.1.1 Designated Uses

Water quality criteria are developed according to the waterbody's designated uses (NJDEP, 2011c). The Musconetcong River is classified as FW2-TM, or freshwater (FW) trout maintenance (TM). "FW2" refers to waterbodies that are used for maintenance, migration, and propagation of natural and established biota; primary contact recreation; industrial and agricultural water supply; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "TM" means those freshwaters designated for the support of trout throughout the year (NJDEP, 2011c). The applicable water quality criteria for this project are detailed in Table 6.1.

6.1.2 Impairments

Based upon numerous monitoring sources, including the New Jersey Department of Environmental Protection (NJDEP) Ambient Biomonitoring Network (AMNET), the NJDEP/United States Geological Survey (USGS) water quality monitoring network, and the Metal Recon Program, the Musconetcong River near Bloomsbury was listed on Sublist 5 of the New Jersey 2002 Integrated Water Quality Monitoring and Assessment Report (NJDEP, 2002a) for fecal coliform and pH. The Musconetcong River at New Hampton Road in Lebanon Township was listed on Sublist 5 for Aquatic Life, as well. The fecal coliform impairment has been addressed through the TMDL process. A TMDL for fecal coliform has been adopted for the Musconetcong River; therefore, this parameter has been moved to Sublist 4a. This TMDL requires 93% reductions in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands (NJDEP, 2003).

The Musconetcong River near Bloomsbury was listed on Sublist 5 of the New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report (NJDEP, 2004) for pH. The Musconetcong River at New Hampton road in Lebanon was listed on Sublist 5 for benthic macroinvertebrates. According to the 2006 Integrated List, which used a HUC-14 based water quality impairment listing methodology, the Musconetcong River (HUC 02040105160040 and 50) had no listing on Sublist 5 (NJDEP, 2006). In addition, the Musconetcong River at New Hampton Road in Lebanon was delisted for benthic macroinvertebrates, and the Musconetcong River near Bloomsbury was delisted for pH based on more recent and/or more accurate data that demonstrated that the designated use was being met for the waterbody (NJDEP, 2006). According to the most recent listings (i.e., the 2008 Integrated List and 2010 Integrated List) the Musconetcong River (HUC 02040105160040 ~ 75d 00m to Rt. 31) is on Sublist 5 for aquatic life (general and trout) and the Musconetcong River (HUC 02040105160050 ~ I-78 to 75d 00m) is on Sublist 5 for aquatic life (trout). The specific pollutant identified in this case is temperature (NJDEP, 2009; NJDEP 2011b).

Based on the conditions/impairments described above, the Musconetcong River Watershed Restoration and Protection Plan project team, North Jersey Resource Conservation &

Development Council, Rutgers Cooperative Extension Water Resources Program, and the Musconetcong Watershed Association, was assembled. A 319(h) grant proposal was submitted by the team to NJDEP in 2006 to develop a plan for the 19.6 square mile Musconetcong River Watershed from Route 31 in Hampton to the USGS gauging station #01457000 near Bloomsbury. The goal of the overall project is to develop a watershed restoration and protection plan that, through its implementation, will improve water quality in the project area. The development of the Musconetcong River Watershed Restoration and Protection Plan was funded in 2006 by the NJDEP (RP06-073) under the 319(h) program.

Table 6.1 Applicable Surface Water Quality Criteria –
N.J.A.C.7:9B (*Last Amended: April 4, 2011 43 N.J.R. 833(a)*)

Substance	Surface Water Classification	Criteria
Bacterial quality (Counts/100 ml) *E. coli*	FW2	*E. coli* shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL
Bacterial quality (Counts/100 ml) *Fecal Coliform – former criterion for bacterial quality*	*FW2*	*Fecal coliform 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*
Dissolved oxygen (mg/L)	FW2-TM	24 hour average not less than 6.0. Not less than 5.0 at any time.
pH (Standard Units)	FW2	6.5 – 8.5
Total Phosphorus (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.
Solids, Suspended (Non-filterable residue) (mg/L)	FW2-TM	25.0
Temperature (°C)	FW2-TM	Temperatures shall not exceed a daily maximum of 25 degrees Celsius or rolling seven-day average of the daily maximum of 23 degrees Celsius, unless due to natural conditions. *(Current criterion)*
Temperature (°C) – former criterion	*FW2-TM*	*No thermal alterations which would cause temperatures in excess of 20 °C*
Nitrate (mg/L)	FW2	10 mg/L (human health criterion)

6.2 Monitoring Stations

For the most part, the sampling locations for this study are established sampling locations from a 2004 NJDEP Priority Waters initiative. An initial visual assessment and data collection provided by the WMA 1 Technical Advisory Committee identified priority sites where sampling for fecal coliform could provide additional data or site-specific information.

6.2.1 Monitoring Program May 2007 - October 2007

To further characterize the impairments identified in the *Integrated List of Waterbodies* from 2002, 2004 and 2006 within the Musconetcong River Watershed, the Rutgers Cooperative Extension Water Resources Program began surface water quality monitoring in May 2007 in accordance with an approved QAPP (See Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan). Surface water quality samples were collected from ten sampling locations within the Musconetcong River Watershed as described in Table 6.2 and mapped in Figure 6.1.

6.2.2 Monitoring Program for August 2008

The project team identified seven additional monitoring locations to obtain a more complete picture of the sources of impairment in the Turkey Hill Brook and West Portal Brook subwatersheds. Additional monitoring was conducted during August 2008 to further characterize the input of bacteria, in particular fecal coliform and *E. coli*, along these two subwatersheds. The seven additional monitoring locations are shown in Figure 6.1 and in Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan (See Addendum: June 30, 2008 – *revised July 18, 2008)* and are described in Table 6.3. Sampling was conducted in accordance with the approved July 2008 addendum to the QAPP (See Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan). Site #12 was dry during August 2008; therefore only six sites were monitored.

6.2.3 Monitoring Program for May 2009

Six additional locations were selected to obtain a more complete picture of the sources of impairment in the West Portal Brook, the unnamed tributary along Shurts Road, and the unnamed tributary in Hampton Borough. The additional sampling locations are shown in Figure 6.1 and in Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan (See Addendum: March 9, 2009 – *revised April 24, 2009)* and described in Table 6.4. Sampling was conducted in accordance with the approved April 2009 addendum to the QAPP (See Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan) and included sampling at established sites #2, #11, #7, #13, and #14. Sites #2, #21, and #22 were dry for most of the sampling events.

Table 6.2 Description of and basis for water quality monitoring locations within the Musconetcong River Watershed, 2007 monitoring program

Site	Description	Basis for Sampling
1	Musconetcong River at the Route 31 crossing in Hampton, NJ	Site #1 was selected to serve as the upstream control prior to potential effluent from Hampton septic systems and cesspools entering the river. This site delineates the upstream boundary of the study area.
2	Unnamed Tributary/Stormwater Outfall flowing through Hampton, just upstream of confluence with the Musconetcong River	Site #2 was selected to show if fecal impairments in the Musconetcong are coming from potentially failing septic systems in the Borough of Hampton.
4	Musconetcong River at the Valley Road crossing downstream of Hampton	Site #4 was selected to determine the levels of fecal coliform in the river downstream of potential septic effluent from Hampton.
11	Unnamed Tributary at Maple and Shruts Road in Washington Township	Site #11 was selected to determine a baseline fecal coliform level and to determine how this tributary influences the river between Site #4 and Site #6.
5a	Unnamed Tributary flowing from the village of Asbury, just upstream of confluence with the Musconetcong River	Site #5a was selected to determine if the Asbury village septic systems are influencing the tributary.
6	Musconetcong River downstream of Asbury	Site #6 was selected to determine the levels of fecal coliform in the river downstream of potential septic effluent from Asbury.
7	West Portal Brook just upstream of confluence with Musconetcong River	Site #7 was selected to help identify if loadings are coming from the livestock in this subwatershed.
8	Musconetcong River at the Valley Station Road crossing	Site #8 was selected to determine the levels of fecal coliform in the river downstream of the potential agricultural inputs of Site #7.
9	Unnamed Tributary just upstream of confluence with Musconetcong River	Site #9 was selected to help identify if loadings were coming from the livestock in this subwatershed.
10	Musconetcong River at Person Road crossing at the USGS monitoring station near Bloomsbury (#01457000)	Site #10 was selected as it delineates the downstream end of the priority subwatershed.

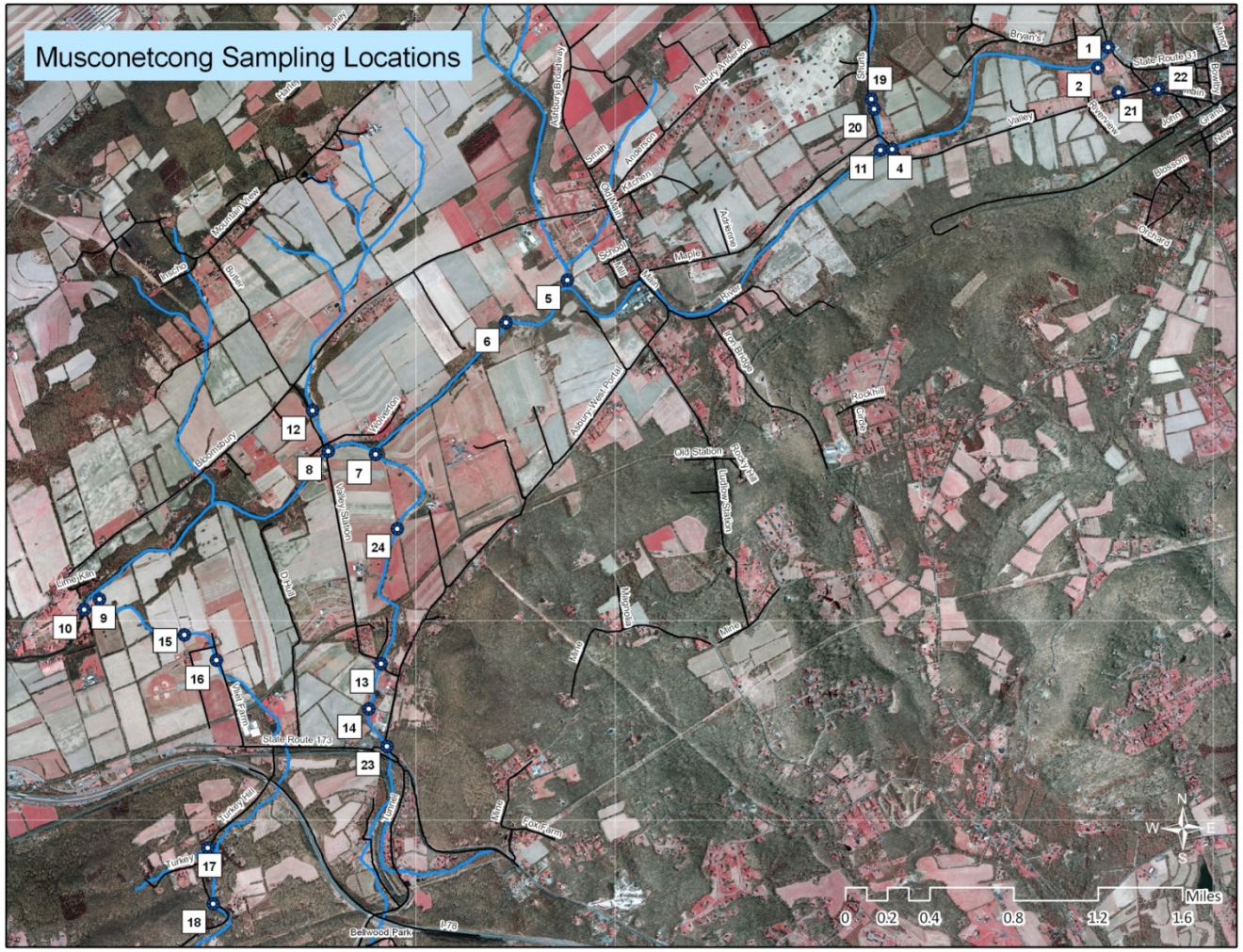

Figure 6.1 Musconetcong River Watershed monitoring locations, May 2007 - September 2010

Table 6.3 Additional monitoring locations for August 2008 bacteria monitoring

Site	Description	Basis for Sampling
#12	Unnamed Tributary, Warren County, Wolverton Road, by pipeline	Site #12 was selected to further characterize any bacteria input from the Warren County tributaries in the watershed.
#13	West Portal Brook, Hunterdon County, Valley Station Road, near bridge by old stone structure	Sites #13 and #14 were selected to characterize bacteria from suspected septic inputs and from livestock along West Portal Brook, upstream of the establish Site #7
#14	West Portal Brook, Hunterdon County, behind school	
#15	Turkey Hill Brook, Hunterdon County, downstream from small animal farm near Heritage Park	Sites #15 and #16 were selected to characterize bacteria inputs from a small animal farm along Turkey Hill Brook, upstream of Site #9.
#16	Turkey Hill Brook, Hunterdon County, upstream from small animal farm near Heritage Park	
#17	Turkey Hill Brook, Hunterdon County, off Turkey Hill Road, approximately 0.6 miles up road	Sites #17 and #18 were selected to characterize bacteria inputs from miscellaneous agricultural operations, as well as suspected septic inputs along Turkey Hill Brook, upstream of established Site #9 and Sites #15 and #16.
#18	Turkey Hill Brook, Hunterdon County, off Turkey Hill Road, approximately one mile up road	

Table 6.4 Additional monitoring locations for May 2009 bacteria monitoring

Site	Description	Basis for Sampling
Site #19	Unnamed Tributary, Warren County, Shurts Road	Sites #19 and #20 were selected to characterize bacteria inputs to an unnamed tributary along Shurts Road prior to its confluence with the Musconetcong River just downstream from established Site #4.
Site #20	Unnamed Tributary, Warren County, Shurts Road below pond outlet	
Site #21	Unnamed Tributary, Hunterdon County, Hampton Borough off Valley Road above Borough Park	The Hampton locations, #21 and #22, were selected after discussions with Borough officials while sharing the 2007 and 2008 sampling data information. Potential human sources of bacteria were suspected in this area.
Site #22	Unnamed Tributary, Hunterdon County, Hampton Borough upstream of Site #21 off Main Street	
Site #23	West Portal Brook, Hunterdon County, Asbury-West Portal Road just after stop sign above school	Sites #23 and #24 were selected to further characterize bacteria from suspected septic inputs and from livestock along West Portal Brook, upstream of the established Site #7 to help further justify the implementation and benefit of a project on agricultural property along West Portal Brook.
Site #24	West Portal Brook, Hunterdon County, Asbury-West Portal Road in between agricultural properties	

6.3 Summary of Water Quality Data - Results and Trend Analyses

6.3.1 Monitoring Program May 2007 - October 2007

To further characterize the impairments identified in the *Integrated List of Waterbodies* from 2002, 2004 and 2006 within the Musconetcong River Watershed, the Rutgers Cooperative Extension Water Resources Program began surface water quality monitoring in May 2007 in accordance with an approved QAPP. Surface water quality samples were collected from ten sampling locations within the Musconetcong River Watershed as described in Table 6.2 and mapped in Figure 6.1.

The temporal and spatial aspects of the surface water quality monitoring program for 2007 are summarized in Table 6.5. The tabulated water quality monitoring results from the biweekly and additional bacteria sampling are presented in Appendix B of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan. Basic summary statistics (i.e., n, minimum, maximum, mean, and standard deviation) are provided with the tables. The results from the biweekly and additional bacteria sampling for suspected parameters of concern (i.e., pH, temperature, total phosphorus, fecal coliform, and *Escherichia coli* (*E. coli*)) are graphed in Appendix C of the August 2011 Water Quality Monitoring Data Report found in Appendix B of this plan.

According to the approved May 2007 QAPP, three wet weather sampling events, at a minimum, were to be conducted between May and October 2007 at each sampling location. It was difficult to capture wet weather events as proposed in the approved QAPP. The laboratories will not accept samples after 4 pm and before 7 am, as well as on weekends; many, if not all, of the significant rainfall events that occurred between May and October 2007 were during these time periods. Furthermore, it was difficult to capture runoff from "scattered thundershowers," especially when they only occurred in a portion of the watershed, as was common during the designated sampling period of May through October 2007.

The USGS program “PART” was used to estimate base flow in the Musconetcong River at Site #10 (http://water.usgs.gov/ogw/part/). Based on flows above the calculated base flow and 36 hour rainfall totals from local weather stations, probable storm events that were captured during the biweekly surface water sampling included June 4, July 30, and August 13, 2007. Elevated pathogen counts (i.e., fecal coliform and *E. coli*) were observed on these sampling dates, and it was concluded, based on the PART analysis, that the 2007 monitoring program did include wet weather surface water sampling to some extent.

To evaluate the health of the Musconetcong River Watershed, the monitoring results were compared to applicable surface water quality criteria. The percentage of samples that exceeded the surface water quality criteria is provided in Table 6.6. A high percentage of the samples collected throughout the Musconetcong River Watershed, as part of the biweekly and additional bacteria sampling exceeded both the current bacteria criteria for *E. coli* and the former criteria for fecal coliform. Elevated temperature levels were observed throughout the watershed. A single violation of the pH minimum criterion at Site #9 and at Site #5a was observed, and a single violation of the total phosphorus criterion was observed at Site #9, at Site #7, and at Site #8.

The NJDEP’s Integrated Water Quality Monitoring and Assessment Methods indicates 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, 2011a). Clearly the Musconetcong River Watershed's quality is compromised given the continual and persistent violations of the surface water quality criteria for bacteria and the occasional elevated surface water temperatures. Total phosphorus and pH are not parameters of concern for the Musconetcong River Watershed.

To evaluate the relationship of water quality to land use within the Musconetcong River Watershed, the median concentration/level of the parameters of concern (i.e., temperature, *E. coli*, and fecal coliform) were plotted in relation to increasing agricultural land use (Figures 6.2-6.5), increasing forested land use (Figures 6.6-6.9), and increasing urban land use (Figure 6.10-6.13). Agricultural, forested, and urban land uses are the three largest land uses found within the watershed (See Figure 6.14). With an increase in agricultural land use, a slightly decreasing trend in *E. coli* and fecal coliform concentrations was noted. With an increase in forested land use, an increasing trend in *E. coli* and fecal coliform concentrations was found. No trends were noted for temperature, *E. coli*, or fecal coliform with respect to increasing urban land use. In addition, no trends were noted for temperature with respect to agriculture or forest land uses.

Table 6.5 Summary of temporal and spatial aspects of surface water quality monitoring program for the Musconetcong River Watershed, 2007 monitoring program

Type:	**Biweekly Surface Water Sampling**	**Additional Bacteriology Sampling**
Frequency:	Two (2) times a month from May - October 2007 (12 events)	Three (3) times, in addition to biweekly samples, in June, July, & August 2007 (9 events)
Parameters:	pH, temperature, dissolved oxygen (DO), stream width, stream depth, stream velocity, ammonia-N (NH_3-N), nitrate-N (NO_3-N), nitrite-N (NO_2-N), total Kjeldahl nitrogen (TKN), total phosphorus (TP), dissolved orthophosphate phosphorus (DOP), total suspended solids (TSS), fecal coliform, *E. coli*	Stream width, stream depth, stream velocity, fecal coliform, *E. coli*
1	X	X
2	X	X
4	X	X
11	X	X
6	X	X
5a	X	X
8	X	X
7	X	X
9	X	X
10	X	X

Table 6.6 Percentage of samples from the biweekly and additional bacteria sampling that exceeded surface water quality criteria (SWQC)

Site	SWQC	Count	Minimum	Maximum	Mean	% not satisfying SWQC
pH (SU)						
10	minimum 6.5 (SU)	14	6.64	8.01	7.40	0
9		8	5.71	7.62	7.11	13% (1/8)
7		12	6.67	8.15	7.44	0
8		12	6.93	8.01	7.58	0
5a		12	6.31	7.82	7.05	8% (1/12)
6		12	6.74	7.89	7.59	0
11		12	6.99	7.80	7.53	0
4		12	6.90	8.33	7.78	0
1		14	6.94	8.26	7.86	0
Temperature (°C)						
10	No thermal alterations which would cause temperatures in excess of 20°C	14	13.1	21.5	17.7	0
9		8	14.4	23.3	17.7	13% (1/8)
7		12	11.0	17.8	15.4	0
8		12	13.3	21.9	18.1	33% (4/12)
5a		12	12.6	22.0	18.0	25% (3/12)
6		12	13.6	22.0	18.2	25% (3/12)
11		12	13.5	16.4	14.6	0
4		12	14.3	22.3	18.7	33% (4/12)
1		14	14.6	22.6	19.2	33% (4/12)
***E. coli* (org./100 ml)**						
10	Single sample maximum of 235 (counts/100 ml)	21	110	4,100	346	81% (17/21)
9		17	320	80,000	6,629	100% (17/17)
7		21	670	92,000	9,221	100% (21/21)
8		21	200	5,100	519	86% (18/21)
5a		20	200	7,300	502	75% (15/20)
6		21	90	2,500	286	57% (12/21)
11		21	20	2,900	129	38% (8/21)
4		21	120	2,500	284	71% (15/21)
1		21	120	3,300	278	52% (11/21)
Fecal Coliform (col/100 ml)						
10	No more than 10% of the total samples taken during any 30-day period can exceed 400 (counts / 100 ml)	21	100	960	307	38% (8/21)
9		17	580	28,000	3,654	100%(17/17)
7		21	180	42,000	6,039	95% (20/21)
8		21	100	1,400	468	52% (11/21)
5a		21	60	10,000	528	48% (10/21)
6		21	100	1,000	315	29% (6/21)
11		21	8	2,300	151	19% (4/21)
4		21	120	1,100	307	29% (6/21)
1		21	44	1,400	222	19% (4/21)
Total Phosphorus (mg/L)						
10	0.1mg/L in any stream	12	0.03	0.09	0.06	0
9		8	0.05	0.19	0.08	13% (1/8)
7		12	0.06	0.11	0.08	8% (1/12)
8		12	0.03	0.11	0.05	8% (1/12)
5a		12	0.03	0.08	0.05	0
6		12	0.03	0.08	0.05	0
11		12	0.01	0.09	0.03	0
4		12	0.03	0.11	0.05	0
1		12	0.03	0.08	0.05	0

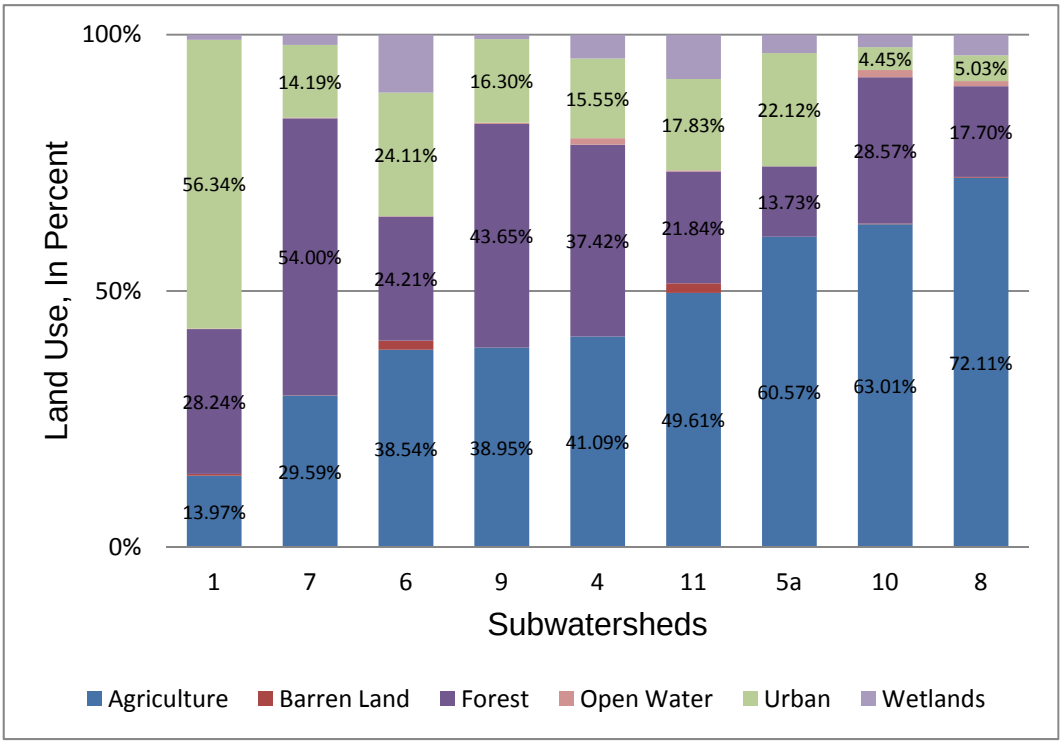

Figure 6.2. Increasing percent agriculture land use by subwatershed

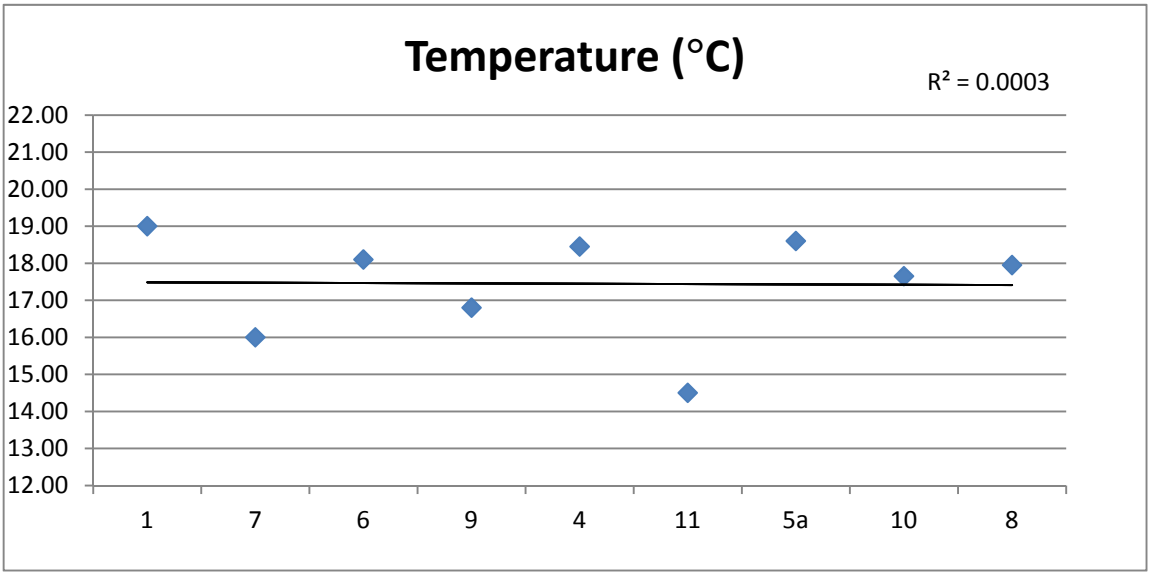

Figure 6.3. Relation of median value of temperature to percent agriculture land use within the Musconetcong River Watershed

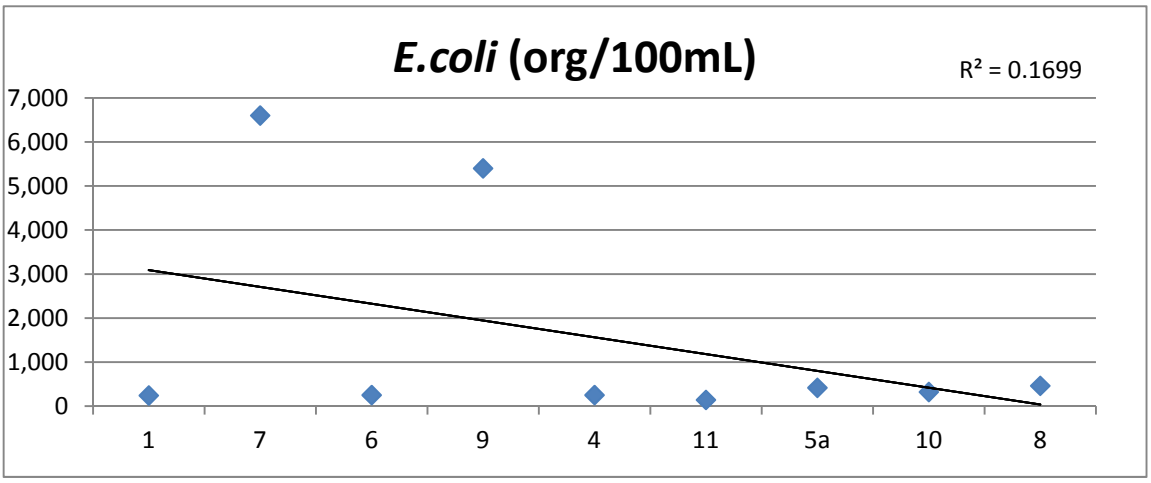

Figure 6.4. Relation of median value of E. coli to percent agriculture land use within the Musconetcong River Watershed

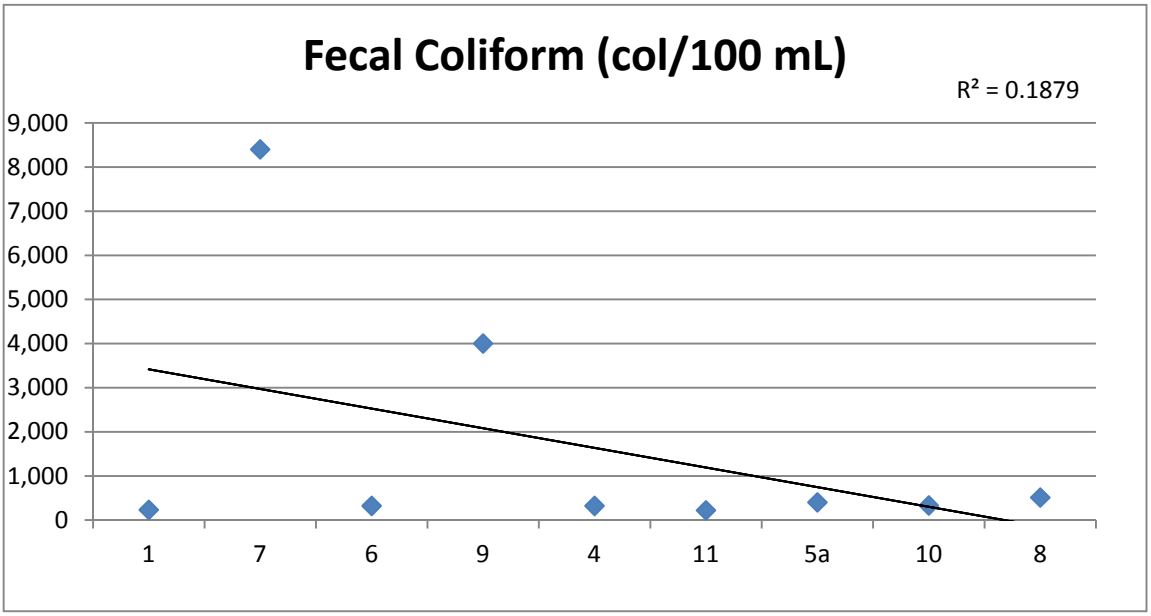

Figure 6.5. Relation of median value of fecal coliform to percent agriculture land use within the Musconetcong River Watershed

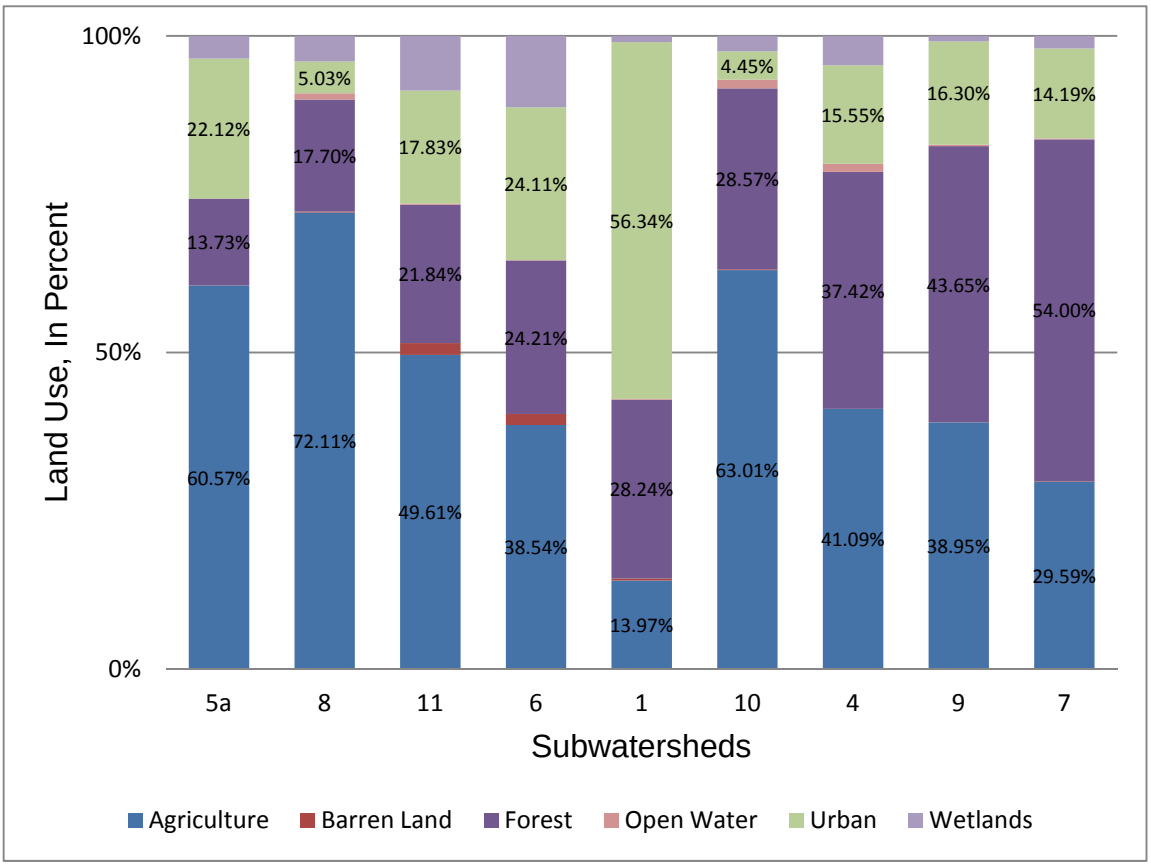

Figure 6.6. Increasing percent forest land use by subwatershed

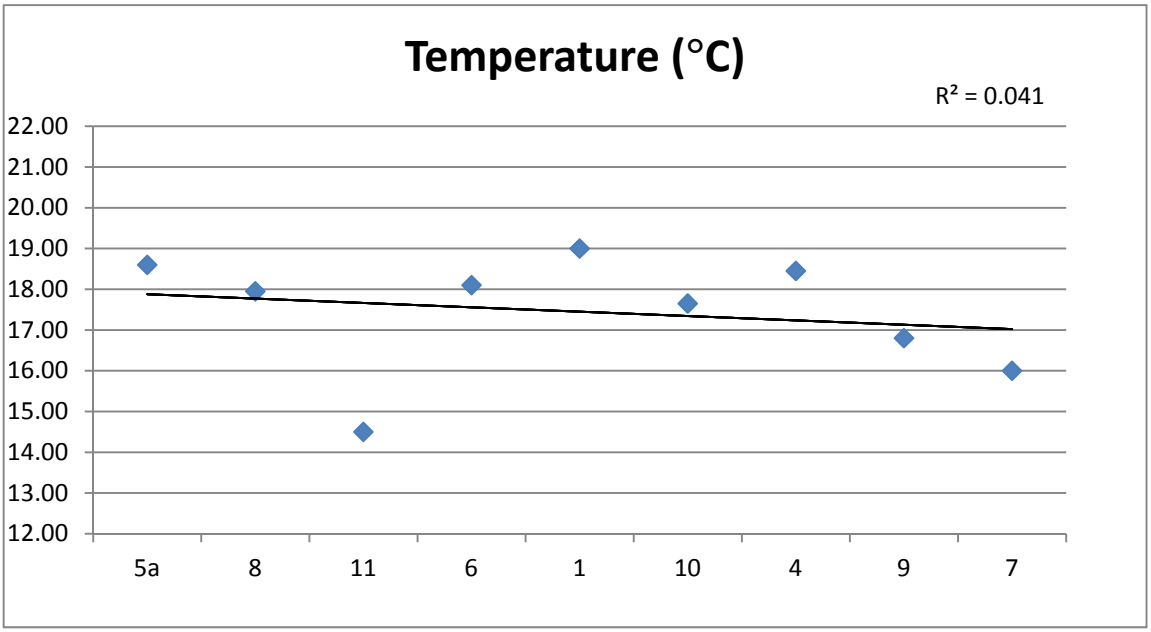

Figure 6.7. Relation of median value of temperature to percent forest land use within the Musconetcong River Watershed

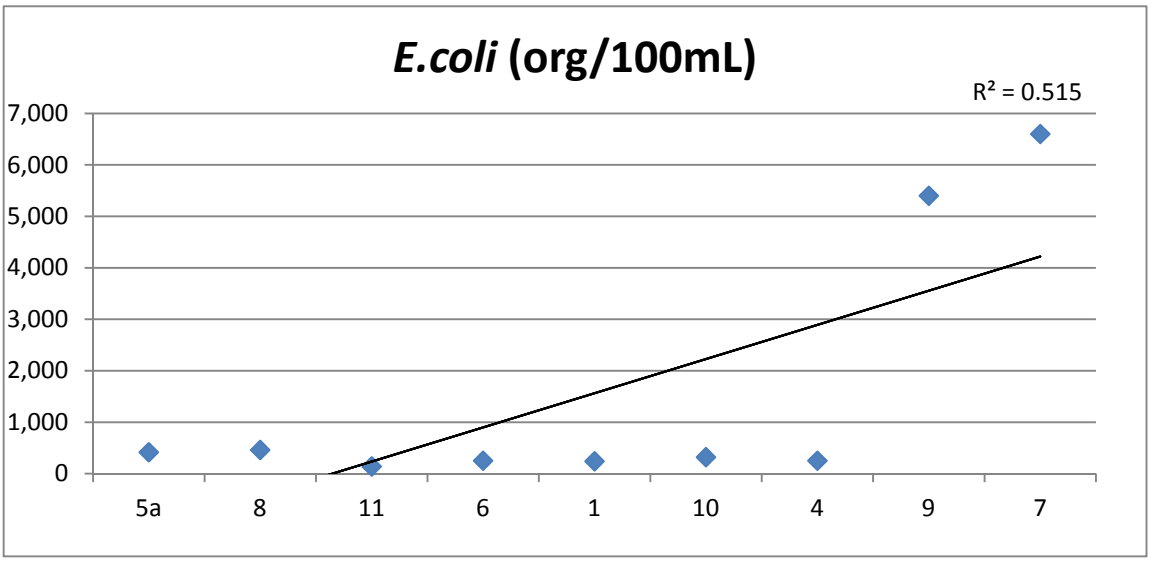

Figure 6.8. Relation of median value of E. coli to percent forest land use within the Musconetcong River Watershed

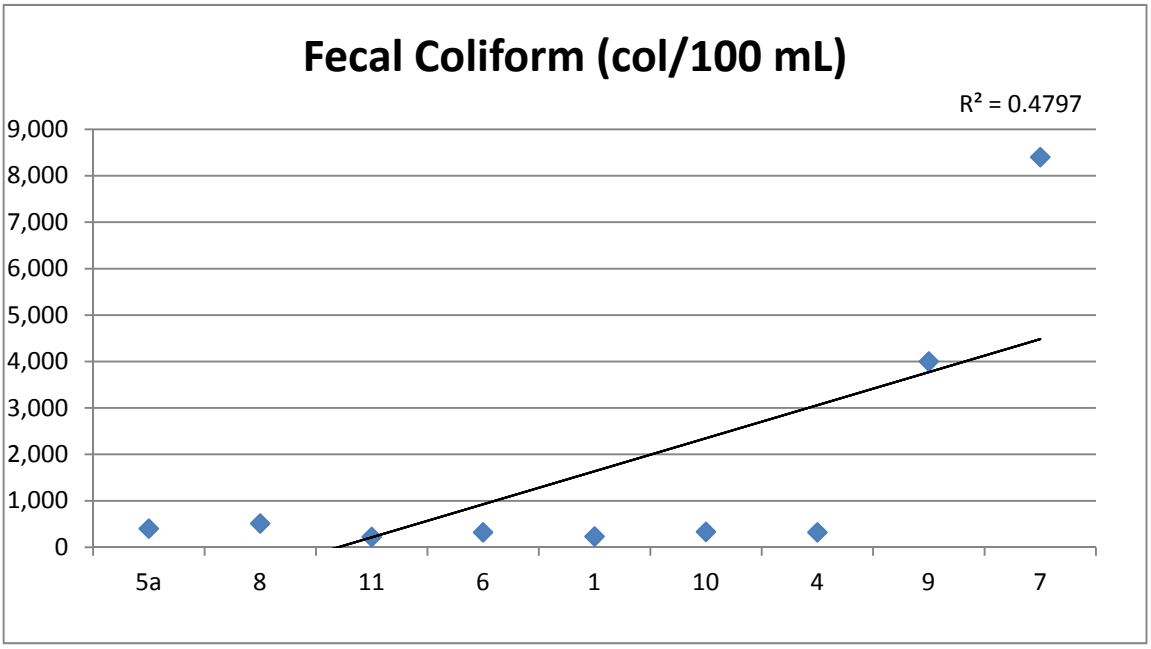

Figure 6.9. Relation of median value of fecal coliform to forest land use within the Musconetcong River Watershed

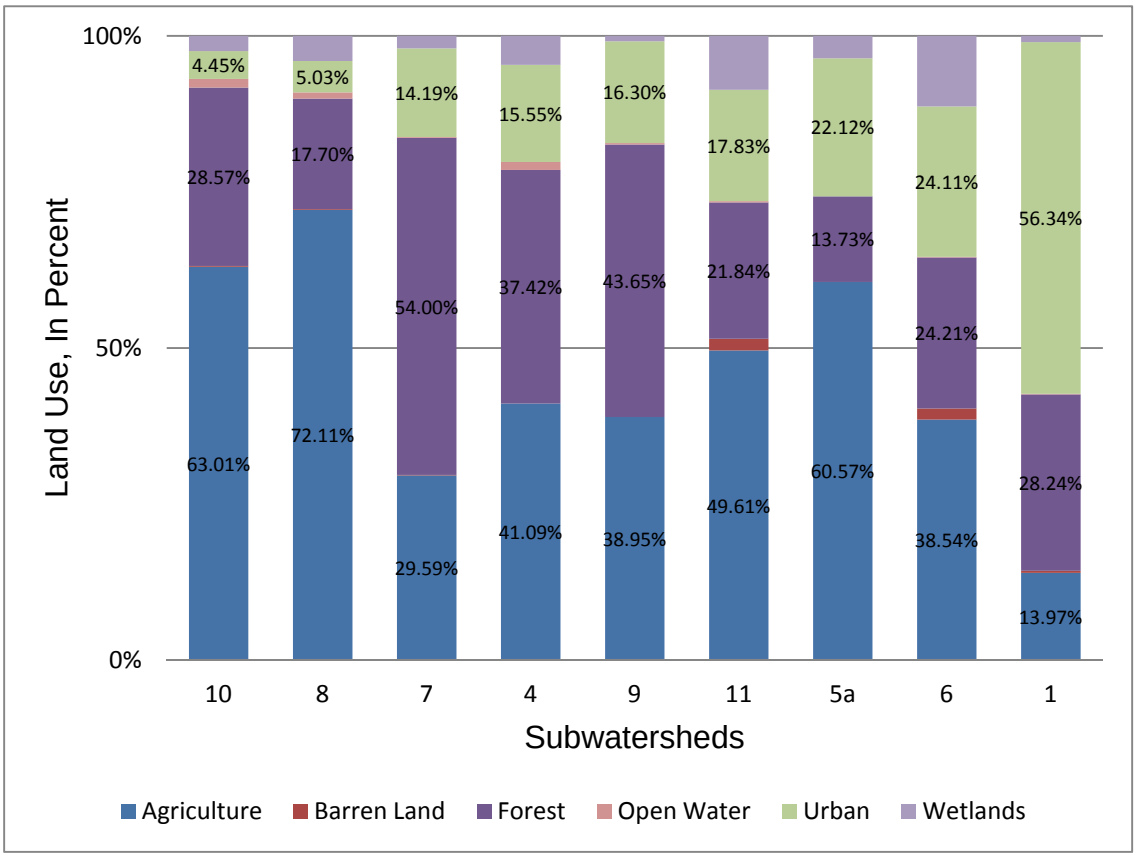

Figure 6.10. Increasing percent urban land use by subwatershed

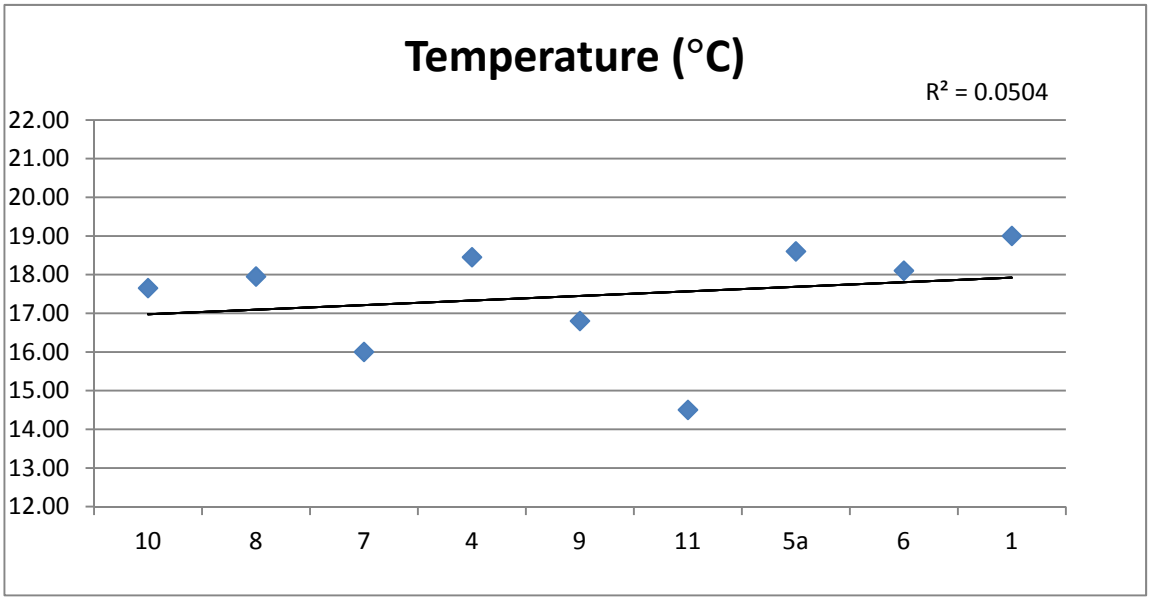

Figure 6.11. Relation of median value of temperature to percent urban land use within the Musconetcong River Watershed

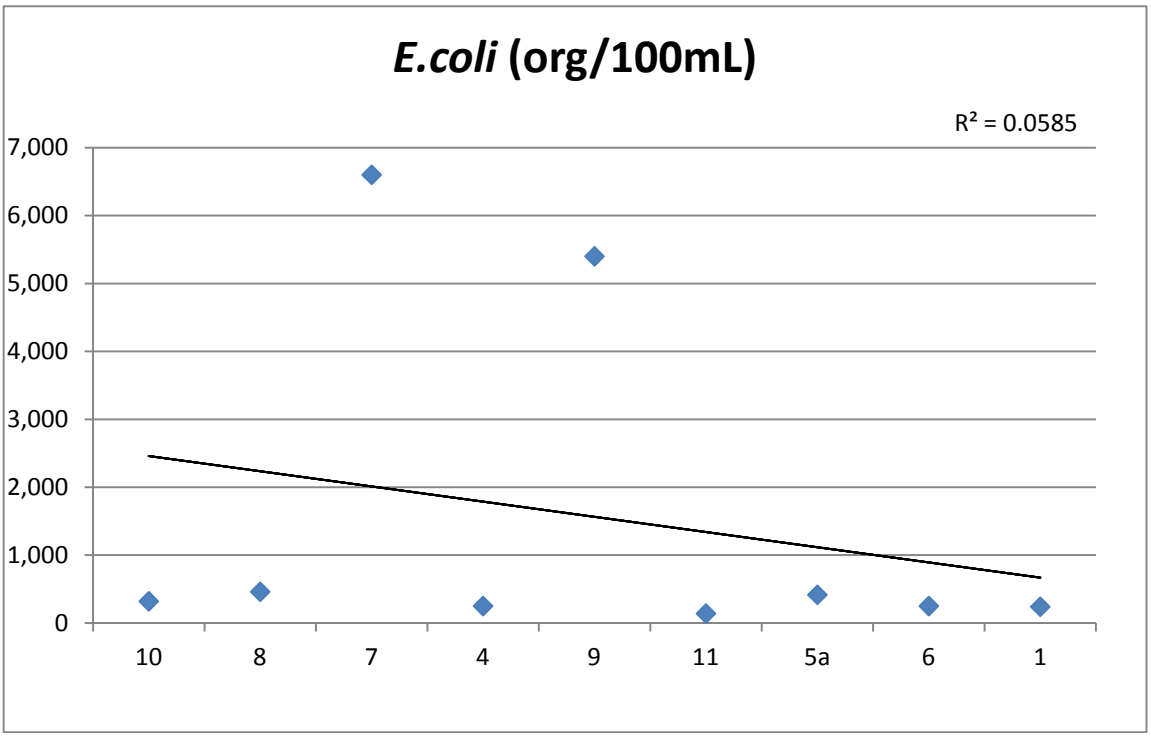

Figure 6.12. Relation of median value of E. coli to percent urban land use within the Musconetcong River Watershed

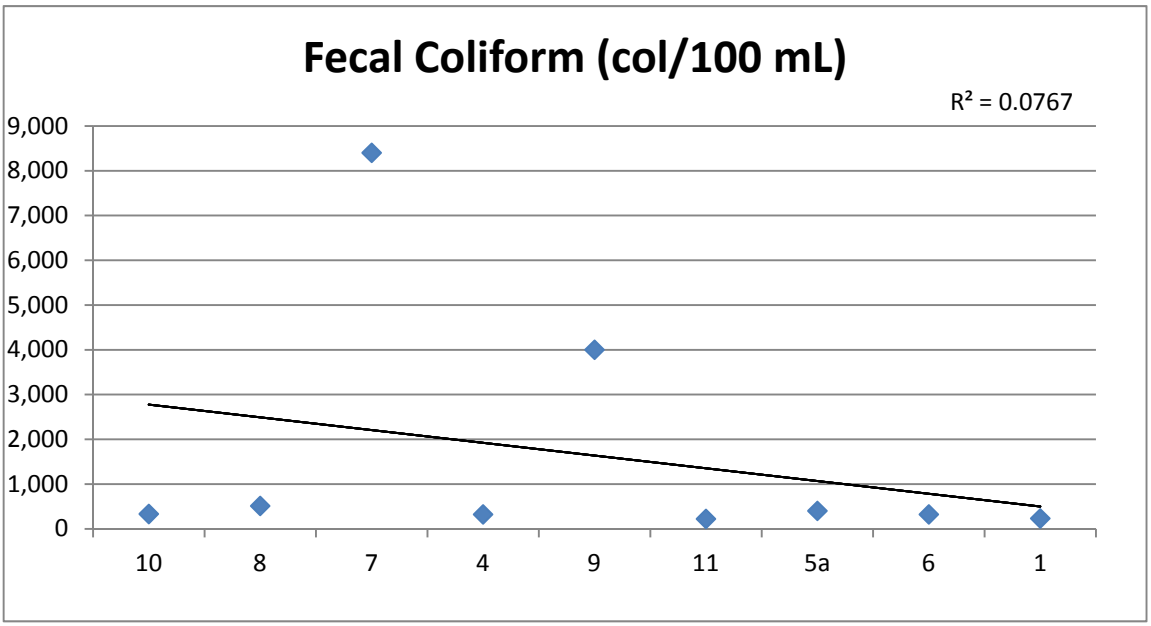

Figure 6.13. Relation of median value of fecal coliform to urban land use within the Musconetcong River Watershed

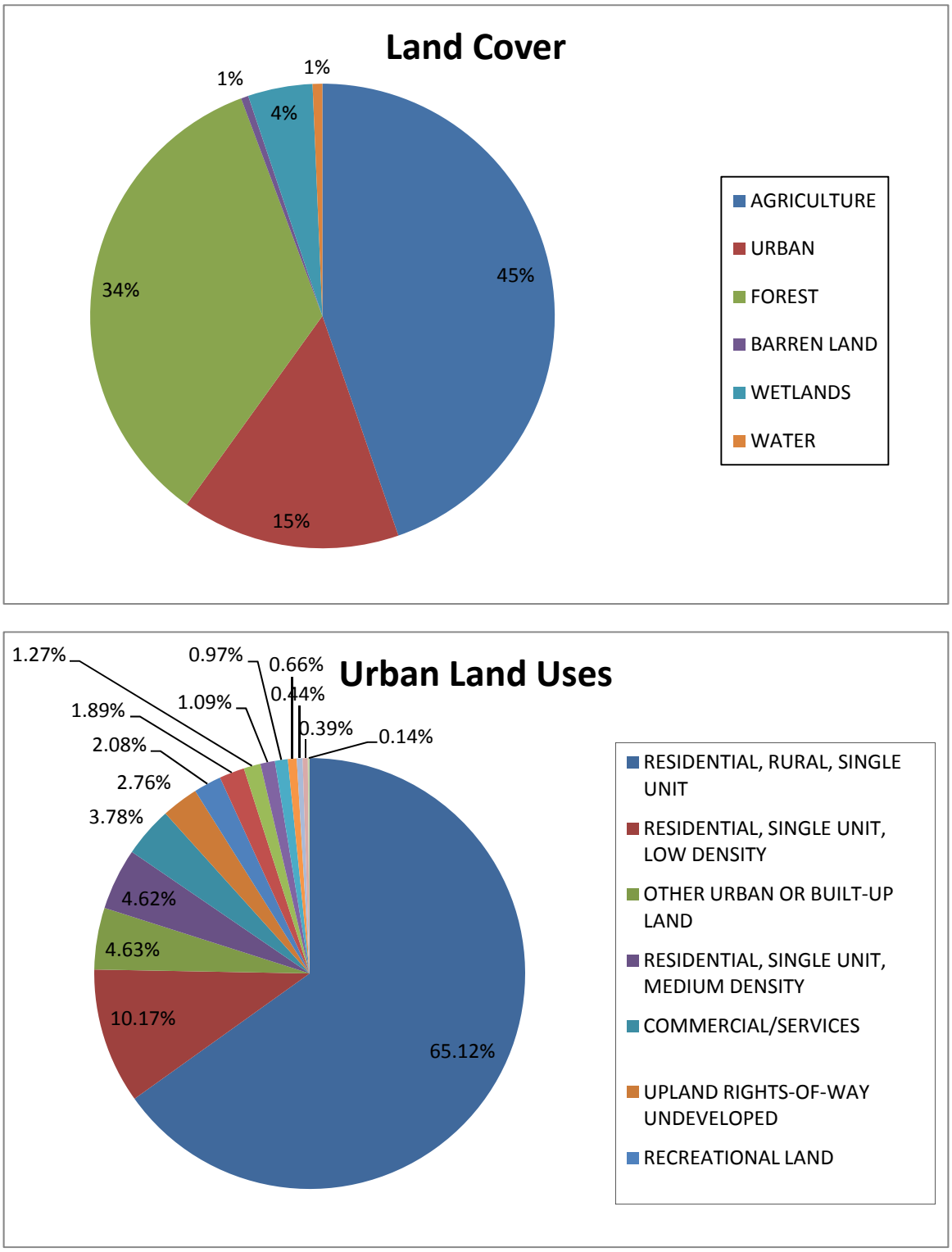

Figure 6.14. Land cover and urban land distribution for the Musconetcong River Watershed (NJDEP, 2002b)

6.3.2 Monitoring Program for August 2008

In February 2007 the North Jersey RC&D, along with the Rutgers Cooperative Extension Water Resources Program and the Musconetcong Watershed Association, met with NJDEP to present findings from the 2007 monitoring program. Two of the most severely impacted subwatersheds, West Portal Brook and Turkey Hill Brook, were identified. Monitoring conducted during May 2007 through October 2007 revealed highly elevated fecal coliform and *E. coli* levels in the West Portal Brook subwatershed at Site #7 and in the Turkey Hill Brook subwatershed at Site #9, just upstream of their confluence with the Musconetcong River.

Rather than continue to try to collect wet weather surface water samples as defined in the approved May 2007 QAPP, the Project Team identified seven additional monitoring locations to obtain a more complete picture of the sources of impairment in the Turkey Hill Brook and West Portal Brook subwatersheds. Additional monitoring was conducted during August 2008 to further characterize the input of bacteria, in particular fecal coliform and *E. coli*, along these two subwatersheds. The seven additional monitoring locations are shown in Figure 6.1 and are described in Table 6.2. Sampling was conducted in accordance with the approved July 2008 addendum to the QAPP. Site #12 was dry during August 2008; therefore only six sites were monitored.

Three out of the six sites monitored (i.e., #13, #15, and #17) exceeded the surface water quality criterion for *E. coli* (i.e., *E. coli* shall not exceed a geometric mean of 126 counts/100 mL), and 43% of the samples collected exceeded the single sample criterion for *E. coli* (i.e., single sample maximum of 235 counts/100 mL). The same three sites (i.e., #13, #15, and #17) exceeded the former surface water quality criterion for fecal coliform (i.e., fecal coliform shall not exceed a geometric mean of 200 counts/100 mL), and 47% of the samples collected exceeded the former single sample criterion for fecal coliform (i.e., single sample maximum of 400 counts/100 mL). These monitoring results are summarized in Table 6.7.

In addition, *E. coli* was monitored at the seven additional monitoring locations and at the ten established sampling locations from the 2007 monitoring program during three storm events on July 14, 2008, July 24, 2008, and September 26, 2008. In regard to this wet weather sampling, 86% of the samples collected exceeded the surface water quality criterion for *E. coli* (i.e., single sample maximum of 235 counts/100 mL). These data are summarized in Table 6.8.

Table 6.7. Results of August 2008 bacteria monitoring

Site	Date	*E. coli* (col/100 ml)	Fecal Coliform (col/100 ml)
#13	08/06/08	240	520
#13	08/14/08	150	480
#13	08/20/08	230	220
#13	08/26/08	560	280
#13	08/28/08	320	390
mean		***272***	***359***
#14	08/06/08	20	50
#14	08/14/08	230	690
#14	08/20/08	100	50
#14	08/26/08	190	40
#14	08/28/08	20	60
mean		***71***	***84***
#15	08/06/08	4,800	6,900
#15	08/14/08	3,900	7,500
#15	08/20/08	2,900	2,800
#15	08/26/08	6,500	11,000
#15	08/28/08	5,000	5,800
mean		***4,460***	***6,211***

Site	Date	*E. coli* (col/100 ml)	Fecal Coliform (col/100 ml)
#16	08/06/08	90	540
#16	08/14/08	680	1,300
#16	08/20/08	40	40
#16	08/26/08	70	60
#16	08/28/08	20	60
mean		***81***	***159***
#17	08/06/08	560	1,200
#17	08/14/08	5,800	7,800
#17	08/20/08	210	350
#17	08/26/08	190	100
#17	08/28/08	180	180
mean		***472***	***568***
#18	08/06/08	250	1,200
#18	08/14/08	570	660
#18	08/20/08	30	20
#18	08/26/08	40	20
#18	08/28/08	10	5
mean		***70***	***69***

Table 6.8. Results of bacteria monitoring conducted during three storm events during the summer of 2008

Site	Date	*E. coli* (col/100 ml)
#1	7/14/08	360
	7/24/08	1,500
	9/26/08	850
#2	7/14/08	*NO FLOW*
	7/24/08	860
	9/26/08	1,300
#4	7/14/08	1,400
	7/24/08	1,000
	9/26/08	400
#11	7/14/08	80
	7/24/08	80
	9/26/08	100
#6	7/14/08	360
	7/24/08	540
	9/26/08	350
#5a	7/14/08	3,600
	7/24/08	140
	9/26/08	1,600
#8	7/14/08	220
	7/24/08	1,000
	9/26/08	1,200
#7	7/14/08	8,600
	7/24/08	900
	9/26/08	2,900
#9	7/14/08	9,000
	7/24/08	6,600
	9/26/08	3,700
#10	7/14/08	880
	7/24/08	960
	9/26/08	1,300

Site	Date	*E. coli* (col/100 ml)
#12	7/14/08	18,000
	7/24/08	540
	9/26/08	5,100
#13	7/14/08	1,800
	7/24/08	580
	9/26/08	900
#14	7/14/08	560
	7/24/08	420
	9/26/08	500
#15	7/14/08	3,600
	7/24/08	1,100
	9/26/08	3,400
#16	7/14/08	2,700
	7/24/08	1,300
	9/26/08	200
#17	7/14/08	6,800
	7/24/08	4,800
	9/26/08	4,600
#18	7/14/08	200
	7/24/08	280
	9/26/08	600

6.3.3 Monitoring Program for May 2009

The results of bacteria monitoring conducted during three storm events during the summer of 2008 and during August 2008 revealed elevated fecal coliform and *E. coli* levels in three subwatersheds of the Musconetcong River. Additional monitoring was conducted to further characterize the input of bacteria, in particular fecal coliform and *E. coli*, along the three subwatersheds. Six additional locations were selected to obtain a more complete picture of the sources of impairment in the West Portal Brook, the unnamed tributary along Shurts Road, and the unnamed tributary in Hampton Borough. The additional sampling locations are shown in Figure 6.1 and described in Table 6.4. Sampling was conducted in accordance with the approved April 2009 addendum to the QAPP and included sampling at established sites #2, #11, #7, #13, and #14. Sites #2, #21, and #22 were dry for most of the sampling events.

Three out of the eight sites monitored (i.e., #7, #24, and #13) exceeded the surface water quality criterion for *E. coli* (i.e., *E. coli* shall not exceed a geometric mean of 126 counts/100 mL), and 48% of the samples collected exceeded the single sample criterion for *E. coli* (i.e., single sample maximum of 235 counts/100 mL). Two sites (i.e., #7 and #24) exceeded the former surface water quality criterion for fecal coliform (i.e., fecal coliform shall not exceed a geometric mean of 200 counts/100 mL), and 39% of the samples collected exceeded the former single sample criterion for fecal coliform (i.e., single sample maximum of 400 counts/100 mL). These monitoring results are summarized in Table 6.9.

Table 6.9. Results of May 2009 bacteria monitoring

Site	Date	*E. coli* (org/100 ml)	Fecal Coliform (org/100 ml)
#7	05/07/09	2,600	1,300
#7	05/11/09	2,700	1,200
#7	05/14/09	2,000	950
#7	05/18/09	2,400	1,100
#7	05/21/09	1,500	390
mean		***2,191***	***913***
#24	05/07/09	2,200	1,600
#24	05/11/09	780	600
#24	05/14/09	2,400	2,300
#24	05/18/09	1,100	1,000
#24	05/21/09	1,000	530
mean		***1,353***	***1,032***
#13	05/07/09	480	230
#13	05/11/09	210	120
#13	05/14/09	490	210
#13	05/18/09	210	40
#13	05/21/09	130	60
mean		***267***	***107***
#14	05/07/09	380	380
#14	05/11/09	140	90
#14	05/14/09	30	20
#14	05/18/09	50	50
#14	05/21/09	10	20
mean		***60***	***58***
#23	05/07/09	470	510
#23	05/11/09	180	70
#23	05/14/09	20	20
#23	05/18/09	70	20
#23	05/21/09	20	10
mean		***75***	***43***
#11	05/07/09	23,000	20,000
#11	05/11/09	40	20
#11	05/14/09	10	10
#11	05/18/09	30	30
#11	05/21/09	10	40
mean		***77***	***86***
#20	05/07/09	270	300
#20	05/11/09	10	<10
#20	05/14/09	10	<10
#20	05/18/09	40	10
#20	05/21/09	10	10
mean		***26***	***20***
#19	05/07/09	47,000	44,000
#19	05/11/09	40	30
#19	05/14/09	10	<10
#19	05/18/09	<10	<10
#19	05/21/09	10	<10
mean		***72***	***67***
#2	05/07/09	2,600	3,500
#21	05/07/09	1,000	1,400
#21	05/11/09	6,200	26,000
#22	05/07/09	3,100	6,700

6.3.4 Temperature Monitoring Program for Summer 2010

Sites #1, #4, and #10 were selected to monitor temperature conditions in the mainstem of the Musconetcong River. Temperatures were found to be elevated in the summer of 2007, and several exceedances of the surface water quality criteria for temperature were noted at that time. The North Jersey RC&D, Rutgers Cooperative Extension Water Resources Program, and the Musconetcong Watershed Association, in consultation with NJDEP, decided that a more extensive database through continuous monitoring would help confirm if temperature impairments do in fact occur along the mainstem. The Rutgers Cooperative Extension Water Resources Program, in accordance with the approved QAPP (See Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix A of this plan- Addendum June 28, 2010 – *revised September 13, 2010*) deployed three (3) HOBO® U22 Water Temp Pro v2 Logger units in the Musconetcong River at Sites #1, #4, and #10. The HOBO units were programmed to continuously monitor temperature at two minute increments from late June through late September 2010. Unfortunately, the HOBO unit at Site #4 was vandalized, and only the data from Sites #1 and #10 were recovered for the monitoring period.

The daily maximum temperatures recorded at Sites #1 and #10 for the monitoring period were plotted (See Figure 6.15) with respect to the first part of the current surface water quality criterion for temperature (i.e., *Temperatures shall not exceed a daily maximum of 25 °C* … (NJDEP, 2011c)). Only 1% of the daily maximum temperatures at Site #10 exceeded the daily maximum portion of the criterion for the monitoring period, whereas 9% of the daily maximum temperatures at Site #1 exceeded the criterion. The seven-day rolling/moving average of the daily maximum temperatures was calculated for Sites #1 and #10 for the monitoring period and plotted (See Figure 6.16) with respect to the second part of the current surface water quality criterion for temperature (i.e., …*or rolling seven-day average of the daily maximum of 23 °C* (NJDEP, 2011c). Approximately 23% of the daily maximum temperatures measured at Site #10 and 38% of the daily maximum temperatures measured at Site #1 exceeded the rolling seven-day average of the daily maximum portion of the criterion during the monitoring period.

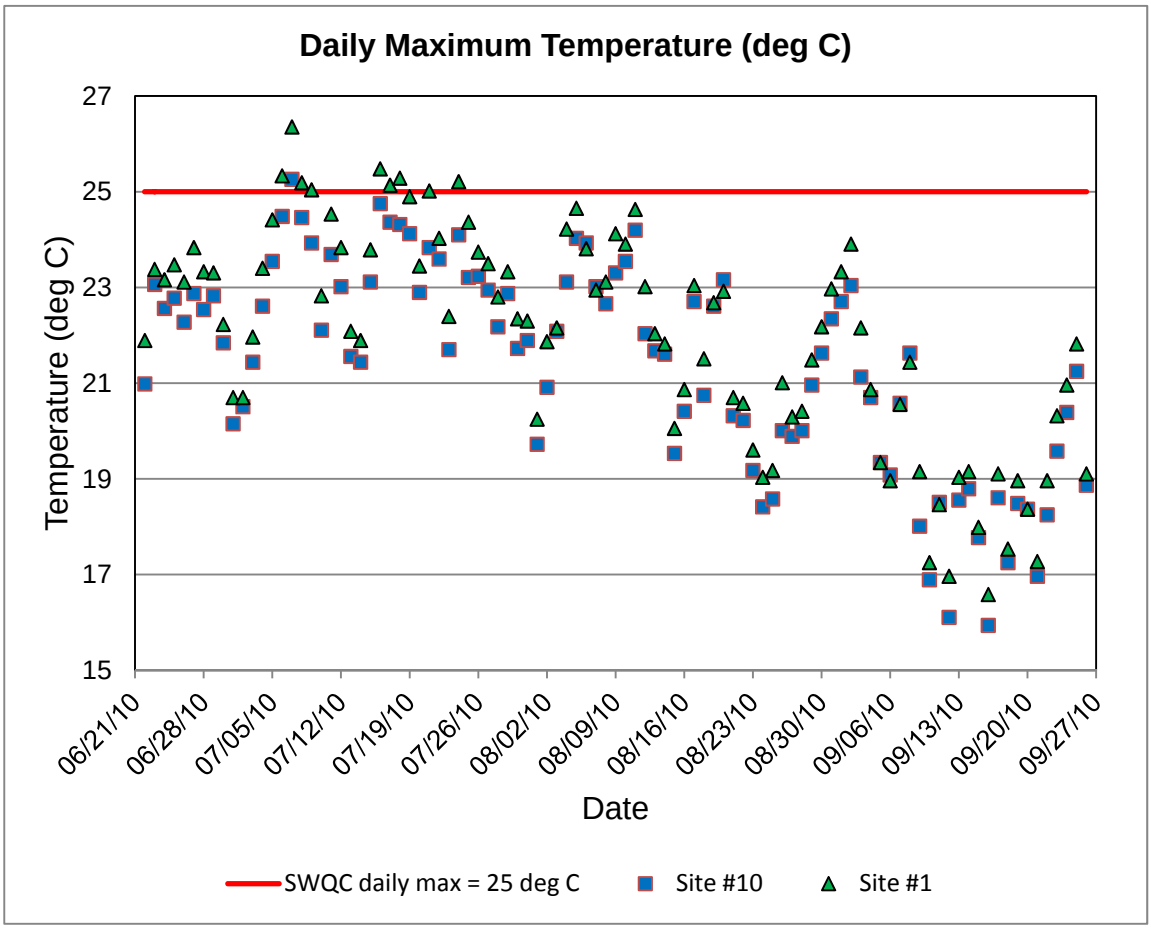

Figure 6.15. Daily maximum temperatures, June 22, 2010 to September 26, 2010

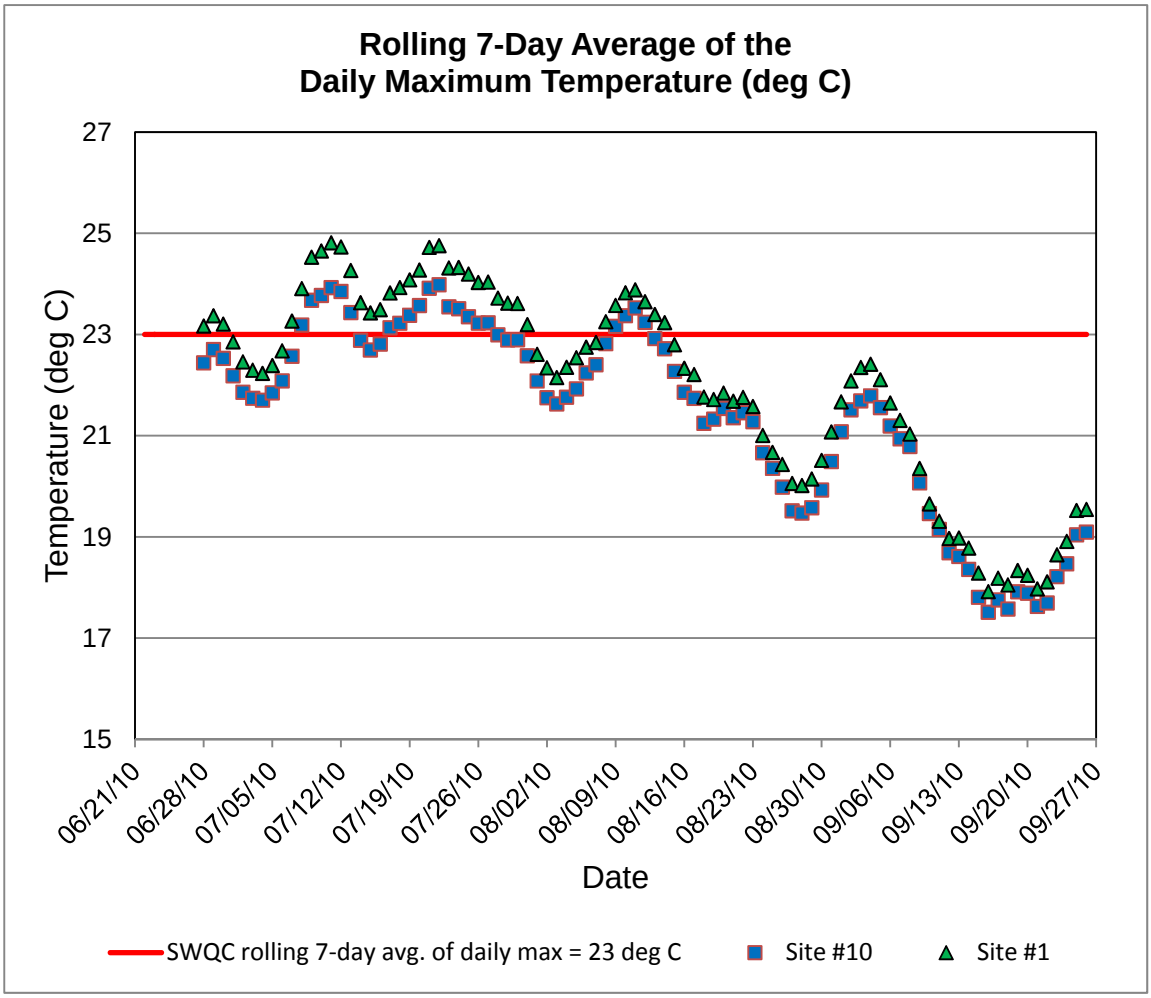

Figure 6.16. Rolling 7-day average of daily maximum temperatures, June 22, 2010 to September 26, 2010

6.3.5 Microbial Source Tracking

Microbial source tracking (MST) is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods to identify the origin of fecal pollution (Scott *et al.*, 2002). MST techniques typically report fecal contamination sources 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).

MST techniques applied within the Musconetcong River Watershed were supplemental to the sampling and analyses conducted under the approved QAPP and Addenda provided in Appendix A of the August 2011 Water Quality Monitoring Data Report found in Appendix A of this plan. The results of the bacteria monitoring conducted during May 2007 through October 2007 revealed highly elevated fecal coliform and *E. coli* levels in the West Portal Brook subwatershed at Site #7 and in the Turkey Hill Brook subwatershed at Site #9, just upstream of their confluence with the Musconetcong River. To further characterize the input of bacteria within the Musconetcong River, MST samples were collected during three wet weather events in 2008 (i.e., July 14, 2008; July 24, 2008, September 26, 2008) from all the established sampling locations from the 2007 monitoring program (i.e., #1, #2, #4, #11, #5a, #6, #7, #8, #9, and #10), as well as additional sites along the West Portal Brook (#13 and #14), Turkey Hill Brook (i.e., #15, #16, #17, and #18), and an unnamed tributary draining from Warren County (i.e., #12). A map showing the approximate location of these sites within the Musconetcong River Watershed is provided in Appendix D of the August 2011 Water Quality Monitoring Data Report found in Appendix A of this plan and also in Figure 6.1.

In May 2009, samples for MST analyses were collected at eleven sites total to obtain a more complete picture of the sources of impairment in the West Portal Brook (i.e., #7, #13, #14, #23, and #24), the unnamed tributary along Shurts Road (i.e., #11, #19, #20) , and the unnamed tributary in Hampton Borough (i.e., #2, #21, #22) . A map showing the approximate location of these sites within the Musconetcong River Watershed is provided in Figure 6.1. Samples were collected, independent of weather conditions, on May 7, 11, 14, 18, and 21, 2009.

Samples were collected in sterile bottles and held at 4˚C until processing. A 100 mL aliquot of each sample was filtered aseptically onto a membrane filter, and DNA was extracted from total filtered biomass using a DNeasy® tissue kit. The protocol used for the Musconetcong River Watershed samples is a modification of the procedure found in the DNeasy Tissue Handbook (Qiagen, Inc., 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. Three sets of PCR primers (targets) were used to quantify *Bacteroides* from 1) human sources (“HuBac”), 2) bovine sources (“BoBac”), and other sources (“OtherBac”) (e.g., wildlife). This assay is based on published results from a study sponsored by the Tennessee Department of Environmental Conservation (Layton *et al.*, 2006).

The results of the qPCR analyses from the samples collected during three wet weather events in 2008 are provided in Appendix D of the August 2011 Water Quality Monitoring Data Report found in Appendix A of this plan. These data show that some sites (i.e., #2, #7, #8, #11, and #17) have a higher incidence, during wet weather events, of contamination with human feces. Some sites (i.e., #7, #8, #11, and #17) were found to have a higher incidence, during wet weather events, of contamination with bovine feces. These findings are summarized in Table 6.10 and indicate that fecal contamination occurs within the West Portal Brook, the unnamed tributary along Shurts Road, and the unnamed tributary in Hampton Borough.

The results of the qPCR analyses from samples collected in May 2009 are provided in Appendix D of the August 2011 Water Quality Monitoring Data Report. These data show that some sites (i.e., #2, #11, #19, #21, and #22) have a higher incidence of contamination with human feces following storm events. The rainfall total within 48 hours of sample collection on May 7, 2009 was 1.16 inches, and human *Bacteroides* were only detected from the samples collected on May 7, 2009. Bovine *Bacteroides* were detected at Sites #7, #11, #13, #19, #21, and #24, and bovine *Bacteroides* were detected in the majority of the samples collected from Sites #7, #13, and #24, which are located downstream from livestock occurring within the West Portal Brook subwatershed (See Table 6.11).

Other sources of *Bacteroides*, not surprisingly, were detected at all the sampling locations during each sampling event. These other sources of *Bacteroides* may include wildlife, birds, horses, domestic animals, etc. Although these data illustrate the highly variable nature of water quality measures, these data are useful in regard to determining the potential sources and extent of fecal contamination within the watershed.

Table 6.10. Presence (+) and absence (-) of human and bovine *Bacteroides* within the Musconetcong River Watershed during three wet weather sampling events in 2008

Station	Date		
	7/14/08	7/24/08	9/26/08
Human *Bacteroides*			
#1	-	-	-
#2	NS	+	NS
#4	-	-	-
#5a	-	-	-
#6	-	-	-
#7	-	+	-
#8	-	+	-
#9	-	-	-
#10	-	-	-
#11	+	+	-
#12	-	-	-
#13	-	-	-
#14	-	-	-
#15	-	-	-
#16	-	-	-
#17	+	-	-
#18	-	-	+
Bovine *Bacteroides*			
#1	-	-	-
#2	NS	-	NS
#4	-	-	-
#5a	-	-	-
#6	-	-	-
#7	-	+	-
#8	-	+	-
#9	-	-	-
#10	-	-	-
#11	-	+	-
#12	-	-	-
#13	-	-	-
#14	-	-	-
#15	-	-	-
#16	-	-	-
#17	+	-	-
#18	-	-	-

NS – no sample due to low/no flow

Table 6.11. Presence (+) and absence (-) of human and bovine *Bacteroides* within the Musconetcong River Watershed in May 2009

Station	Date				
	5/7/09	5/11/09	5/14/09	5/18/09	5/21/09
	Human *Bacteroides*				
#2	+	NS	NS	NS	NS
#7	-	-	-	-	-
#11	+	-	-	-	-
#13	-	-	-	-	-
#14	-	-	-	-	-
#19	+	-	-	-	-
#20	-	-	-	-	-
#21	+	-	NS	NS	NS
#22	+	NS	NS	NS	NS
#23	-	-	-	-	-
#24	-	-	-	-	-
Bovine *Bacteroides*					
#2	-	NS	NS	NS	NS
#7	+	+	+	+	+
#11	+	-	-	-	-
#13	-	+	-	+	+
#14	-	-	-	-	-
#19	+	+	-	-	-
#20	-	-	-	-	-
#21	-	+	NS	NS	NS
#22	-	NS	NS	NS	NS
#23	-	-	-	-	-
#24	-	+	+	+	+

NS – no sample due to low/no flow

6.3.6 Biological Monitoring

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

The AMNET program began in 1992 and is currently comprised of more than 800 stream sites with 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 are 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 are 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) (NJDEP, 2007). The NJIS has been 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 for the NJIS 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 (NJDEP, 2007).

Starting with the second round of sampling under the AMNET program, 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, as presented in the USEPA RBP II. 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 (i.e., epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, channel sinuosity, bank stability, vegetative protection, riparian vegetative zone width) to evaluate instream substrate, channel morphology, bank structural features, and riparian vegetation. Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal, or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200; sites with suboptimal/good habitat conditions have total scores ranging from 110 to 159; sites with marginal/fair habitat conditions have total scores ranging from 60 to 109, and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential within a study area (NJDEP, 2007).

The NJDEP Bureau of Biological & Freshwater Monitoring maintains two Ambient Biomonitoring Network (AMNET) stations within the Musconetcong River Watershed (i.e., Stations AN00072 and AN0073) in the vicinity of the project area. Station AN0072 is approximately 0.94 miles upstream from Site #1. Station AN0073 is approximately 2.0 miles downstream from Site #10. In 1992 Station AN0072 was assessed as being non-impaired by NJDEP (NJDEP, 1994). However, in 1997 Station AN0072 was assessed as being moderately impaired with optimal habitat conditions (NJDEP, 1999). This particular assessment most likely is the reason for this section of the Musconetcong River being listed in the *New Jersey 2004 Integrated Water Quality Monitoring and Assessment*

Report as an impaired waterway for benthic macroinvertebrates (NJDEP, 2004). In 2002, NJDEP assessed Station AN0072 as being non-impaired with optimal habitat conditions (NJDEP, 2008). Also, in the fall of 2007, NJDEP assessed Station AN0072 as having optimal habitat conditions and having a rating of "good" under the High Gradient Macroinvertebrate Index (HGMI) (NJDEP, 2010). Station AN0072 is considered to be at full attainment of the regulatory threshold. In 1993, 1997, and 2002, Station AN0073 was assessed as being non-impaired by NJDEP, and in 1997 and 2002, optimal habitat conditions were noted at Station AN0073 (NJDEP, 1994; NJDEP, 1999; NJDEP, 2008). In the fall of 2007, NJDEP assessed Station AN0073 as having optimal habitat conditions and having a rating of "excellent" under the HGMI (NJDEP, 2010). Station AN0073, like AN0072, is considered to be at full attainment of the regulatory threshold.

A biological assessment was conducted by the Rutgers Cooperative Extension Water Resources Program in the early and late summer of 2007 within the Musconetcong River Watershed at Site #1 and Site #10. The biological assessment is fully described in Appendix E of the August 2011 Water Quality Monitoring Data Report found in Appendix A of this plan. The assessment demonstrates that the biological condition has remained at a non-impaired status, and the habitat condition has remained as optimal within this section of the Musconetcong River Watershed. The assessments conducted by NJDEP at Stations AN0072 and AN0073 in the early fall of 2007, following the assessment conducted by the Rutgers Cooperative Extension Water Resources Program, confirm these findings. Since no impairments have been noted at this time, there is no reason to conduct the U.S. Environmental Protection Agency (USEPA) Stressor Identification (SI) process, which is used to identify any type of stressor or combination of stressors that might cause biological impairment (USEPA, 2000).

6.4 Point and Nonpoint Source Loadings

Impairments caused by point source pollution are decreasing, while those caused by nonpoint sources appear to be increasing. Impacts from nonpoint sources of pollution such as urban stormwater, agricultural runoff and habitat degradation, are becoming increasingly evident as historically more pronounced impacts from point sources (i.e., industrial effluents, municipal wastewater treatment plants) are reduced. While successes resulting from the abatement of point sources have been documented, nonpoint sources are more difficult to pinpoint and control. Nonpoint source runoff, siltation and habitat degradation are common reasons for aquatic life impairments. These impairments are typically the result of agricultural land use, intensive urbanization, suburban development, the latter of which is emerging as one of the most significant threats to watersheds. Increasingly, water pollution problems are associated with nonpoint sources such as construction sites, farm land, domestic sewage systems, manure and treatment process residuals.

6.4.1 Point Sources

Any direct discharge into a river, stream lake or wetland from sources such as sanitary sewage treatment plants or industry are required to submit a permit through the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program. This permit program helps regulate the pollution of the waters of the state through monitoring and controlling amounts being discharged from industry or sanitary sewage treatment plants. There are four (4) surface water discharges within the watershed project area.

- **Asbury Graphite Mills Inc**
  PTERMDATE: 1/1/1996
  RECWATERS: Musconetcong R via Mill Run raceway
  NJPDES: NJ0031208
  PIPE: 001A, 002A
  STAT CODE: E - Existing in the Point Source Permitting Regions

- **Asbury Graphite Mills Inc**
  PTERMDATE: 1/1/1996
  RECWATERS: Musconetcong R via Mill Run raceway
  NJPDES: NJ0031208
  PIPE: 003A, 004A, 005A
  STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **Asbury Graphite Mills Inc**
  RECWATERS: Musconetcong R via Mill Run raceway
  NJPDES: NJG0105953
  PIPE: 001A, 002A
  STAT CODE: X - Transferred to BNPC - Permits transferred to Bureau of Nonpoint Pollution Control

- **Kappus Plastics Co Inc**
  RECWATERS: Musconetcong R via unnamed tributaries & streams
  NJPDES: NJG0134902
  PIPE: 001A
  STAT CODE: E - Existing in the Point Source Permitting Regions

Information on these points was obtained from The New Jersey Department of Environmental Protection (NJDEP), Environmental Regulation (ER), Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1) <http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesswd.zip>.

6.4.2 Nonpoint Sources

Common pollutants include but are not limited to: fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks, bacteria and nutrients from livestock, pet wastes, and failing septic systems. It is estimated that nonpoint source pollution is the primary contributor to bacteria loads within this watershed project area. The most populated portion of the subwatershed study area is located in the small borough of Hampton, the village of Asbury and Bethlehem Township. These areas rely solely on individual onsite wastewater disposal systems.

6.4.3 Estimated Loading Targets and Priorities

Loading Targets

Load reduction targets will adhere to the TMDL approved by the USEPA. In this plan, reduction targets are defined by the total pollutant load reductions that are required to satisfy the water quality standards for FW2-TM streams. These targets will dictate the management plan developed for the Musconetcong River Watershed. As stated previously, a TMDL for fecal coliform has been adopted for the Musconetcong River. This TMDL requires a 93% reduction in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands (NJDEP, 2003).

Priority Ranking

One of the goals of the watershed restoration and protection plan is to prioritize the implementation of various best management practices. As part of the development of this watershed restoration and protection plan, water quality data and flow data were collected at ten sampling locations within the Musconetcong River Watershed in 2007. Each of these sampling locations represents the outlet of a subwatershed within the Musconetcong River Watershed. To identify which subwatershed was contributing the most pollution to the Musconetcong River, data from each of these sampling locations was used to determine the annual pollutant load leaving each of the subwatersheds. Average loading rates of *E. coli* and fecal coliform were calculated for each subwatershed; the subwatersheds were then ranked by their annual pollutant load.

The primary pollutants of concern in the Musconetcong River Watershed for this watershed restoration and protection plan are fecal coliform and *E. coli*, indicators of pathogen contamination. Flow and pollutant concentration from each sampling event were used to calculate the daily load at each sampling location. The annual total load for each subwatershed was determined by averaging the daily loads and multiplying this average daily load by 365 days (number of days in a year). At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then the fecal coliform standard has been replaced by an *E. coli* standard. Because the TMDL established refers to fecal coliform, both fecal coliform and *E. coli* loading rates were calculated.

The differentiation between "wet" and "dry" weather sampling can be used to improve the understanding of the impact of stormwater on pollutant concentrations. To more accurately determine which monitoring events were collected under wet conditions when the stream velocities exceeded baseflow conditions, the HYSEP procedure was used. HYSEP is a data analysis program developed by the USGS to separate river flow into baseflow and storm-flow (Sloto and Crouse, 1996). When flow was more than 10% greater than baseflow and rain occurred on the day of or the day preceding sampling, the event was considered as storm-related flow and assigned the term "wet."

Average annual loading rates for *E. coli* and fecal coliform during both wet weather and dry weather conditions are presented in Table 6.12. The annual loads were then normalized by the area of each of the individual subwatersheds. These loading rates are provided in Table 6.13.

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

The subwatershed with the highest loading rate was given one (1) point, the next highest was given two (2) and so on. This method was repeated for the area-normalized loading rate. The points were combined, and the subwatersheds were ranked highest to lowest according to their total points (maximum of 18 points, with lower values indicating highest loading impact). The results of the ranking process are shown in Tables 6.14a and 6.14b. The loading rates show which subwatershed is contributing the most pollutants into the stream. The area normalized loading rates show which subwatershed is contributing the most pollutant per acre. Combining both parameters ensures that the subwatersheds with the highest priority are those where the greatest impact can be had with the least amount of implementation. For the pollutants of concern in the Musconetcong River Watershed (i.e., *E. coli* and fecal coliform), loadings from subwatersheds 10, 7, 8, and 6 are the top contributors to water quality impairments.

The final step in this analysis was to combine the priority rankings for *E. coli* and fecal coliform to create an overall ranking for each subwatershed. These rankings will help prioritize the implementation of stormwater best management practices. Tables 6.15a and 6.15b summarize overall rankings for *E. coli* and fecal coliform. Subwatersheds of top priority are in bold.

Table 6.12: Annual Loading Rates for Individual Subwatersheds

Subwatershed	*E. coli* (Colonies/Year)		Fecal Coliform (Colonies/Year)	
	Wet	Dry	Wet	Dry
10	7.34E+14	5.64E+14	4.81E+14	2.56E+14
9	1.23E+14	5.20E+13	1.23E+14	1.77E+13
7	4.28E+14	2.09E+14	2.76E+14	1.69E+14
8	3.58E+14	- 3.11E+14	3.58E+14	1.94E+13
5a	1.49E+12	2.42E+12	1.49E+12	3.23E+12
6	6.11E+14	7.05E+14	6.11E+14	3.74E+14
11	4.51E+12	2.55E+13	4.51E+12	2.16E+13
4	- 3.04E+13	- 1.06E+14	5.37E+13	2.92E+13
2	7.69E+10	-	6.04E+10	-
1	7.54E+14	3.44E+14	4.45E+14	2.78E+14

Table 6.13: Annual Loading Rates Normalized to Area for Individual Subwatersheds

Subwatershed	*E. coli* (Colonies/Acre/Year)		Fecal Coliform (Colonies/Acre/Year)	
	Wet	Dry	Wet	Dry
10	5.81E+11	4.47E+11	3.81E+11	2.02E+11
9	1.08E+11	4.57E+10	4.66E+10	1.55E+10
7	2.43E+11	1.19E+11	1.57E+11	9.60E+10
8	2.27E+11	- 1.97E+11	7.90E+10	1.23E+10
5a	3.67E+09	5.98E+09	4.87E+09	7.97E+09
6	1.78E+11	2.05E+11	1.47E+11	1.09E+11
11	5.14E+09	2.17E+10	1.22E+10	1.84E+10
4	- 2.50E+10	- 8.69E+10	4.42E+10	2.40E+10
2	1.51E+08	-	5.13E+07	-
1	NA		NA	

Table 6.14: Summation of Rankings for Loadings and Area-Normalized Loadings

a. *E. Coli*

Site	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Total
10	1	1	2
9	5	5	10
7	3	2	5
8	4	3	7
5a	7	7	14
6	2	4	6
11	6	6	12
4	9	9	18
2	8	8	16

b. Fecal Coliform

Site	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Total
10	2	1	3
9	5	5	10
7	4	2	6
8	3	4	7
5a	8	8	16
6	1	3	4
11	7	7	14
4	6	6	12
2	9	9	18

Table 6.15: Priority Watersheds by Surface Water Quality Parameter

a. *E. Coli*

Site	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Overall Priority Ranking
10	**1**	**1**	**1**
9	5	5	5
7	**3**	**2**	**2**
8	**4**	**3**	**3**
5a	7	7	7
6	2	4	4
11	6	6	6
4	9	9	9
2	8	8	8

b. Fecal Coliform

Site	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Overall Priority Ranking
10	**2**	**1**	**1**
9	5	5	5
7	**4**	**2**	**3**
8	3	4	4
5a	8	8	8
6	**1**	**3**	**2**
11	7	7	7
4	6	6	6
2	9	9	9

7.0 Municipal Regulations and Resources

7.1 Stormwater Management Regulations

It is important to note that the strongest water protection in the project area come from the state and not the municipality. The Musconetcong River in the project area was classified as a Category One waterbody in 2008 under N.J.A.C. 7:8, Stormwater Management Regulations.

Category One waters are defined as waters protected from measurable changes in water quality characteristics because of their clarity, color, scenic setting, other characteristics of aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resources.

The New Jersey Department of Environmental Protection (NJDEP) upgraded the antidegradation designation of several waterbodies including the Musconetcong River based upon a finding of exceptional ecological significance. These upgrades are based upon use of an integrated ecological assessment of data including benthic macroinvertebrate data, in-stream habitat, fish community, chemical water quality data, and sightings and habitat of aquatic-dependent endangered and threatened species.

The study area, from its beginning in Lebanon Township downstream to Valley Station Road in Bethlehem Township Hunterdon County is classified as a Category One under the Exceptional Ecological Significance - Endangered or Threatened Species definition. The lower half of the project area, from Valley Station Road south of West Portal Creek to the Delaware River, including all unnamed and unlisted tributaries was upgraded to a Category One based upon the presence of an exceptional aquatic community. Protections derived from this classification extend to all tributaries named or unnamed.

According to the publication announcing the upgrade “Special water resource protection areas shall be established along all waters designated Category One at N.J.A.C. 7:9B and perennial or intermittent streams that drain into upstream of the Category One waters… These areas shall be established for the protection of water quality, aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, and exceptional fisheries significance of those established Category One waters.”

For more information on NJ Stormwater Regulations:

NJDEP - Bureau of Nonpoint Pollution Control
PO Box 029
Trenton, NJ 08625-0029
www.njstormwater.org

7.2 Highlands Act/Highlands Regional Master Plan

Another state regulation that supersedes some water protections at the municipal level is the Highlands Water Protection and Planning Act which was signed on August 10, 2004. The rules incorporate required standards of various land use, water resource and environmental protection.

The entire study area is within the Highlands area and is roughly divided into Planning Area (Washington and Franklin, Warren County) and Preservation Area (Lebanon, Hampton Borough and Bethlehem, Hunterdon County). The Preservation Area is defined by the Act as containing lands absolutely essential to generating drinking water and so is under stringent state restrictions on development. The Planning Area lands also contribute to water generation but in many cases are already developed, so they remain under local control where further growth is concerned.

The Highlands Act requires that all municipalities with land located in the Preservation Area bring their master plans and development regulations regarding those lands into conformance with the "goals, requirements and provisions of the regional master plan (RMP)." Conformance is voluntary for towns that are all or partly located in the Planning Area.

For more information on the Highlands Act:

Highlands Council
100 North Road
Route 513
Chester, New Jersey 07930
(908) 879-6737
Fax (908) 879-4205
www.nj.gov/dep/highlands

New Jersey Department of Environmental Protection
Division of Coastal and Land Use Planning
Bureau of Watershed Regulation
P.O. Box 420
Mail Code 401-07C
401 East State Street
Trenton, New Jersey 08625-0418
(609) 984-0058

NJ Highlands Coalition
508 Main Street
Boonton, NJ 07005
Phone (973) 588-7190
Fax (973) 588-7193
E-mail: info@njhighlandscoalition.org

7.3 Stream Buffers

Buffers are vegetated areas adjacent to waterways that provide protection to water quality. In the past, these areas were established (or not) by various rules and the buffers varied in width. Under the Stormwater Regulation protections for Category One waterbodies discussed above, every water body in the study area must be protected by a 300 foot buffer, measured from each bank. No municipality in the study area has an ordinance that surpasses this requirement.

Waterbodies in municipalities in the Highlands Preservation Area (Lebanon, Hampton Borough and Bethlehem) are protected by 300 foot buffers by virtue of protection under the Highlands Act.

7.4 Agriculture

Each of the five municipalities that run along the banks of the Musconetcong River has a Right to Farm Ordinance. In Bethlehem, Franklin, Washington, Lebanon, and Hampton Borough farmers are allowed by this ordinance to perform any and all farm practices as long as these activities conform to acceptable agricultural management practices and are not done so as to pose a direct threat to public health or safety. Right to Farm ordinances confers the right to:

- Clear woodlands using open burning and other accepted techniques and install and maintain vegetative and terrain alterations and other physical facilities for water and soil conservation and surface water control in wetland areas.
- Use irrigation pumps and equipment, aerial and ground seeding and spraying, tractors and other customary farm equipment.
- Utilize the land for grazing of animals subject to the restrictions for intensive fowl or livestock farms or such restrictions as may be required by county, state and federal law.

7.5 Steep Slopes

Four of the five municipalities that run along the banks in the study area of the Musconetcong River have a Steep Slope ordinance. Hampton Borough does not have a Steep Slope ordinance. Zoning regulations for development on and disturbance of steep slopes can prevent erosion and reduce the risk of landslides that endanger lives, damage property and infrastructure, harm water quality, and degrade wildlife habitat.

7.6 Septic Systems

None of the municipalities in the study area have ordinances regulating the maintenance or inspection of septic systems. In each municipality the County Board of Health or Health Department are responsible for site inspections, review of septic designs, installation inspections, repair guidance, certification of completed systems, and complaint investigations.

7.7 NJ Wild and Scenic Rivers

In 2006 the Musconetcong Wild and Scenic Rivers Act, which designates portions of the Musconetcong River as a Wild and Scenic River, was signed into law. The subwatershed that is the subject of this restoration plan is within a stretch of the river that is a part of the National Wild and Scenic River System.

As a part of the Wild and Scenic designation process, a River Management Plan (RMP) was written; the Musconetcong RMP guides cooperative management of the Musconetcong River as a component of the National Wild and Scenic River System and recognizes the importance of the various roles of landowners, government, business and industry, and other citizens in the protection of the river corridor.

The Musconetcong RMP calls for the formation of a Musconetcong River Management Council which meets bimonthly. Each municipality in the project area has appointed a representative to the MRMC and is party to memorandum of understanding which formalizes a cooperative commitment on the part of the municipality to participate in the long-term management of the river and to implement those parts of the Management Plan under their jurisdiction or for which they assume responsibility.

The purpose of the Musconetcong River Management Council is to implement the RMP and promote the long-term protection of the Musconetcong River by: (1) bringing those involved in river issues together on a regular and ongoing basis, (2) stimulating cooperation and coordination among those organizations and individuals, (3) providing a forum for all river interests to discuss and resolve issues, and (4) coordinating implementation of the River Management Plan.

The River Management Plan sets forth five major goals and recommends actions to maintain and improve the Musconetcong River corridor, its tributaries and watershed, and surrounding natural, cultural and recreational resources. Three of the goals of the River Management would be served by the successful implementation of this subwatershed restoration plan.

Goal 1: Encourage recreational use that is compatible with the preservation of natural and cultural qualities of the river corridor while respecting private property.

Goal 2: Preserve and protect the character of archaeological sites and historic structures, districts, sites, and landscapes in the river corridor.

Goal 3: Preserve farmland and open space within the river corridor and the watershed.

Goal 4: Preserve, protect, restore and enhance the outstanding natural resources in the river corridor and the watershed, including rare and endangered species, forests, steep slopes, floodplains, headwaters and wetlands.

Goal 5: Maintain existing water quality in the Musconetcong River and its tributaries and improve where possible.

8.0 Restoration Strategies and Protection Projects

8.1 Watershed Wide Restoration Projects and Best Management Strategies

8.1.1 Stormwater Best Management Practices

The three primary land uses in the Musconetcong River are agriculture (45%), forested (34%) and urban (15%) with urban primarily consisting of rural to low density residential. For the agricultural lands, the primary stormwater best management practices (BMPs) to address the pathogen contamination and aquatic life impairments in the watershed are: Minimum Till Drill Program, Vegetative Buffers, Cover Crops and Manure Management. For the urban land use, three primary BMPs are being recommended: Rain Gardens, Detention Basin Retrofits, and Roadside Ditch Retrofits. Each of these recommended BMPs is described in the following pages.

A. No Till and Residue Management Program

Residue management practices using no-tillage are described in the NRCS New Jersey Field Operation Technical Guide as managing the amount of plant residue on the soil surface year round while limiting soil-disturbing activities to only those necessary to place nutrients, condition residues, and plant crops. This management style often involves specialized equipment to drill seeds in below residue and inject fertilizers. This style of cropping has lent well to soybean farmers and is growing with types of crops successful under this management style, including vegetables.

No-till farming has been widely successful with some farming styles, such as soybean, while it is still in its infancy with other styles. The benefits of no-till farming in regards to soil health and runoff reduction are fully realized by many agricultural professionals. It requires some trial and error to incorporate into different crops. With proper promotion, education, experimentation and assistance no-till farming can be tried on different crop types.

The cost of no-till farming is often in the equipment required for this system. The upfront equipment costs are obstacles for farmers who are unsure if no-till will work right for their crops. If programs to help farmers convert to these styles become more prevalent, this might become a more easily realized management possibility.

No-till farming will result in increased soil health. No-till farming ensures that the soil is always protected from soil particles becoming dislodged by rain and becoming runoff. These two factors will lead to a reduction in agricultural pollutants. In addition crop residue will break down overtime releasing nutrients that can be used by plants, reducing the amount of fertilizer application required.

Recommendation: Promote no-till, strip till, mulch till and ridge till systems to reduce erosion and sedimentation. Seek methods of funding this procedure.

B. Conservation (Vegetative) Buffers

Current Conditions

The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for pH, fecal coliform and temperature. A significant source of fecal coliform in an agricultural watershed is stormwater runoff from pastures. Animal waste left by the livestock on the pasture can be a source of bacteria to the watershed. It is recommended that this waste be collected and stored in a central location with stormwater best management practices to treat the stormwater runoff the waste generates to prevent the bacteria from entering the waterway. Many farmers do not have the capabilities to do this level of maintenance, and the waste is left on the pasture for long periods of time. During storm events the runoff generated from the pasture picks up and carries bacteria from the waste and carries the bacteria to the stream. Croplands that use manure as fertilizer are potential sources of fecal coliform. Vegetative buffers along the edge of a waterway can treat stormwater runoff and remove pollutants.

Vegetative buffers can be implemented by farmers with little to zero assistance from others. Buffers are not usually in place because they require the farmer to sacrifice some of their crop space for the buffer. The farmers see this loss of space as a loss of revenue and usually are not inclined to use them even if they can be used to grow hay for sale because the hay isn't as profitable as the crop. Farmers with livestock avoid using vegetative buffers because it reduces the space available to the livestock thus reducing the amount of livestock they can keep on their farm. Programs have been implemented in the past to create economic incentives for farmers to create and maintain buffers over many years.

Vegetative Buffer

An area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation is called a vegetated filter strip. The vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. It is important to note that all runoff to a vegetated filter strip must enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's pollutant removal capabilities.

Proposed Location

Map 8.16 show the location of a potential buffer project along agricultural land uses. Any portion of stream or water body that is surrounded by agricultural land use and appears to have little or no existing buffer along the stream is considered a potential site for a buffer project. This project has approximate 66,872 feet (12.66 miles) of potential vegetated buffer sites.

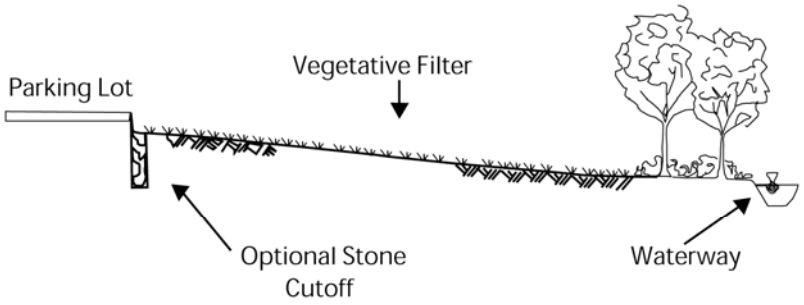

Figure 8.1: Typical Profile of a Vegetative Buffer (Semple et al 2004)

Implementation

This project will be a product of the collaborative effort of the Rutgers Water Resources Program and North Jersey Resource Conservation and Development (NJRC&D). The two organizations will collaborate to create a program that will reach out to local stakeholders to install vegetative buffers, determine appropriate sites, design, provide funding and supplies, oversee the implementation and periodically inspect each buffer.

First, both programs will use the potential vegetative buffer location map 8.16. The map was created by using landuse data from the NJDEP and reviewing aerials throughout the entire watershed to determine all the locations where vegetative buffers can be installed on farmland. After the location map has been reviewed, both programs will begin its outreach to the local stakeholders. The group will focus on the farmers that have been targeted for a vegetative buffer.

Once the group has collected enough agreements from the farmers to install vegetative buffers on their property, the Water Resources Program will design each of the buffers. Next, the Water Resources Program and NJRC&D will solicit bids from local contractors to install the vegetative buffers. The NJRC&D and the Water Resources Program will oversee the construction of each of the vegetative buffers. Periodically, a staff member from the Water Resources Program or the NJRC&D will visit each vegetative buffer and inspect it to determine if it is being maintained properly and if it is functioning as intended. If a problem does arise, the Water Resources Program and NJRC&D will be informed immediately and actions will be taken to correct the situation.

Maintenance

Vegetated filter strips are expected to trap debris and bacteria therefore they must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding one inch of rainfall. Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations. (Semple et al, 2004)

Mowing of filter strips must be performed on a regular schedule based on specific site conditions (typically once every six months is the minimum). Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs. (Semple et al, 2004)

Cost

The cost of each vegetative buffer will vary with the difficulty and complexity of each design and size of the project. Vegetative buffers that consist of warm season grasses will be considerably less expensive than designs that require larger vegetation in a more complex design.

Prioritization

The potential sites should be prioritized according to the estimated individual fecal coliform loading rates of each subwatershed. The subwatersheds with the highest individual fecal coliform loading rates should have buffers installed at the potential sites before the subwatersheds with the lowest individual fecal coliform loading rates.

Expected Results

The New Jersey Best Management Practice Manual does not have an accepted fecal coliform removal rate for vegetative filter strips. The removal rates found in literature tend to vary a little. The literature values are high. The bacteria are removed the same way that sediment is removed from the water column. The bacteria settle out as the water slows down. The removal values can range from 91% to 74%. It is safe to assume that the fecal coliform in the runoff generated from pastures or cropland (with manure as fertilizer) will be reduced by 91 to 74% for each rain storm.

Recommendation 1: Install conservation buffers throughout the watershed as the primary stormwater best management practice to improve water quality and address water quantity issues.

Recommendation 2: Provide education and outreach to the many smaller farms in the watershed to provide guidance on the many benefits that can be achieved through the proper installation of stream buffers.

C. Cover Crops

Cover crops are grasses, legumes, forbs, or other herbaceous plants established for seasonal cover and other conservation purposes. Cover crops are widely accepted by agricultural professionals and farmers to have many benefits, with improving water quality being just one of them. Proper cover crop selection has led to operators reducing cost, reducing tillage, reducing herbicide uses and increasing soil health. Cover crops can easily be worked into any cropping system that has fields not in use for all or part of the year. With proper promotion, education and assistance cover crops can be implemented watershed wide with excellent benefits.

Cover crops vary in cost depending on the cover crop selection. According to NRCS AWEP 2010 practice catalog, the least costly is winter cover crop at $71.50 per acre while a legume in the summer is estimated at $443.40 per acre. There is cost sharing available for these practices. There is often a return to the operation with reduced fertilizer needs and increased soil health. An implementation of cover crops to barren crop fields can help to reduce runoff. Cover crops reduce both wind and water erosion. Nutrients left over from previous fertilizer and manure applications in the soil profile will be captured and recycled making them unavailable for runoff. Figure 8.8 shows the location of a potential cover crop installation.

Recommendation: An education and assistance program should be implemented to help farmers implement cover crops in their crop production to achieve the promising water quality and other environmental benefits.

D. Livestock Access Control – Exclusion Fencing

Direct access to streams by livestock is a threat to water quality in the Musconetcong River Watershed. Nutrients and pathogens from livestock manure can be transmitted to streams via direct deposit and runoff. Livestock access to streams may also damage stream banks and cause soil erosion. Installation of exclusion fences along a stream would protect streams from such contamination. Fencing also allows for the healing of the riparian area. A fully functioning riparian buffer would further filter those pollutants from reaching the streams. The NRCS BMP Practice Manual requires that livestock exclusion fencing should be installed at least 35 feet from the stream banks depending on the stream width and other site specific conditions. The 35 foot corridor allows for the establishment of a riparian zone for additional protection from pastureland runoff. The type of fencing utilized depends on livestock type and site conditions. Once installed, livestock are no longer able to directly deposit manure while watering or crossing. Additional damage that may have occurred on stream banks can be repaired, and the stream will heal to a more natural state, reducing stream bank erosion.

Exclusion fencing should be installed along all waterways which run through property with livestock that have access to the waterway. While fencing may be installed by any contractor or landowner, technical assistance should be obtained from NRCS or other support agency to ensure the effectiveness and longevity of the fence. While fencing prices can vary according to livestock type and landowners' preferences, NRCS approximates the unit cost of fencing to be $4.78 per foot for use for livestock exclusion. There is also the potential for cost sharing to help offset any expenses

accrued by the landowners. Cost sharing will very often help fund the practices associated with the installation of exclusion fencing such as the installation of an alternate water source for livestock. There are currently many sources of cost share from both state and federal government including the NRCS Agricultural Water Enhancement Program (AWEP). This cost will be greatly offset if the landowner applies and qualifies for cost sharing. Currently funding can be up to 100 percent of the installation cost.

Recommendation: All farms that house any number of animal units should install fencing to deter the entrance of these animals into the waterways.

E. Regional Composting Facility

Currently in the Musconetcong River Watershed, there are agricultural properties which produce manure that may not be able to be used onsite. In some cases this manure may be handled in a fashion which can potentially pose an environmental threat. Manure piled in hydrologically sensitive areas or without proper distance from streams can leak phosphorus and fecal contaminants into surface water. A remedy is to compost the raw manure to a safe and biologically stable organic material.

A composting facility can be a simple windrow or a static pile which is turned to allow for aerobic conditions. The location on the property must be at least 50 feet from the property line and 250 feet from an occupied dwelling with no part located within a flood plain unless it is protected against the 100 year flood. The facility will also be designed to manage any runoff in a safe manner.

The task of installing a composting facility varies in difficulty and should be done with assistance from the NRCS or another support agency or non-profit to help make technical decisions that will ensure the facility is sited properly and designed to deal with any runoff potential. There may also be local and state ordinances which must be met to install this practice. There is cost sharing to help offset any expenses accrued by the landowner. This practice may also require some training for the operator, as temperature and proper ratio of carbon-to-nitrogen must be maintained to encourage this biological process.

There is a range of prices for composting facilities based on the needs and preference of a land owner. The price range listed in the NRCS AWEP 2010 practice catalog ranges from $.10 to $16.73 per square foot. There is cost share available for the construction of the facility. There is not cost share available for some of the equipment which is required to run the facility, such as a tractor or a windrow turner. If an operator does not own this equipment it will be an out of pocket expense.

Composting facilities should be considered as a possible solution for any livestock operation that cannot safely use or remove manure from the property in regards to water quality. This would include land that is overstocked. The locations can be prioritized by the subwatershed ranked according to the combined fecal coliform and total phosphorus loading.

The use of composting facilities as a means to safely manage manure generated on a farm will help to mitigate any potential phosphorus and fecal contamination generated through manure storage in the watershed. Secondary benefits are from turning manure into a safer alternative fertilizer than the spreading of raw manure.

Recommendation: A composting facility for manure produced in the watershed should be made available to those farmers that require this proper waste disposal. Those in need should check with the local Solid Waste Facility.

F. Wildlife Management

Wildlife such as deer and geese can contribute pathogen contamination in the watershed. This contribution could be heavy during the winter season when vegetation is down, allowing areas of bird foraging. This reduction in vegetation also plays a role in the ease of contaminant runoff.

The resident population of Canada geese in New Jersey has become a focus of several pathogen management programs. In the Musconetcong River Watershed, both Canada geese and Snow geese have been identified in fields (particularly fallowed fields) and large turf areas. Potential solutions include the planting of dense ground cover crops, noise devices, dogs and mylar tape. The ground cover will also serve to stabilize the soil and the nutrients that the soil may carry if it erodes. The installation of conservation buffers will also serve to reduce the direct runoff of pathogens into the waterway.

Recommendation: Nuisance wildlife should be identified and discouraged from becoming residents of the area's surrounding streams.

G. On-Site Wastewater Treatment System (OWTS) Education and Management

The majority of residential homes and businesses in the Musconetcong River Watershed rely on OWTS for treatment and disposal of wastewater. Functioning OWTS require regular maintenance. Failing OWTSs are often very expensive to repair and sometimes require rebuilding. To help control the pathogen contamination in the Musconetcong River and its tributaries, a comprehensive OWTS education and management program can be implemented. The comprehensive education and management program should include the following elements:

- An education campaign by distributing flyers, newspaper articles and regional education workshops to make the residents and businesses aware of their on-site wastewater treatment system and their functioning status
- A regular inspection program (3 or 5 years)
- A technical assistance program on OWTS inspection, operation and maintenance
- A financial incentive program combined with fines and subsidies, and public and private funds that motivate the residents and business to operate their systems at their optimal status.

Recommendation: All septic systems in the watershed should be inventoried and regularly inspected. Management plans for each system should be compiled.

H. Rain Gardens

Current Conditions

The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as being impaired for pH, fecal coliform and temperature. A source of fecal coliform for the watershed is wildlife and house pets. Rain gardens are mostly installed in residential areas. Residential areas are large sources of nutrients for watersheds across the state. Rain gardens installed at residential neighborhoods across the watershed will reduce the amount fecal coliform entering the waterways and protect the watershed from increasing the amount of phosphorus, nitrogen and total suspended solids (TSS) entering the stream.

Traditional stormwater management techniques promote end-of-the pipe treatment stormwater at a centralized location, typically a detention basin. These stormwater management facilities are often large in size, occupying one or more acres of land and typically requiring regular maintenance such as weekly mowing. Additionally, detention basins are limited in their ability to remove phosphorus and TSS as pollutant removal processes within these systems are limited to settling. An effective and less costly approach is to build multiple smaller stormwater best management practices (BMPs) such as rain gardens to capture and treat pollutants at the source, rather than to build single, large end-of-the-pipe stormwater management facilities.

Figure 8.2: Home Rain Garden

Rain Gardens

A rain garden is a landscaped, shallow depression designed to intercept, treat, and infiltrate stormwater at the source before it becomes runoff. Plants used in the rain garden help retain pollutants that could otherwise degrade nearby waterways. Rain gardens are becoming popular in suburban and urban areas. These systems not only improve water quality, but also help homeowners minimize the need for watering and fertilizing large turf grass areas and promote groundwater recharge. If designed properly, these systems improve the aesthetics of the urban/suburban neighborhoods through use of flowering native plants and attractive trees and shrubs.

A typical rain garden is designed to capture, treat and infiltrate the water quality storm of 1.25 inches of rain from a 1,000 square foot impervious area from an individual lot (i.e., a 25 ft by 40 ft roof for a house or a 20 ft wide by 50 ft long driveway). By collecting runoff generated by the first 1.25 inches of rainfall, the rain garden prevents the “first flush” of runoff from entering the stream, which characteristically has the highest concentration of contaminants. For the water quality storm of 1.25 inches of rainfall, the rain garden needs to be 10 ft by 20 ft and six inches deep. Since 90% of all rainfall events are less than one inch, rain gardens are able to treat and recharge a majority of runoff from these storms. If forty homes incorporated rain gardens to each treat runoff from 1,000 square

feet of impervious areas (rooftops, sidewalks, patios, and driveways), the result would be over one million gallons of stormwater being recharged each year.

Residential Rain Gardens

Residential rain gardens typically are designed to treat stormwater runoff from a roof downspout or from a driveway or patio. Although runoff from these areas is typically low in pollutants, rain gardens help to manage stormwater flows, reducing the volume of runoff during each storm. By capturing and recharging stormwater, residential rain gardens in a community can collectively help reduce stream flows during storm events, minimizing stream bank erosion and scouring of the streambed. This reduction in the flashy hydrology of the stream ultimately reduces nutrient loads that come from the eroding stream banks.

Residential rain gardens are often placed in easements, and deed restrictions are placed on them so that they cannot be eliminated when property transfers ownership. The home owner is responsible for maintaining the condition of the rain garden. It is this responsibility that encourages the home owner to learn about the importance of stormwater management.

Roadway Rain Gardens

Figure 8.3: Road Rain Garden
(http://www.minnehahacreek.org)

Rain gardens can also be used to capture and treat runoff from roadways. Roadway rain gardens are usually built in the existing right-of-way of a local road or on a purchased easement (see Figure 8.4). These gardens are publicly owned and can be maintained by the municipality or county that owns the roadway, or they can be given to homeowners to maintain in a similar way that homeowners mow the lawn in the right-of-way or shovel the sidewalks in the right-of-way. Many home-owners agree to take on the maintenance responsibilities because these gardens can improve the landscaping of their property, thereby increasing the value of their home. Since runoff from roadways has been shown to have high concentrations of TSS and phosphorus, roadway rain gardens can substantially reduce TSS and phosphorus loading to the local waterways.

Proposed Locations

Rain gardens are excellent systems for retrofitting urban and suburban areas. With relative ease, they can be incorporated into existing landscapes to capture, treat and infiltrate stormwater runoff from impervious and pervious surfaces. They can be used in full or partial sunlight or in completely shaded areas. They are inexpensive to build and relatively easy to maintain. They can be built to discharge to the underlying groundwater or to an underdrain system that carries the treated stormwater runoff to a local waterway or storm sewer system.

There are over 665 acres of area classified as have been identified as potential rain garden drainage areas (see attached map). Many of these communities would be ideal locations for rain gardens as a means of source control for bacteria and nutrients, as well as reducing stormwater runoff volumes.

Implementation

Municipalities can begin outreach efforts to educate the public about stormwater infrastructure and begin installing rain gardens on private and public properties (as a roadway or residential rain garden). It is important to get the public involved in the beginning and to keep their attention. Rain gardens will change the way neighborhoods look and residents need to understand the benefits to the community. After home owners are educated about rain gardens and are excited about the benefits these systems can provide, specific properties need to be identified for rain garden retrofits. Specific rain garden designs will be created for each site with the input of local residents. Construction of a rain garden will include limited excavation, soil amendments, and planting. A curb cut may be necessary if a roadway rain garden is installed in a curbed community. A typical residential rain garden can be constructed in a single day.

Rain gardens need to be inspected for clogging and excessive debris and sediment accumulation at least four times a year, as well as after every storm exceeding one inch of rainfall. Sediment removal should take place when the garden is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations (Semple *et al.*, 2004).

Vegetated areas should also be inspected at least once a year for unwanted growth. Weedy plants should be removed with minimum disturbance to the planting soil bed and remaining vegetation. When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice a year. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the rain garden system. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. The rain garden should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs (Semple *et al.*, 2004).

The system's drain time should be evaluated after rain storms larger than one inch. If the drain time is longer than 72 hours, the system needs to be evaluated to find a way to decrease the drain time to at least 72 hours, which is the maximum drain time allowed by NJDEP (Semple et al., 2004).

Prioritization

The subwatershed ranking for greatest need of rain gardens has been based bacteria loading ranking from the water quality data.

Rain gardens are best installed in residential and commercial areas. Municipalities can partner with local environmental organizations, environmental commissions and other community organizations

to reach out to home and business owners to identify target neighborhoods willing to have rain gardens installed on their property and maintain them for the town.

Expected Results

Rain gardens are designed to treat only small storms but these events make up the majority of storms throughout a given year. It is fair to assume, if designed correctly, rain gardens will reduce the pollutant loading from a drainage area by 90% wherever they are installed. Furthermore, they will reduce stormwater runoff volumes and reduce the flashy hydrology of local streams. This reduction of flashy hydrology will minimize stream bank erosion and stream bed scour, thereby reducing TSS and phosphorus loads in the waterway.

Recommendation: Education and outreach programs and demonstration projects should be conducted to educate the general public and the municipal officials and to train landscape professionals in installing rain gardens.

I. Detention Basin Retrofit Designs

Current Conditions

The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for pH, fecal coliform and temperature. Stormwater runoff from developed areas is a source of fecal coliform. Although runoff from many developed sites is managed with detention basins, these systems are mainly designed to reduce downstream flooding and do little to address water quality. In most cases, detention basins can be retrofitted to enhance their pollutant removal capabilities and achieve water quality improvements.

An inspection of the four detention basins in the watershed shows they are standard detention basins that have little to no affect on the water quality of the effluent from each detention basin. These systems are only designed to mitigate the peak flow from intense rain storms. The runoff from smaller more frequent rain storms simply pass through the detention basin without the slightest impact. Many of these detention basins can be altered or retrofitted to improve their ability to remove bacteria loads from stormwater runoff and achieve water quality improvements. If these improvements are made correctly, they could improve water quality, as well as reduce maintenance costs for municipalities and homeowner associations. The adjustments made to the basins force the basin to act less like a detention basin and more like a bioretention basin.

Figure 8.4: Detention Basin in Franklin Township

Detention Basin Retrofit Design Alternatives

The rainfall event used to analyze and design stormwater best management practices (BMPs) for water quality improvements is the "water quality storm" of 1.25 inches of rain over two hours. This storm can be used to compute runoff volumes and peak rates to ensure that stormwater quality BMPs, whether they are based on total runoff volume or peak runoff rate, will provide a standard level of stormwater pollution control. Since approximately 90% of storms in New Jersey are typically smaller than the water quality storm, BMP designs and retrofits that treat these small storms will have a significant impact on improving water quality in the watershed.

Low Flow Vegetated Channel

A common design feature for detention basins is a low flow concrete channel that carries runoff from the inlets to the outlet structure of the detention basin. This feature is intended to force water to quickly pass through the basin during small storm events to avoid ponding and maintenance issues. Due to sediment and debris accumulation in these channels and the lack of regular maintenance, these channels frequently tend to clog, causing ponding of water in the channel. The small stagnant ponds become ideal mosquito breeding habitat, thereby creating a problem they originally intended to avoid.

Low flow concrete channels act as an impediment to improving water quality in a detention basin. It is recommended to remove the concrete channel and replace it with a vegetated swale (see attached detail). The swale should have a 0.1% side slope to ensure easy maintenance and a slope not exceed 3%. The swale should be seeded with native grasses to minimize maintenance. Where possible, replacement soils should be installed with the top 1.5 feet of soil composed of a bioretention soil mix to encourage infiltration (see detail). Below this infiltration media, a 6" layer of 3/4" diameter clean stone should be installed. The native vegetation in the swale should be cut once or twice a year.

Dense native vegetation creates friction along the flow path of runoff through the detention basin. This friction slows the water allowing bacteria to settle out of the water column. Water will be held in the detention basin longer, increasing infiltration reducing the amount of water that discharges

from the basin Native vegetation that is allowed to grow taller will develop a deep root structure allowing a much greater infiltration rate than soil with short turf grass, further decreasing the amount of water that discharges from the basin. The channel should be designed to infiltrate and pass water through within 48 hours after a storm to prevent mosquito breeding.

Low Flow Rip-Rap Channel

This design is similar to the vegetated channel but instead of vegetation, the channel is filled with rip-rap stone. The channel should not be any wider than 10 feet with the bottom at least three feet above the seasonal-high groundwater elevation. The channel should be designed to hold the runoff volume of the water quality storm from the detention basin's drainage area. The infiltration rate of the soil where the channel will be installed should be taken into consideration before sizing. The channel will infiltrate any storm equal to or smaller than the water quality storm within 48 hours.

When retrofits are installed, the concrete channel should be completely removed.

Native and Low Maintenance Grasses and Vegetation

Detention basins with turf grass provide for minimal infiltration. Turf grass has a shallow root structure that does not open up the soil below the surface allowing water to infiltrate. By introducing native grasses and reducing the frequency of mowing from once a week to once or twice a year (in the winter), native grasses develop a deep root structure. The height of the grass is directly proportional to the depth of the root structure. Limiting mowing and allowing the grass to grow taller will ensure development of a deep root structure. This method reduces maintenance costs due to less mowing and improves water quality through increases in infiltration and subsequent decreases in stormwater discharges to nearby waterways.

Additionally, many basins throughout New Jersey are over-compacted, thereby limiting their infiltration capacity. Although the root structure of native vegetation may increase infiltration rates, some of these over-compacted basins may need to be deep-tilled to loosen up the soil, and soil amendments may need to be added. Promoting infiltration in these basins is important to improve water quality in the watershed.

Location

Figure 8.5 shows the location of each detention basin in the watershed. The location of the detention basins were determined using aerial photography. There is estimated to be four detention basins in this watershed.

Implementation

The watershed is estimated to only have four detention basins in it (1 in Hampton Borough, 1 in Washington Township and 2 in Franklin Township). Each municipality will have to retrofit its own detention basin. The Water Resources Program and North Jersey Resource Conservation and Development Council will work with the municipalities to ensure the proposed improvements to each detention basin are installed correctly.

The modifications of the detention basins should take a short amount of time. Although heavy equipment may be needed to remove the concrete channel and install the vegetative channel, precautions should be taken to avoid over-compacting the basin. Deep-tilling may be needed to loosen the soil in areas where heavy equipment is driven. The native grass will be seeded in the basins after the turf grass in the basin has been eliminated with an herbicide. Seed will need to be covered and protected from erosion.

The detention basins must be inspected for excessive debris and sediment accumulation at least four times annually, as well as after every storm exceeding one inch of rainfall. Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment, and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations (Semple *et al.*, 2004).

Mowing of these newly vegetative basins must be performed on a regular schedule based on specific site conditions (approximately once every six months). Vegetated areas must be inspected at least annually for erosion, scour and unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When the vegetation is establishing itself, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. Use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. Vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. The vegetative detention basin system should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs (Semple *et al.*, 2004).

Prioritization

There are only four detention basins for the entire watershed. The detention basins should be prioritized according to the loading rate of bacteria in each subwatershed. The basin or basins in the watershed with the highest loading rate should be retrofitted first. The basin or basins in the subwatershed with the lowest bacteria loading rate should be retrofitted last.

Expected Results

Retrofit designs should target infiltration of runoff generated from the water quality storm. Since approximately 90% of all storms in each year in New Jersey come in storms smaller than the water quality storm, this will have a dramatic effect on water quality in the watershed. While it is hard to measure the exact effect, the basins will have many of the same characteristics as a vegetated filter strip. It is difficult to estimate the reductions for each pollutant because many of the functions of the basin will be enhanced by the proposed changes.

Recommendation: Retrofit detention basins with native vegetation for lower maintenance and higher pollutant removal efficiency.

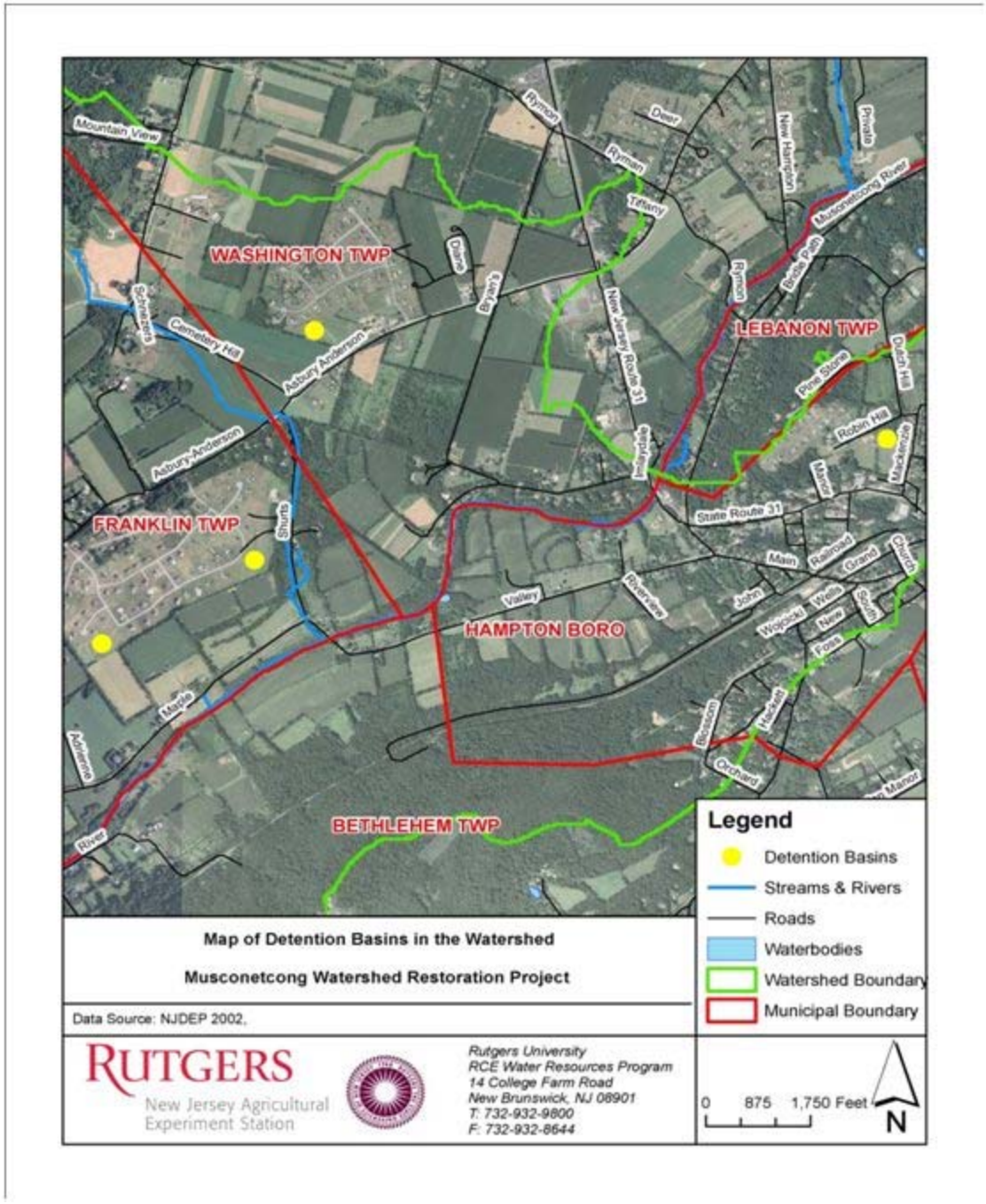

Figure 8.5: Map of Detention Basins within the project area

J. Roadside Ditch Design Alternatives

Current Conditions

There is a TMDL for fecal coliform in the Musconetcong River Watershed and its streams are impaired for pH, fecal coliform and temperature. Sources of fecal coliform in the watershed are live stock and chicken manure as fertilizer. The Musconetcong River Watershed is comprised mostly of agricultural land uses. Runoff from pastures or fields that use chicken manure as fertilizer can be discharge large concentrations of fecal coliform for the watershed during storm events. The runoff generated from pastures and cropland typically discharges to roadside ditches that lead to a local waterway (a tributary of the Musconetcong River or the river itself). The roadside ditches do not treat the stormwater runoff as the runoff travels through it. The roadside ditches are not vegetated they typically are channels of exposed soil along the side of the road. Roadside ditches do not have design standards unlike more conventional stormwater systems. Ditches are adhoc creations. The ditches appear to be designed not for stormwater management but convenience to the landowner. This approach to ditch design exacerbates water quality issues. In addition, typical ditches are not well maintained and usually consist of bare soil.

Without proper design, drainage ditches will continue to be deterrents to water quality. Simple designs, that take advantage of nature's mechanism for treating stormwater, can have positive effects on water quality and quantity issues in stormwater runoff that it is transported by ditches.

Ditch Design Alternative

Design Objectives:

The recommended management strategy is meant to protect the existing drainage ditches from erosion and improve the water quality of runoff traveling through them. The NJ Department of Transportation (NJDOT) Roadway Design Manual requires outlet protection of conduits for runoff velocity generated during the 25 year storm (at a minimum) to prevent erosion. Therefore it is recommended that any alteration of designs for a drainage ditch should provide for the capacity of a 25-year storm to prevent erosion in the ditch. The other goal of the strategy is to improve water quality of the runoff entering the ditch. A common method of improving water quality is to reduce the velocity of runoff to allow contaminants it carries to settle out. Designs should work to mimic the flow reductions seen in grassed filter strips for water quality improvement. An additional benefit of reducing velocities is encouraging infiltration of stormwater by retaining runoff in the ditch for more time (another way to improve water quality).

When recommendations are made to improve road side ditches, it is typically planned to widen and plant with a diverse mix of vegetation. Vegetation creates friction to reduce flow and encourage infiltration. The Musconetcong River Watershed has very narrow right of ways. Ditches need to be widened when vegetation is added to make maintenance of the ditches easier and more affordable. There is very little space available to widen the ditches in the Musconetcong River Watershed due to the limiting size of the right of ways. Instead, this strategy recommends using rip-rap (large stones), gabion baskets and weirs in different ways to control the flow as the vegetation would. Due to the space constrictions in the Musconetcong River Watershed, this is seen as the easiest way to transform the roadside ditches from a potential pollution source to a treatment device for stormwater.

Strategy 1

Stone-filled gabion baskets are inexpensive and easy to install. The gabion basket is an empty cube made of wire mesh. The mesh is filled with large stone; the stone can provide structural support while the mesh holds the stone in place. Gabion baskets have been used in the past as check dams for swales and other drainage channels. While the baskets are porous, they restrict flow through them. Gabions baskets can be installed periodically in drainage ditches to serve as an obstruction reducing the velocities in the channel and improving water quality. Gabion baskets reduce the velocity of the runoff allowing contaminants to settle out. Reductions in velocity retain runoff in the channel longer allowing more time for stormwater to infiltrate. The reduction in velocity will require the ditches to have a larger storage capacity. While there is little room to widen the ditch it can be deepened to meet the additional storage capacity requirements.

Strategy 2

A French drain is an underground trench filled with stone. The trench is a drainage device that creates a path of least resistance for water to flow. This proposed strategy is a French drain exposed to the surface. The basic design for this strategy proposes stone filled channels. The size of the channels filled with stone and portions of the ditch upstream of the exposed French drain need to be designed to account for the additional storage capacity required in the ditch due to the reduction in velocity of the runoff. The front and end of the French drain need to have structural support to prevent stone from dispersing up and down stream over time. A gabion basket check dam placed at the front and back of each exposed french drain would provide sufficient support. Essentially, this is a longer check dam. It is useful for locations that require vehicles to cross the ditch on a routine basis (farmers often require this and it could also be used for driveways).

Strategy 3

Gabion baskets provide a basic form of velocity control. They do not have the flexibility of flow control that other devices have such as weirs. A weir is simply a wall with a notch cut out of it. The size and placement of the notch has a strong effect on the amount of flow that the weir will allow through it. The flow is controlled by the shape, elevation and size of the notch and the height of the water behind the notch. The higher the water behind the weir and the larger the shape and size, the higher the flow rate. Weirs have been used for centuries. They can easily be constructed with a concrete footing and cinder blocks. This strategy is interchangeable with Strategy 1. They accomplish the same goals and have the same requires for additional storage capacity. The weir's advantage over the check dam is that you get greater control over the flow but it will cost more to design and implement than the basket.

The space between the weirs or other flow control mechanisms can be transformed into rain gardens. Rain gardens can make ditches more aesthetically pleasing and can be used as a tool to convince stakeholders to embrace the proposed changes to ditches as many of these changes may not be aesthetically pleasing.

Location

Figure 8.7 shows a map of the watershed and existing roadside ditches. The strategies listed above should be implemented where feasible. If all existing ditches were retrofitted with the recommended strategies in the Musconetcong Watershed it would have an impact on 12.7 miles of roadway and many more acres of surrounding drainage areas.

Implementation

After municipalities identify a road side to implement one of the recommended strategies, several existing parameters would need to be measured to ensure a successful design. The existing infiltration rate of the soils for the ditch should be tested. The test should be conducted for every 500 ft of ditch length or noticeable change in soil type. A survey should be conducted or existing topography data should be collected to determine the drainage area for the ditch (it may be more than the roadway). While the topography data is being collected, the slope of the ditch should be included. The two limiting parameters for the strategies are the width of the right-of-way and the depth to groundwater. The system cannot exceed the width of the right-of-way and the system should always be located above the seasonal high groundwater elevation (at least two feet).

Figure 8.6: Existing Drainage Swale

The strategies will involve relatively minor work for implementation. The activities included would be re-shaping the ditch (excavation), installing the flow constriction device (gabion basket check dams, weirs, and/or rip-rap), reseeding any bare soil and following the soil erosion and sediment control protocol to protect bare soil from erosion. If during the construction of the design, over 5000 square feet of land is disturbed then the project will require a Soil Erosion Sediment Control Permit. The municipality should have a discussion with the NJDOT about its drainage plans. If the design adheres to recommendations there should no problem with the NJDOT. The NJDOT have criteria for drainage of the roads in New Jersey but they are flexible in the approach as long as it meets the standards.

The drainage system will require inspection every three months (a visual inspection while driving along the system will suffice). The ditch should be inspected for standing water, debris, excess sediment, and health of vegetation. While vegetation is not part of the recommended strategies, there should be no bare soil in the ditch; the ditch should retain grass for additional erosion protection and infiltration. The grass in the ditches shall be allowed to grow with debris and excess sediment removed on a routine basis. Excess sediment can be removed by hand with a flat bottomed shovel and dead vegetation immediately removed and replaced. Vegetation should appear healthy with no visible bare spots in the system. Clean edges should be maintained between the road and the system with no signs of erosion or litter. Any noted evidence of vehicle compaction should be addressed and standing water remaining after 24 hours is evidence that additional maintenance is needed.

Prioritization

The roadside ditch projects are prioritized by the bacteria loading rates developed from the water quality sampling results. The subwatersheds with the highest loading rates should be set as first priority to have their road side ditches improved first. The subwatersheds with the lowest loading rates should have their roadside ditches improved last. This method allows for the roadside ditches that are most likely having the worst effect on the water quality will be mitigated first giving the watershed it's largest improvements first.

Expected Results

There is no accepted fecal coliform removal rate for this type of BMP. The removal rates found in literature tend to vary a little. This BMP will act like a vegetative filter strip and a bioretention basin. The literature removal values for both BMPs are high. The bacteria settle out as the water slows down. The removal values can range from 99% to 74% for bioretention basins and vegetative buffers. It is safe to assume that the fecal coliform in the runoff generated from pastures or cropland (with manure as fertilizer) will be reduced by 99 to 74% for each rain storm. There are no agreed upon loading rates for fecal coliform in agricultural operations, so load reductions cannot be predicted but based on the acceptable removal rates the load reductions will be substantial.

Recommendation: All ditches should be retrofitted with native vegetation to reduce flow, filter and stabilize banks. Funding agencies (e.g. NJDEP 319(h) can coordinate efforts with Highway Department or County Engineering Department.

Figure 8.7: Locations of potential roadside ditch retrofits.

Project Name: #7 Retrofit of Roadside Ditch on Turkey Hill Road

Location:	Subwatershed Priority:
Along southern side of Turkey Hill Road in Bethlehem Township (See location map)	High

BMP Type and Description:
Roadside Ditch improvement

Issues and Concerns:
The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for pH and fecal coliform. A significant source of fecal coliform in an agricultural watershed is stormwater runoff from pastures. Animal waste left by the livestock on the pasture can be source of bacteria to the watershed. It is recommended that this waste be collected and stored in a central location with stormwater best management practices to treat the stormwater runoff the waste generates to prevent the bacteria from entering the waterway. Many farmers do not have the capabilities to do this level of maintenance and the waste is left on the pasture for long periods of time. During storm events the runoff generated from the pasture picks up and carries bacteria from the waste and carries the bacteria to the stream. Croplands that use manure as fertilizer are potential sources of fecal coliform.

Existing Conditions:
The roadside ditch that runs along the northside of Turkey Hill Road has an estimated drainage area of 3.73 acres. The drainage area is the Turkey Hill Road and pastures. Each roadside ditch is approximately 500 feet long and approximately 3 to 5 feet wide. There is scouring along the entire length of the ditch. There is no vegetation in this ditch. Bare soil is exposed along the entire bottom and side slopes of the ditch. This bare soil allows the ditch to become a source of sediment during storm events. There is no inlet to this ditch, runoff flows over land and enters the ditch along the entire length of the ditch. These ditches do not offer any treatment of stormwater runoff and only exacerbate the poor water quality in the runoff from the drainage area instead of reduce it.

Proposed Solutions:
The purpose of roadside ditches is to transport runoff from a drainage area to the nearby waterway while improving the water quality of the runoff not diminishing it. The roadside ditches along Turkey Run Road are a source of pollution to the runoff and as runoff passes through the ditch, its water quality decreases. There are several factors that negatively affect the water quality of the runoff discharged from the ditch. The ditch is shaped very poorly. It has high steep side slopes that force the elevation to rise quickly in the channel. The runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallow side slopes.

After the ditch is re-graded it needs to be re-vegetated. The plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive with dry and very wet environments. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing bacteria and other pollutants from the runoff. Stabilizing the side slopes and bottom of the ditch and adding the appropriate vegetation prevents the ditch from decreasing the water quality of the runoff but also treats the stormwater runoff and improves the water quality of the runoff.

Finally, the size of this roadside ditch like many in the watershed is constrained by the size of the Right – of – Way (ROW). This ditch has a very small ROW. This limits how much the ditch can be

shaped during the re-grading process. If the shape of the ditch cannot be dramatically changed then other methods must be used to reduce the velocity of the runoff traveling through the ditch.

Gabion mattresses can be used as check dams in the ditch to reduce the velocity of the runoff traveling through the ditch. Gabion mattresses are metal cages in the shape of long, wide and flat boxes. The cages can be several feet long and several feet wide and only six inches tall. The cages are filled with large stone (rip-rap). After the stones have been placed in the rock the cage is closed tight. The mattresses would be placed across the side slopes and bottom of the ditch. The mattresses would be placed in the ditch approximately every 100 feet. The mattresses would obstruct the flow of the runoff for small storms reducing its velocity. Flow from larger storms would be reduced due to the presence of the mattresses but most of the runoff would flow over the mattresses and be less affected than the flow from larger storms.

Anticipated Benefits:

The improvements to the roadside ditch described above will allow the ditch to treat stormwater runoff similar to the way vegetative filter strips treat stormwater runoff. The New Jersey Best Management Practice Manual does not have an accepted fecal coliform removal rate for vegetative filter strips. The removal rates found in literature tend to vary a little. The literature values are high. The bacteria are removed the same way that sediment is removed from the water column. The bacteria settle out as the water slows down. The removal values can range from 91% to 74%. It is safe to assume that the fecal coliform in the runoff generated from pastures or cropland (with manure as fertilizer) will be reduced by 91 to 74% for each rain storm. There are no agreed upon loading rates for fecal coliform in agricultural so load reductions cannot be predicted but based on the acceptable removal rates the load reductions will be substantial.

Major Implementation Issues:

The one serious obstacle to implementation will be stakeholders. This design calls for the vegetation not to be mowed every week but only once a year. The vegetation needs to grow tall for the system to work properly. This will be seen by some residents as the township not doing their job of maintaining the ditches. A concentrated effort on the park of the town and the Hunterdon county soil conservation district needs to be made to inform the public about these new projects and their new natural aesthetic. By keeping the public informed, this obstacle should be easily avoided.

Possible Funding Sources:

319(h) grants from the New Jersey Department of Environmental Protection

Partners/Stakeholders:

North Jersey RC&D
Bethlehem Township
Hunterdon County Soil Conservation District

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$3,000
4	Prepare Maintenance Plan			$5000
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Costs	Quantity	
	Re-vegetate the Ditch (assuming installed by volunteers)	$0.5/sq. ft.	$2,500	$1,250
	Supervision of Volunteers	$2,000	1	$2,000
	Re-grade Ditch	$5,000	1	$5,000

	Rip Rap Check Dam	$1000/100 linear feet	5	$5,000
	Soil Erosion and Sediment Control	$1,000	1	$1,000
	Contingency (20%)		1	$2,850
	Total BMP installation costs			$17,100
Total project cost				**$27,600**
Annual operation and maintenance cost				$2,000

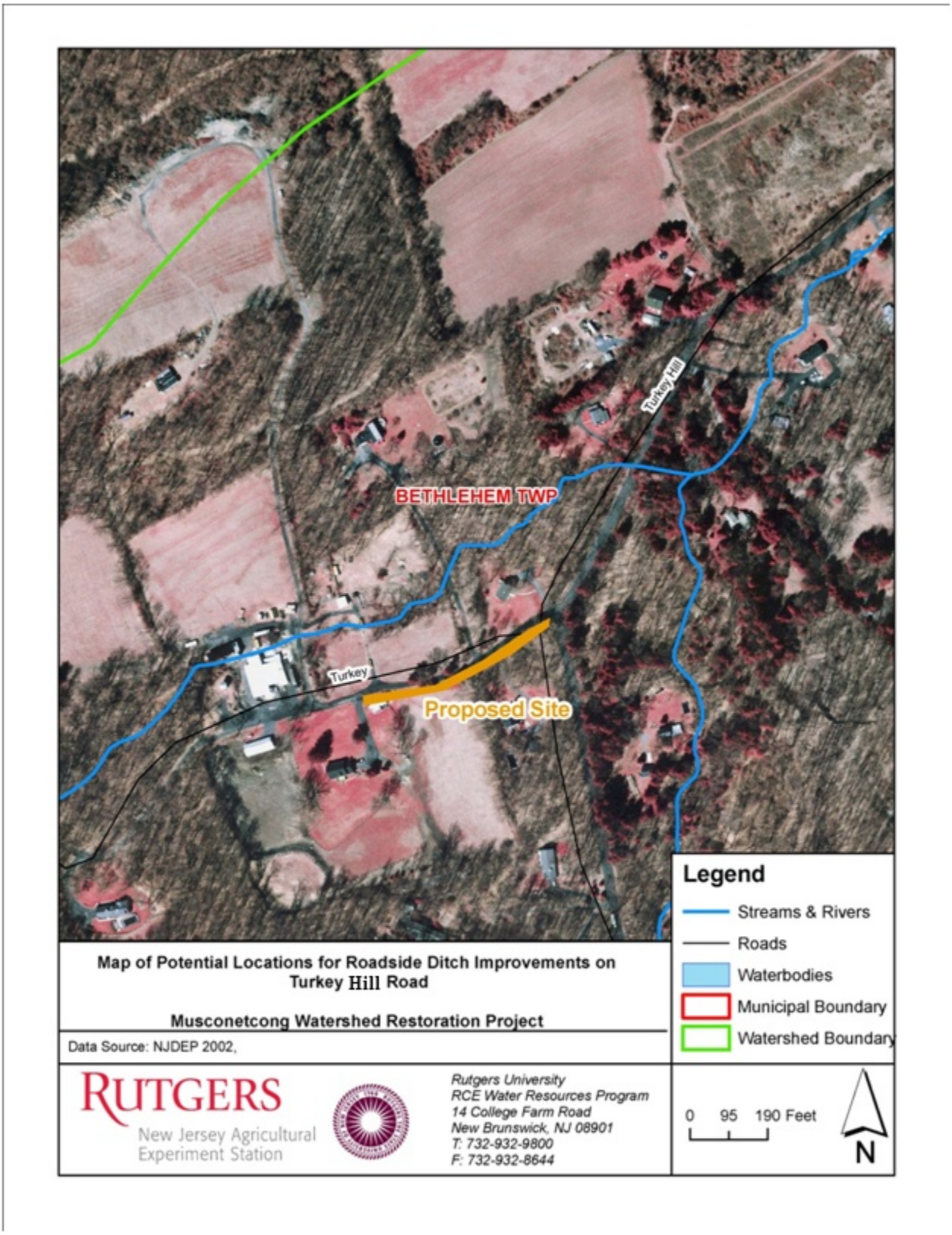

Figure 8.14: Location for roadside ditch improvements on Turkey Hill road.

Project Name: #8 Agricultural Vegetative Buffer	
Location: South of Route 173 in Bethlehem Township	Subwatershed Priority: Medium
BMP Type and Description: Vegetative Buffer	
Issues and Concerns: The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for both pH and fecal coliform. A significant source of fecal coliform in an agricultural watershed is stormwater runoff from pastures. Animal waste left by livestock on the pasture can be a source of bacteria to the watershed. It is recommended that this waste be collected and stored in a central location with best management practices to treat stormwater runoff generated from the waste area preventing bacteria from entering adjacent waterways. Many farmers/landowners do not have the capabilities to implement this level of maintenance and waste is left on the pasture for long periods of time. During storm events, runoff generated from the pasture picks up and carries bacteria from the waste carrying the bacteria to the adjacent stream. Croplands that use manure as fertilizer are also a potential source of fecal coliform.	
Existing Conditions: The proposed site for this project is a small tributary in Bethlehem Township. The stream in the site is approximately 1,900 feet long. This tributary runs through a farm with cropland and pastures. Despite a few trees and small shrubs along the edge of the shoreline, there is no buffer along either shoreline. The drainage area of the vegetative buffer is approximately 54 acres.	
Proposed Solutions: All of the stormwater runoff generated from the drainage area flows over land and discharges to a tributary of the Musconetcong River. This land is used for crops and pastures; any proposed solution must have the minimum amount of interference to the existing operations. Vegetative buffer strips meet the needs of this project. The buffer is only located along the edge of the shoreline and only has to be 30 feet wide. It will only operate on the edges and have the smallest impact on the everyday operations of the farm. Vegetative buffers do not require much maintenance through the year. They are mostly comprised of hay or warm season grasses that should be harvested or mowed every six months. Finally, buffers are easy for farmers to install themselves. The farmer will be provided the necessary material and compensation for the project and be able to install it at the most opportune time due to the schedule of the farm.	
Anticipated Benefits: The New Jersey Best Management Practice Manual does not have an accepted fecal coliform removal rate for vegetative filter strips. The removal rates found in literature tend to vary a little. The literature values are high. The bacteria are removed the same way that sediment is removed from the water column. The bacteria settle out as the water slows down. The removal values can range from 91% to 74%. It is safe to assume that the fecal coliform in the runoff generated from pastures or cropland (with manure as fertilizer) will be reduced by 91 to 74% for each rain storm. There are no agreed upon loading rates for fecal coliform in agricultural so load reductions cannot be predicted but based on the acceptable removal rates the load reductions will be substantial.	

Major Implementation Issues:
The one serious obstacle to implementing the vegetative buffer is convincing farmer to install this BMP on its property. The farmer also has to agree keep the vegetative buffer for a long period of time and to properly maintain the buffer for the entire time. If the buffer is not properly maintained the vegetative buffer will not work properly. This problem can be overcome making the process as simple and stress free for the farmer as possible. The farmer is being asked to give up some land for this effort; the worst thing to do is then make it very difficult for the farmer to do this. The buffer will take as little space as possible because the most space on the farm they take the more money they could cost the farmer.

Possible Funding Sources:
319(h) grants from the New Jersey Department of Environmental Protection

Partners/Stakeholders:
North Jersey RC&D
Bethlehem Township
Hunterdon County Soil Conservation District
Trout Unlimited-Musconetcong Home River's Initiative

Task	Task Description			Estimated Cost
1	Complete Topographic Survey and soils test			$500
2	Prepare Final Design			$1,000
	Activities for BMP installation	Unit Costs	Quantity	
	Install Vegetative Buffer (assuming most work completed by volunteers)	$5,000	1	$5,000
	Supervision of Volunteers	$1,000	1	$1,000
	Contingency (20%)	$200	1	$1,200
	Total BMP installation costs			$7,200
Total project cost				**$8,700**
Annual operation and maintenance cost				$100

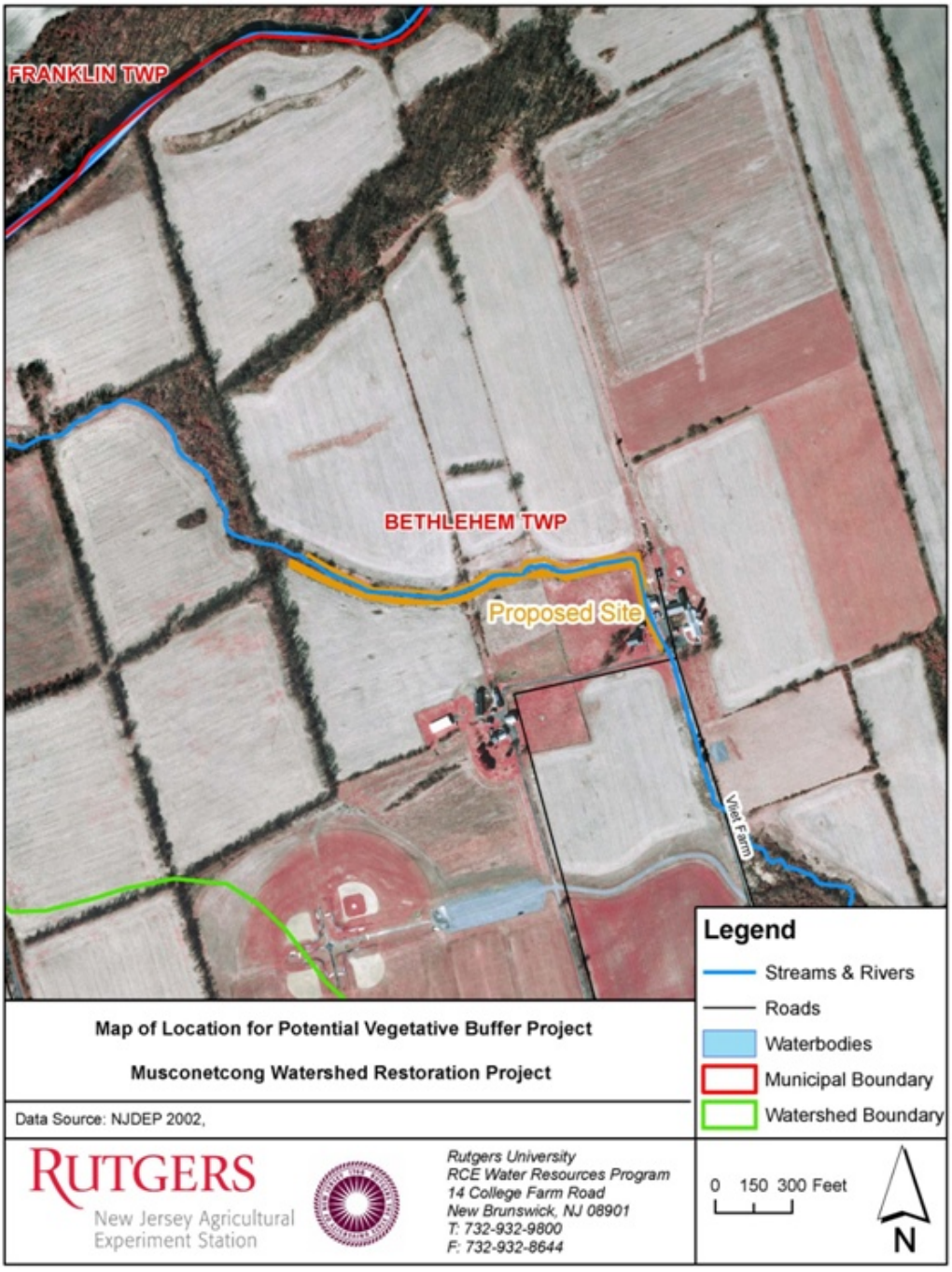

Figure 8.15: Location for potential vegetative buffer project

Project Name: #9 Wetland and Streambank Restoration Project	
Location: On State Route 173, just East of D Hull Lane in Bethlehem Township behind Spain Inn 2 Restaurant	Subwatershed Priority: High
BMP Type and Description: Wetland and Streambank Restoration work	
Issues and Concerns: A Total Maximum Daily Load (TMDL) has been established to address a fecal coliform impairment that has been identified in the Musconetcong River Watershed. The TMDL calls for a 93% reduction of fecal coliform in the water column. Equine facilities can be large sources of bacteria in agricultural watersheds. If the properties are not properly managed and the waste from the livestock is not taken care of on a daily basis runoff from the equine facility can become a large source of bacteria during each rain storm. The runoff generated from equine facility has a high concentration of bacteria which it typically carries directly to the surface water without being treated.	
Existing Conditions: There is a large area behind Spain Inn 2 Restaurant (1045 State Route 173, Asbury, NJ). It appears this area was formerly an outdoor pool. The drainage area of the pond just upstream of the project site consists of several equine farms with very little buffer protecting the stream from the stormwater runoff generated from the equine facilities. The buffer surrounding the stream is only a few young trees wide with very little other vegetation. This area behind Spain Inn 2 often floods during even small storms. The flood waters pick up more non-point source pollution from drainage area as it widens. Along the streambanks upstream and downstream of Spain Inn 2 there is clear evidence of an unstable streambank with streambank erosion. The project location in question does not appear to have any current use. At one time it may have been an above ground pool but that pool is very dilapidated (one wall of the possible above ground pool is missing).	
Proposed Solutions: The Water Resources Program proposes transforming this unused space behind Spain Inn 2 and a portion of an adjacent equine facility into a restored wetland. The soil and vegetation surrounding the site indicate that at one time it was a wetland before the property owner decided to develop it. The proposed site is one acre. This site would be transformed into a stormwater wetland that would have the stream routed through the wetland to treat the stream water before it travels further downstream. The wetland will reduce the amount nutrients, sediment and bacteria that contribute to the excessive load of pollutants the Musconetcong River currently carries.	
Anticipated Benefits: Wetland is a very beneficial ecosystem to the greater environment. It is a habitat for a large diverse group of animals and insects. It can mitigate flooding in local areas and treat the water that passes through it with its reduced flow rate and large amounts of diverse vegetation. The wetland will be designed to mitigate flooding in the area. The wetland will have the capacity to reduce flooding by hold a larger volume of water during storm events The vegetative buffer is expected to treat the stormwater runoff from every storm each year. The vegetation in the vegetative buffer will treat and filter the runoff from every storm. The vegetative buffer typically removes 90% of TSS, 50% of total phosphorus and 30% total nitrogen. Based upon aerial loading calculations for the drainage area of 100 pounds of total	

suspended solids/acre/year, 0.2 pounds of total phosphorus/acre/year, and 5.0 pounds of total nitrogen/acre/year, this project would reduce TSS by 1,335 pounds/year, total phosphorus by 1.5 pounds/year and total nitrogen by 22.3 pounds/year.

Major Implementation Issues:

The one serious implementation issue for this project is that the project is planned on private land. The property owner of Spain Inn 2 would have to forfeit any future plans he or she had for the property and sign an easement allowing for the installation of the wetland. Depending on the future plans of the property owner this may be a very hard sell. When this piece of the property was a pool it probably helped attract additional business for the restaurant. A natural wetland at the end of the property will not have the same draw as an above ground pool did.

Possible Funding Sources:

319 (h) Grant

Partners/Stakeholders:

North Jersey RC&D

Hunterdon County Soil Conservation District

Task	Task Description			Estimated Cost
1	Complete Topographic Survey and soils test			$7,000
2	Prepare Final Design			$15,000
3	Develop maintenance plan for site			$3,000
	Activities for BMP installation	Unit Costs	Quantity	
	Wetland Installation	$30/sq. ft.	43,560	$130,680
	Contingency (20%)	$26,136	1	26,136
	Total BMP installation costs			**$156,816**
Total project cost				$181,816
Annual operation and maintenance cost				$1,000

Project Name: #10 Retrofit of Roadside Ditch on Butler Road	
Location: Along both sides of Butler Road in Franklin Township between Mountain View Road and Bloomsbury Road	Subwatershed Priority: Medium
BMP Type and Description: Roadside Ditch improvement	
Issues and Concerns: Roadways and agricultural landscapes can be a source of sediment, phosphorus and bacteria for a local waterway. Pollutants accumulate on streets (sediment, phosphorus, nitrogen and bacteria). The fertilizer used on agricultural land uses can be a source of phosphorus and nitrogen. Manure used as fertilizer and wildlife grazing agricultural land can be a source of fecal coliform in a watershed. These accumulated pollutants can be carried to the local waterways via stormwater runoff. Roadside ditches carry the runoff from these potential sources directly to the stream or one of its tributary.	
Existing Conditions: The roadside ditches that run along both sides of Butler Road have an estimated drainage area of 115 acres. The drainage area is the Butler Road and agricultural land uses. Each roadside ditch is approximately 3,000 feet long and approximately 5 to 10 feet wide. There is scouring along the entire length of the ditch. The vegetation in the ditch is only turf grass where there is vegetation in the ditch. Bare soil is exposed along the entire bottom of the ditch. This bare soil allows the ditch to become a source of sediment during storm events. There is no inlet to this ditch, runoff flows over land and enters the ditch along the entire length of the ditch.	
Proposed Solutions: The purpose of roadside ditches is to transport runoff from a drainage area to the nearby waterway while improving the water quality of the runoff not diminishing it. Currently roadside ditch SD-389 is a source of pollution to the runoff and as runoff passes through the ditch, its water quality decreases. There are several factors that negatively affect the water quality of the runoff discharged from the ditch. The ditch is shaped very poorly. It has high steep side slopes that force the elevation to rise quickly in the channel. The runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallow side slopes. After the ditch is re-graded it needs to be re-vegetated. The plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive with dry and very wet environments. This vegetation should thrive in the ditch environment. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream. Finally, the size of this roadside ditch like many in the watershed is constrained by the size of the Right – of – Way (ROW). This ditch has a very small ROW. This limits how much the ditch can be shaped during the re-grading process. If the shape of the ditch cannot be dramatically changed then other methods must be used to reduce the velocity of the runoff traveling through the ditch. Gabion mattresses can be used as check dams in the ditch to reduce the velocity of the runoff	

traveling through the ditch. Gabion mattresses are metal cages in the shape of long, wide and flat boxes. The cages can be several feet long and several feet wide and only six inches tall. The cages are filled with large stone (rip-rap). After the stones have been placed in the rock the cage is closed tight. The mattresses would be placed across the side slopes and bottom of the ditch. The mattresses would be placed in the ditch approximately every 100 feet. The mattresses would obstruct the flow of the runoff for small storms reducing its velocity. Flow from larger storms would be reduced due to the presence of the mattresses but most of the runoff would flow over the mattresses and be less affected than the flow from larger storms.

Anticipated Benefits:

The ditches will be expected to infiltrate a greater amount of water during each storm event and remove more nutrients and sediment from the runoff of each storm. The new native vegetation will be allowed to grow tall. The larger vegetation will have a strong filtration effect on the stormwater runoff by removing sediment and nutrients. The larger vegetation will have a larger root structure underground. The root structure will make the soil at the bottom of the basin more porous and increase the infiltration rate. The increased infiltration rate of the basin will allow less water to leave the basin after each storm which would prevent sediment and nutrients from entering the local water way. After the retrofits are complete, the ditch would be very similar to a vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80% of TSS, 30% of total phosphorus and total nitrogen. Based upon aerial loading calculations for the drainage area, 100 pounds of total suspended solids/acre/year, 0.6 pounds of total phosphorus/acre/year, and 5.0 pounds of total nitrogen/acre/year, this project would reduce TSS by 3.4 to 4.6 tons/year, total phosphorus by 27.9 pounds/year, and total nitrogen by 172.5 pounds/year.

Major Implementation Issues:

The one serious obstacle to implementation will be stakeholders. This design calls for the vegetation not to be mowed every week but only once a year. The vegetation needs to grow tall for the system to work properly. This will be seen by some residents as the township not doing their job of maintaining the ditches. A concentrated effort on the part of the town and the Warren County Soil Conservation District needs to be made to inform the public about these new projects and their new natural aesthetic. By keeping the public informed, this obstacle should be easily avoided.

Possible Funding Sources:

319(h) grants from the New Jersey Department of Environmental Protection

Partners/Stakeholders:

North Jersey RC&D
Franklin Township
Warren County Soil Conservation District

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$5,000
3	Prepare Final Design			$10,000
4	Prepare Maintenance Plan			$1,000
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Costs	Quantity	
	Re-vegetate the Ditch (assuming installed by volunteers)	$0.5/sq. ft.	60,000	$30,000

	Supervision of Volunteers	$7000	1	$7,000
	Re-grade Ditch	$15,000	1	$15,000
	Rip Rap Check Dam	$1000/100 linear feet	60	$60,000
	Soil Erosion and Sediment Control	$1000	1	$5,000
	Contingency (20%)	32,800	1	$32,800
	Total BMP installation costs			$196,800
Total project cost				**$214,300**
Annual operation and maintenance cost				$2,000

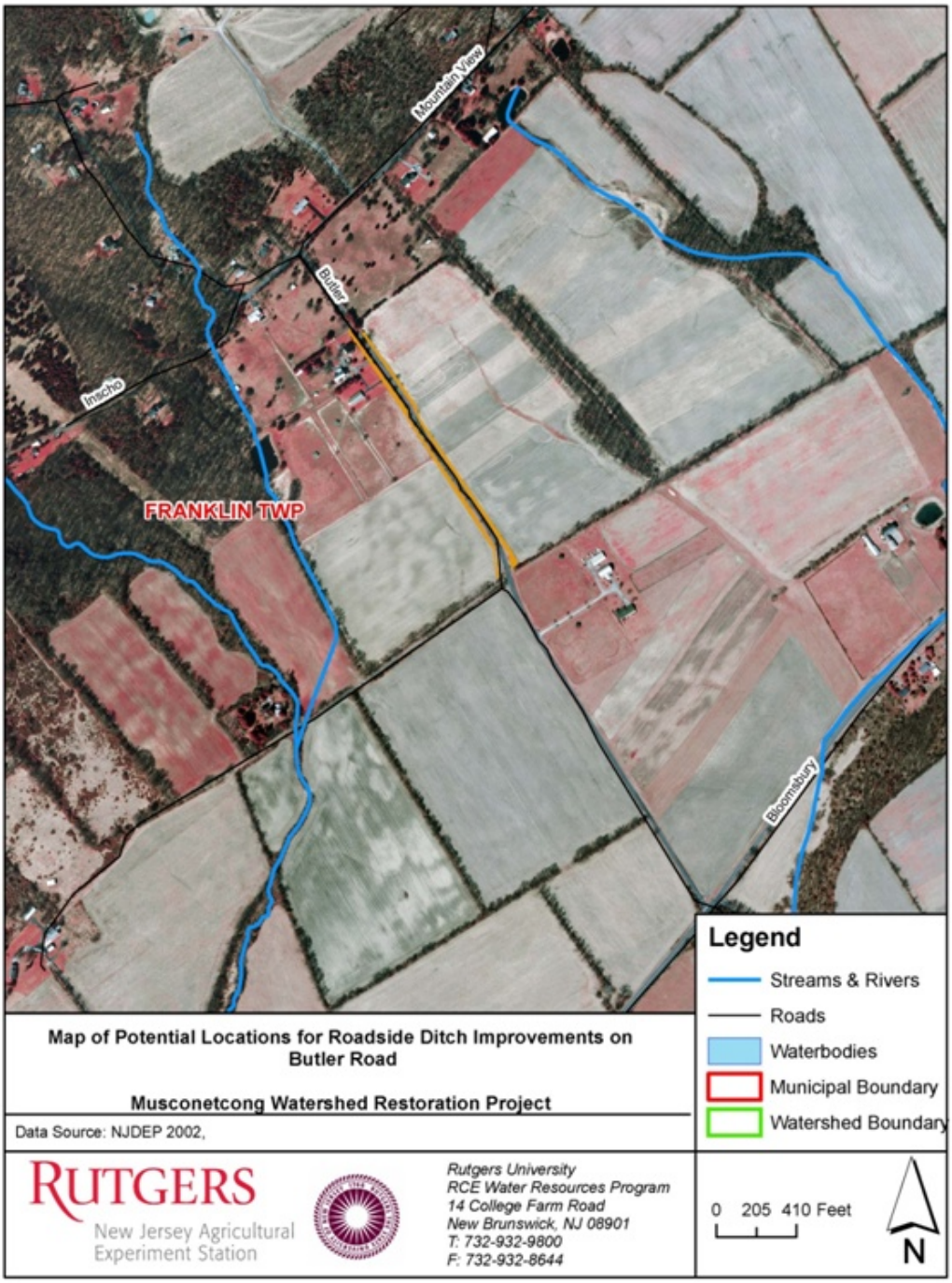

Figure 8.16: Location for potential roadside ditch improvements on Butler road

Project Name: #11 Roadside Residential Rain Garden	
Location: The neighborhood of Pacesetter Drive in Washington Township, Warren County	Subwatershed Priority: Low
BMP Type and Description: Road Rain Garden	
Issues and Concerns: Roofs, lawns and roadways in residential neighborhoods are considered potential sources of nutrients, bacteria and sediment in a watershed. Pollutants accumulate on streets (sediment, phosphorus, nitrogen and bacteria). The fertilizer used in residential neighborhoods can be a source of phosphorus and nitrogen. Waste from house pets and wildlife found on home owners properties can be a source of fecal coliform in a watershed. These accumulated pollutants can be carried to the local waterways via stormwater runoff. The Musconetcong River Watershed has fecal coliform Total Maximum Daily Load (TMDL) that calls for a 93% reduction of fecal coliform in the watershed.	
Existing Conditions: The neighborhood consists of 37 houses on approximately 101 acres of land with approximately 13.3 acres of impervious surfaces. Most of that impervious surface is the roadway. The other impervious surfaces of development drain to the roadway. Just like driveways and other landscapes, roadways accumulate sediment and other pollutants that get washed away into the stream. The entire development drains into a large detention basin but it is have been well documented that detention basins do not treat stormwater runoff very well especially for small storms. Before the stormwater runoff is routed to the detention basin it passes over a measurable amount of the roadway to reach a catch basin. The runoff from the lawns, roofs, driveways and roadways are combined on the roadway before it reaches the catch basin and ultimately the Musconetcong River.	
Proposed Solutions: The roadway for this development routes the stormwater runoff from all the landscapes into the catch basins. Rain gardens can be installed along the roadway to capture the runoff just upstream of a catch basin. These rain gardens can be strategically placed throughout the development to capture all the runoff generated from the developed for the New Jersey Stormwater Quality Storm (1.25 inches). A curb cut will be made near each of the catch basin and the curb cut will allow stormwater runoff to flow off the roadway and into the "road" rain garden. During storms that produce more runoff that the road rain gardens can capture the water elevation in the rain garden will be equal to the elevation in the road and the runoff will bypass the rain garden and discharge directly to the catch basin. The road rain garden will be vegetated with woody shrubs and herbaceous plugs.	
Anticipated Benefits: The rain garden is expected to capture approximately 90% of all the storms that occur each year on the property. The New Jersey Stormwater Quality Storm is larger than 90% of all the storms that occur in a typical year in New Jersey. The vegetation in the rain garden will treat and filter the runoff from storms that are larger than the New Jersey Stormwater Quality Storm. By capturing approximately 90% of all the storms during the course of a year the rain garden will allow much less runoff to leave the basin for the year which would prevent sediment, bacteria and nutrients from the entering the local water way. During storms larger than the design storm of the road rain garden the runoff will bypass the rain garden and not be treated. It is fair to assume that most if not all of pollutant removal ability of these rain	

gardens are from capturing all the runoff from small storms. Based upon aerial loading calculations for the drainage area of 100 pounds of total suspended solids/acre/year, 0.2 pounds of total phosphorus/acre/year, and 5.0 pounds of total nitrogen/acre/year, this project would reduce TSS by 1,197 pounds/year, total phosphorus by 2.4 pounds/year, and total nitrogen by 59.9 pounds/year. There are no accepted loading rates or removal rates for fecal coliform. A removal rate of 99% was found in the literature for bioretention basin. Without an accepted loading rate, the researchers cannot estimate the amount of bacteria the rain garden will remove but it is fair to assume that the basin will remove a substantial amount of bacteria from runoff.

Major Implementation Issues:

The one serious obstacle to implementing individual rain gardens is the property owner. The property owner has to first agree to have the rain garden installed on their property. The property owner also has to agree keep the rain garden for a long period of time and to properly maintain the rain garden for the entire time. If the rain garden is not properly maintained the rain garden will not work properly. This problem can be overcome by involving the property owner in the design process as much as possible and incorporating their ideas as much as possible.

This project may prove more difficult because it requires the installation of multiple rain gardens in close proximity to each and all of the land owners must be willing to cooperate for the project to be implemented.

Possible Funding Sources:

319(h) grants from the New Jersey Department of Environmental Protection

Partners/Stakeholders:

North Jersey RC&D
Washington Township

Task	Task Description (for just one rain garden)			Cost
1	Complete Topographic Survey and soils test			$2,000
2	Prepare Final Design			$5,000
	Activities for BMP installation (per Rain Garden)	Unit Costs	Quantity	
	Install Rain Garden (assuming most work completed by volunteers)	$2,000	1	$2,000
	Supervision of Volunteers	$1,000	1	$1,000
	Contingency (20%)	$200	1	$300
	Total BMP installation costs			$3,300
Total project cost				$10,300
Annual operation and maintenance cost				$500

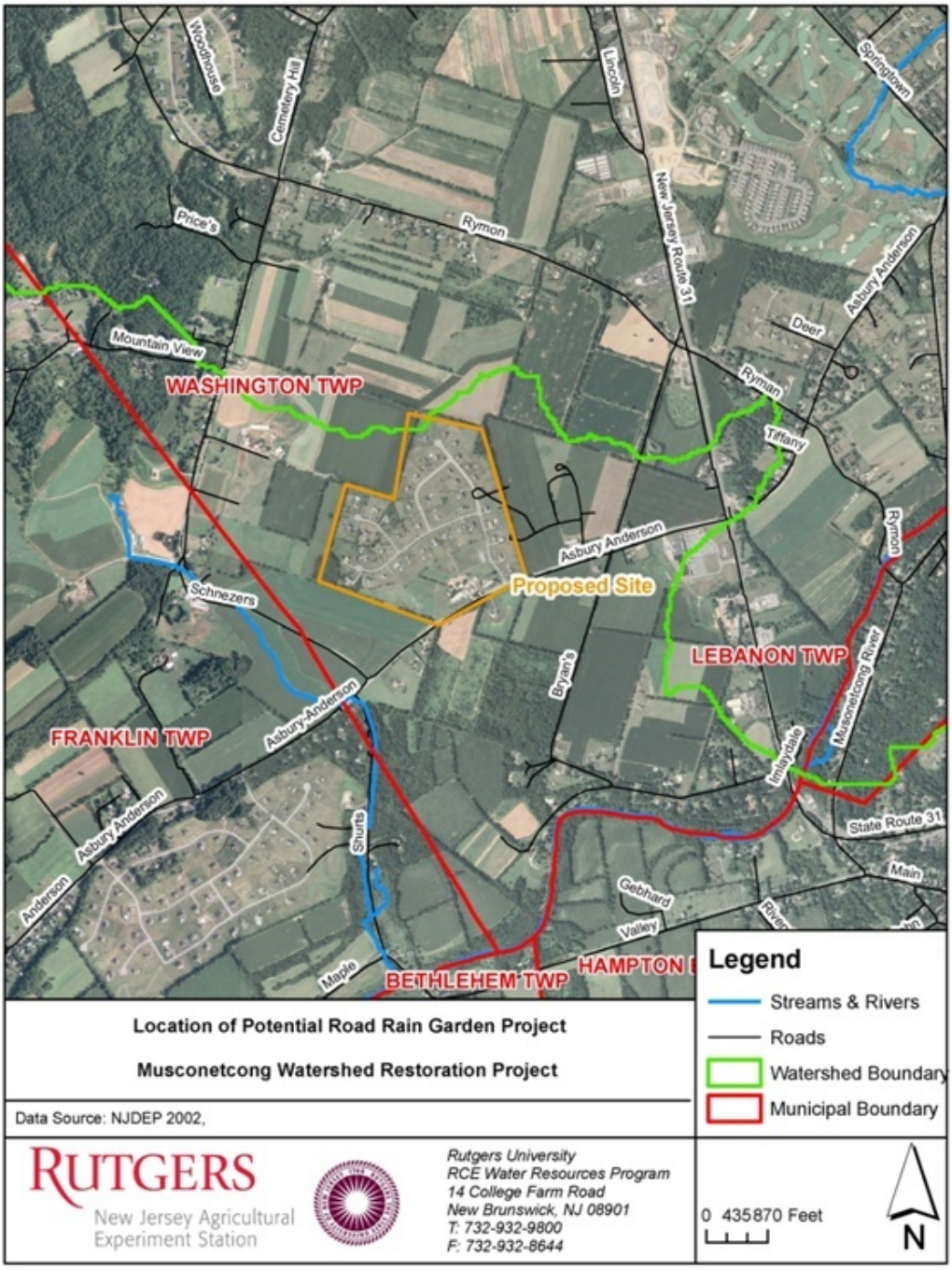

Figure 8.17: Location of potential road rain garden project

Project Name: #12 Stream Corridor Restoration	
Location: On Person Road in Bethlehem Township. Just north of the USGS monitoring station at the bottom of the watershed.	Subwatershed Priority: Medium
BMP Type and Description: Streambank Stabilization and Habitat Creation	
Issues and Concerns: Deteriorating streambanks can be large sources of sediment in the stream. Unstable streambanks create poor habitats and contribute to a poor ecosystem. Poor streambanks starting in one section of the stream can spread removing habitat and decreasing water quality. The Musconetcong River Watershed does not have a TMDL for Total Suspended Solids (TSS) but that does not mean it could have one in the future. Watersheds in the surrounding areas have water quality problems related to TSS. It is not hard to imagine TSS affecting the water quality of the Musconetcong River in the near future. It is better to remove or mitigate any sources of pollutants such as TSS. Proactively addressing sources of pollutants that do not have a TMDL yet will prevent the need to create a TMDL by keeping the pollutant concentrations below the standard.	
Existing Conditions: The proposed site for stream corridor restoration is at the very bottom of the watershed in a hunting and fishing club's property. The stream of the stream corridor is approximately 500 feet. The streambanks on either side of that section of the Musconetcong are severely eroded. The banks have a steep slope and there is very little vegetation on either side of the bank. The banks are clearly eroding whenever the water elevation rises due to storm events. The stream corridor was assessed to have poor conditions to create habitat.	
Proposed Solutions: Currently the stream corridor has steep slopes and very few opportunities for local wildlife to develop habitat. The proposed solutions while simple are intended to change both characteristics. The side slopes along either side of the stream need to be re-graded with much shallower slopes where possible. After the portions of the stream corridor that could be re-graded have been re-graded, erosion protections need to be put in place to protect the banks and encourage vegetation to establish itself on the banks. Bank stabilization can be done by a number of ways. Gabion mattresses can be installed along the banks to protect the banks from erosion. While gabion mattresses have proven to effectively protect stormwater they do not encourage vegetation growth. There are newer techniques and designs (Crib walls, cross logs, live stakes and brush mattresses) such as that will prevent erosion just as effectively as gabion mattresses. The difference between the newer techniques and gabion mattresses is the newer techniques use vegetation for erosion control. This is a more natural approach and one more conducive to establishing a diverse habitat in the stream corridor.	
Anticipated Benefits: The purpose of the project is to implement a streambank stabilization project. This project will be a showcase for the watershed and its surrounding area of new streambank stabilization techniques that take advantage of the local vegetation and facilitate a more diverse habitat while preventing streambank erosion. The streambank restoration will remove any invasive species that have establishment themselves on that streambank.	
Major Implementation Issues: The only implementation issue for this project would be getting the owner's permission for	

the work. The owner of the property is local hunting and fishing club. One of the project partners of this project North Jersey RC&D know this organization and has a good relationship with them. As long as they are included in this project from the beginning it should not be a serious problem because this organization will be happy to work on a project that makes the stream more habitable to for fish.

Possible Funding Sources:
319(h) grants from the New Jersey Department of Environmental Protection

Partners/Stakeholders:
North Jersey RC&D
Franklin Township
Bethlehem Township
Hunterdon County Soil Conservation District
Warren County Soil Conservation District
Warren Rod & Gun Club

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$5,000
3	Prepare Final Design			$25,000
4	Prepare Maintenance Plan			$1,000
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Costs	Quantity	
	Install Streambank Stabilization Methods	$150,000	1	$150,000
	Contingency (20%)	$30,000	1	$30,000
	Total BMP installation costs			$180,000
Total Estimated Project Cost				**$212,500**
Annual operation and maintenance cost				$300

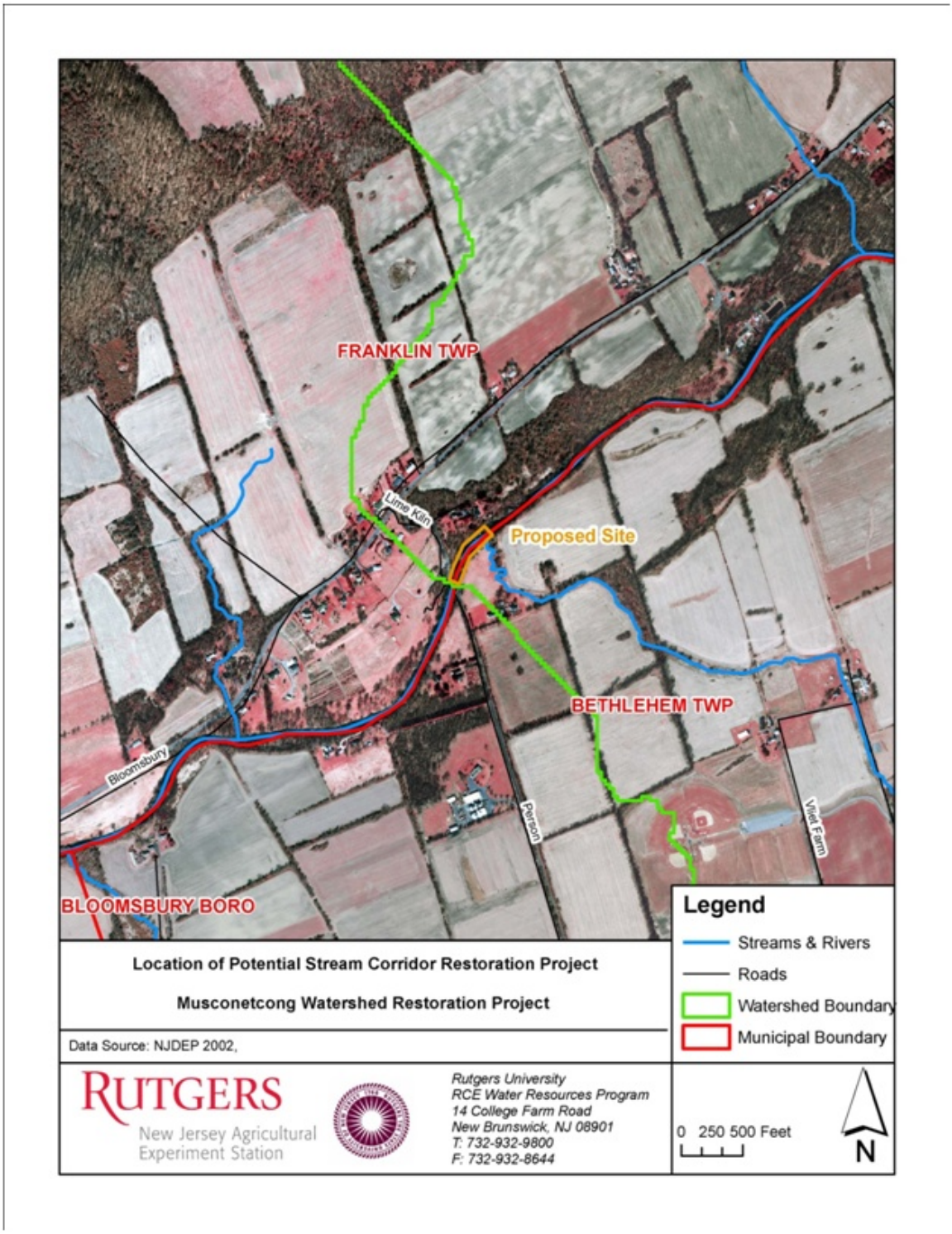

Figure 8.18: Location for potential stream corridor restoration

Project Name: #13 On-site Waste Water Treatment: Education and Outreach	
Location: Throughout Project Area	Subwatershed Priority: High
BMP Type and Description: Education and Outreach	
Issues and Concerns: The Musconetcong River Watershed has been listed in the New Jersey Integrated Water Quality Monitoring and Assessment Report, which includes the 305(b) Report and 303(d) List, as impaired for both pH and fecal coliform. A significant source of fecal coliform is failed septic systems. This is very prevalent within this specific project area due to the karst geology present through much of the project area. This geological feature causes sink holes, caused by either the dissolution of carbonate rocks or suffusion, a process by which water infiltrating through soil above limestone layer with fissures or depressions washes away the soil slowly creating a sinkhole, that can destroy or damage septic systems functionality. (Khomenko, 2006)	
Existing Conditions: Initial water quality testing confirmed the presence of fecal coliform throughout the project area. The presence of fecal coliform was then analyzed using bacteroide data, which is a test to isolate the bacteria found in the fecal coliform species that is specific to the species it comes from, to establish that in addition to bovine fecal coliform there was also human coliform making its way to the Musconetcong River.	
Proposed Solutions: A comprehensive outreach, education and marketing platform designed to inform residents of the impact and responsibility of on-site waste disposal systems (septic systems). This plan should be designed to provide information about the waterway impairments within the project area as well as the causes and effects of inaction; it should inform the community of actions that can be taken to reduce various pollution. The program should address resident concerns with funding opportunities should a problem be found with their specific system.	
Anticipated Benefits: By educating the general public about the personal responsibility required to ensure proper functioning septic systems, such as through frequent testing, we can increase the chances of identifying the source of potential human fecal coliform pollution sites. Establishment of impairment locations is the first step in decreasing the impact of non-point source pollution. Once we establish the location of these impairments a plan can be formulated for addressing these issues.	
Major Implementation Issues: North Jersey RC&D currently provides outreach and technical assistance throughout the project area and can implement an education campaign to address the public; however the willingness of residents to accept and address this problem is the main issue with these types of education campaigns. There will likely be those that readily have their systems tested, but there will always be people who do not believe that it could possibly be their problem and will never submit to testing. This is a hurdle that cannot be overcome easily and will take time and effort to spread this information to the public.	
Possible Funding Sources: 319(h) grants from the New Jersey Department of Environmental Protection Private Foundations supporting education EPA Environmental Education grants	

Partners/Stakeholders: North Jersey RC&D Hunterdon County Warren County Franklin Township Bethlehem Township Lebanon Township Hampton Borough Washington Township Rutgers Cooperative Extension-Water Resources Program		
Task	Task Description	Estimated Cost
1	Design Educational Campaign	$4,160
2	Develop/Compile Educational Materials	$4,620
3	Presentations to project area residents	$2,560
4	Outreach and Marketing	$3,080
5	Funding Identification (for communities)	$2,080
	Contingency (20%)	$3,300
Total Estimated Project Cost		**$19,800**

8.2 Project Prioritization

Section 8.1.2 presents detailed information about the implementation of individual BMPs at specific sites within the watershed or for representative farms. Information for individual BMP projects is scaled up to estimate watershed reductions in TP and sediment, and the total and annual costs at the watershed scale. The cost effectiveness of these BMPs in reducing TP and sediment is calculated by dividing the annual watershed cost by the reduction in TP and sediment.

Table 8.1 summarizes the water quality effects, the costs and cost-effectiveness of the agricultural BMPs in the Musconetcong River watershed assuming each BMP is individually applied to a suitable land type within the watershed. The scale-up for cover crops, riparian buffers, prescribed grazing, livestock access control, contour farming and nutrient management are based on information in section 8.1.1. Information on the assessment unit, reduction in TP and sediment, assessment costs and land type suitable for BMP implementation are taken from the agricultural project descriptions in section 8.1.1. Reductions in TP and sediment for the agricultural BMPs are based on the reduction rates from used literature and the land suitable for BMP implementations. Total watershed costs are the product of total assessment costs and the applicable unit divided by the assessment unit. The assessment unit is the acreage of a representative farm used for estimating the BMP implementation costs. The applicable unit is the total acreage of the agricultural lands the BMP can be potentially applied to.

Table 8.1: Water quality effects, costs and cost-effectiveness of agricultural BMPs in the Musconetcong River Watershed

		Cover Crop	Presc. Grazing	Access Control	Contour Farming	Nutrient Mgmt.	Conser. Buffers
1	Assessment Unit	62 Acres	30 Acres	500 feet	62 Acres	62 Acres	3 Acres
2	TP Reduction Rate (%)	15	25	60	20	47	50
3	Sediment Reduction Rate (%)	20	25	75	40	0	50
4	Installation Cost ($)	18,526	9,576	2,868	5,580	5,580	9,132
5	Maintenance Cost ($)			1,000			3,750
6	Other Costs ($)	1,000	3,750	1,900	1,650	1,650	5,200
7	Total Assessment Unit Cost ($)	19,526	13,326	5,768	7,230	7,230	18,082
8	Land Type Suitable for BMP	Row crops	Pasture	Riparian areas of pasture	Row Crops	Crops, hay, pasture	HASs
9	Applicable Unit	2,528 Acres	562 Acres	15,538 feet	1,164 Acres	6,079 Acres	623 Acres
10	Annual TP Reduction (lbs)	494	239	575	319	2,766	2,333
11	Annual Sediment Reduction (tons)	50	10	4	46	0	158
12	Total Watershed Cost ($)	796,320	249,528	179,308	136,188	711,243	3,754,821
13	Lifespan of BMP (years)	3	5	10	3	3	15
14	Annual Watershed Cost ($)	265,440	49,905	17,930	45,396	237,081	250,321
15	Cost-eff. of TP Reduction (lbs/$1,000)	1.861	4.790	32.069	7.027	3.889	9.320
16	Priority Rank for TP Reduction	6	4	1	3	5	2
17	Cost-eff. of Sed. Reduction (T/$1,000)	0.188	0.200	0.223	1.013		0.631
18	Priority Rank for Sed. Reduction	5	4	3	1	6	2

The total watershed costs are calculated based on the life span of the BMPs. Water quality effects are measured by the annual average reduction in TP and sediment. The cost-effectiveness of these BMPs is based on the annual watershed costs for cover crops, contour farming and nutrient management are estimated assuming farmers enter into three year contracts to maintain the BMPs once enrolled in the programs. Second, life spans are five years for the facilities used in prescribed grazing and ten years for livestock access control. After the initial program period farmers are assumed to continue these practices due to the added economic benefits, their increased environmental awareness and tighter regulatory requirements. Third, the lifespan for riparian buffers and conservation buffers is assumed to be 15 years.

The annual watershed cost equals the total watershed cost divided by the years in the effective assessment period plus annual operation and maintenance costs, if any. Cost-effectiveness for the TP reduction equals the annual average TP reduction divided by the annual watershed cost. Cost-effectiveness for sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Therefore, cost-effectiveness measures the reduction in TP or sediment per $1,000 spent on the BMP in the watershed. For example, every $1,000 of expenditure would reduce TP by 1.861 pounds if spent on cover crops and 32.069 pounds if spent on livestock access control. BMPs were prioritized based on their cost-effectiveness with BMPs resulting in a larger reduction in pollutant load receiving higher priority for implementation.

Table 8.2 presents the water quality effects, costs and cost-effectiveness for stormwater BMPs in the Musconetcong River watershed. Estimation of the effects assumes each BMP is individually applied to suitable agricultural or park lands within the watershed. The watershed has 665 potential sites for rain gardens and 66,872 feet of riparian segments suitable for vegetative buffers in the non-agricultural, developed lands. It was also identified that there are 50 segments of roadside swales and ditches and 4 detention basins. The scale-up for rain gardens, roadside ditch retrofitting, detention basin retrofitting and vegetative buffers in developed lands is based on the information from Section 8.1.2 on the site specific projects. Information on the assessment unit, reduction rates for TP and sediment and assessment costs come from the project descriptions given in Section 2.5. Total annual reductions in TP and sediment are the products of the reductions achieved by individual projects and the applicable units divided by the assessment unit. The total watershed cost is the product of the total assessment cost and the applicable units divided by the assessment unit. Lifespans for all stormwater BMPs are assumed to be 15 years. Annual watershed cost is total watershed cost divided by 15 years, which is the assumed life span.

Table 8.2: Water quality effects, costs and cost-effectiveness of stormwater BMPs in Musconetcong River Watershed

		Rain Garden	Roadside Ditch Retrofitting	Detention Basin Retrofitting	Vegetative Buffers on Developed Lands
1	Assessment Unit	1 unit	1 unit	1 unit	1,900 feet
2	TP Reduction Rate (%)	50	30	50	30
3	Sediment Reduction Rate (%)	90	60	90	60
4	Installation Cost ($)	1,650	13,000	17,000	6,200
5	Maintenance Cost ($)	1,500	7,500	7,500	1,500
6	Other Costs ($)	1,000	3,000	5,000	1,500
7	Total Assessment Cost ($)	4,150	23,500	29,500	9,200
8	Applicable Unit	665 units	50 units	4 units	66,872 feet
9	Annual TP Reduction (lbs.)	8	11	29	92
10	Annual Sediment Reduction (tons)	0.75	2	4	46
11	Total Watershed Costs ($)	2,759,750	1,175,00	118,000	323,660
12	Life span of BMP (years)	15	15	15	15
13	Annual Watershed Cost ($)	183,983	78,333	7,866	21,577
14	Cost-eff. for TP Reduction (lbs./$1,000)	0.043	0.140	3.687	4.264
15	Priority Rank for TP Reduction	4	3	2	1
16	Cost-eff. for Sediment Reduction (T/$1,000)	0.004	0.026	0.509	2.132
17	Priority Rank for Sediment Reduction	4	3	2	1

Similarly, the cost-effectiveness of TP reduction is the annual average TP reduction divided by the annual watershed cost for each stormwater BMP. Cost-effectiveness of sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Cost-effectiveness measures the average reduction in TP or sediment per $1,000 of expenditure on each stormwater BMP in the watershed. For example, if $1,000 is spent on vegetative buffers on developed lands, TP would decrease by 4.264 pounds and sediment would decline by 2.132 tons. Rain gardens would only reduce TP by 0.043 pounds and sediment by 0.004 tons per $1,000 spent on each unit. BMPs were prioritized based on their

cost-effectiveness, with the BMPs resulting in a larger reduction in pollutant load are given a higher priority for implementation.

All BMPs have other hydrological and water quality benefits. For example, stormwater BMPs, such as rain gardens result in a large reduction in the amount of stormwater runoff and runoff velocity to receiving streams. As discussed in Section 2.2.1, one of the most significant water quality issues in the Musconetcong River watershed is pathogenic contamination. Manure mismanagement and livestock access to waterways contribute a large portion of this pathogenic load along with application of animal manure to row-crop fields and livestock access to streams. Fate and transport of pathogens are not as well understood as fate and transport of TP and sediment. Therefore, the effectiveness of the BMPs in reducing pathogenic loads to the streams cannot be assessed as precisely as reductions in TP and sediment. With that said cost-effectiveness of BMPs for reducing the pathogenic loads was assessed differently.

Table 8.3: Cost of three major BMPs for reducing pathogenic loads in the Musconetcong River Watershed

Types of BMPs	Applicable Units	Unit Costs ($/unit)	Life span (years)	Total Cost ($)	Annual Cost ($/year)
Manure Management					
Regional Animal Waste Storage and composting Structure	1 units	90,000	10	90,000	9,000
Manure Application Incorporation Technology	208 acres	156	1	32,448	32,448
Subtotal				122,448	41,448
Livestock Stream Access Control					
Livestock Access Control	15,538 feet	11.54	10	179,308	17,930
Subtotal				179,308	17,390
Total				301,756	58.838

Table 8.3 gives the costs of two BMP types for reducing pathogenic loads: manure management and livestock stream access control. Manure management includes establishing and operating a regional animal waste storage and composting structure and implementing manure application incorporation technology for row-crop fields in the watershed, in addition to being compliant with the New Jersey Animal Waste Rules. Total cost for BMP projects for manure management is $122,448 and the annual cost is $41,448. Manure management is expected to reduce pathogenic loads by up to 31 percent. The cost of reducing pathogenic loads by 1 percent is $3,950. As discussed before, the annual cost of livestock stream access control is $17,390. Such control will reduce pathogenic loads to streams in the watershed by up to 19 percent. The cost for reducing pathogen loads to streams by 1 percent is $915 for livestock access control practice. In summary, livestock access control and manure management are the two most cost effective options to reduce pathogenic loads within the project area.

Table 8.4 summarizes the priority ranks of all BMP projects in terms of their cost-effectiveness in reducing TP, sediment and pathogens in the Musconetcong River Watershed. The highest-ranked BMP in terms of cost-effectiveness has the highest priority for implementation.

The top 5 ranked BMPs for reducing TP loads are:

1. Livestock access control
2. Nutrient management
3. Conservation buffers on agricultural lands
4. Contour farming
5. Prescribed grazing

The top 5 ranked BMPs for reducing sediment are:

1. Vegetative buffers on developed land
2. Livestock access control
3. Contour farming
4. Conservation buffers on agricultural lands
5. Detention basin retrofitting

The top 5 ranked BMPs for reducing pathogenic loads to streams are:

1. Livestock access control
2. Livestock waste storage and composting structures
3. Manure application incorporation technology
4. Prescribed Grazing
5. Detention Basin Retrofitting

Additional criteria that can be utilized in ranking BMP projects include, but are not limited to, the following:

- Landowner access and cooperation
- Permitting requirements
- Site constraints (i.e., topography, wetlands, stream encroachment, etc.)
- Funding sources
- Expected time frames
- Project partners needed
- Ecological benefits
- Long term maintenance/monitoring needs

Table 8.4: Priority ranks for all BMP projects in the Musconetcong River Watershed

BMP Project		Priority Rank in Reducing		
		TP	Sediment	Pathogens
1	Cover Crops	8	7	
2	Prescribed Grazing	5	6	4
3	Livestock Access Control	1	2	1
4	Contour Farming	4	3	
5	Nutrient Management	2		7
6	Conservation Buffers in Agricultural Lands	3	4	8
7	Livestock Waste Storage and Composting Structure	12		2
8	Manure Application Incorporation Technology	11		3
9	Rain Gardens	10	9	
10	Road Ditches	9	8	9
11	Detention Basin Retrofitting	7	5	5
12	Vegetative Buffers on Developed Lands	6	1	6

9.0 Next Steps

9.1 Milestones and Implementation Strategies

The implementation plan refers to how the agricultural and stormwater BMPs will be implemented within the watershed over time. The planning time horizon for implementing the plan is 10 years. The implementation plan will be discussed in several timeframes: 1-2 years, 5 years and 10 years. Milestones are measurements of the expected decreases in pollutant loads from implementing these BMPs. The implementation plan and milestones are discussed together in different timeframes during the planning time horizon.

9.1.1 Milestones and Implementation in the First Two Years

During the first two years after the plan has been adopted, the municipalities in the watershed should:

- Educate residents, farmers and businesses on water quality of the Neshanic River and responsible stewardship in land use and management
- Establish concrete steps for implementing the New Jersey State Rules for improving water quality and/or preventing water quality from continuous deterioration. These rules include the New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program rules (N.J.A.C. 7:14A), the Stormwater Management Rules (N.J.A.C. 7:8), the Flood Hazard Area Control Act rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act rules (N.J.A.C. 7:7A), the Criteria and Standards for Animal Waste Management (N.J.A.C. 2:91) and the Fertilizer Control Law for commercial and residential lawn care and management.
- Refine open space and farmland preservation plans that address the protection of hydrologically sensitive areas from future development.
- Work with federal, state and county governmental agencies, universities, non-governmental and non-profit agencies and local environmental consulting firms to apply and secure the necessary funding and technical assistance needed to implement the proposed BMP projects in the watershed.

Table 9.1 describes the implementation goals, expected pollutant load reduction in TP and sediment and the implementation costs in the first two years of plan implementation. The implementation goal is expressed as a percentage of full implementation and in physical units, such as acres and feet. The expected load reductions for TP and sediment assume BMP projects are implemented individually. The expected total load reduction from all BMP projects is 1,237 pounds for TP and 48 tons for sediment. In reality, several BMP projects might be implemented in the same field, and therefore the load reduction level could make the load reductions smaller than the sum of the expected load reductions from all BMPs. However, if all the BMP projects were implemented in high priority areas the load reduction could be even greater than the load reduction given in Table 9.1, which estimated from average reduction rates. The total implementation cost is estimated at $904,480.

Table 9.1: Implementation goals, expected pollutant load reductions and implementation costs of BMP projects for the Musconetcong River Watershed in the first two years.

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
				TP (lbs.)	Sed. (tons)		
		%	Unit			$	%
1	Cover Crops	10	253 acres	49	5	79,695	8.8
2	Prescribed Grazing	10	56 acres	24	1	24,864	2.7
3	Livestock Access Control	25	3,885 feet	144	8	44,833	5.0
4	Contour Farming	25	291 acres	80	12	34,047	3.8
5	Nutrient Management	25	1,520 acres	691		177,840	19.7
6	Conservation Buffers in Agricultural Lands	10	62 acres	232	16	373,674	41.3
7	Livestock Waste Storage and Composting Structure	0	0 units			0	0.0
8	Manure Application Incorporation Technology	25	52 acres			8,112	0.8
9	Rain Gardens	1	7 units			29,050	3.2
10	Road Ditches	5	3 units	1		70,500	7.8
11	Detention Basin Retrofitting	25	1 unit	7	1	29,500	3.3
12	Vegetative Buffers in Developed Lands	10	6,687 acres	9	5	32,365	3.6
Total				1,237	48	904,480	100.0

The first two-year implementation of the BMP projects and regulatory framework as well as the education and outreach efforts would achieve the following milestones for pollutant and education goals and attainment of water quality standards.

- Prevent continuous deterioration in water quality and watershed hydrology
- Reduce annual TP loads by as much as 1,237 pounds
- Reduce annual sediment load by as much as 48 tons
- Reduce annual pathogenic loads by as much as 2.6 percent of the total goal

9.1.2 Milestones and Implementation Plan in the First Five Years

Table 9.2 shows the cumulative implementation goals, expected pollutant load reduction in TP and sediment and implementation costs during the first five years of the plan. In addition to expanding the BMP projects started in the first two years of implementation, the first five years involves substantial work to reduce pathogenic loads to the streams, including retrofitting all failed OSDSs in HSAs found through OSDS inspection, completing regular OSDS maintenance, establishing and operating the small regional animal waste storage and composting structure facilities and improving manure application efficiency. A total cumulative cost of plan implementation for the first five years is $2,196,213.

Table 9.2 Implementation goals, expected pollutant load reductions and implementation costs of BMP projects in the Musconetcong River watershed in the first five years

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
				TP (lbs.)	Sed. (tons)		
		%	Unit			$	%
1	Cover Crops	25	632 acres	124	13	199,080	9.1
2	Prescribed Grazing	25	141 acres	60	3	62,604	2.9
3	Livestock Access Control	50	7,769 feet	288	17	89,654	4.1
4	Contour Farming	50	582 acres	160	23	68,094	3.1
5	Nutrient Management	50	3,040 acres	1,383		355,680	16.2
6	Conservation Buffers in Agricultural Lands	25	156 acres	584	40	940,212	42.8
7	Livestock Waste Storage and Composting Structure	100	1 unit			90.000	4.0
8	Manure Application Incorporation Technology	50	104 acres			16,224	0.7
9	Rain Gardens	2.5	17 units			70,550	3.2
10	Road Ditches	13	7 units	2		164,500	7.5
11	Detention Basin Retrofitting	50	2 units	14	2	59,000	2.7
12	Vegetative Buffers in Developed Lands	25	16,718 feet	23	12	80,915	3.7
Total				2,638	110	2,196,513	100.0

The first five-year implementation of the BMP projects and regulatory framework as well as education and outreach efforts could achieve the following milestones for pollutant reduction targets and attainment of water quality standards:

- Improvement of the water quality and watershed hydrology
- Reduction of the annual TP load by as much as 2,638 pounds
- Reduction of the sediment load by as much as 110 tons
- Reduction of the annual pathogen load by as much as 38 percent of the total goal

9.1.3 Milestones and Implementation Plan in the First Ten Years

Table 9.3 gives the cumulative implementation goals, estimated costs and expected load reductions for TP and sediment during the first ten years of the plan. In this second five years, the BMP projects implemented during the first five years are to be expanded to cover more area within the watershed. Total cost of accomplishing the implementation goals for the first ten years is $4,025,055.

Table 9.3: Implementation goals, expected pollutant load reductions and implementation costs of BMP projects within the Musconetcong River watershed in ten years

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
				TP (lbs.)	Sed. (tons)		
		%	Unit			$	%
1	Cover Crops	50	1,264 acres	247	25	398,160	9.9
2	Prescribed Grazing	50	281 acres	120	5	124,764	3.1
3	Livestock Access Control	100	15,538 feet	575	33	179,308	4.5
4	Contour Farming	75	873 acres	240	35	102,141	2.5
5	Nutrient Management	75	4,557 acres	2,073		533,169	13.2
6	Conservation Buffers in Agricultural Lands	50	311 acres	1,165	79	1,874,397	46.6
7	Livestock Waste Storage and Composting Structure	100	1 unit			90,000	2.2
8	Manure Application Incorporation Technology	75	156 acres			24,336	0.6
9	Rain Gardens	5	33 units			136,950	3.4
10	Road Ditches	25	12 units	3		282,000	7.0
11	Detention Basin Retrofitting	100	4 units	28	4	118,000	3.0
12	Vegetative Buffers in Developed Lands	50	33,436 feet	46	24	161,830	4.0
Total				4,497	205	4,025,055	100

The ten-year implementation of the BMP projects and regulatory framework as well as the education and outreach efforts could achieve the following milestones toward achieving pollutant reduction goals and attaining water quality standards:

- Further and continuing improvement of water quality and watershed hydrology
- Reduction of annual TP load by as much as 4,497 pounds
- Reduction of annual sediment load by as much as 205 tons
- Achieves a 56 percent of the required annual load reduction for pathogens and attains the water quality standards for pathogens.

9.2 Additional Watershed Protection Efforts and Previous Projects

There are and have been many different projects happening in the Musconetcong River Watershed throughout the past several years. Table 9.4 talks about these projects in greater detail.

Table 9.4: Additional Watershed Protection Efforts and Projects within the Musconetcong River Watershed

Program	Description	Status
North Jersey RC&D: Protecting and Improving Wildlife Habitat through Riparian Restoration	Installation of riparian corridors along Upper Delaware rivers and streams	Completed: December 2011 Installed and enhanced 2 riparian buffer areas in project area in 2009 and in 2010. Agricultural property along West Portal Brook and along the Musconetcong River in Asbury at the Musconetcong River Resource Center
North Jersey RC&D: Musconetcong River Subwatershed Hampton to Bloomsbury Priority Stream Segment	Development of a subwatershed protection plan on the lower Musconetcong River through Washington & Franklin Township in Warren County & Bethlehem Twp, Hampton Borough, & Lebanon Twp in Hunterdon County. Through the project we will design and execute a limited water quality monitoring program to fill in data gaps needed to complete a characterization of the area.	Completed: February 2007
North Jersey RC&D: MST Sampling	Funding support from Conservation Resources Inc. for North Jersey RC&D and Rutgers Cooperative Extension: Water Resources Program to conduct microbial source tracking (MST) sampling and analysis.	Completed: March 2010
North Jersey RC&D: Conservation Resources Inc-Riparian Restoration Support in the Musconetcong Watershed	Grant funds to off-set costs for a riparian restoration project for a agricultural property in the Musconetcong Watershed, particularly along the West Portal Brook in Bethlehem Township, Hunterdon County.	Completed: November 2011
Musconetcong Wild & Scenic River Management Council		On-going: See section 4.7 National Wild and Scenic Designation for more information
North Jersey RC&D: Watershed Restoration Strategy	Protect & Improve water quality thru riparian restoration and regional open space programs	Completed: December 2006 project installed 4 buffers in Musconetcong River Watershed
Highlands Act and Regional Master Plan	State is developing a master plan for the protection of water resources in the New Jersey Highland. Preservation areas were delineated where more stringent requirements will be imposed before land-altering activities can occur.	On-going.

Princeton Hydro revised the phosphorus TMDL for Lake Musconetcong and developed a Restoration plan for the lake and watershed; this was approved by NJDEP in 2006. A dredging feasibility plan is being developed for the lake.

9.3 Monitoring and Evaluation

Monitoring is a necessary step in assessing water quality improvements resulting from installation and implementation of various BMPs in the proposed plan. Long-term monitoring of water quality and stream conditions is generally expensive and funding for such monitoring is limited and hard to find. It is not realistic to expect the same intensive monitoring conducted in the project area to be continued in the long run. However we must understand the importance of this type of data in the long run so as to continue to improve water quality.

Two state criteria can be used to evaluate whether watershed restoration efforts are successful. Three issues relevant to the first criterion, which has to do with the impacts of the BMP projects on the actions and attitudes of the general public, are: (1) how much and where are the proposed BMP projects implemented within the watershed? (2) Are stakeholders aware of the impacts of their land use and management decisions on water resources? and (3) do stakeholders continue to practice environmentally friendly BMPs even after initial BMP funding ends? The second criterion deals with the outcomes observed in streams and their riparian areas. Two issues relevant to the second criterion, which has to do with the improvement of the stream over time, are: (1) do the water quality and biological conditions in the streams improve over time? and (2) are stream channels being stabilized? Based on these two sets of criteria, the following monitoring programs are recommended to be implemented to evaluate the success of the watershed restoration efforts in the watershed:

9.3.1 BMP Documentation Database

Water quality improvement in streams must be achieved by implementing various BMPs in different areas within the watershed. An important monitoring effort is to document the efforts in educating the stakeholders and implementing both structural and nonstructural BMPs in the watershed. The documentation should include, but not be limited to:

- Educational materials being developed by municipalities and relevant agencies and organizations to educate stakeholders on NPS control and stormwater management in the watershed
- Ordinances and rules related to water resource protection being developed and implemented by municipalities
- Local implementation of federal, state and county regulations pertaining to water resource protection
- Location, scale and expected effects of BMPs funded and implemented in the watershed. For each BMP implementation, there should be documentation of the expected water quality improvement. Water quality impacts can be estimated using quantitative models and tools, such as STEPL models and others. Onsite monitoring during and after BMP implementation should be conducted and documented.

9.3.2 Water Quality Monitoring

It is expected that NJDEP and USGS will continue their streamflow and water quality monitoring work at the USGS Bloomsbury Gage Station (monitoring station #10). The basic water quality parameters may include for_NH3-N, NO3-N, NO2-N, TK, TP, dissolved orthophosphate phosphorus, TSS, and *E. coli*. Annual water quality and bacteria sampling results may provide the basis to assess the possible progress in water quality improvement in the Musconetcong streams. As the drainage area to the Bloomsbury Gage Station contains the entirety of the Musconetcong River Watershed Project Area, these monitoring results would provide a great snapshot of how the water quality is being affected by land uses upstream.

9.3.3 Biological Monitoring

NJDEP should continue biological monitoring at the two Ambient Biomonitoring Network (AMNET) stations within the Musconetcong River Watershed just upstream and downstream of the project area. These monitoring stations are AN00072 and AN00073 respectively. Biological monitoring at selected stations is usually conducted once every five years. This frequency of monitoring should be sufficient to determine whether improvements in water quality and watershed hydrology eventually translate into improvements in biological conditions in the streams within the Musconetcong River watershed.

9.3.4 Stream Visual Assessment

The Visual Assessment Project Plan (VAPP) August 2007 developed by NJDEP is a tool to assess the health of the stream, identify pollutant sources and identify potential management measures to reduce pollutant sources. It uses visual inspection of the physical and biological characteristics of in stream and riparian segments of the assessed stream reaches. Local watershed and environmental organizations should use VAPP as an educational tool for encouraging community volunteers to document changes in stream and riparian area conditions. This project did not utilize this protocol because it was not available at the time the 319 grant contract was finalized.

10.0 Summary

Non point sources of pollution appear numerous and sporadic throughout the watershed study area. Agricultural practices appear to contribute organic enrichment, nitrate-nitrite, nutrients, phosphorus and fecal coliform. Riparian zones have been destroyed by unrestricted livestock access and by farming in riparian zones and urban development. Residential and commercial development has sprawled out of the central cities and into the rural areas. The outward migration of development leads to the deterioration of water quality by habitat and flow alterations, the importing of sediment and nutrients into tributaries and by decreasing the amount of dissolved oxygen within the waters. Failing commercial and home septic systems also appear to be a contributor to bacterial and nutrient contamination in the watershed.

The following problem statements identify concerns, however it is important to note that although these problems exist, the list is not comprehensive and upon further investigation/data collection there may be additional concerns identified in the future.

1. Streams, floodplains and wetlands continue to be impacted through:
    A. Lack of established riparian buffer
    B. Channel instability
    C. Increased stormwater flows due to the lack of stormwater retention areas/management
    D. Excess amounts of nutrients

2. Excessive sedimentation limits in-stream habitat for macro invertebrates and fish
    A. Stormwater runoff from roadways and other development
    B. Excessive streambank erosion
    C. Lack of floodplain storage within the watershed

3. Elevated bacteria levels within Musconetcong River
    A. Failing home and septic systems and gray water discharges
    B. Direct accessibility of livestock to the stream
    C. Contributions from wildlife populations, namely Canada Geese

Future goals should include, but are not limited to: further sampling events to isolate sources within the entire watershed/basin area through inventories and volunteer monitoring, educational outreach to landowners/municipalities to promote an understanding of the importance of wetland and riparian areas for maintaining water quality and providing essential habitat for flora and fauna, promote the restoration of preexisting functions in damaged or destroyed wetland and riparian systems, removal of sediment from runoff, streambank stabilization, education of new innovative stormwater practices, the creation of ordinances for the reduction of environmental impacts, and lastly; provide suggestions as to which methods should be used to reduce environmental impacts to the watershed.

10.1 Nine Elements of a Watershed Plan

The United States Environmental Protection Agency put out a set of nine elements that must be addressed within a watershed restoration plan in order for it to be funded through the Clean Water Act section 319h funds. These elements as quoted from the USEPA's "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" are as follows:

- Identification of cause of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed.

The causes of impairment are identified in section 2.2 beginning on page 13 as pathogens such as *E. coli* and fecal coliform, nutrients such as phosphorus and nitrogen, sediment and temperature. These sources are also explained in greater detail and to what extent they are found within the watershed in Chapter 6 beginning on page 52.

- An estimate of the load reductions expected from management measures.

In section 2.7 table 2.4 on page 22 illustrates the load reduction goals for each type of BMP project. For example 15,538 feet of livestock access control is estimated to have a reduction of approximately 575 lbs of TP and 33 tons of sediment. This is also discussed in more detail in section 9.1 beginning on page 164 with a breakdown of the two, five and ten year goals.

- A description of the nonpoint source management measures that will be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement the plan.

Management measures are highlighted in sections 2.4, beginning on page 15, and 2.5, beginning on page 19, management measures and recommended projects respectively. These strategies are further broken down to explain the types of management needed to reduce pathogens, nutrient and sediment loads within the watershed. Types of projects that are recommended for implementation include BMPs such as cover crop, vegetative buffers, detention basin retrofitting, rain gardens and others.

- Estimate of the amounts of technical assistance needed associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

Technical assistance is discussed in section 2.8 beginning on page 25 and provides a table for reference to the total cost of BMP projects and where money is available for the implementation of these practices. It is estimated that the overall cost of implementing the recommended BMP projects is $4,025,055 with approximately $514,000 going towards technical assistance.

- An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

Educating the public is an important part of any management plan. This component of the plan begins on page 27 in section 2.10 and includes programs such as Sustainable Jersey™, River Friendly Programs, Stewardship of Open Space as well as the development of an on-site waste water treatment education and outreach program.

- Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

The schedule for implementation is discussed in both sections 2.7 on page 23 and 2.9 on page 26. Table 2.5 on page 23 gives a breakdown into two, five and ten year goals for implementation of BMP projects throughout the watershed. This plan, for example, shows that the project team estimates having 25 percent of the detention basin retrofitting projects completed by year two while only have 10 percent of the total conservation buffers completed within the same time frame.

- A description of interim measureable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

Measureable milestones are outlined in section 2.7 beginning on page 23 and are separated into two, five and ten year time periods. In these broken down sections there is an estimate for the money needed to complete the projects necessary to achieve certain milestones such as the reduction of 900 pounds of annual TP load from the Musconetcong River.

- A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

There are two criteria that are proposed to be utilized in determining if a project is successful. These two criteria are brought up in section 2. 9 on page 26. These two criterion have to do with changes in land use management practices and the outcomes observed within the streams and local riparian areas. For instance the first criteria wants to know the types of projects that were implemented and how

they affected the people who lived in the surrounding areas and their attitude towards them. The second criteria work more with water quality issues.

- A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item 2.2.8 immediately above.

The monitoring program that is to be developed for this project is based off of the criteria from the previous section. This is outlined in section 2.9 on page 26 as well as section 9.3 beginning on page 169. These include establishing a database to document established BMP projects and estimate their water quality impacts, continuing water quality and biological testing throughout the watershed and utilizing volunteer support to conduct stream assessment.

References

Dick, L.K., A.E. Bernhard, T.J. Brodeur, J.W. Santo-Domingo, J.M. Simpson, S.P. Walters and K.G. Field. 2005. Host Distributions of Uncultivated Fecal *Bacteroidales* Bacteria Reveal Genetic Markers for Fecal Source Identification. *Appl. Environ. Microbiol.* 71(6):3184-3191.

Fish and Wildlife in the Upper Delaware Watershed, A Technical Report for the Upper Delaware Watershed Management Project, December 2002, North Jersey Resource Conservation & Development.

Khomenko, Victor P. 2006. *Suffosion Hazard: Today's and Tommorrow's Problem for Cities.* IAEG2006 Paper Number 577.

Layton, A., L. McKay, D. Williams, V. Garrett, R. Gentry and G. Sayler. 2006. Development of *Bacteroides* 16S rRNA gene TaqMan-Based Real-Time PCR Assays for Estimation of Total, Human, and Bovine Fecal Pollution in Water. *Appl. Environ. Microbiol.* 72(6):4214-4224.

Musconetcong Advisory Committee et.al. Musconetcong River National Wild and Scenic Rivers Study: River Management Plan. April 2003.

Musconetcong River Subwatershed Hampton to Bloomsbury Priority Stream Segment, February 2007, North Jersey Resource Conservation and Development.

New Jersey Department of Environmental Protection (NJDEP), 2002, NJDEP Aerial Photography of Salem County. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP), 2006, NJDEP Aerial Photography of Salem County. Trenton, NJ.

New Jersey Department of Environmental Protection (NJDEP). 1994. Ambient Biomonitoring Network, Delaware River Drainage Basin, 1992 Benthic Macroinvertebrate Data. http://www.nj.gov/dep/wms//bfbm/download/udel92.pdf.

New Jersey Department of Environmental Protection (NJDEP). 1999. Ambient Biomonitoring Network, Watershed Management Areas 1, 2, and 11, Upper Delaware Region, 1999 Benthic Macroinvertebrate Data. http://www.nj.gov/dep/wms//bfbm/download/udel98.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2002a. New Jersey 2002 Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)).

New Jersey Department of Environmental Protection (NJDEP). 2002b. NJDEP 2002 Land Use/Land Cover Update, Upper Delaware Watershed Management Area, WMA-1, Edition 20080304. http://www.state.nj.us/dep/gis/lulc02shp.html.

New Jersey Department of Environmental Protection (NJDEP). 2003. Total Maximum Daily Loads for Fecal Coliform to Address 28 Streams in the Northwest Water Region. Approved (by EPA Region 2): September 29, 2003. http://www.nj.gov/dep/wms/bear/Northwest%20FC.pdf

New Jersey Department of Environmental Protection (NJDEP). 2004. New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report (305(b) and 303(d)). http://www.state.nj.us/dep/wms/bwqsa/2004_Integrated_Report.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2006. New Jersey Integrated Water Quality Monitoring and Assessment Report 2006. http://www.state.nj.us/dep/wms/bwqsa/2006IntegratedReport.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2007. Standard Operating Procedures, Ambient Biological Monitoring Using Benthic Macroinvertebrates, Field, Lab, and Assessment Methods. Bureau of Freshwater and Biological Monitoring Document No. BMNJ2. http://www.nj.gov/dep/wms//bfbm/download/AMNET_SOP.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2008. Ambient Biomonitoring Network, Northwest Water Region, Upper Delaware and Wallkill River Drainages, Watershed Management Areas 1, 2, and 11, Round 3 Benthic Macroinvertebrate Data, Volume 1 and 2. http://www.nj.gov/dep/wms//bfbm/download/udelRnd3.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2009. 2008 New Jersey Integrated Water Quality Monitoring and Assessment Report. http://www.nj.gov/dep/wms/bwqsa/2008_final_IR_complete.pdf.

New Jersey Department of Environmental Protection (NJDEP). 2010. Ambient Biomonitoring Network (AMNET) Data Comparison Table, Round 4 Results for Northwest Basin (Upper Delaware) 2007/2008. http://www.nj.gov/dep/wms//bfbm/amnetRnd4.html.

New Jersey Department of Environmental Protection (NJDEP). 2011a. 2010 Integrated Water Quality Monitoring and Assessment Methods. http://www.state.nj.us/dep/wms/bwqsa/2010_appendix_f_final_methods_document_with_response_to_comments.pdf

New Jersey Department of Environmental Protection (NJDEP). 2011b. 2010 New Jersey Integrated Water Quality Monitoring and Assessment Report. http://www.state.nj.us/dep/wms/bwqsa/2010_integrated_report_with_appx.pdf

New Jersey Department of Environmental Protection (NJDEP). 2011c. Surface Water Quality Standards, N.J.A.C. 7:9B. Last Amended April 4, 2011 (43 N.J.R. 833(a)) http://www.nj.gov/dep/rules/rules/njac7_9b.pdf.

New Jersey Department of Environmental Protection (NJDEP), Environmental Regulation (ER), Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1) <http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesswd.zip>

New Jersey Department of Environmental Protection NJDEP, New Jersey Geological Survey NJGS. April 5 2004. <http://www.state.nj.us/dep/njgs/geodata/dgs04-5.htm>

New Jersey Department of Environmental Protection NJDEP, New Jersey Geological Survey NJGS July 27, 2007 edition. <http://www.state.nj.us/dep/njgs/geodata/dgs02-2.htm>

New Jersey Pollution Discharge Elimination System (NJPDES) Regulated Discharge to Ground Water Facility Locations, (Source: NJDEP/DWQ/BNPC. July 18, 2007. http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesgwd.zip

Pinelands Nursery & Supply 2008 Wholesale Catalog, Columbus, NJ

Qiagen, Inc.. 2004. DNeasy® Tissue Handbook. Valencia, CA.

Riparian Zones in the Upper Delaware Watershed: A Technical Report for the Upper Delaware Watershed Management Project: Methodology for Delineating and Characterizing the Health of Riparian Areas in the Upper Delaware Watershed Management Area (NJDEP WMA1) using Geographic Information Systems, April 2002

Scott, T.M., J.B. Rose, T.M. Jenkins, S.R. Farrah, J. Lukasik. 2002. Microbial Source Tracking: Current Methodology and Future Directions. *Appl. Environ. Microbiol.* 68(12):5796-5803.

Semple, Alice; Blick, Sandra; Kelly, Fred and Skupien, Joseph; New Jersey Stormwater Best Management Practices Manual. New Jersey Department of Environmental Protection, Trenton, 2004

Sloto, RA and MY Crouse. 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis. US Geological Survey, Water Resources Investigations Report 96-4040.

Standards for Individual Subsurface Sewage Disposal Systems, N.J.A.C. 7:9A-1 et seq New Jersey Department of Environmental Protection and Energy, Land Use Regulation Program, Subsurface Disposal Unit, CN1.. .

Total Maximum Daily Loads for Fecal Coliform to Address 28 Streams in the Northwest Water Region, April 2003, New Jersey Department of Environmental Protection,

United States Environmental Protection Agency (USEPA). 2000. Stressor Identification Guidance Document. EPA/822/B-00/025.

United States Environmental Protection Agency (USEPA). 2005. Microbial Source Tracking Guidance Document. EPA/600/R-05/064.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2007. National Engineering Handbook, Title 210-VI, Part 630, Chapter 7, Hydrologic Soil Groups. Washington, DC.

http://www.minnehahacreek.org/ManagingWateronYourProperty.php

http://en.wikipedia.org/wiki/New_York-New_Jersey_Highlands