

Watershed Restoration and Protection Plan for the Musconetcong Watershed from: Hackettstown to Hampton



Prepared by Musconetcong Watershed Association for New Jersey Department of Environmental
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Table of Contents

Table of Contents	2
1.0 Acknowledgements	12
2.0 Executive Summary	14
3.0 Introduction and Background.....	16
3.1 Purpose of the Plan	19
3.2 Partnership	20
3.3 Nine Elements of a Watershed Plan	21
4.0 Watershed Description.....	23
4.1 Geography and Topography	23
4.2 Demographics.....	26
4.3 Climate	26
4.3.1 The Current State of Climate Change in New Jersey	27
4.3.2 The Future of Climate Change in New Jersey	27
4.4 Hydrology	28
4.5 Geology	29
4.5.1 Karst Geology	30
4.6 Soils	32
4.7 Groundwater Recharge and Stream Hydrology.....	34
4.8 Land Use and Land Cover	35
4.9 Critical Environmental Areas	39
4.9.1 Hydric Soils	39
4.9.2 Wetlands	39
4.9.3 Floodplains	42
4.10 Open Space Preservation and Protected Areas.....	43
4.11 Ecological Resources	46
4.11.1 Wildlife and Wildlife Habitat.....	46

4.11.2 Fisheries	49
4.11.3 Fish Consumption Advisories.....	53
4.11.4 Typical Vegetation, Rare Plant Species and Terrestrial Invasives	54
4.11.5 Aquatic Invasive Species.....	57
5.0 Physical Condition	58
5.1 Erosion.....	58
5.2 Hydromodification.....	59
5.3 Riparian Areas	59
5.4 Habitat Assessment Protocol.....	60
6.0 Surface Water Quality	60
6.1 Designated Uses and Impairments	60
6.1.1 Designated Uses	60
6.1.2 Impairments	62
6.1.3 Wild and Scenic Designation	65
6.2 Monitoring Programs	65
Microbial Source Tracking for <i>E.coli</i>	66
6.2.1 Monitoring Program June 2021- September 2021	67
Biological Monitoring	80
6.2.2 Monitoring Program for April 2022 - May 2023 (MWA Macro)	82
6.3 Point and Nonpoint Source Loadings	86
6.3.1 Point Sources.....	86
6.3.2 Nonpoint Sources	88
7.0 Criteria #1 – Causes and Sources of Pollution	89
7.1 Pathogens.....	90
7.2 Temperature	91
7.3 Sediment	91
7.4 Nutrients	91
7.5 pH and Other Parameters	92
8.0 Criteria # 2 - Required Load Reductions	93
8.1 Load Reduction Estimation Approach	93
8.2 Baseline Loads and Land Use Assignments	93
8.3 Standardization of BMP Units.....	94
8.4 Pollutant Removal Efficiencies	94

8.5 Implementation Goals	95
8.6 Calculation of Load Reductions	96
8.7 OSDS Loading and Reductions.....	101
9.0 Criteria #3 - Management Measures and Targeted Critical Areas.....	103
9.1 Temperature	103
9.2 Bacteria	104
9.3 Total Suspended Solids (TSS)	105
9.4 Total Phosphorus (TP)	105
9.5 Management Measures	105
9.5.1 Management Measures to Reduce Temperature	105
9.5.2 Management Measures to Reduce Bacterial Loads (E. coli).....	106
9.5.3 Management Measures to Reduce Sediment (TSS)	108
9.5.4 Management Measures to Reduce Nutrients	110
9.5.5 Management Measures to Restore Hydrology and Streamflow	111
10.0 Criteria #4 Estimate Technical and Financial Assistance Needed	112
11.0 Criteria #5 – Develop an Informational and Educational Component.....	123
11.1 River-Friendly Programs	123
11.2 Rain Garden Program	123
11.3 Rain Barrel Workshop.....	123
11.4 Sustainable Jersey™	124
11.5 Detention Basin Retrofit Program	124
11.6 Agriculture Mini-Grant Program.....	124
11.7 Soil Testing Program.....	124
11.8 Stewardship of Open Space (SOS)	125
11.9 Greening of Department of Public Works (DPW)	125
11.10 River Watchers Program	127
11.11 Watershed Allies Training Program	127
11.12 Outreach.....	127
11.12.1 Flow Together Outreach Meetings.....	127
11.12.2 Flow Together Outreach Feedback	127
11.12.3 Flow Together Outreach Survey Responses	129
12.0 Criteria #6 - Implementation Schedule.....	130
13.0 Criteria #7 – Describe Interim, Measurable Milestone.....	134

14.0 Criteria #8 – Identify Indicators to Measure Progress	135
15.0 Criteria #9 - Monitoring Program	137
16.0 Regulations and Ordinances.....	138
16.1 Stormwater Management Regulations	138
16.1.1 Municipal Stormwater Regulation Program (MS4).....	139
16.2 Highlands Act/Highlands Regional Master Plan.....	141
16.3 Stream Buffers.....	142
16.4 Agriculture.....	143
16.5 Steep Slopes	143
16.6 Septic System Maintenance	144
16.7 NJ Wild and Scenic Rivers	145
17.0 Specific Restoration Projects	146
17.1 Project Name: Hackettstown Medical Center and Willow Grove Medical Plaza	147
17.2 Project Name: Hackettstown Lowes Detention Basin Naturalization.....	150
17.3 Project Name: Hances Brook – left branch.....	152
17.4 Project Name: Hances Brook – right branch	155
17.5 Project Name: Mansfield Municipal Building and adjacent recreational area.....	158
17.6 Project Name: Manfield Elementary School.....	161
17.7 Project Name: Pilot Septic Pumping and Maintenance program & stormwater infrastructure retrofit	163
17.8 Project Name: Lebanon Township Ditch Retrofits or Installations	165
17.9 Project Name: Changewater Rd tributary	166
17.10 Project Name: Blue Army Shrine (BAS).....	169
18.0 Summary	171
References.....	173
Appendices.....	178
A. Bedrock Geology	178
B. Groundwater Recharge	179
C. Bedrock Aquifer.....	180
D. Impervious Surfaces.....	181
E. Point Source Permitted Discharges	182
F. Sewer Service	183
G. Drainage Basins.....	184

H. Stormwater Infrastructure.....	185
I. Potential Cover Cropping Locations	186
J. Agricultural Parcels Adjacent to a River or Stream	187
K. Flow Together Phase One Survey	188
L. Flow Together Phase Two Survey.....	191
M. Model Ordinance Septic Maintenance and Pumping	194
N. Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers	197
O. USEPA Rapid Bioassessment Protocol II	199
P. Best Management Practices (BMPs).....	201
Agricultural Best Management Practices	201
No-Till and Residue Management Program	201
Conservation (Vegetative) Buffers.....	201
Cover Crops	202
Nutrient Management.....	202
Livestock Access Control – Exclusion Fencing	202
Prescribed Grazing	203
Regional Composting Facility.....	203
Heavy Use Protection Area (HUPA)	203
Urban Stormwater Best Management Practices.....	203
Rain Gardens	204
Roadside Ditch Retrofits	207
Detention Basin Retrofits	208
Vegetated Buffers on Developed Land.....	211
Pervious/Permeable Pavers.....	211
Bioswales / Grassed Waterways.....	212
Parking Lot Diversions (Vegetative Filter Strips).....	212
Wastewater Best Management Practices	212
On-Site Disposal Systems (OSDS) – Maintenance, Inspection, and Pumping	212
Retrofitting Failed or Outdated OSDS.....	213
Wildlife Management.....	213

Figures List

Figure 4.5.1– Sinkhole formation in karst geology.

Figure 5.1 Natural ground cover and impervious cover and effects on infiltration

Figure 6.2 - MST markers for 2018 and 2021 study and relative abundance of source

Figure 6.2.1.a Log copies of DNA from each species

Figure 6.2.1.b Land use by percentage, arranged by sampling location

Figure 6.2.1.c Daily pH values across sample sites from 2021 MST study.

Figure P.1 – Residential rain garden in Ocean County NJ

Figure P.2 -Rain Garden on Main Street in Asbury, NJ. A trench captures runoff and pipes it into the rain garden.

Figure P.3 – End of pipe into Rain Garden bed

Figure P.4 – Wet detention basin in Hackettstown NJ

Figure P.6 – Profile of typical bioretention basin retrofit

Figure P.7 – Low flow concrete channels directing all stormwater to one area

Figure P.8 – 24 hours after a storm and the stormwater is spread out and native vegetation.

Tables List

Table 3.0 HUC14 Subwatersheds in the Study Area and Water Quality Impairments

Table 4.1 Municipalities in focus area with breakdown of amount of land in drainage area

Table 4.2 Musconetcong Project Area Demographics

Table 4.6 Soil Complexes in Musconetcong Watershed and in focus area

Table 4.7 Groundwater recharge rates based on soil class and percentage of each in focus area

Table 4.8.a Musconetcong River Watershed Land Use Classifications

Table 4.8.b Land Use Land Cover Comparison from 1986 to 2020

Table 4.9.2 Wetland type in Musconetcong Watershed and focus area

Table 4.10 Number of Preserved Farms in each county and focus area

Table 4.11.1 List of rare, threatened, and endangered species in the Project Area

Table 4.11.2.a Potentially Impaired sites for the Musconetcong River Watershed Project Area

Table 4.11.2.b FIBI sites of concern

Table 6.1.2.a Describes the sections of the Musconetcong River listed with a TMDL or listed on the 303(d) list

Table 6.1.2.b Applicable Surface Water Quality Criteria – N.J.A.C.7:9B (Last Amended – December 18, 2023 (52 N.J.R.711(a))

Table 6.2 Sample sites with site code, location, description and reason for concern.

Table 6.2.1.a Temporal and Spatial aspects of 2021 water quality monitoring in Musconetcong Watershed focus area

Table 6.2.1.b MST results from 2021 monitoring at Site HT- Hampton Borough Park (main stem)

Table 6.2.1.c MST results from 2021 monitoring at Site HR- Hollow Rd (tributary)

Table 6.2.1.d MST Results from 2021 monitoring at Site PM – Point Mountain (main stem)

Table 6.2.1.e MST Results from 2021 monitoring at Site WR – Watters Rd (tributary)

Table 6.2.1.f MST Results from 2021 monitoring at Site RR – River Rd (main stem)

Table 6.2.1.g MST Results from 2021 monitoring at Site ST – Stephensburg Brook (tributary)

Table 6.2.1.h MST Results from 2021 monitoring at Site HB – Hances Brook (tributary)

Table 6.2.1.i MST Results from 2021 monitoring at Site KH – Kings Highway (main stem)

Table 6.2.1.j MST Results from 2021 monitoring at Site DQ – Route 57 before Mountain Ave (main stem)

Table 6.2.1.k Summary statistics of *E.coli* results from 2021 monitoring, June – August

Table 6.2.1.l Summary statistics of *E.coli* results from 2021 monitoring July – September

Table 6.2.1.m Exceedances of SWQS from 2021 monitoring

Table 6.2.1.n Describes the disconnected relationship between average *E.coli* concentration and average MST

Table 6.2.1.o Overview of change at Hampton Park from 2007 to 2021, the most long-standing site within project area.

Figure 6.2.1.p Land use by percentage, arranged by sampling location

Table 6.2.1.q. Relation of wet weather events where *E. coli* threshold was exceeded vs total *E. coli* threshold exceedances across study period by site

Table 6.2.1.r. Further impacts of wet weather across study sites

Table 6.2.1.s. Provides background for historical bacterial monitoring to reveal trends

Table 6.2.1.t AMNET sites within Project Area

Table 6.2.2.a Results from the 2022 Biological Monitoring Program

Table 6.2.2.b Results of 2022 Biological monitoring program highlighting species diversity

Table 7.0 Land Use Land Cover Comparison from 1986 to 2020

Table 7.4.a Loading for sediment and total phosphorus per land use classification

Table 7.4.b Pollutant Loads for Project Area for Total Phosphorus and Total Suspended Solids

Table 8.3 Standardization of best management practices for unit calculations

Table 8.5 Implementation goals for best management practices

Table 8.6.a Load reduction coefficients for BMPs and source of information

Table 8.6.b Estimated Annual Load Reductions on Applicable Land for Implementation Goals for TP and TSS

Table 8.6.c Estimated Load Reductions combined with projected Implementation Schedule (TP, TSS)

Table 8.6.d Estimated Bacterial Load Reductions

Table 8.7.a: Loading scenarios with a 5% leaky septic system assumption
 Table 8.7.b: Reduction Scenario with 40% OSDS Retrofit
 Table 10.0.a Recommended BMP Projects for the Musconetcong River Watershed and associated costs
 Table 10.0.b Summary of BMP and their priority ranking for each parameter
 Table 10.0.c Funding Sources for Agricultural BMPs
 Table 10.0.d Funding Sources for Urban/Suburban Stormwater BMPs and Wastewater BMPs
 Table 10.0.e Cost out for BMPs over Implementation Goals, 2-5-10 year time frames
 Table 12.0.a Implementation targets for the recommended BMP projects in the Musconetcong River Watershed
 Table 12.0.b BMP Implementation schedule in the Musconetcong River Watershed
 Table 12.0.c BMP Schedule with cost out for 2-5-10 year goals
 Table 14.0 – Indicators to Measure Progress

Map List

Map 2.1 Surface Water Quality Classifications
 Map 3.0 2021 Project Area with Municipal Boundaries
 Map 4.1 Associated HUC14s and 2021 Project Area
 Map 4.8 2020 Land Use/Land Cover
 Map 4.9.2 Wetlands Habitat
 Map 4.9.3 FEMA Flood Hazard zones
 Map 4.10 Preserved Farmland and Open Space
 Map 4.11.1 Landscape Project v3.4 Map
 Map 4.11.2 FIBI Monitoring Location
 Map 4.11.4 Forested Land Use
 Map 6.1.1 Surface Water Quality Classifications
 Map 6.2.1.a Hances Brook with surrounding land use
 Map 6.2.1.b DQ Sampling location and surrounding land use
 Map 6.2.1.c Urban land use throughout the whole watershed
 Map 6.2.1.d AMNET sampling location in Project Area
 Map 6.2.2 2021 Bacteria and macroinvertebrate monitoring locations in Project Area
 Map 9.1 TU Riparian Restoration Tool
 Map 10.0 Overburdened Communities
 Map 11.9 Potential Stormwater Infrastructure Retrofit locations
 Map 16.1.1 Registered and Unregistered Stormwater Infrastructure
 Map 16.5 Slopes of the Project Area

Map A.1 Bedrock Geology
Map A.2 Groundwater Recharge
Map A.3 Bedrock Aquifer
Map A.4 Impervious Surfaces
Map A.5 Point Source Discharges
Map A.6 Sewer Service Areas
Map A.7 Drainage Basins
Map A.8 Stormwater Infrastructure
Map A.9 Potential Cover Cropping Locations
Map A.10 Agricultural Parcels adjacent to a river or stream within the Project Area

List of Acronyms

AMNET – Ambient Biomonitoring Network
ANJEC – Association of New Jersey Environmental Commissions
ARPA – American Rescue Plan Act
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
C1 – Category One Waters
CR – County Routes
CREP – Conservation Reserve Enhancement Program
CSP – Conservation Stewardship Program
CWSRF – Clean Water State Revolving Fund
DO – Dissolved Oxygen
DPW – Department of Public Works
DRWI – Delaware River Watershed Initiative
E. coli – Escherichia coli
EI – Erodibility Index
EPA / USEPA – U.S. Environmental Protection Agency
EPT – Ephemeroptera, Plecoptera, Trichoptera
EQIP – Environmental Quality Incentives Program
FEMA – Federal Emergency Management Agency
FOTG – Field Office Technical Guide
FSA – Farm Service Agency
FW – Freshwater
FW2-TM – Freshwater Trout Maintenance
FW2-TP – Freshwater Trout Production

GPS – Global Positioning System
GSI – Green Stormwater Infrastructure
GWLF-E – Generalized Watershed Loading Functions – Enhanced (MapShed)
HCSCD – Hunterdon County Soil Conservation District
HGMI – High Gradient Macroinvertebrate Index
HRU – Hydrologic Response Unit
HSA – Hydrologically Sensitive Areas
HUC – Hydrologic Unit Code
HYSEP – Hydrograph Separation Program
I-Bank – New Jersey Infrastructure Bank
ICM – Integrated Crop Management
LU/LC – Land Use / Land Cover
LURP – Land Use Regulatory Program
MOS – Margin of Safety
MRRP – Musconetcong River Restoration Partnership
MST – Microbial Source Tracking
MS4 – Municipal Separate Storm Sewer System
MUSYM – Map Unit Symbol
MWA – Musconetcong Watershed Association
NASS – National Agricultural Statistics Service
NEMO – Nonpoint Education for Municipal Officials
NJCWST – New Jersey Center for Water Science & Technology
NJDA – New Jersey Department of Agriculture
NJDEP – New Jersey Department of Environmental Protection
NJEIFP / NJWB – New Jersey Environmental Infrastructure Financing Program / Water Bank
NJGS – New Jersey Geological Survey
NJIS – New Jersey Impairment Score
NJIT – New Jersey Institute of Technology
NJPDES – New Jersey Pollutant Discharge Elimination System
NJRC&D – North Jersey Resource Conservation & Development Council
NRCS – Natural Resources Conservation Service
NPS – Nonpoint Source Pollution
NT – Non-Trout Waters
OQA – Office of Quality Assurance
OSDS(s) – On-site Sewage Disposal System(s)
PCR – Polymerase Chain Reaction
PDSI – Palmer Drought Severity Index
PFAS – Per- and Polyfluoroalkyl Substances
PIG – Planning Incentive Grant
QAPP – Quality Assurance Project Plan
qPCR – Quantitative Polymerase Chain Reaction
RCE – Rutgers Cooperative Extension
RHA – Rapid Habitat Assessment
ROW – Right of Way
RTMUA – Raritan Township Municipal Utilities Authority
SADC – State Agriculture Development Committee
SI – Stormwater Infrastructure
SRF – State Revolving Fund
SSA – Sewer Service Area
SSURGO – Soil Survey Geographic Database

STEPL – Spreadsheet Tool for Estimating Pollutant Load
SWAT – Soil and Water Assessment Tool
SWQS – Surface Water Quality Standards
TMDL – Total Maximum Daily Load
TM – Trout Maintenance
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids
UNT – Unnamed Tributary
USDA – U.S. Department of Agriculture
USGS – U.S. Geological Survey
VAPP – Visual Assessment Project Plan
VSA – Variable Source Area
WAT – Watershed Allies Training
WFPO - Watershed Protection and Flood Prevention Operations
WHIP – Wildlife Habitat Incentive Program
WIP – Watershed Improvement Plan
WRPP – Watershed Restoration and Protection Plan

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2.0 Executive Summary

The Musconetcong River is a federally designated Wild and Scenic River, draining nearly 157 square miles across Hunterdon, Warren, Morris, and Sussex Counties. Despite its ecological and cultural significance, the river faces ongoing water quality challenges. This Watershed Restoration and Protection Plan provides a ten-year roadmap, consistent with the EPA's Nine Elements framework, to restore impaired uses, protect high-quality waters, and strengthen resilience to future pressures.

Land use across the watershed has shifted significantly since 1986. Urban areas expanded by fourteen percent, while farmland declined by thirty-seven percent. Forest cover increased by sixteen percent, but overall impervious cover rose by more than fifty percent, now accounting for a quarter of the project area. These changes have altered watershed hydrology, leading to flashier storm flows, more unstable channels, and increased erosion and sediment delivery.

Water quality monitoring conducted in 2021 confirmed persistent problems with *E. coli* contamination. Eight of nine sampling locations exceeded both the geometric mean and statistical threshold criteria for safe recreation. Microbial source tracking demonstrated that human wastewater from septic systems is the leading source of pathogens, followed by livestock in agricultural areas. Tributaries such as Hances Brook and the Watters Road stream were identified as persistent "hot spots."

Thermal stress presents another major concern, particularly for the river's trout production and maintenance waters. Continuous temperature data from Hampton Borough Park revealed that summer maximum exceeded the state's trout threshold of 25°C on eighty-three days in 2022, four days in 2023, and twenty-three days in 2024. Loss of riparian shade, heated stormwater runoff, and altered baseflows are the primary drivers.

Sediment and nutrients also remain important contributors to degradation. Streambank erosion is now recognized as the dominant sediment source, compounded by stormwater sheeting off developed lands and bare agricultural fields. Phosphorus is mobilized with sediment, and while not listed as impaired in the project reach during 2021, reductions are necessary to protect aquatic life and downstream uses.

The community engagement process, branded Flow Together, revealed strong resident support for restoration. Participants expressed willingness to adopt septic maintenance, install rain gardens, and expand native planting. Many residents highlighted safe drinking water, recreation, and flood resilience as shared priorities, reinforcing both the urgency and the feasibility of this plan.

The plan addresses the root causes of impairment through a mix of septic system programs, stormwater retrofits, agricultural practices, and riparian restoration. The highest priority is

reducing pathogen loads from failing or unmaintained septic systems. This requires inspection and maintenance programs, targeted retrofits, homeowner education, and coordination with municipal sewer service areas. In agricultural subwatersheds, fencing livestock from streams, providing off-stream watering, and expanding manure management are critical.

Riparian reforestation and streambank stabilization will restore shade, habitat, and bank stability. At the same time, stormwater management will shift from traditional detention to green infrastructure retrofits, rain gardens, bioswales, permeable pavement, roadside ditch retrofits, and bioretention basins, designed to cool, filter, and infiltrate runoff. Agricultural best management practices, including cover crops, no-till farming, nutrient management, grazing systems, and conservation buffers, will reduce erosion and nutrient runoff. Together, these measures address pathogens, temperature, nutrients, and sediment, while also restoring natural hydrology.

Education and monitoring are integral to the strategy. Building on the MWA's River Watchers and Watershed Allies Training, the plan expands public training and outreach, links municipal ordinances to statewide requirements, and continues long-term biological and water quality monitoring to guide adaptive management.

The total cost of implementing all recommended best management practices is estimated at \$24.7 million. A practical ten-year implementation scenario would require about \$12.4 million. This investment is expected to achieve:

- a 93 percent reduction in pathogen loads, meeting recreational water quality standards,
- a reduction of approximately 1,597,040 pounds of sediment per year, achieving standards for total suspended solids, and
- an estimated 6,697 pounds of phosphorus reduction annually, with further benefits expected as pathogen-focused projects are installed.

The plan envisions phased implementation. In the first two years, quick-win actions will include septic inspections, initial rain garden and roadside retrofits, targeted livestock exclusion, and reforestation of priority riparian patches. These early investments, costing roughly \$2 million, will prevent further degradation and deliver measurable reductions in bacteria, sediment, and phosphorus. By year five, half of the cover crop acreage and septic inspections will be complete, and one regional manure facility will be under design. By year ten, full implementation targets will be met across all major practice categories.

Funding will draw on a blend of sources: USDA programs such as Environmental Quality Incentives Program (EQIP), Conservation Reserve Enhancement Program (CREP), and Conservation Stewardship Program (CSP) for agricultural practices; the Clean Water State Revolving Fund and NJ Water Bank for stormwater and septic; 319(h) Nonpoint Source grants; and federal programs like American Rescue Plan Act (ARPA). Projects sited in Overburdened Communities, particularly in the Hackettstown area, qualify for additional subsidies and higher

competitive ranking, improving cost-effectiveness. Stakeholders will be responsible for long-term maintenance of installed practices, ensuring sustainability beyond initial funding cycles. Appendix P provides details about the various Best Management Practices (BMPs) that are recommended for implementation including background information, implementation approaches, cost considerations, expected benefits, and practical recommendations suitable for inclusion in a 319(h) watershed-based plan.

The Musconetcong Watershed Restoration and Protection Plan charts a clear, actionable course to restore impaired uses and safeguard high-quality waters. By tackling septic system failures, retrofitting stormwater infrastructure, improving agricultural management, and restoring riparian corridors, this plan positions the watershed for both immediate improvement and long-term resilience. With strong community support, proven practices, and a realistic funding strategy, the Musconetcong River can remain a treasured Wild and Scenic resource while supporting the health, recreation, and quality of life of the communities along its banks.

3.0 Introduction and Background

The Musconetcong River serves as a natural boundary between Hunterdon and Warren Counties and Morris and Sussex Counties, forming a vital component of the Upper Delaware Watershed (WMA1). As a major tributary to the Delaware River, the Musconetcong River watershed spans approximately 156.7 square miles across four counties, with the main stem extending 42 miles before joining the Delaware River. Twenty-six (26) municipalities lie within the watershed's boundaries. In December 2006, the Musconetcong Wild and Scenic Rivers Act was signed into law, designating portions of the river as part of the National Wild and Scenic Rivers System. Of the twenty-six municipalities in the watershed, fourteen are eligible for Wild and Scenic designation (Musconetcong Advisory Committee, 2003).

In 2017, water resource professionals from several organizations—including the North Jersey Resource Conservation and Development Council (NJRC&D), Montclair State University (MSU), and the Musconetcong Watershed Association (MWA)—convened to discuss a coordinated approach to addressing water quality concerns within the watershed. These discussions led to the development of a proposal for the Musconetcong River Watershed Restoration and Protection Plan (WRPP), submitted under the Clean Water Act Section 319(h) program administered by the New Jersey Department of Environmental Protection (NJDEP). In 2019, NJDEP awarded MWA and its collaborators a grant (Grant Identifier WQR-2019-Musconetcong Watershed-As-00134) to develop and expand upon the 2012 Musconetcong River Restoration and Protection Plan – Hampton to Bloomsbury, originally prepared by NJRC&D from 2006 to 2012 under a previous NJDEP 319(h) grant.

The current project area consists of six U.S. Geological Survey HUC14 sub-watersheds, encompassing 74.5 square miles of drainage and approximately 26 river miles. This section of the river extends southwest from just above Route 46 in Allamuchy and Mount Olive Townships, covering portions of 14 municipalities: Alexandria Township, Allamuchy Township, Bethlehem Township, Franklin Township, Glen Gardner Borough, Hackettstown, Hampton Borough, Independence Township, Lebanon Township, Mansfield Township, Mount Olive Township, Washington Borough, Washington Township (Morris), and Washington Township (Warren) (see Map 3.0 and Table 4.1). Within the project area, numerous named and unnamed tributaries contribute approximately 149 additional stream miles. Waters in these reaches are primarily classified as Category One (C1), Freshwater-Trout Maintenance (FW2-TM), and Freshwater-Trout Production (FW2-TP).

According to the three most recent NJDEP 303(d) lists, two sub-watersheds that were impaired for aquatic life in 2016 are now attaining that use; however, one remains impaired for temperature (trout), two for pH, and all six for *E. coli* (Table 3.0). The purpose of this WRPP is to provide a roadmap for reducing pollutant loadings through stormwater runoff management, restoring impaired uses, and protecting those that are currently attaining. Historically, the Musconetcong River segment from Waterloo to the Delaware River was listed as impaired for fecal coliform in the 2002 Integrated Water Quality Monitoring and Assessment Report, prompting a Total Maximum Daily Load (TMDL) to be established. Prior to 2008, New Jersey's Surface Water Quality Standards (SWQS) used fecal coliform as the indicator for fecal contamination and associated pathogens (N.J.A.C. 7:9B-1.14(c)). In 2006, these standards were updated to adopt *Escherichia coli* (*E. coli*), a more specific indicator of fecal contamination, consistent with U.S. Environmental Protection Agency (USEPA) recommendations. The Musconetcong River segment between Route 31 and Saxton Falls has also been listed as impaired for pH and temperature (2014).

In parallel with these efforts, the Musconetcong Watershed Association joined the Delaware River Watershed Initiative (DRWI) in 2011, a collaborative effort funded by the William Penn Foundation. As part of the NJ Highlands Cluster, alongside the Association of New Jersey Environmental Commissions (ANJEC), Hunterdon Land Trust, New Jersey Audubon, and others, MWA implemented multiple best management practices (BMPs) and advanced land preservation to protect water quality. Over the past decade, numerous restoration projects have been completed within the Hampton-to-Bloomsbury corridor, and two water quality studies were conducted in 2018 (original focus area) and 2021 (expanded area), improving understanding of water quality conditions, land use, and land cover change in the middle Musconetcong.

Despite these advances, nonpoint source pollution remains a persistent challenge. The inclusion of the Musconetcong River in the Draft 303(d) List for Water Quality Limited Waters highlights the need for continued proactive management. In response, MWA expanded the plan to include three additional HUC14 sub-watersheds, broadening restoration and protection efforts upstream through increased funding and community engagement. This expansion also led to the formation of the Musconetcong River Restoration Partnership (MRRP), a coalition of organizations that share resources, expertise, and capacity to address complex watershed issues beyond the scope of any single organization.

Complementary regulatory programs further support these efforts. Since 2004, New Jersey's Municipal Separate Storm Sewer System (MS4) program has required municipalities, public complexes, and highway agencies to manage stormwater runoff and reduce nonpoint source pollution. Through measures such as public education, illicit discharge detection, and implementation of BMPs, the MS4 program helps prevent pollutants from entering waterways and supports the overall goals of the WRPP to restore and protect the Musconetcong River watershed.

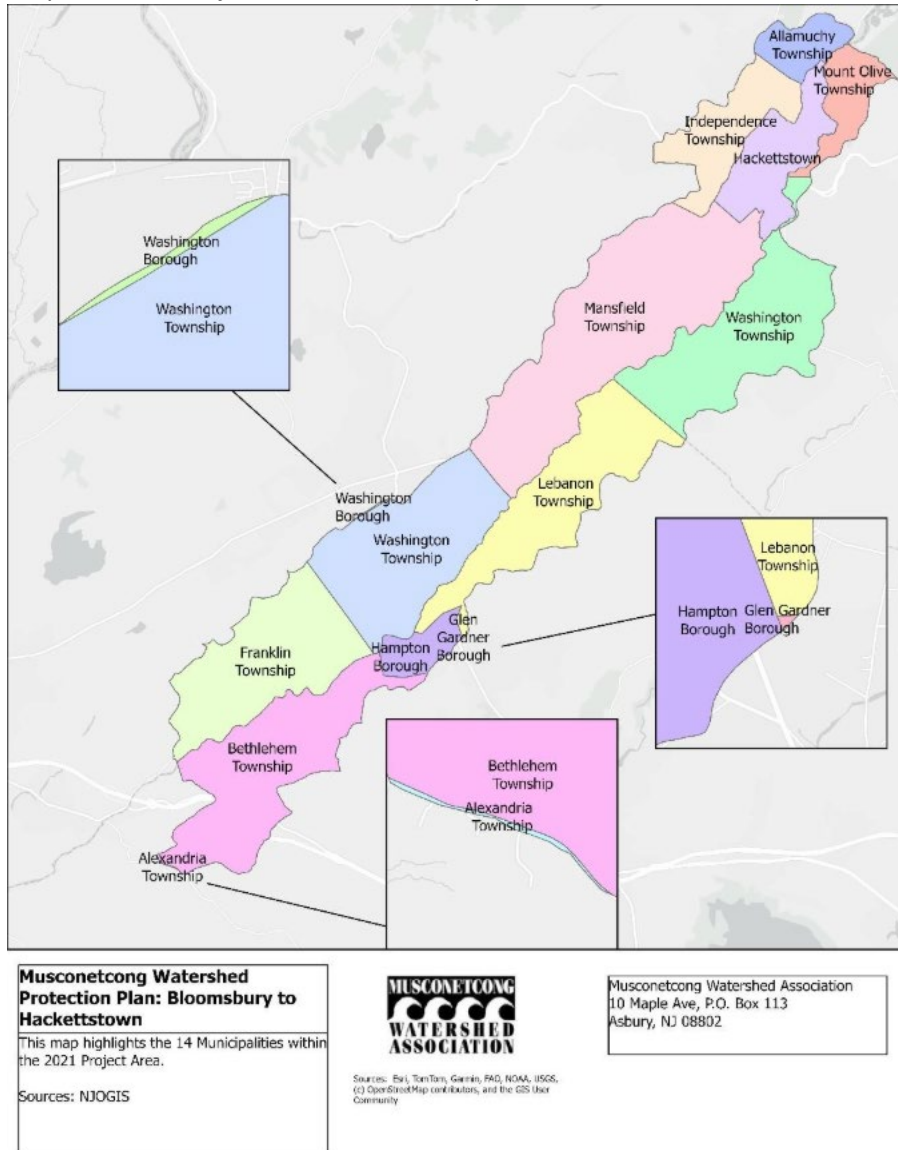
Table 3.0 HUC14 Subwatersheds in the Study Area and Water Quality Impairments

Waterway Name (Subwatershed)	HUC 14	303(d) List**	Attaining SWQS?*								
			Bio.	DO	E.coli	Temp. (Trout)	pH	TP	N	TSS	As
Musconetcong R (Trout Bk to Saxton Falls)	02040105150100	2016 2018/20 2022	N	Y	N	Y	N	Y	Y	Y	N
			Y	Y	N	Y	N	Y	Y	Y	N
			Y	Y	N	Y	N	Y	Y	Y	N
Musconetcong R (Hances Bk thru Trout Bk)	02040105160010	2016 2018/202022	N	Y	N	N	Y	Y	Y	Y	N
			Y	Y	N	N	Y	Y	Y	Y	N
			Y	Y	N	N	Y	Y	Y	Y	N
Musconetcong R (Changewater to Hances Bk)	02040105160020	2016 2018/20 2022	Y	Y	N	Y	N	Y	Y	Y	N
			Y	Y	N	Y	N	Y	Y	Y	N
				Y	N	Y	N	Y	Y	Y	N
Musconetcong R (Rt 31 to Changewater)	02040105160030	2016 2018/20 2022	Y	Y	Y	Y	Y	Y	Y	Y	I
			Y	Y	N	Y	Y	Y	Y	Y	N
			Y	Y	N	Y	Y	Y	Y	Y	N
Musconetcong R (75d 00m to Rt 31)	02040105160040	2016 2018/20 2022	Y	Y	N	Y	Y	Y	Y	Y	I
			Y	Y	N	Y	Y	Y	Y	Y	N
			Y	Y	N	Y	Y	Y	Y	Y	N
Musconetcong R (I-78 to 75d 00m)	02040105160050	2016 2018/20 2022	Y	Y	N	Y	Y	Y	Y	Y	I
			Y	Y	N	Y	Y	Y	Y	Y	I
			Y	Y	N	Y	Y	Y	Y	Y	I

*N = non-attaining, Y = full attainment, I = Insufficient data

**303(d) list of impaired waterbodies list year

Map 3.0 2021 Project Area with Municipal Boundaries



3.1 Purpose of the Plan

The development of the Musconetcong River Watershed Restoration and Protection Plan (WRPP) is funded by the Federal Clean Water Act Section 604(b). Program administered through the Division of Watershed Protection and Restoration, Bureau of Watershed Management, formerly the Division of Watershed and Land Management, at NJDEP.

This plan is to design a kit of strategies aimed at guiding municipalities and other entities in their efforts to enhance water quality. This comprehensive plan outlines a range of management measures essential for achieving significant reductions in bacterial pollution levels and meeting water quality standards for Temperature, pH, Total Phosphorus (TP) and Total Suspended Solids (TSS). Additionally, it aims to mitigate aquatic life impairments, striving to restore the Musconetcong River's base flow within the 74.5 square miles of the watershed encompassed by the project area.

This plan serves as a toolbox, offering many tools and strategies to address various water quality challenges effectively. Municipalities and other stakeholders can utilize these resources to tailor interventions to their specific needs and circumstances. By providing clear guidance and a diverse array of approaches, this plan empowers local communities to take meaningful action towards improving the health and resilience of the Musconetcong River watershed.

3.2 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: Bureau of
Environmental Analysis, Restoration and Standards (BEARS)
Contact Information: Kimberly Cenno
P.O. Box 420
Trenton, NJ 08625-0420
(609) 633-2201
<http://www.nj.gov/dep/watershedmgt/>

Lead Agency

Musconetcong Watershed Association
Contact Information: Eileen Murphy
Executive Director
P.O. Box 113
Asbury, NJ 08802
(908) 537-7060
<http://www.musconetcong.org>

Collaborative Agencies

North Jersey Resource Conservation & Development (NJRC&D)
Contact Information: Laura Tessieri
Executive Director
P.O. Box 113

Asbury, NJ 08802
(908) 574-5368
<http://www.northjerseyrcd.org>

Montclair State University, New Jersey Center for Water Science and Technology
Contact Information: Meiyin Wu
Director & Professor, Department of Biology
Montclair, NJ 07043
(973) 655-7117
<https://www.montclair.edu/water-science/>

The project team, water quality professionals from MWA and MSU, identified and completed eight tasks to develop the plan. The MWA and MSU initiated the project by reviewing historical data and designing a study to expand the focus area. The monitoring plan was executed during the summer of 2021, followed by eight months of data analysis. The findings revealed that none of the sites met the standards for *E. coli*, either based on the Geometric Mean standard or the new Statistical Threshold Value (10% of 320/100 cfu/mL).

Subsequently, a presentation was delivered to stakeholders at a MRMC meeting in February of 2023 and statewide to the New Jersey Water Monitoring Council (NJWMC) in May 2023. A series of community input sessions were then organized, with seven sessions held over the following four months. Attendees represented a diverse range of stakeholders, including Environmental Commission members, local farmers, business owners, and residents. These feedback sessions facilitated an understanding of the community's readiness to implement various BMPs and their perceptions regarding economic growth, infrastructure, housing, preservation, and the role of the environment and water quality within these contexts.

This plan will detail the management measures needed to achieve the necessary reduction in fecal indicator bacteria and attain water quality standards for pH, temperature and reduce the aquatic life impairments to a non-impaired level. The plan follows the Environmental Protection Agency's (EPA) 9- Element framework, detailed below.

3.3 Nine Elements of a Watershed Plan

This plan follows the USEPA's 9-Elements for watershed restoration; these elements as quoted from the USEPA's "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" are as follows:

1. Identify causes and sources of pollution

- 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 7.0, as pathogens like *E. coli* and fecal coliform, 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 section 6.3
2. Estimate pollutant loading into the watershed and the load reductions expected
 - In section 8.0 the load reduction goals for each type of BMP project are calculated. This is also discussed in more detail in table 8.6.c with a breakdown of the two-, five- and ten-year goals.
 3. Describe management measures and targeted critical areas
 - Management measures are highlighted in section 9.0; 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 recommended for implementation include BMPs such as cover crops, vegetative buffers, detention basin retrofitting, rain gardens and others.
 4. Estimate technical and financial assistance needed
 - Technical assistance is discussed in section 10.0 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 \$12,371,173 with approximately \$4,948,469 or 40% going towards technical assistance
 5. Develop an information and education component
 - Educating the public is an important part of any management plan. This component of the plan is in section 11.0 and includes programs such as Sustainable Jersey™, River Friendly Programs, and MWA's Watershed Allies Training (WAT) programs for do-it-yourself (DIY) Septic Inspection, How to Make Your Public Comment Count and DIY Solutions for Sustainable Stormwater Management. In addition, MWA trains and educates the public through their River Watcher program about non-point source (NPS) pollution and how to monitor and assess water quality and riparian habitat.
 6. Develop a project schedule

- The schedule for implementation is discussed in section 12.0. Table 12.0.b 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 conservation buffers on agricultural lands projects completed by year five while not having the regional composting facility completed within the same time frame, due to scope, scale and permitting.
7. Describe interim, measurable milestones
 - Measurable milestones are outlined in section 13.0 and are separated into two-, 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 93% of bacteria from the Musconetcong River.
 8. Identify indicators to measure progress
 - There are two criteria proposed to be used in determining if a project is successful. These two criteria are brought up in section 14.0. These two criteria are about 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.
 9. Develop a monitoring component
 - The monitoring program to be developed for this project is based off the criteria from the previous section. This is outlined in section 15.0. 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.

The following sections provide detailed characterization of the watershed to establish the context necessary for addressing the nine elements of this plan.

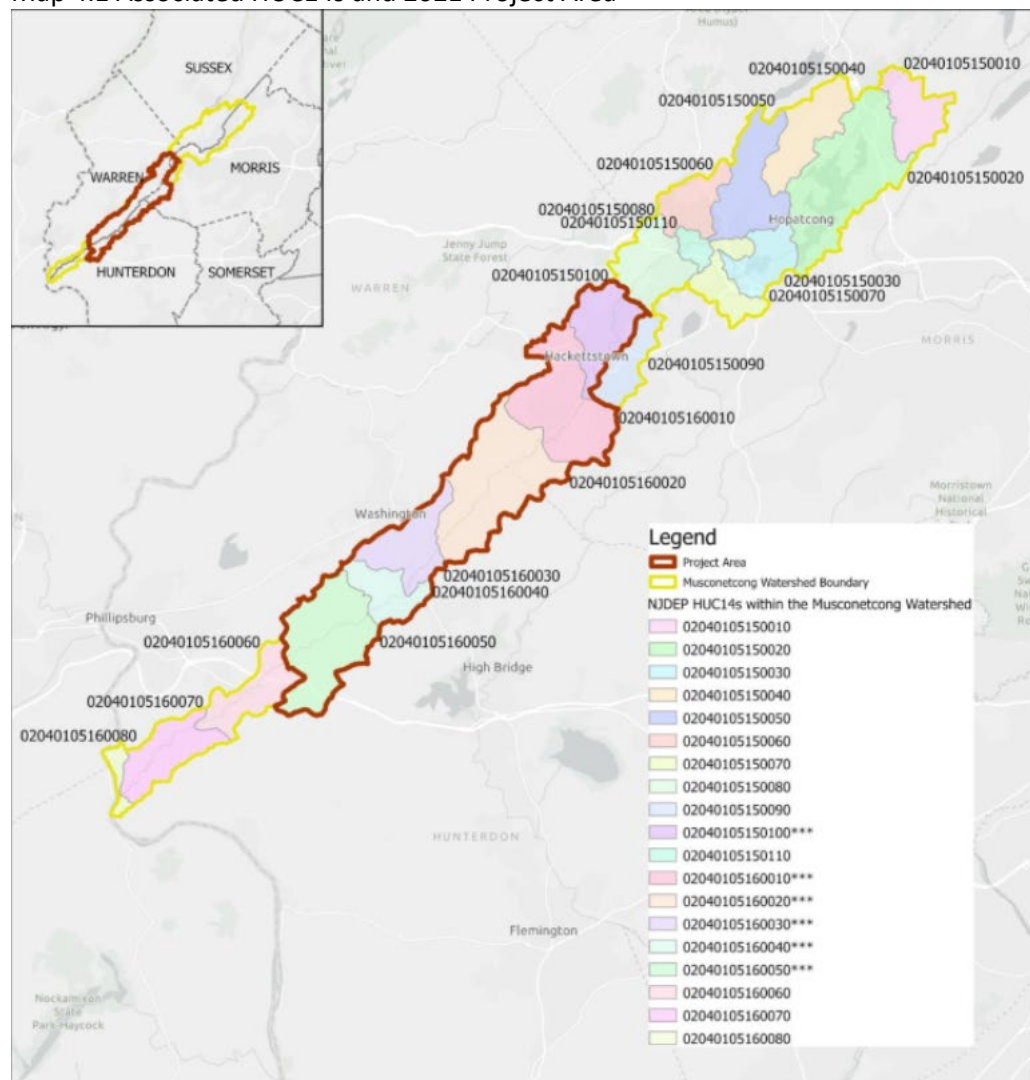
4.0 Watershed Description

4.1 Geography and Topography

The Musconetcong River, serving as a major tributary to the Delaware River, is an integral part of the Upper Delaware Watershed, which includes five subwatershed basins, of which, the Musconetcong Watershed is classified as one of the major contributors. The river itself extends

for 42 miles and encompasses a drainage area of 156 square miles. It originates from its headwaters at Lake Hopatcong and Lake Musconetcong and flows into the Delaware River in Riegelsville. The associated project area, detailed below in Map 4.1, spans 14 municipalities within Hunterdon, Warren, and Morris Counties, accounting for approximately 43% of the entire Musconetcong River Watershed.

Map 4.1 Associated HUC14s and 2021 Project Area



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the USGS HUC14s within the Musconetcong Watershed as well as the HUC14s within the Project area. HUC14s with "****" denoted in Legend are within the Project area.

Sources: NJDEPGIS



Musconetcong Watershed Association
10 Maple Ave, P.O. Box 113
Asbury, NJ 08802

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Delaware Geological Survey - New Jersey/Delaware boundary data through the Delaware River within the 12 mile circle centered on the old New Castle County Courthouse (used prior to 1881).

New Jersey Department of Agriculture, State Agricultural Development Committee, Farmland Preservation Program - preserved farmland boundary data from property surveys New Jersey Department of Environmental Protection, Green Acres Program - open space

This project area begins on Musconetcong Mountain, located southeast of Route 22, encompassing parts of Bloomsbury and Alexandria. It then progresses through the

Musconetcong Valley, crossing into several other municipalities such as Bethlehem Township, Hampton Borough, and Glen Gardner in Hunterdon County. From there, the area extends into Washington Borough, Washington Township, and other parts of Warren County, including Franklin, Mansfield, Independence, Hackettstown, and Allamuchy Townships. It concludes in Washington and Mount Olive Townships in Morris County, just before reaching Saxton Lake below Route 80.

The project's municipalities vary considerably in the extent of their contributions to the watershed. Alexandria Township and Glen Gardner Borough, for instance, contribute only 0.12% to the project area's overall drainage. In contrast, Lebanon Township, a 31-square-mile area in northern Hunterdon County, directs 23% of its drainage to the project area. The township, historically agricultural, has seen recent growth that has increased impervious surfaces, affecting drainage. Hampton Borough, another part of Hunterdon County, has about 89% of its 1.5-square-mile area draining into the project area. Similarly, Washington Township in Warren County contributes 45.9% of its drainage from its 17.9 square miles, while Hackettstown, also in Warren County, sends 100% of its 3.7 square miles into the project area. This information can be found in Table 4.1 below. A map of the municipalities within the project area can be found on Map 3.0.

Table 4.1 Municipalities in focus area with breakdown of amount of land in drainage area

Municipality	County	Total Acres	Acres in Project Area	Percent of Municipality Draining into Project Area
Alexandria Township	Hunterdon	17,758	3	0.02%
Allamuchy Township	Warren	12,973	1,067	8.22%
Bethlehem Township	Hunterdon	13,287	5,567	41.90%
Franklin Township	Warren	15,051	4,950	32.89%
Glen Gardner Borough	Hunterdon	990	1	0.10%
Hackettstown	Warren	2,374	2,374	100.00%
Hampton Borough	Hunterdon	970	866	89.28%
Independence Township	Warren	12,785	2,433	19.03%
Lebanon Township	Hunterdon	20,272	4,719	23.28%
Mansfield Township	Warren	19,001	9,144	48.12%
Mount Olive Township	Morris	19,991	1,286	6.43%
Washington Borough	Warren	1,258	12	0.95%

Washington Township	Warren	11,547	5,300	45.90%
Washington Township	Morris	28,726	5,405	18.82%

4.2 Demographics

According to the 2020 census population estimates from the U.S. Census Bureau shown in Table 4.2 below, Morris County has not only the largest population but also greatest percent change over the past 20 years, however, only 2 percent of Morris County falls in the project area. Hunterdon County has a quarter of the population but twice as much influence in the project area. The county with the greatest influence in the project area, while also sharing the lowest population, is Warren County with 11 percent of the county in the project area. Both Hunterdon and Warren Counties saw similar population increases over the past twenty years, 6 and 7 percent respectively, which according to the Department of Economic and Social Affairs of the United Nations, this raises concerns for the potential magnified impact of harmful economic process and increased material resource consumption on the environment (Wilmoth, Menozzi and Bassarsky, 2022).

Table 4.2 Musconetcong Project Area Demographics

County	2000	2010	2018	2020	% change from 2000-2010	% change from 2000-2020	% of County in Project Area
Hunterdon	121,989	128,349	124,807	128,947	5%	6%	4%
Warren	102,437	108,692	105,528	109,632	6%	7%	11%
Morris	470,212	492,276	493,070	509,285	5%	8%	2%

4.3 Climate

The region's climate is Moist Subtropical Mid-Latitude subtropical, with typical hot and humid summer and cold winter months (NOAA, 2023c). According to weather data collected by the National Oceanic and Atmospheric Administration (NOAA) between the 50-year period of 1971-2021 the average low temperature for the summer months (June-August) was 62.1°F (16.7°C), as opposed to the average high temperature for the same time frame of 83°F (28.3°C). The average low temperature during the winter months (December-February) was 24.3°F (-4.3°C) while the average high for the same time period was 41.8°F (5.4°C). Spring and autumn can exhibit wide ranges in temperature variation, from chilly to warm, with relatively mild and low humidity. Overall, a general upward trend can be seen in annual temperatures with the average annual temperature of 52°F (11°C) in 1971 and an average annual temperature of 55.1°F (12.8°C) in 2021 (NOAA National Centers for Environmental Information [NCEI], 2023a).

Mean annual precipitation throughout the region was about 49 inches during the 50-year period of 1971-2021 (NOAA NCEI, 2023b). The region had an average Palmer Drought Severity Index (PDSI) of 0.28 (on a scale of -10 being the driest and +10 being wettest conditions). Over the same time period, the region saw its highest PDSI of 5.61 in September of 2011 and lowest PDSI of -4.56 in February of 2002, which is considered extreme drought-like conditions (NOAA NCEI, 2023c). 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 (NOAA NCEI, 2023d).

4.3.1 The Current State of Climate Change in New Jersey

Over the past century, New Jersey has experienced a significant warming trend, with an analysis of 122 years of climate data (1895-2016) by Rutgers University's State Climatologist Office revealing that the average annual temperature has steadily increased. The coldest average annual temperatures were recorded before 1941, while the warmest have occurred since 1997. Precipitation patterns have varied, but the average annual precipitation over the last four decades has been higher than in the early 20th century. Notably, sea level rise has accelerated, with the 20th century seeing rates three times faster than any time in the past 2,700 years, a situation exacerbated by increasing carbon dioxide emissions leading to ocean acidification. The last 15 years alone saw sea levels rise by approximately 4 inches in New Jersey—double the global average—and projections suggest a rise of 7-12 inches over the next 15 years. If greenhouse gas emissions remain constant, the sea level could rise by 29-54 inches along the New Jersey coast over the next century. New Jersey's flat marshes, especially along the Delaware Bay coast, are particularly at risk, potentially resulting in nearly 3% of the state's landmass being lost to rising waters.

4.3.2 The Future of Climate Change in New Jersey

If climate change continues to accelerate, New Jersey may face a series of environmental challenges. Air and water quality could decline significantly, exacerbating the "heat island" effect in its urbanized areas. The state's forest composition may alter, impacting bird and wildlife habitats, as well as migratory corridors and breeding areas. More severe weather patterns are expected, including intense storms interspersed with prolonged droughts, leading to significant flooding and reduced aquifer recharge due to rapid runoff from hardened soils. In the summer of 2023, New Jersey saw frequent storms with totals in the Warren, Morris, Sussex County, Hunterdon County areas reaching 5 inches of precipitation per storm (Driscoll, 2023). The intense storms of 2023 were followed by a declaration of drought conditions in the fall of 2024 from the New Jersey Governor and NJDEP Commissioner. (NJDEP, 2024) The frequency and intensity of storm surges, coastal flooding, erosion, and property damage are likely to increase along the densely populated coasts, with sea level rise worsening these issues. Additionally,

increased salt-water intrusion into coastal aquifers could jeopardize the fresh water supply. These changes will place increased stress on both natural and managed ecosystems throughout New Jersey.

4.4 Hydrology

By utilizing NJDEP data, which is presented in the Appendix, Map A.1, A.2, and A.3 (Bedrock Geology, Groundwater recharge, and Bedrock Aquifer respectively), a picture can be painted regarding the hydrology of the project area. The hydrology of the Musconetcong River and its tributaries reflects a predominantly groundwater-fed system that responds quickly to storm events while maintaining sustained baseflow through much of the year. Together, the river's lakes, headwater wetlands, valley-bottom floodplains, and steep upland slopes interact to control the timing, quantity, and quality of water moving through the project area.

The Musconetcong River originates at Lake Hopatcong and Lake Musconetcong, which function as major headwater storage features moderating downstream flows. Releases from these lakes, combined with a dense network of small tributary streams, springs, and seeps, provide a relatively steady baseflow under normal conditions. This baseflow is supported by the region's moderate to high groundwater recharge rates in upland areas (as detailed in Map A.2, particularly where fractured bedrock and well-drained soils allow precipitation to infiltrate and slowly discharge back to surface waters. In contrast, lower-recharge areas underlain by carbonate bedrock and hydric soils tend to route water more quickly to surface channels or shallow subsurface conduits, resulting in more variable flow response during storms.

Throughout the project area, hydrologic behavior is strongly influenced by topography and land use. Steep slopes along Musconetcong Mountain and the Highland ridges generate rapid runoff during intense rainfall events, particularly where forest cover has been replaced by roads, rooftops, and compacted soils. As stormwater descends into the Musconetcong Valley, it converges into the mainstem and its tributaries, expanding onto floodplains and low-lying agricultural lands during high-flow events. In these valley bottoms, wetlands and floodplain soils temporarily store stormwater, attenuate peak flows, and slowly release water back to the channel, helping to moderate downstream flooding where these natural features remain intact.

Human activities have altered the natural flow regime over time. Historic and existing dams, mill ponds, road crossings, undersized culverts, and stormwater outfalls interrupt longitudinal connectivity, create impoundments, and locally modify sediment transport and water temperature patterns. In developed portions of the watershed—particularly in and around Washington Borough, Hampton, and Hackettstown—increased impervious cover and conventional stormwater infrastructure have shifted a portion of precipitation from slow, infiltrating pathways to faster overland and pipe-conveyed routes. This shift contributes to “flashier” hydrographs, with higher and more frequent peak flows, shorter lag times between storms and peak discharge, and reduced groundwater recharge in urbanized catchments. These hydrologic changes can exacerbate streambank erosion, channel incision, and flood risk in downstream communities.

At the same time, large areas of forest and agricultural land remain within the project area, especially on the surrounding ridgelines and in less-developed townships. Forested uplands, riparian buffers, and intact wetlands continue to play a critical role in intercepting precipitation, promoting infiltration, and stabilizing baseflow. Where agricultural practices include cover cropping, residue management, and conservation buffers, these working lands can also contribute positively to watershed hydrology by reducing surface runoff, improving soil structure, and increasing water storage in the root zone. Conversely, fields lacking conservation practices, compacted pastures, and unbuffered stream corridors tend to shed water more quickly, reinforcing elevated runoff and sediment delivery to streams during storm events.

Overall, the Musconetcong River watershed within the project area exhibits a mixed hydrologic response shaped by its headwater lakes, karst and fractured-rock aquifers, valley-bottom wetlands and floodplains, and a patchwork of forest, agricultural, and urban land uses. The average annual precipitation of approximately 48–49 inches is partitioned among evapotranspiration, groundwater recharge, and surface runoff, with estimated watershed-scale annual means on the order of 16–23 inches for evapotranspiration, 11–15 inches for groundwater recharge, and 1–7 inches for direct runoff (NJWSA, 2000). These patterns underscore the importance of protecting and restoring infiltration areas, headwater streams, wetlands, and riparian corridors to maintain stable baseflow, reduce peak flows, and support the long-term hydrologic and ecological integrity of the Musconetcong River and its tributaries.

4.5 Geology

The ridges of these HUC 14 drainage basins are igneous and metamorphic rocks which contain older soils due to their southern location in the terminal moraine. The inner most stretch of the project area sits on primarily Bushkill Member which presents with thick-bedded shale and slate while also having lesser occurring, thin-bedded siltstone and dolomite at its base. (Dalton, R.F., et al, 1999).

Sedimentary rocks like siltstone, dolomite and limestone are present as a minor contributor throughout the region in both the Upper and Lower Part of Beekmantown Group, Jacksonburg and Allentown formations. This region's karst geology, characterized by the soluble dolomite and limestone bedrock, plays a particularly challenging role in restoration due to the ease of sinkhole formation. Because of this, BMP implementation in these regions must be widely dispersed to reduce the accumulation of large pools of water which exacerbate the dissolution of the aforementioned bedrock.

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. (A. Volkert and Nj Geological Survey, 1999).

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.

4.5.1 Karst Geology

The Musconetcong Watershed is underlain by karst in a large portion of the focus area. Special care needs to be taken before a retrofit of a detention basin takes place. It is important that post-construction stormwater management (PCSM) designs in karst terrain consider the potential risks associated with concentrating flow and infiltration in this unique geology, such as the soil collapse shown in Figure 4.5.1. For sites where karst features are identified through site investigation it is recommended; that the PCSM Plan preparer include on the design team 1) a hydrogeologist; 2) a licensed professional geologist (PG) or geotechnical engineer experienced in the design of stormwater management in karst regions; 3) a soils scientist; and 4) water resources engineer. When proper engineering guidance is followed, green stormwater infrastructure has many benefits for water quality to convey and should not be seen as a deterrent.

Water Quality Protection in Karst

To protect water quality in active karst areas, stormwater runoff should first infiltrate through at least two feet of natural soil or other media filters before being directed underground. If stormwater is directed underground without this initial infiltration, Stormwater Control Measures (SCMs) must be analyzed and designed according to DEP guidance.

Karst Terrain Characteristics:

- Geology: Subsurface carbonate fracture zones and weathered flow conduits.
- Hydrology: Large under-drained valleys with few baseflow-driven streams.
- Surface Drainage: Primarily wide ephemeral karst drainageways, active during extreme rainfall, frozen ground, or snowmelt events.

Stream Behavior: Streams often disappear into the subsurface, reappearing further downstream, known as losing or disappearing streams and gaining streams.

Site assessments in Karst

- Site Description: Existing and proposed.
- Geotechnical Investigation: Approach and methodology.
- Karst Features and Hydrogeology: Identify and map historic and current features, drainage patterns.

- Site Geology and Hydrology: Geology, groundwater hydrology, recharge characteristics.
- Soil Survey: Drainage characteristics, thickness, depth to bedrock and groundwater, soil infiltration capacity, and infiltration test results.
- Geophysical Testing: Results and recommendations, including electrical resistivity, tomography, or other methods.
 - Note: Absence of sinkholes and caves doesn't mean karst problems won't occur.
- Infiltration Considerations: Avoid groundwater contamination, identify nearby groundwater wells.
- Plan View Drawing: Show important karst features, test locations, areas suitable and unsuitable for infiltration, and development limitations.
- Contingency Plan: For unexpected conditions or unmapped karst features during excavation.
- Risk Analysis: Address potential sinkhole collapse, public water supply protection, management planning, and proximity to vulnerable features.

Site Designs in Karst

In karst regions, site designs should maintain natural conditions to the extent practicable. This includes:

- Include karst losses in stormwater management analysis.
- Maintain existing drainage patterns and features:
- Buffer karst drainageways to protect water quality; limit construction access.
- Protect water quality of springs and seeps with appropriate buffering along outflow paths.
- Preserve karst swales for their infiltration capacity.
- Avoid impacting sinkholes that capture off-site runoff; protect karst drainageways with stream buffering or naturalized SCMs.
- Replicate natural hydrologic conditions in infiltration SCMs design.

Avoid Excess Runoff Concentration in Karst

To prevent sinkhole development in karst areas, avoid excessive flow concentration using these approaches:

- Minimize impervious areas.
- Implement multiple smaller infiltration SCMs as site conditions allow.
- Line peak rate control basins in active karst areas to prevent failure from larger ponding depths.
- Minimize flow concentration in narrow channels; use broad, shallow swales for flow dispersion. If unavoidable, use watertight subsurface conveyance systems.

- Avoid using roof runoff sumps or dry wells.

Inspection, Operations and Maintenance Program in Karst

For active karst areas:

- **Regular Inspections:** Conduct regular and frequent SCM and drainage system inspections based on local conditions and failure risks. DEP recommends biannual inspections post-project and post-permit, with spot inspections after heavy storms exceeding one-year events.
- **Monitor for Subsidence:** During inspections, check for subsidence in SCMs and surface/subsurface conveyance elements. Address any signs of subsidence or pipe leakage promptly to prevent soil loss and sinkhole formation.
- **Action Plan:** Develop and maintain a rapid-response action plan. This plan should detail contacts, responsibilities, and actions for addressing subsidence, cover collapse, or other failures.
- **Repair Details:** Include anticipated subsidence and cover collapse repair details in the maintenance narrative. These should be reflected in the stormwater site plan and as-built drawings and incorporated into the owner's Operations and Maintenance (O&M) plan.



Figure 4.5.1– Sinkhole formation in karst geology. Image- PA Post-Construction Stormwater Manual

4.6 Soils

There are various unique soils identified within the watershed, however there are soils in which two or more dissimilar major components occur in a regularly repeating pattern or in an unpredictable pattern and thus can be classified as complexes. Complexes are important because

much of soil morphology or behavior is relative to the soils within a larger system so by grouping soils together, larger mechanisms can be identified. Within the watershed, there are twenty (20) complexes identified and of those twenty complexes, sixteen (16) are also present within the study area, these complexes are listed in Table 4.6. The soils present in the Project Area 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.

Table 4.6 Soil Complexes in Musconetcong Watershed and in focus area

Soil Complexes within Musconetcong Watershed	Soil Complexes within Subwatershed Project Area
Chatfield-Hollis-Rock outcrop complex	Chatfield-Hollis-Rock outcrop complex
Farmington-Wassaic-Rock outcrop complex	Fredon-Halsey complex, very stony
Fredon-Halsey complex, very stony	Gladstone and Parker soils, extremely stony
Hatboro-Codorus complex, frequently flooded	Hatboro-Codorus complex, frequently flooded
Hazen-Paulins Kill complex, very stony	Hazen-Paulins Kill complex, very stony
Hollis-Rock outcrop-Chatfield complex, New Jersey Highlands	Hollis-Rock outcrop-Chatfield complex, New Jersey Highlands
Parker-Gladstone complex, extremely stony	Parker-Gladstone complex, extremely stony
Parker-Rock outcrop complex	Parker-Rock outcrop complex
Paulins Kill-Hazen complex, very stony	Paulins Kill-Hazen complex, very stony
Paulins Kill-Otisville complex, very stony	Paulins Kill-Otisville complex, very stony
Rock outcrop-Farmington-Galway complex	Rock outcrop-Farmington-Galway complex
Rockaway-Chatfield-Rock outcrop complex	Rockaway-Chatfield-Rock outcrop complex
Rockaway-Rock outcrop complex	Udorthents-Urban land complex
Rockaway-Urban land complex, thin fragipans	Urban land-Berks complex
Udorthents-Urban land complex	Urban land-Hazen-Paulins Kill complex
Urban land-Berks complex	Urban land-Washington complex
Urban land-Chatfield-Rock Outcrop complex	
Urban land-Hazen-Paulins Kill complex	
Urban land-Riverhead complex	
Urban land-Washington complex	

Soil surveys for Hunterdon, Warren and Morris Counties were used to obtain the descriptions listed below. Soil surveys are updated annually by NRCS to ensure the most accurate and up-to-date information. Overall, the soils of Warren County comprise 59 percent of the project area (25,350 acres), while the soils of Hunterdon and Morris County make-up 26 percent (11,300 acres) and 15 percent (6,500 acres) respectively.

The southeastern most portion of the project area extending from Bloomsbury to Port Murray on the Hunterdon County side of the Musconetcong River basin is comprised of mostly Parker cobbly loam which equates to a 5.8 percent of the total project area - one of the major contributors. This soil type is characterized as being extremely stoney, formed from weathered granite and gneiss, with an average slope rating of 29 percent and somewhat excessive drainage. Other soil contributors to this region of the project area are Gladstone, Califon, Washington and Duffield loam complexes all of which share relatively low slope ratings and moderately well drained to excessively well drained, with well drained soils being the dominate characteristic.

Moving along the project area, to the Warren County side of the Musconetcong River, in the same stretch as previous described from Bloomsbury to Port Murray, the most abundant soil complex types are Washington, Bartley and Berks. These primarily silt loam complexes derived from limestone and siltstone parent materials, along with the variety of minor contributors correlates to an average of 10 percent slope rating throughout the region while sharing a range of drainage characteristics from poorly to excessively drained with stony complexes favoring the poorly drained and silt complexes favoring the well-drained soil types.

The uppermost, northwestern section of the project area from Port Murray through Hackettstown, but still within the Warren County boundaries, reflects a more stony and poorly drained region, comprised of Netcong, Rockaway and Chatfield-Hollis-Rock outcrop complexes among other minor contributors. This region, bordering the Musconetcong Valley, form the ridges of such valley, with upwards of 85-90 percent of the complexes composed of stony or similar soils derived from parent materials such as gneiss and granite. The infiltration rate of these soils ranges from moderate to slow when thoroughly wet placing them in Groups B and C of the Hydrologic Soil Groups denoted by NRCS.

The remaining northeastern portion of the project area, in Morris County, from Port Murray to Hackettstown, while being the smallest contributor, highlights a rich density of soil types. With no soil type producing more than 2 percent of the project area, the 39 different map units, with an average of 9 percent slope rating, share a range of drainage characteristics leaning heavily towards the well-drained end of the spectrum. Much like the soils found to the west of this region, as described above, the Parker, Gladstone, Cokesbury and Califon soils are sourced from gneiss whether it be weathered, tilled, or colluvium. Despite the variety of soils, most form a thick layer (greater than 6 feet) over the bedrock surface.

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. Focusing in on the relationship between bedrock geology and groundwater recharge, a weaker groundwater recharge of <12in per year can be seen in the lower portion of the project area correlating to a higher occurrence of Allentown Dolomite and Quartz-Oligoclase Gneiss

while a stronger groundwater recharge of >12in per year can be seen in the upper portion of the project area correlating to a higher occurrence of Bushkill Member and Pyroxene Granite. In terms of bedrock aquifers and groundwater recharge, the limestone heavy regions correspond to a weaker recharge whereas the igneous and metamorphic heavy regions correspond to a stronger recharge. 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 4.7 Groundwater recharge rates based on soil class and percentage of each in focus area

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. The 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 2020 Land Use Land Cover (LU/LC) data set is the seventh in a series of land use mapping efforts initiated in 1986 by NJDEP. The revisions and additions to the initial baseline layer from 1986, were captured from aerial imagery in 1995/7, 2002, 2007, 2012, 2015, and 2020. The current 2020 dataset was updated from the 2015 LU/LC layer from NJDEP's Geographic Information Systems (GIS) database to color infrared (CIR) imagery and delineating and coding areas of change. This iteration of the LU/LC data set was done by Aerial Information Systems, Inc., Redlands, CA, under the direction of NJDEP, Bureau of Geographic Information Systems

(BGIS). By directly adding new line work and attribute data to the 2015 base layer, the 2020 data was captured; what this does is allow a change analysis to be conducted for the period 2015-2020 (NJDEP, 2020).

All seven LU/LC data sets contain important land use data used in a wide variety of environmental analyses. The current, 2020 land use land cover dataset uses a modified LU/LC Classification system established by Anderson et al. Every effort has been made to ensure that all land use data sets are as accurate as possible. However, LU/LC 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 4.8.a below. Dominant land uses, listed in order of greatest to least influence, for the Musconetcong River Watershed consist of urban, forest and agriculture. Land use within the subwatershed study area, listed in order of greatest to least influence, is dominated by urban, forest, and agricultural 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 Map 4.8).

Map 4.8 2020 Land Use/Land Cover

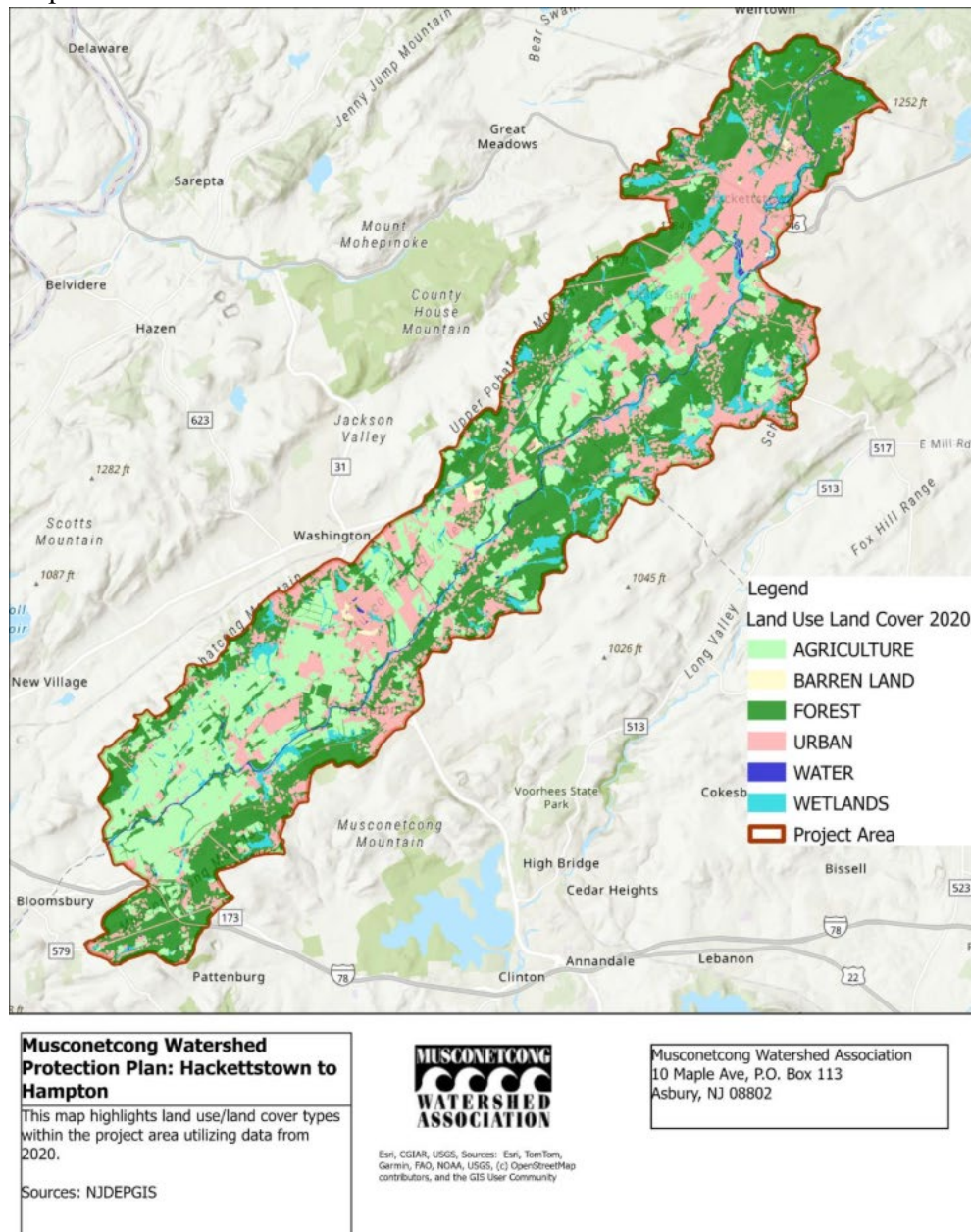


Table 4.8.a Musconetcong River Watershed Land Use Classifications

Land Use Land Cover Type	Entire Musconetcong River Watershed		Subwatershed Project Area	
	Area (Acres)	%Coverage	Area (Acres)	% Coverage
Agriculture	15,099.57	15.03%	11,902.55	27.60%

Barren Land	953.22	0.95%	209.63	0.49%
Forest	47,558.7	47.33%	17,209.62	39.90%
Urban	24,747.15	24.63%	10,760.91	24.95%
Water	5,001.32	4.98%	403.7	0.94%
Wetlands	7,122.12	7.09%	2,642.87	6.13%
Totals	100,482.08	100.00%	43,129.28	100.00%

NJ Dept. Of Environmental Protection, Bureau of GIS- 2020, GIS Data Layer.

According to Table 4.8.b below, land use/land cover comparison from 1986 to 2020, shows that there has been a decrease in agriculture and wetlands, and an increase in forest, urban, water and barren land use throughout the whole watershed. 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 4.8.b Land Use Land Cover Comparison from 1986 to 2020

Land Use / Land Cover Type	Percent Coverage of Whole Watershed in 1986	Percent Coverage of Whole Watershed in 2020	Percent Change of Whole Watershed from 1986 to 2020	Percent Coverage of Project Area in 1986	Percent Coverage of Project Area in 2020	Percent Change of Project Area from 1986 to 2020
Agriculture	21.38%	15.03%	-30%	25.06%	27.60%	10%
Barren Land	0.73%	0.95%	30%	0.17%	0.49%	186%
Forest	45.58%	47.33%	4%	57.48%	39.90%	-31%
Urban	18.91%	24.63%	30%	13.52%	24.95%	85%
Water	2.89%	4.98%	72%	0.49%	0.94%	91%
Wetlands	10.51%	7.09%	-33%	3.28%	6.13%	87%

NJ Dept. Of Environmental Protection, Bureau of GIS- 1986, 2020, GIS Data Layer.

Looking at the Project Area's land use changes, a dramatic decrease in forested lands is opposed by growth in all other land use types, most notably, barren lands with a 186% increase. It is, however, important to note that barren lands still make up less than 1% of land use coverage within the project area. One of the more concerning land use changes would be that of urban land use, which went from approximately 13% of the project area in 1986 to almost 25% coverage in 2020.

4.9 Critical Environmental Areas

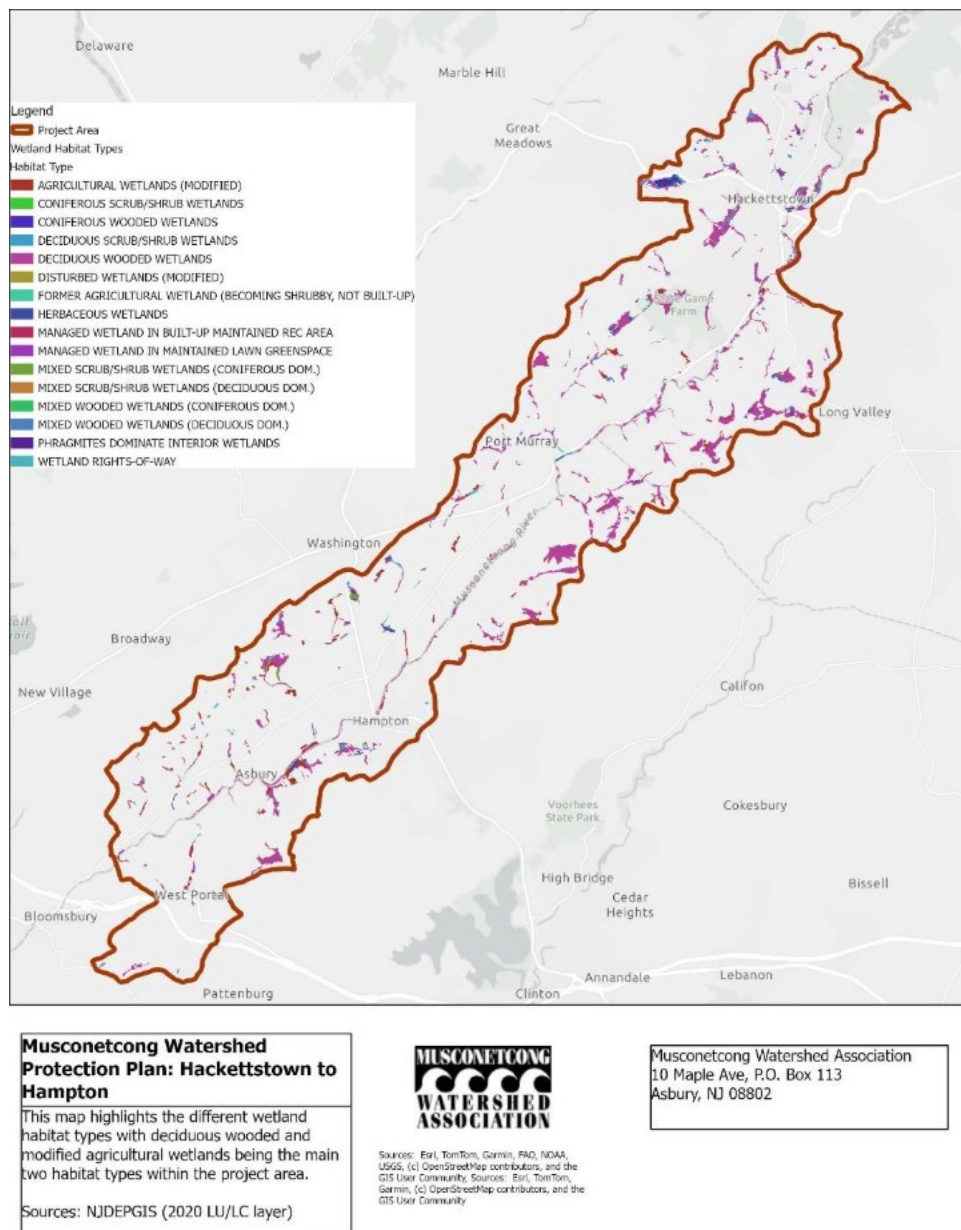
4.9.1 Hydric Soils

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 ~~and 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 to many of the water quality and quantity problems observed today. The different types of wetlands located within the project area are shown on Map 4.9.2.

Map 4.9.2 Wetlands Habitat



NJDEP developed and maintains wetlands information for general planning and regulatory purposes. The first type is mapped wetlands listed in the NJDEP land use/cover change database. These wetlands are mainly located along intermittent stream systems and wetlands modified for recreational, agricultural or industrial uses. There are a total of 7,132.27 acres of mapped wetlands within the Musconetcong River Watershed and 2,642.07 acres of mapped wetlands in the project area, based on the NJDEP 2020~~42~~ land use/cover database. Table 4.6 lists the types of wetlands and acreages within the Musconetcong Watershed as well as the project area. The dominant types of wetlands in the watershed are deciduous wooded wetlands and deciduous scrub/shrub wetlands,

which comprise 73.76% and 9.59% of the total wetlands in the watershed respectively. The remaining 13 wetland types comprise a cumulative 16.65% of the mapped wetlands within the watershed. In terms of dominant wetland types of the Project Area, deciduous wooded wetlands at 70.75% are still by far the majority with agricultural wetlands being the second highest contributor at 14.46%. The remaining 12 wetland types comprise a cumulative of 14.79% of the mapped wetlands withing the project area.

Table 4.9.2 Wetland type in Musconetcong Watershed and focus area

Type of Wetland	Acres Watershed wide	Percent	Acres in Project Area	Percent
AGRICULTURAL WETLANDS (MODIFIED)	483.93	6.79%	382.09	14.46%
CONIFEROUS SCRUB/SHRUB WETLANDS	1.57	0.02%	0.72	0.03%
CONIFEROUS WOODED WETLANDS	10.3	0.14%	N/A*	N/A*
DECIDUOUS SCRUB/SHRUB WETLANDS	684.01	9.59%	129.46	4.90%
DECIDUOUS WOODED WETLANDS	5260.94	73.76%	1869.19	70.75%
DISTURBED WETLANDS (MODIFIED)	15.84	0.22%	10.67	0.40%
FORMER AGRICULTURAL WETLAND (BECOMING SHRUBBY, NOT BUILT-UP)	19.32	0.27%	9.76	0.37%
HERBACEOUS WETLANDS	402.83	5.65%	121.96	4.62%
MANAGED WETLAND IN BUILT-UP MAINTAINED REC AREA	24.37	0.34%	8.98	0.34%
MANAGED WETLAND IN MAINTAINED LAWN GREENSPACE	33.52	0.47%	19.18	0.73%
MIXED SCRUB/SHRUB WETLANDS (CONIFEROUS DOM.)	7.11	0.10%	7.11	0.27%
MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	24.74	0.35%	21.64	0.82%
MIXED WOODED WETLANDS (CONIFEROUS DOM.)	14.15	0.20%	6.38	0.24%
MIXED WOODED WETLANDS (DECIDUOUS DOM.)	40.13	0.56%	20.87	0.79%

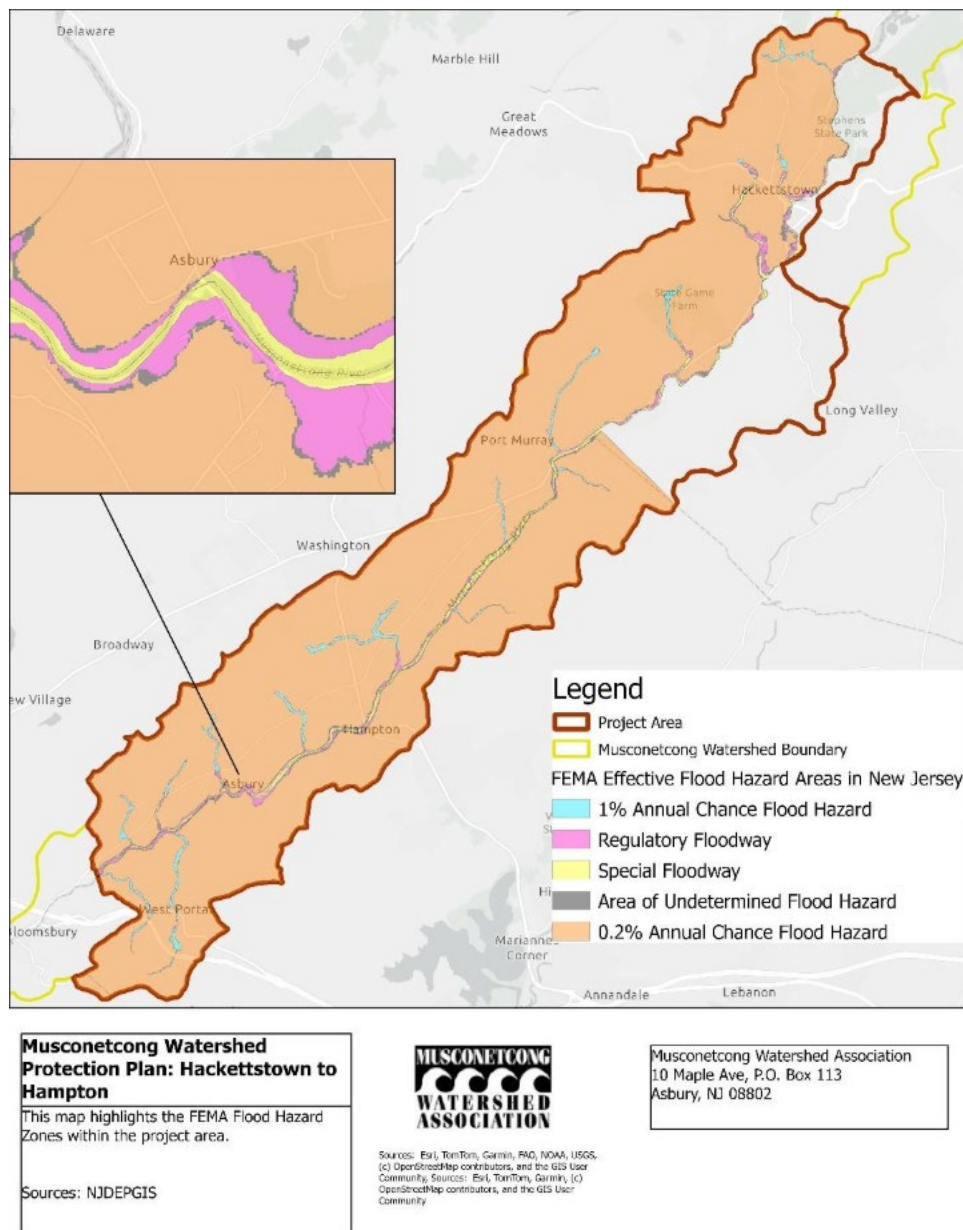
PHRAGMITES DOMINATE INTERIOR WETLANDS	26.97	0.38%	11.74	0.44%
WETLAND RIGHTS-OF-WAY	82.54	1.16%	22.32	0.84%
Totals	7132.27	100.00%	2642.07	100.00%

**Coniferous wooded wetlands are not present in Project Area. Sources: NJDEP 2012 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. Map 4.4 below showcases the FEMA Flood Zones within the Project Area, with emphasis on the 1% and 0.2% annual flood chance imagery.

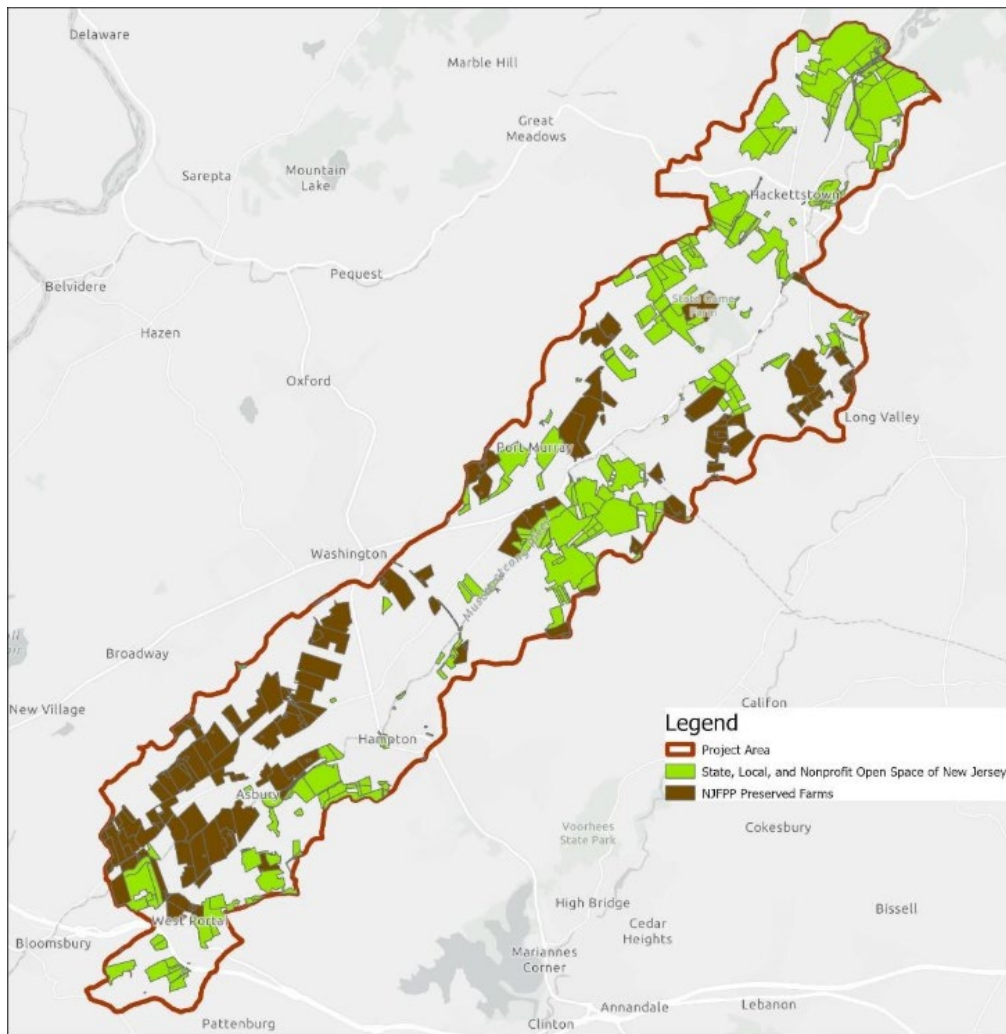
Map 4.9.3 FEMA Flood Hazard zones



4.10 Open Space Preservation and Protected Areas

Hunterdon, Warren, and Morris Counties participate in the Farmland Preservation Program and Open Space preservation in the region. These preserved lands are important to decrease the impact of urban sprawl and secure a green future for generations to come. There are over one hundred and fifty (15% of the project area) preserved farms within the project area (Table 4.10 and Map 4.10). Map 4.10 shows the locations of over two hundred and eighty open space parcels (18.5% of the project area) within the project area.

Map 4.10 Preserved Farmland and Open Space



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the preserved farmland and state, local and nonprofit open space within the project area.

Sources: NJDEPGIS and NJFPP



Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community.

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Table 4.10 Number of Preserved Farms in each county and focus area

County	# of Preserved Farms in County	# located in Project Area
Hunterdon	478	36
Warren	259	98
Morris	138	43
Total	875	177

Reference: Information obtained via Hunterdon, Warren, and Morris Counties Farmland Preservation plans (<https://www.nj.gov/agriculture/sadc/home/genpub/comprehensiveplans.html>) and NJGIS data layer.

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 2018).

The Musconetcong Watershed supports two federally listed species, seven state endangered species, 10 state threatened species, and several species of special concern. The bog turtle is a federally threatened reptile dependent on wet meadow and pasture wetlands, while the Indiana bat is federally endangered and roosts in forested ridges and caves. State endangered species include the northern harrier, upland sandpiper, short-eared owl, vesper sparrow, green floater mussel, and brook floater mussel, along with the historically present American burying beetle. State threatened wildlife includes the barred owl, bobolink, Cooper's hawk, grasshopper sparrow, red-headed woodpecker, savannah sparrow, wood turtle, long-tailed salamander, eastern lampmussel, and triangle floater mussel. Other rare or special concern wildlife in the watershed include the Allegheny woodrat and timber rattlesnake. Latin names for these species can be found in the New Jersey Wildlife Action Plan (NJDEP, 2018).

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.

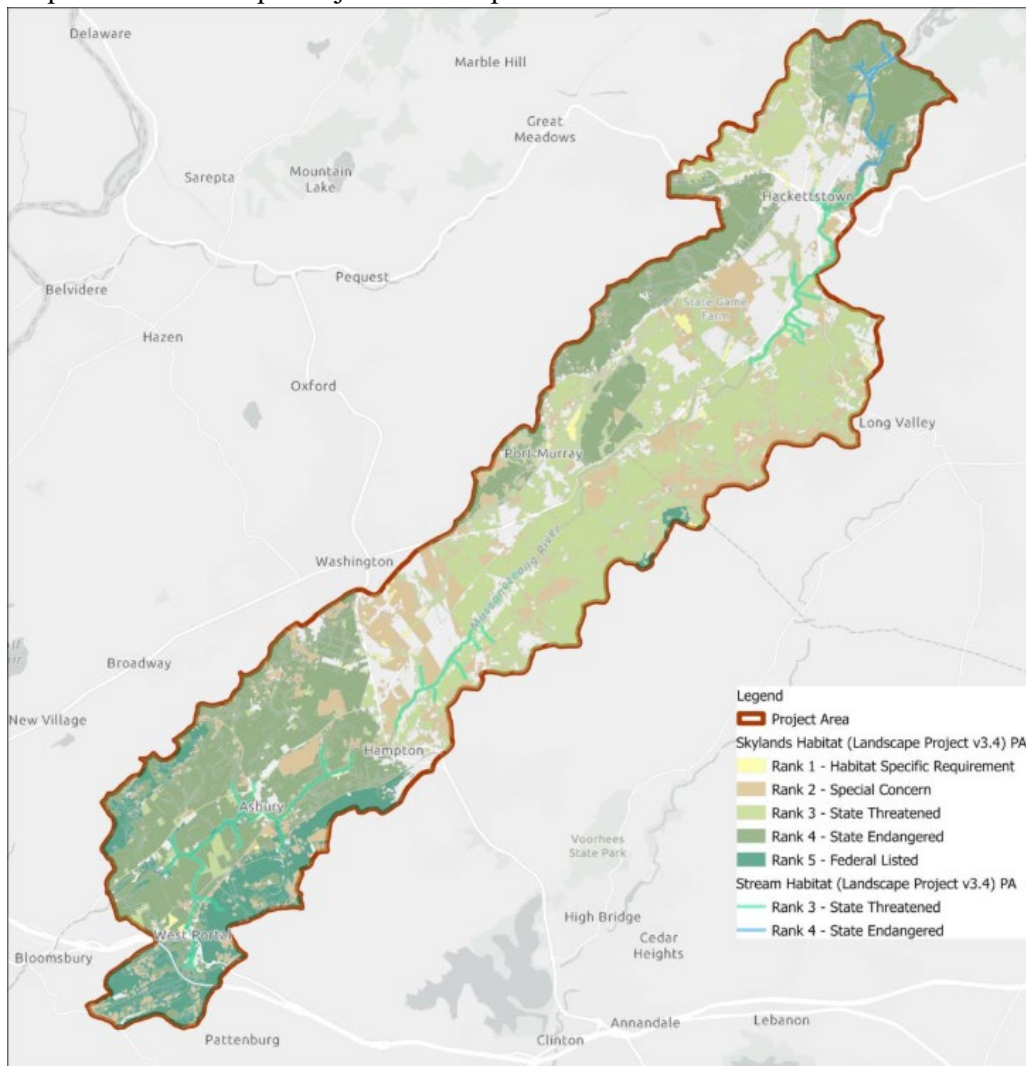
Table 4.11.1 List of rare, threatened, and endangered species in the Project Area

Common Name	Scientific Name	Class	NJ / Federal Status	Landscape Project Habitat Rank & Description
Bog Turtle	<i>Glyptemys muhlenbergii</i>	Reptile	NJ Endangered / Federal Threatened	Rank 5 – Wet meadows, pasture wetlands
Indiana Bat	<i>Myotis sodalis</i>	Mammal	Federal Endangered	Rank 5 – Forested ridges, roost trees, caves
Northern Harrier	<i>Circus hudsonius</i>	Bird	NJ Endangered	Rank 4 – Marshes, grasslands
Upland Sandpiper	<i>Bartramia longicauda</i>	Bird	NJ Endangered	Rank 4 – Grasslands
Short-eared Owl	<i>Asio flammeus</i>	Bird	NJ Endangered	Rank 4 – Grasslands, open fields
Vesper Sparrow	<i>Pooecetes gramineus</i>	Bird	NJ Endangered	Rank 4 – Grasslands, open fields
Green Floater	<i>Lasmigona subviridis</i>	Mollusk	NJ Endangered	Rank 4 – Rivers, wetlands
Brook Floater	<i>Alasmidonta varicosa</i>	Mollusk	NJ Endangered	Rank 4 – Clean, fast-flowing streams
Barred Owl	<i>Strix varia</i>	Bird	NJ Threatened	Rank 3 – Forests, swamps
Bobolink	<i>Dolichonyx oryzivorus</i>	Bird	NJ Threatened	Rank 3 – Grasslands
Cooper's Hawk	<i>Accipiter cooperii</i>	Bird	NJ Threatened	Rank 3 – Forests, wooded edges
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	Bird	NJ Threatened	Rank 3 – Grasslands
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	Bird	NJ Threatened	Rank 3 – Open forests, mature trees
Savannah Sparrow	<i>Passerculus sandwichensis</i>	Bird	NJ Threatened	Rank 3 – Fields, marsh edges
Wood Turtle	<i>Glyptemys insculpta</i>	Reptile	NJ Threatened	Rank 3 – Streams, riparian corridors
Long-tailed Salamander	<i>Eurycea longicauda</i>	Amphibian	NJ Threatened	Rank 3 – Moist woodlands, streams
Eastern Lampmussel	<i>Lampsilis radiata</i>	Mollusk	NJ Threatened	Rank 3 – Rivers, streams
Triangle Floater	<i>Alasmidonta undulata</i>	Mollusk	NJ Threatened	Rank 3 – Small rivers, creeks
Allegheny Woodrat	<i>Neotoma magister</i>	Mammal	NJ Special Concern / Rare	Rank 2 – Rocky outcrops, forest edges
Timber Rattlesnake	<i>Crotalus horridus</i>	Reptile	NJ Endangered	Rank 4 – Highlands forest and rocky slopes

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 one 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.

Although the Musconetcong Watershed supports many rare, threatened and endangered species, as seen in, Map 4.11.1 below, 84% of the Project Area is ranked under the Landscape Project v3. Of the 47,469 acres of ranked habitat, Rank 1 (2%), Rank 2 (16%), Rank 3 (32%), Rank 4 (37%) and Rank 5 (13%), their survival depends on clean water and connected habitats. Species such as the bog turtle, wood turtle, and brook floater mussel are highly sensitive to pollution, sedimentation, and changes in hydrology, while grassland and forest birds require large, intact tracts of habitat to sustain viable populations. Fragmentation from dams, road crossings, and land conversion isolates wildlife and disrupts critical life-cycle movements. Protecting and restoring water quality, reconnecting rivers and riparian corridors, and conserving contiguous forest and grassland areas are essential to ensure the continued presence of these species and the ecological integrity of the watershed.

Map 4.11.1 Landscape Project v3.4 Map



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the Landscape Project Habitat v3.4 Skylands Habitat and Stream Habitat within the project area. This data identifies the habitat suitable for rare, threatened and endangered species.
Sources: NJDEPGIS



Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community

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4.11.2 Fisheries

The Fish Index of Biotic Integrity (FIBI) is a standardized biological monitoring tool applied by NJDEP and partner organizations to evaluate the ecological condition of streams based on their resident fish communities (Vile and Henning, 2018). The index quantifies species richness, trophic composition, and the relative abundance of tolerant versus sensitive taxa, thereby providing a measure of ecological integrity relative to reference expectations for minimally

disturbed systems. Metrics include overall species diversity, the presence and abundance of coldwater and intolerant species, the proportion of generalists and tolerant taxa, and evidence of stress such as disease or deformities (Barbour et al., 1999).

FIBI scores are interpreted alongside a quantitative Habitat Rating, which evaluates instream and riparian physical parameters, including substrate quality, channel morphology, hydraulic diversity, sediment deposition, bank stability, and riparian vegetative condition. This dual assessment framework allows investigators to distinguish between stressors associated with habitat degradation and those related to water quality, connectivity, or broader watershed-level impacts (Barbour et al., 1999; Vile and Henning, 2018).

Recent monitoring data illustrate the variable condition of aquatic habitats within the Musconetcong River system. At the Musconetcong River near Shurts Road (NJS11-170, 2015) and New Hampton Road (FIBI005, 2024), fish assemblages were rated *Good* despite *Sub-Optimal* habitat scores, indicating that water quality conditions are sufficient to support moderately intact communities even in reaches with physical limitations. Conversely, sites such as Park Road (FIBI058, 2007) and Bloomsbury Road (FIBI061, 2008) exhibited *Optimal habitat ratings* but only *Fair FIBI scores*, suggesting that watershed-scale impairments — such as nutrient enrichment, thermal stress, or altered flow regimes — are constraining fish assemblage structure despite suitable habitat features. In contrast, tributary systems including Beattys Brook (FIBI501, 2022) and Schooleys Mountain Brook (FIBI550, 2022) achieved both *Optimal habitat ratings* and *Good fish assemblages*, representing reference-quality conditions within the watershed. These results underscore the utility of paired biological and habitat assessments for diagnosing ecological stressors and prioritizing sites for restoration or protection.

Table 4.11.2.a Potentially Impaired sites for the Musconetcong River Watershed Project Area

FIBI Site	Round	Waterbody	Location	County/ Municipality	Habitat Rating*	IBI Rating/ FIBI score*
NJS11-170-R4	1,2,3,4,2 4	Musconetcong River	Shurts Rd	Warren – Franklin Township	Sub-Optimal	Good
FIBI005-	1,2,3,4,2 4	Musconetcong River	New Hampton Rd	Hunterdon/Warren - Washington Township	Sub-Optimal (147)	Good (67.08)
FIBI058	1,2	Musconetcong River	Park Road	Warren - Hackettstown Township	Optimal (160)	Fair (32)

FIBI061	1,2,2a	Musconetcong River	Bloomsbury Road	Hunterdon County – Bethlehem Township	Optimal (170)	Fair (38)
FIBI062	1	Musconetcong River	Stephensburg Road	Morris – Mansfield Township	Sub-Optimal (153)	Good (40)
FIBI501	1,1r,22	Beatty's Brook	Off Penwell Road	Hunterdon – Lebanon Township	Optimal (168)	Good (77.75)
FIBI549	1	West Portal Creek	Bellwood Park Road	Hunterdon – Bethlehem Township	Sub-Optimal (141)	Good (59.87)
FIBI550	1,22	Schooley's Mountain Brook	Schooley's Mountain Road	Morris – Washington Township	Optimal (166)	Good (77.48)
NJS11-116	3	Musconetcong River	Musconetcong River Road	Hunterdon – Lebanon Township	Sub-Optimal (145)	Good (76.55)
NJS11-158	3	Musconetcong River	Off Park Road	Warren – Hackettstown Township	Sub-Optimal (148)	Fair (46.39)
NJS11-170	4	Musconetcong River	Shurts Road	Warren – Franklin Township	Sub-Optimal (150)	Good (71.72)

(from NJDEP ArcGIS layer: Fish Index of Biotic Integrity, 4/28/2025: ~~FIBI round 4 report~~)

*Habitat Rating and IBI Rating for sites with more than one round of data, will be showing the most recent round's worth of data.

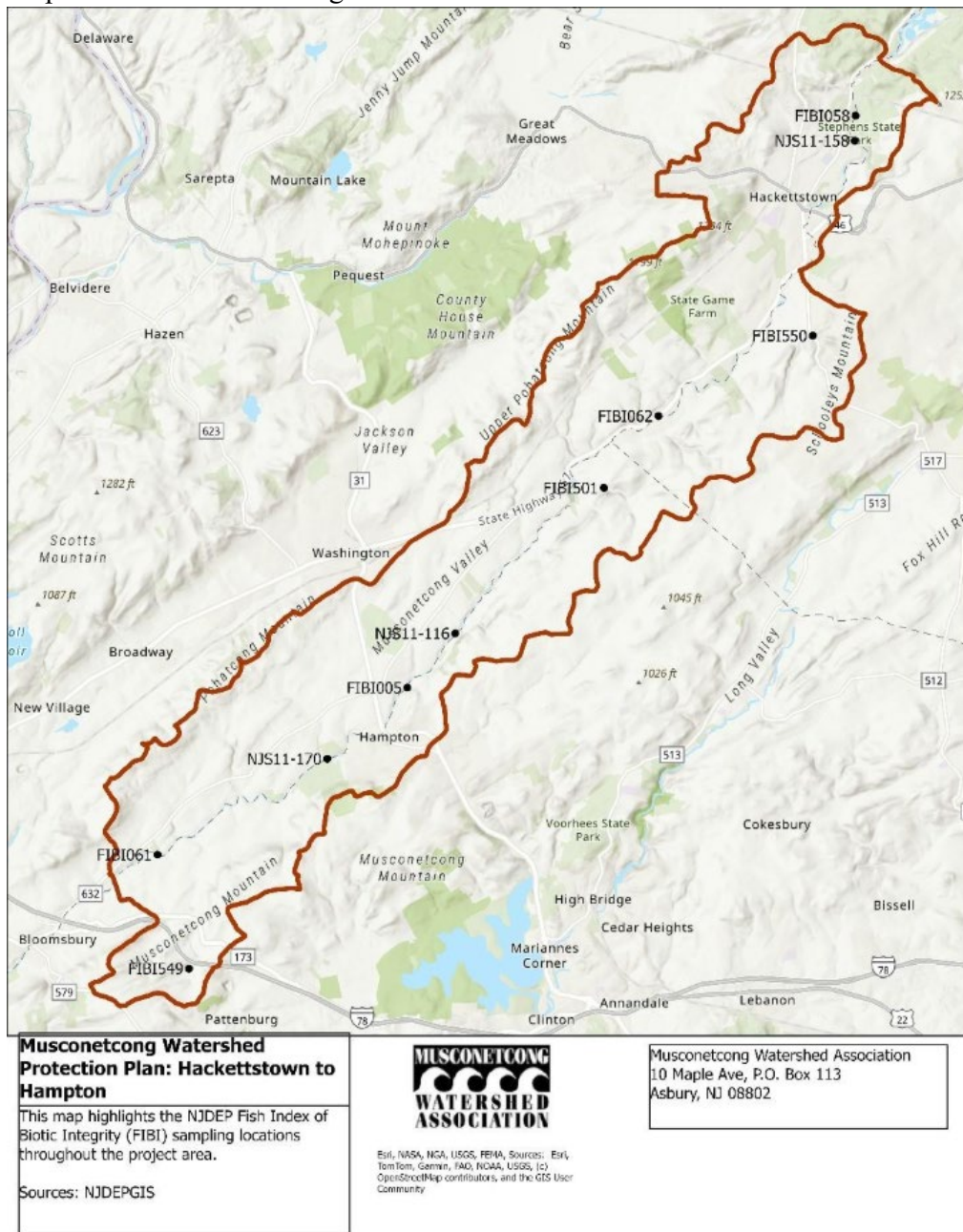
FIBI monitoring across the Musconetcong River and its tributaries highlights varying conditions in fish communities. Table 4.11.2.b below summarizes sites ranked from most concerning to least concerning by weighing both the presence of coldwater species (especially those with the presence of trout) and the condition of fish assemblages. Tributaries with robust coldwater populations ranked as least concerning, while mainstem sites dominated by tolerant species and lacking coldwater taxa emerged as priority areas for concern.

Table 4.11.2.b FIBI sites of concern

Site	Year	Top 3 Species	Concern Level
NJS11-158 – Park Road (Hackettstown)	2014	American Eel (420), Redbreast Sunfish (247), Fallfish (59)	Most concerning – tolerant assemblage, no coldwater taxa
FIBI549 – West Portal Creek (Bethlehem Twp.)	2017	Blacknose Dace (135), Northern Two-lined Salamander (30), Common Crayfish (7)	High concern – low trout presence, dominated by dace
FIBI058 – Park Road (Hackettstown)	2007	American Eel (234), Redbreast Sunfish (49), Smallmouth Bass (27)	High concern – dominated by tolerant species, minimal coldwater presence
FIBI061 – Bloomsbury Road (Bethlehem Twp.)	2008	American Eel (168), Blacknose Dace (152), White Sucker (89)	Moderate concern – good habitat but fish dominated by tolerant species
FIBI062 – Stephensburg Road (Mansfield Twp.)	2003	American Eel (79), Tessellated Darter (22), Redbreast Sunfish (20)	Moderate concern – some brook trout present but low abundance
FIBI005 – New Hampton Road (Washington Twp.)	2024	American Eel (192), Tessellated Darter (38), Blacknose Dace (38)	Moderate – good score, but trout presence limited
NJS11-170 – Shurts Road (Franklin Twp.)	2015	American Eel (330), Blacknose Dace (146), Tessellated Darter (62)	Moderate – diverse community, includes brook and brown trout
NJS11-116 – Musconetcong River Road (Lebanon Twp.)	2012	Blacknose Dace (189), Tessellated Darter (125), American Eel (114)	Low concern – diverse assemblage, coldwater species present
FIBI550 – Schooleys Mountain Brook (Washington Twp.)	2022	Blacknose Dace (83), Brook Trout (81), American Eel (22)	Low concern – strong brook trout population, high habitat quality
FIBI501 – Beattys Brook (Lebanon Twp.)	2022	Blacknose Dace (114), Brook Trout (95), American Eel (48)	Least concerning – highest quality coldwater tributary with robust brook trout

The observed impacts to fish assemblages in the Musconetcong Watershed, as well as many other watersheds, are closely linked to habitat conditions, water quality, and the surrounding land use (Lee, Park, & Lee, 2023). Sites ranked as more concerning often show communities dominated by tolerant species and a lack of coldwater taxa, reflecting stress from altered flow, nutrient enrichment, or degraded riparian conditions. In contrast, the least concerning sites — typically tributaries with strong brook trout populations — benefit from intact vegetative cover and riparian buffers that help maintain cool, clean water and natural stream function. Protecting and restoring these buffers, while addressing stressors in impaired reaches, is essential to sustaining healthy and diverse stream communities throughout the watershed.

Map 4.11.2 FIBI Monitoring Location



4.11.3 Fish Consumption Advisories

The NJDEP's 2021 fish consumption advisories (<https://dep.nj.gov/dsr/fish-advisories-studies/>) guide the public on recommended consumption frequencies for various fish species due to contaminants like PCBs, DDT and its metabolites (DDD & DDE), dioxin, chlordane, mercury, and PFAS. High-risk individuals, including infants, children, pregnant women, nursing mothers, and women of childbearing age, are advised to be particularly cautious. Generally, smaller fish have

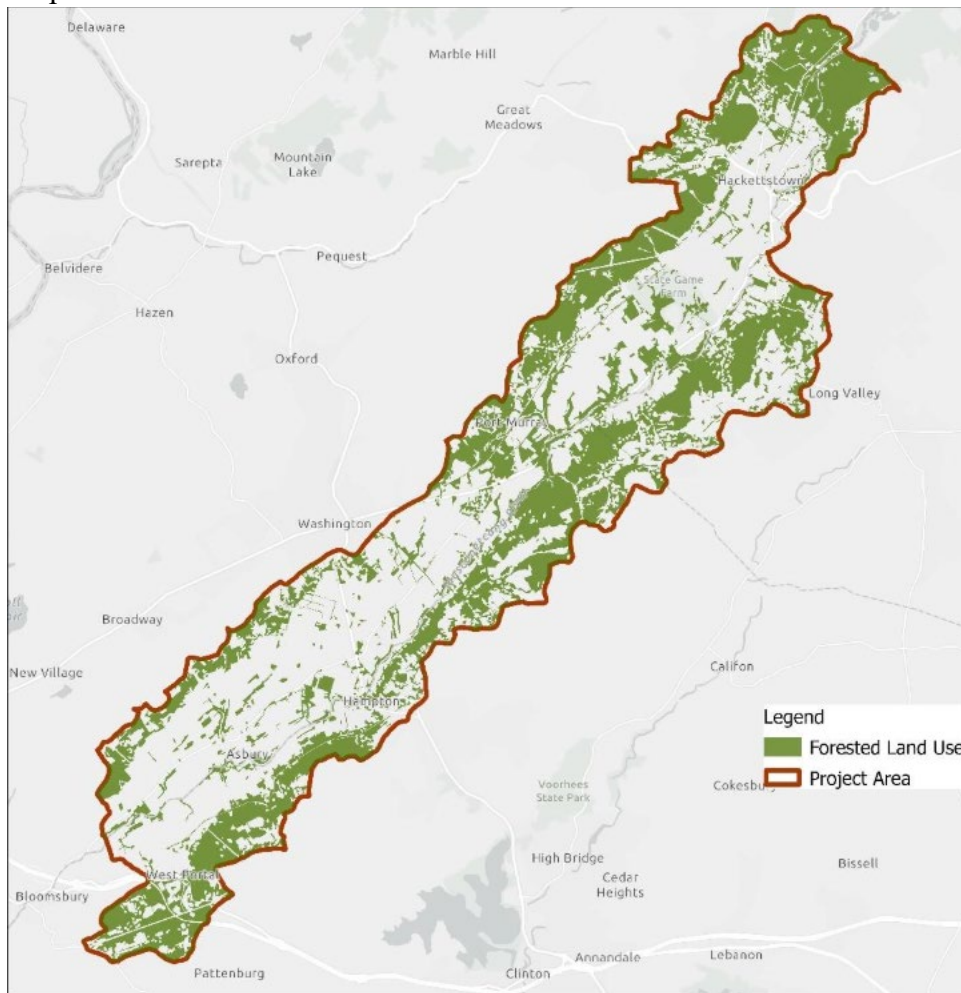
lower contaminant levels, and it's recommended to eat a variety of fish in smaller quantities. Mercury can damage the nervous system, especially in young children, while PCBs can cause cancer and other health issues, with the developing fetus being particularly vulnerable. Dioxin is also linked to cancer and other serious health effects. PFAS, including PFOS, are emerging contaminants that can affect the immune system, liver, and thyroid, and pose developmental risks. For unspecified water bodies such as the Musconetcong River, the statewide advisory applies. For eating trout, the statewide guideline is one meal per week and for eating bass or pickerel, the guideline is one meal per week for the general population and one meal per month for high-risk individuals. This guidance helps balance the benefits of eating fish with the potential health risks from contaminants.

4.11.4 Typical Vegetation, Rare Plant Species and Terrestrial Invasives

The watershed is made up of many different types of habitats including agricultural, forests, wetlands and urban environments. These types of lands include typical vegetation of the New Jersey Highlands and Piedmont Plain Regions which are more generally characterized as the Uplands of New Jersey. Agricultural land is devoted heavily to row crop production including 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 Uplands region of New Jersey 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 pennsylvanica*). 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 caroliniana*) 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).

To better understand how these vegetation communities are distributed across the Musconetcong Watershed, forested land use was mapped using the 2020 Land Use/Land Cover dataset from NJDEP's Bureau of Geographic Information Systems (BGIS). Forested Land Map 4.11.4 below highlights the extent of forest cover within the project areas, and provides an important tool for assessing habitat quality, ecological connectivity, and areas vulnerable to disturbance. The forested area map also establishes a baseline for evaluating how stressors such as deer overpopulation, invasive plant spread, and land use change affect the long-term health and resilience of these habitats.

Map 4.11.4 Forested Land Use



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the forested land use in the project area, derived from the 2020 land use land cover data.

Sources: NJDEPGIS



Sources: Esri, TomTom, Garmin, FGD, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community, Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community, NOAA, Bureau of GIS, Edition 20241101

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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 state's 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 Audubon Society, 2005). A recent, 2019 survey by the New Jersey Farm Bureau has estimated deer density in Warren County to range

between approximately 240 and 200 individuals per square mile. This density is significantly greater than the overall US population density of 90 individuals per square mile (Cohen, 2015). The New Jersey Farm Bureau conducted an informal survey of its farmer members, following their density survey results, to find that 36% reported annual crop damage of \$10,000 or more, 11% claimed \$25,000 in damages and 5% reporting losses greater than \$50,000. On top of the economic impacts of deer overpopulation, ecologically, it has been shown that at deer densities greater than 100 per square mile, woodlands become void of understory from constant deer pressure through herbivory (Horsley et al. 2003).

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 tomentosa*)
 - Sweet cherry, Bird cherry (*Prunus avium*)
 - Black locust (*Robinia pseudoacacia*)
 - Norway spruce (*Picea abies*)
 - Bradford pear (*Pyrus calleryana*)
- Shrubs:
 - Japanese barberry (*Berberis thunbergii*)
 - Autumn olive (*Eleagnus umbellata*)
 - Burning bush winged euonymus (*Euonymus alatus*)
 - Border privet (*Ligustrum obtusifolium*)
 - Tatarian honeysuckle (*Lonicera tatarica*)
 - Multi flora rose (*Rosa multiflora*)
 - Wineberry (*Rubus phoenicolasius*)
 - Siebold's viburnum (*Viburnum sieboldii*)
- Vines:
 - Oriental bittersweet, Asiatic bittersweet (*Celastrus orbiculatus*)
 - English ivy (*Hedera helix*)
 - Japanese honeysuckle (*Lonicera japonica*)
 - Grapevine (*Vitis spp.*)
 - Wisteria (*Wisteria floribunda*)
 - Asiatic tearthumb (*Persicaria perfoliata*)

- 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*)
 - Lesser celandine (*Ficaria verna*)
 - Yellow iris (*Iris pseudacorus*)
 - Dames Rocket (*Hesperis matronalis*)
- 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 browse and invasive species such as multiflora rose (*Rosa multiflora*), barberry (*Berberis thunbergii*) and autumn olive (*Elaeagnus umbellata*) are less palatable 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.

4.11.5 Aquatic Invasive Species

Aquatic ecosystems within the Musconetcong River are under significant threat from invasive species such as hydrilla (*Hydrilla verticillata*), water chestnut (*Trapa natans*), and New Zealand mudsnails, or the right-handed mudsnail, as it is now known (*Potamopyrgus antipodarum*). These non-native species disrupt the natural balance of the river by outcompeting native aquatic plants and animals for space and resources. Hydrilla, for instance, forms dense mats that block sunlight from reaching native submerged vegetation, reducing oxygen levels in the water and degrading habitat quality for fish and other aquatic organisms. Water chestnut similarly dominates surface waters, impeding recreational activities and altering water flow, which can lead to increased sedimentation. New Zealand mudsnails can reach extremely high densities, displacing native invertebrates and disrupting food webs. New Zealand mudsnails reproduce rapidly and can dominate riverbeds, consuming the algae and detritus that would normally sustain native species. These invasive species collectively contribute to the decline of native biodiversity, compromise water quality, and pose ongoing challenges to the health and resilience of the Musconetcong River ecosystem.

5.0 Physical Condition

Streams and rivers convey water from high to low points in the terrain and provide 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 riparian area are major factors in the watershed affecting the stream's physical condition and 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 Figure 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. Map A.4 , in Appendix D shows the impervious coverage of the project area. Analysis of the layers presented in Map A.4 indicates that impervious surfaces—including buildings, roads, and other impervious areas—comprise approximately 16% of the project area.

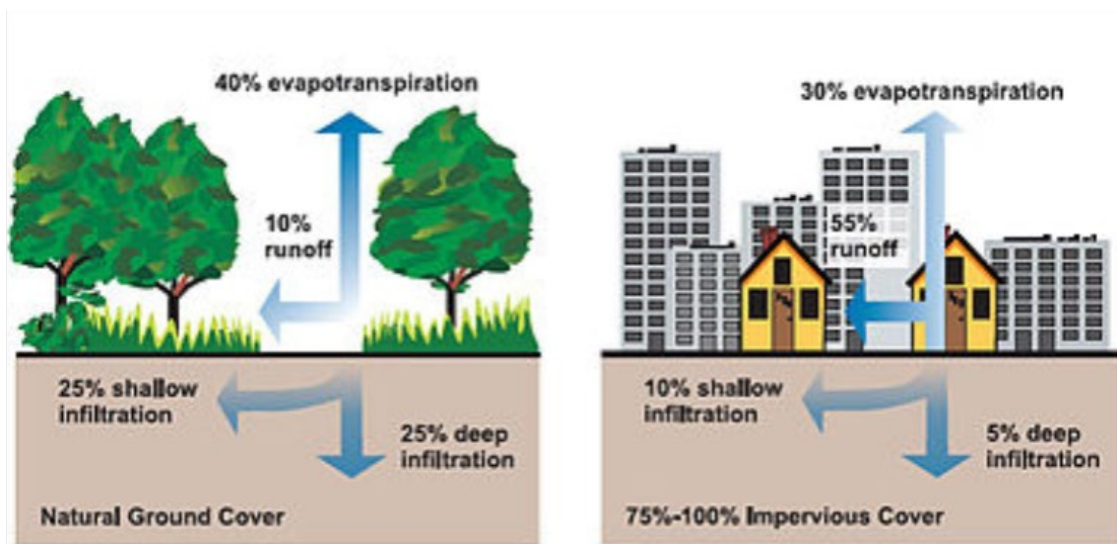


Figure 5.1- Natural ground cover and impervious cover and their effects on infiltration rates

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 through increased streambank erosion 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 because they provide water, food, cover, migration routes and connectors between habitats.

Flood control is often 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 (Kelly and McGinnis, 2001).

The model first defines riparian areas based upon hydrological 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 flood prone 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 characterize all streamside vegetation.

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, LU/LC data from NJDEP and threatened and endangered species data from the NJ Division of Fish & Wildlife's "Landscape Project."

5.4 Habitat Assessment Protocol

This project utilized the Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish developed by the US EPA (Barbour et. al., 1999). The high gradient habitat assessment form utilizes 10 different characteristics using a scale of 0-20 (with 0 being the lowest score and 20 being the highest or most favorable) to help visually assess the integrity of a waterbody. The scores of the assessment are summed together and produce an overall habitat score which is then divided into 4 different categories optimal, sub-optimal, marginal and poor (Appendix N).

The high gradient habitat assessment 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 required consistency of assessors among all of the sites, in doing so the high gradient habitat assessments were conducted by audited Musconetcong Watershed Association staff and audited by NJDEP to confirm consistency with NJDEP conventions.

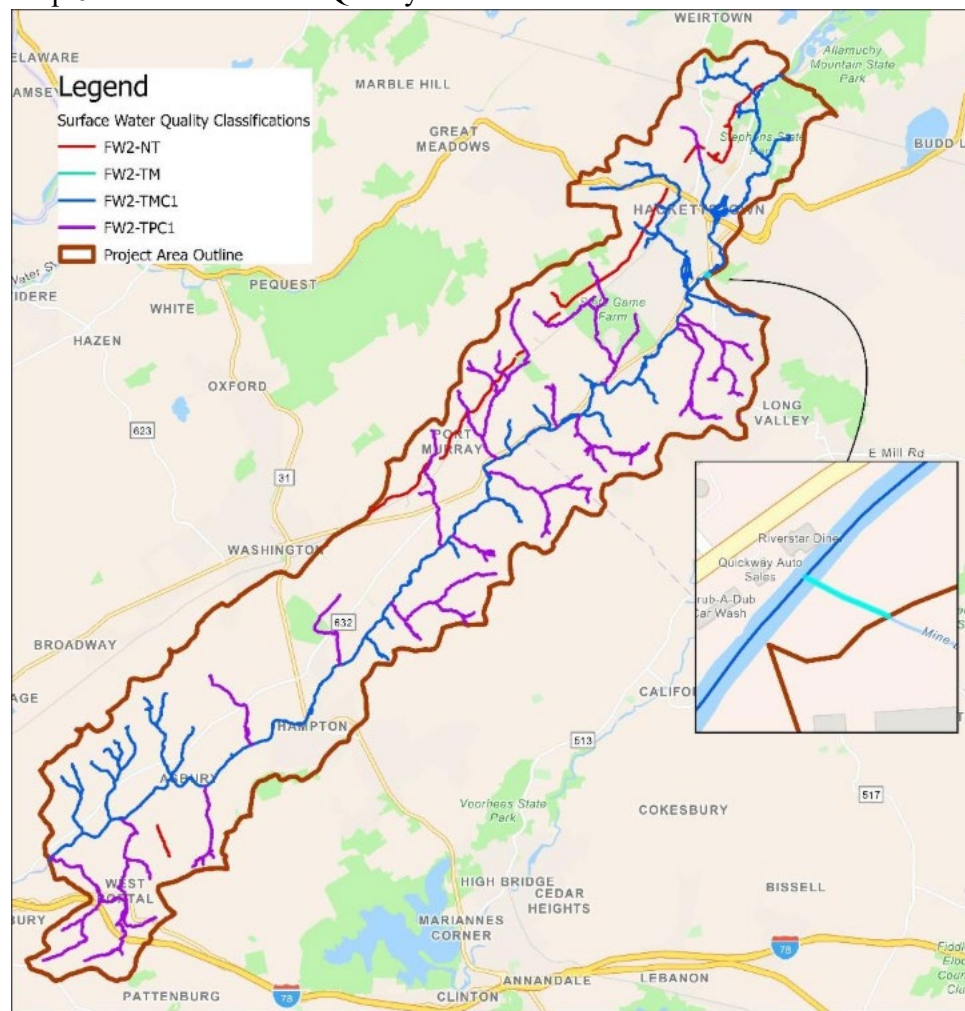
6.0 Surface Water Quality

6.1 Designated Uses and Impairments

6.1.1 Designated Uses

Water quality criteria are developed according to the waterbody's designated uses (NJDEP, 2011). The Musconetcong River is classified as FW2-TM, or freshwater (FW) trout maintenance (TM) (Map 6.1.1). "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, while "TP" means those freshwaters designated for use by trout for spawning or nursery purposes in their first summer; many tributaries within the project area are designated FW2-TP (N.J.A.C. 7:9B-1.15). The applicable water quality criteria for this project are detailed in Table 6.1.2.b.

Map 6.1.1 Surface Water Quality Classifications



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the Surface Water Quality Classifications for the stream segments within the project area.

Sources: NJDEPGIS



Sources: Esri, TomTom, Garmin, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

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6.1.2 Impairments

Since the implementation of the TMDL for fecal coliform (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) in the Musconetcong River, based on the New Jersey 2002 Integrated Water Quality Report, the Musconetcong River has seen numerous segments struggle to adhere to these limits. This has resulted in the New Jersey 2020 Integrated Water Quality Report reflecting 11 HUC14s within the watershed on Sublist 4. Six of those HUC14s listed correspond to the HUC14s of the project area previously listed in Table 6.1.2.a.

The Musconetcong River (HUC 02040105160040 ~ 75d 00m to Rt 31) is the lower most HUC14 within the project area, which appears on Sublist 5 (303(d)) for arsenic. Moving up within the project area, the Musconetcong River (HUC 02040105160030 ~ Rt 31 to Changewater, HUC 02040105160020 ~ Changewater to HancesBk, HUC 02040105160010 ~ Hances Bk thru Trout Bk, HUC 02040105150100 ~ Trout Bk to Saxton Falls) have all landed on Sublist 5 for arsenic as well. Musconetcong River (Trout bk to Saxton Falls) and (Changewater to HancesBk) are also listed for pH while the Musconetcong River (Hances Bk thru Trout Bk) is also listed for temperature. None of the HUC14s within the Musconetcong River Watershed have been delisted from either Sublist 5 (303(d)) or Sublist 4.

Table 6.1.2.a Describes the sections of the Musconetcong River listed with a TMDL or listed on the 303(d) list.

Waterbody	Impairment						
	Temperature	pH	E. coli	Total Suspended Solids	Fecal Coliform	Dissolved Oxygen	Arsenic
Musconetcong R (Wills Bk to LkHopatcong)	X	X	X				
Musconetcong R (SaxtonFalls to Waterloo)		X				X	
Musconetcong R (Trout Bk to SaxtonFalls)		X					X
Musconetcong R (Hances Bk thru Trout Bk)	X						

Musconetcong R (Changewater to Hances Bk)		X					X
Musconetcong R (below Warren Glen)				X			
Musconetcong R (Rt 31 to Changewater)							X
Musconetcong River at Beattystown					X		
Musconetcong River near Bloomsbury					X		
Musconetcong River at Riegelsville					X		
Musconetcong River at Lake Hopatcong	X	X			X		
Musconetcong River at Lockwood					X		
Lubbers Run (below Dallis Pond)			X				
Cranberry Lake / Jefferson Lake & tribs	X						
Mine Brook (Morris Co)			X				

*Waterbodies bolded and with grey backgrounds are those relevant to the Project Area.

Based on the conditions/impairments described above, the Musconetcong River Watershed Restoration and Protection Plan project Team was assembled and an expansion of the preceding Watershed Protection Plan: Bloomsbury to Hampton was conducted. The 319(h) grant proposal was submitted by the team to NJDEP in 2019 focusing on the previously studied area starting from Route 31 in Hampton to Saxton Falls in Allamuchy. The goal of the overall project is to develop a watershed restoration and protection plan that, through its implementation, will restore water quality impaired waters in the project area and protect the healthy waters. The expansion of the Watershed Restoration and Protection Plan was funded in 2021 by the NJDEP (WQR-2019-Musconetcong Watershed-As-00134) under the 604(b) program.

Table 6.1.2.b Applicable Surface Water Quality Criteria – N.J.A.C.7:9B (Last Amended – December 18, 2023 (52 N.J.R.711(a))

Substance	Surface Water Classification	Criteria
Bacterial quality (Counts/100 ml) <i>E. coli</i>	FW2	<i>E. coli</i> levels shall not exceed a geometric mean of 100/100 ml over a 90-day period and a Statistical Threshold Value of 320/100 ml, which shall not be greater than 10 percent excursion frequency over a 90-day period.
<i>Bacterial quality (Counts/100 ml) E. coli -Former criterion</i>	FW2	<i>E. coli shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL</i>
<i>Bacterial quality (Counts/100 ml) Fecal Coliform – former criterion for bacterial quality</i>	FW2	<i>Fecal coliform not used for primary contact</i>
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. <i>(Current criterion)</i>
<i>Temperature (°C) – former criterion</i>	<i>FW2-TM</i>	<i>No thermal alterations which would cause temperatures in excess of 20 °C</i>
Nitrate (mg/L)	FW2	10 mg/L (human health criterion)

6.1.3 Wild and Scenic Designation

The Wild and Scenic designation is a significant recognition bestowed upon certain rivers in the United States to preserve and protect their outstanding natural, cultural, and recreational values. The Musconetcong River earned this prestigious designation when the Musconetcong Wild and Scenic Rivers Act was signed into law in December 2006. This legislation designated portions of the Musconetcong River as part of the larger National Wild and Scenic Rivers System, acknowledging its exceptional scenic beauty, ecological significance, and recreational opportunities.

Maintaining healthy water quality is essential to preserving the Musconetcong River's Wild and Scenic character and fulfilling the goals of this Plan. The river's designation recognizes its outstanding natural, ecological, and recreational values, all of which depend on clean water and intact aquatic ecosystems. Protecting water quality helps prevent nonpoint source pollution that can degrade habitat, threaten aquatic life, and reduce recreational and aesthetic value.

Implementation of the Plan supports these objectives by addressing pollutants at their sources, ensuring that the Musconetcong River continues to meet its designated uses and retain the qualities that make it a valued component of the National Wild and Scenic Rivers System.

6.2 Monitoring Programs

The monitoring program for this update and expansion is based on long-term study sites established by NJDEP, MWA, and MSU. Additional sites were added where concerns were identified (see Table 6.2 and Map A.7). Desktop exercises were conducted, site walks were

performed, local residents and Environmental Commission members were consulted, and ground-truthing was done to assess conditions.

Table 6.2 Sample sites with site code, location, description and reason for concern.

MSU SITE ID	Latitude	Longitude	Description	Concern/Basis for Sampling
DQ	40.832604	-74.82575	Main stem	High impervious surface, stormwater runoff concern
NR	40.823541	-74.832779	Main stem	High impervious surface, stormwater runoff concern
KH	40.813195	-74.841953	Main stem	Leaky septic concern
HT	40.71167	-74.96792	Main stem	Previous MST site, high bacteria
PM	40.76705	-74.91186	Main stem	WMA, wildlife bacterial contamination concern
RR	40.79127	-74.88315	Main stem	Leaky septic concern
HB	40.8046	-74.86003	Tributary	Cropland and livestock upstream
ST	40.79088	-74.87126	Tributary	Cropland and livestock upstream, leaky septic concern
WR	40.7853	-74.89509	Tributary	Cropland and livestock upstream
HR	40.74148	-74.93604	Tributary	Livestock farm in headwaters/Reported leaky septic in area

Microbial Source Tracking for *E.coli*

Microbial Source Tracking (MST) uses microbiological, molecular, biochemical, and chemical methods to identify the origin of fecal contamination (Scott et al., 2002). Among available indicators, *Bacteroides*—anaerobic, gram-negative bacteria that make up roughly 40% of fecal bacteria—are ideal for MST due to their abundance, host specificity, and geographic stability (USEPA, 2005; Dick et al., 2005; Layton et al., 2006).

Earlier NJDEP monitoring placed much of the Musconetcong River on the 303(d) list for fecal coliform contamination, but available technology at that time could not distinguish among fecal sources. In 2018, MSU and the MWA conducted MST analyses at 12 sites in the middle–lower watershed. Results indicated human-sourced bacteria were the dominant contributor, disproving earlier assumptions that agricultural runoff was the primary source. No evidence of chicken manure contamination was found, and it was excluded from subsequent studies (Figure 6.2). The

most upstream site—Hampton Borough Park—showed significant human *E. coli* inputs and was selected as the downstream reference for the 2021 study.

Figure 6.2 - MST markers for 2018 and 2021 study and relative abundance of source

MST Marker 2018	MST Marker 2021	
HUMAN	HUMAN	Very High
COW	COW	High
GOOSE	GOOSE	Low
DEER	DEER	Absent
HORSE	HORSE	
CHICKEN	DOG	

6.2.1 Monitoring Program June 2021- September 2021

As shown in the previous section, the Musconetcong River is abundant in fecal coliforms, and is impaired for aquatic life, pH, dissolved oxygen and temperature (NJDEP, 2002-2020). To further characterize these impairments identified within the Musconetcong River Watershed, MWA and MSU continued surface water and bacterial sampling in accordance with an approved QAPP, on file with NJDEP Office of Quality Assurance (OQA). Surface water quality samples were collected from ten sampling locations within the Musconetcong River Watershed as described in Table 6.2 and mapped in Map 6.2.2. In-situ YSI measurements of water temperature, dissolved oxygen, and pH were taken, while total suspended solids and *Escherichia coli* were performed by the New Jersey Center for Water Science and Technology's laboratory at Montclair State University. Total phosphorus analysis was performed by Aqua Pro-Tech laboratories, a certified NJDEP laboratory.

The temporal and spatial aspects of the surface water quality monitoring program for 2021 are summarized in Table 6.2.1.a. The tabulated water quality monitoring results from the biweekly and additional bacteria sampling are presented in the Tables and Figures below.

Table 6.2.1.a Temporal and Spatial aspects of 2021 water quality monitoring in Musconetcong Watershed focus area

Type:	Surface Water Sampling
Frequency	Five (5) times a month from June - September 2021)(20 events)
Parameters	pH, water temperature, dissolved oxygen (DO), stream width, stream depth, stream velocity, total phosphorus (TP), total suspended solids (TSS), and <i>E. coli</i>
Sampling Locations (by WQX Location ID/MWA Site ID)	
10277/DQ	X
10607/NR	X (No MST at this site)
1325/KH	X

9838/HT	X
11539/PM	X
9837/RR	X
10275/HB	X
NA/ST	X
NA/WT	X
NA/HR	X

The analysis for nutrients (TP), *E. coli*, TSS, and in-situ measurements were performed 5 times a month. In addition, analysis for MST was performed 2 times a month, one wet day and one dry day, at minimum. This requirement was met for every month of the monitoring program; with a total of two wet and three dry days in June, one wet and four dry days in July, three wet and two dry days in August and three wet and two dry days in September (wet weather event dates: 6/3, 6/10, 7/15, 8/12, 8/19, 8/26, 9/3, 9/9, 9/16). Results from the MST monitoring program can be found by site in Table 6.2.1.b through 6.2.1.j, which highlights the presence of human bacterial sources while also sharing an absence of deer and horse and minimal inputs of goose and cow. A summary of the *E.coli* results can be seen in Table 6.2.1.k and Table 6.2.1.l.

Figure 6.2.1.a Log copies of DNA from each species



Table 6.2.1.b MST results from 2021 monitoring at Site HT- Hampton Borough Park (main stem)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	162	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	16	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	ND	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	87	ND	ND	ND	ND	ND
*9/3/2021	4,185	19	ND	ND	ND	ND
9/30/2021	ND	ND	ND	ND	ND	ND

Table 6.2.1.c MST results from 2021 monitoring at Site HR- Hollow Rd (tributary)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	34	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	60	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	ND	ND	ND	ND	106	ND
*9/3/2021	ND	ND	ND	ND	67	ND
9/30/2021	ND	ND	ND	ND	18	ND

Table 6.2.1.d MST Results from 2021 monitoring at Site PM – Point Mountain (main stem)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	118	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	30	97	ND	ND	ND	ND
8/5/2021	118	83	ND	ND	ND	ND
8/12/2021	30	18	ND	ND	ND	ND
*9/3/2021	3,335	ND	ND	ND	ND	ND
9/30/2021	ND	ND	ND	ND	ND	ND

Table 6.2.1.e MST Results from 2021 monitoring at Site WR – Watters Rd (tributary)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	66	ND	ND	ND	154	ND
6/17/2021	263	ND	ND	ND	80	ND
7/8/2021	16	ND	ND	ND	ND	ND
7/29/2021	61	182	ND	18	ND	ND
8/5/2021	154	128	ND	ND	ND	ND
8/12/2021	44	21	ND	ND	ND	ND
*9/3/2021	ND	ND	ND	ND	ND	ND
9/30/2021	20	41	ND	ND	ND	ND

Table 6.2.1.f MST Results from 2021 monitoring at Site RR – River Rd (main stem)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	137	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	ND	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	ND	ND	ND	ND	ND	ND
*9/3/2021	3,572	ND	ND	ND	ND	ND
9/30/2021	ND	ND	ND	ND	ND	ND

Table 6.2.1.g MST Results from 2021 monitoring at Site ST – Stephensburg Brook (tributary)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	64	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	ND	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	ND	19	ND	ND	ND	ND
*9/3/2021	ND	ND	ND	ND	20	ND
9/30/2021	ND	ND	ND	ND	ND	ND

Table 6.2.1.h MST Results from 2021 monitoring at Site HB – Hances Brook (tributary)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	27	18	ND	ND	151	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	102	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	ND	21	ND	ND	ND	ND
*9/3/2021	ND	ND	ND	ND	ND	ND
9/30/2021	ND	16	ND	ND	23	ND

Table 6.2.1.i MST Results from 2021 monitoring at Site KH – Kings Highway (main stem)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	167	ND	ND	ND	ND	ND
6/17/2021	24	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	22	ND	ND	ND	ND	ND
8/5/2021	32	ND	ND	ND	ND	ND
8/12/2021	39	ND	ND	ND	ND	ND
*9/3/2021	4,130	ND	ND	ND	ND	ND
9/30/2021	30	ND	ND	ND	ND	ND

Table 6.2.1.j MST Results from 2021 monitoring at Site DQ – Route 57 before Mountain Ave (main stem)

DATE	HUMAN	COW	DEER	DOG	GOOSE	HORSE
6/3/2021	184	ND	ND	ND	ND	ND
6/17/2021	ND	ND	ND	ND	ND	ND
7/8/2021	ND	ND	ND	ND	ND	ND
7/29/2021	ND	ND	ND	ND	ND	ND
8/5/2021	ND	ND	ND	ND	ND	ND
8/12/2021	ND	ND	ND	ND	ND	ND
*9/3/2021	4,498	ND	ND	ND	ND	ND
9/30/2021	ND	ND	ND	ND	ND	ND

Bold date indicates wet weather sample, *indicates 1 day after Hurricane Ida

Table 6.2.1.k Summary statistics of *E.coli* results from 2021 monitoring, June – August

CFU/100 mL	HT	HR	PM	WR	RR	ST	HB	KH	DQ
Geometric Mean	360.1 7	202.4 7	302.3 9	776.6 1	242.2 8	70.74	1456. 90	259.5 9	840.0 0
GM>100	Y	Y	Y	Y	Y	N	Y	Y	Y
# over 320	6	5	5	11	4	3	15	4	5
%	0.40	0.33	0.33	0.73	0.27	0.20	1.00	0.27	0.33
>10?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Support recreation?	N	N	N	N	N	N	N	N	N

Table 6.2.1.l Summary statistics of *E.coli* results from 2021 monitoring July – September

CFU/100 mL	HT	HR	PM	WR	RR	ST	HB	KH	DQ
Geometric Mean	334.4 2	208.5 4	316.8 5	379.9 3	274.0 0	107.4 0	1007. 88	255.7 0	1596. 00
GM>100	Y	Y	Y	Y	Y	Y	Y	Y	Y
# over 320	5	6	5	7	5	4	15	4	6
%	0.33	0.40	0.33	0.47	0.33	0.27	1.00	0.27	0.40
>10?	Y	Y	Y	Y	Y	Y	Y	Y	Y
Support recreation?	N	N	N	N	N	N	N	N	N

To evaluate the health of the Musconetcong River Watershed, the monitoring results were compared to applicable surface water quality criteria. The number of samples that exceeded the surface water quality criteria is provided in Table 6.2.1.m. Elevated temperature levels were observed at a single location, Site DQ. Three violations of the pH maximum criterion at Site HB, WR and HR was observed, and multiple violations of the total suspended solids criterion was observed at Site HT, ST, WR, and HR with site WR reporting levels five times higher than the criteria. It is important to note that the high TSS concentration reported for WR on 7/29/21 and 8/5/21 could be due to nearby construction.

Table 6.2.1.m Exceedances of SWQS from 2021 monitoring

Surface Water Quality Sampling Results				
Temperature				
Site	Surface Water Quality Standard Criteria	Number of Violations	Value that exceeded (degrees Celsius)	Dates of violation
DQ	daily maximum of 25 degrees Celsius or rolling seven-day average of 23 degrees Celsius, unless due to natural conditions	1	25.6	8/12/2021
pH				
Site	Surface Water Quality Standard Criteria	Number of Violations	Value that exceeded	Dates of violation
HB	6.5-8.5	1	8.55	7/22/2021
WR		2	8.58, 8.6	8/5/21, 8/12/21
HR		1	8.65	6/10/2021
Total Suspended Solids (TSS) Concentration				

Site	Surface Water Quality Standard Criteria	Number of Violations	Value that exceeded (mg/L)	Dates of violation
HT	25mg/L	2	39, 40.88	8/19/21, 9/9/21
ST		1	30.13	8/19/2021
WR		2	116, 156.75	7/29/21*, 8/5/21*
HR		1	35.36	9/23/2021

* Sample affected by nearby construction.

When taking a further look into the *E. coli* results from the 2021 bacterial monitoring program it is evident that most of the sites have concentrations which greatly exceed the criteria limits of 100/100 mL for the geometric mean and 320/100 mL for the STV, with average *E. coli* densities at mainstem sites ranging from 512 to 877 CFU/100mL, throughout the study period. Tributary sites HB and WR were the worst offenders of bacterial water quality with single sample maximums of 18,040 CFU/100mL and 3,000 CFU/100mL respectively. Given these results, these two tributaries should be considered high-priority for future water quality restoration and enhancement actions. Given the exceedances of *E. coli*, a deeper dive into the root cause of the violation, through the lens of microbial source tracking, was implemented. However, when examining the MST results, there seems to be a disconnect. A table describing the *E. coli* concentrations vs MST results can be found in Table 6.16 The reason for this, is that *E. coli* measurements not only include human and animal fecal contributions but also nonfecal sources, such as naturally occurring *E. coli* in the soil. It is because of this, the use of MST was implemented to further characterize the sources of fecal contamination, in order to identify more precise ways of remediating the inputs.

Table 6.2.1. n Describes the disconnected relationship between average *E.coli* concentration and average MST

Site	Average <i>E. coli</i> concentration (cfu/100mL)	Average MST (all markers combined; human, cow, goose, horse, dog, and deer) (copies/100mL)
HT	877	559
HR	515	590
PM	586	479
WR	1003	156
RR	600	464
ST	201	13
HB	2254	42
KH	512	556
DQ	516	585

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods indicates that if the frequency of water quality results exceeded the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2011). 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, dissolved oxygen and total suspended solids.

To evaluate the trends in parameters of concern (bacteria, temperature, DO and TSS) historic data paired with land usage were utilized. By focusing on specific sites, such as Hampton Park (HT), the most long-standing monitoring site in this study, trends in water quality parameters begin to form. From the year 2007 to 2021, there was a significant increase in discharge, *E. coli* loads and TP loads with a decrease in dissolved oxygen as described in Table 6.2.1.o. These trends are supported by land usage data, showcasing the heavy influence urban and agricultural land use has on bacterial exceedances – for a project area extent of forested land use in proximity to a river or stream look to Map A.10 in the Appendix. When looking at Hances Brook, the site with *E. coli* exceedances of the highest magnitude, Map 6.2.1.a, illustrates the proximity of land usage in the area to the waterbody; with urban and agricultural influences being the most abundant. This is then further compounded by wet weather events, which are becoming more frequent and intense, a phenomenon brought on by the change in climate (Cartwright and Costanza, 2016). As made evident by Table 6.2.1.q, in most cases, *E. coli* concentrations continuously exceeded accepted thresholds during wet weather events with wet weather exceedances vs total exceedances reaching as high as 100% with an average of 70% across the study sites. This is a point of concern given the climate changes described in Section 4.3.

Table 6.2.1.o Overview of change at Hampton Park from 2007 to 2021, the most long-standing site within project area. Highlights a significant increase in flow, *E. coli* loads and TP loads with a decrease in Dissolved Oxygen

Parameter	2007 to 2021 change?	Significant?
Discharge	+	Y
Dissolved Oxygen	-	Y
<i>E. coli</i> conc.		N
<i>E. coli</i> loads	+	Y (10%)
TSS conc.	+	Y
TSS loads	+	Y
TP conc.		N
TP loads	+	Y (10%)

Figure 6.2.1.b Land use by percentage, arranged by sampling location

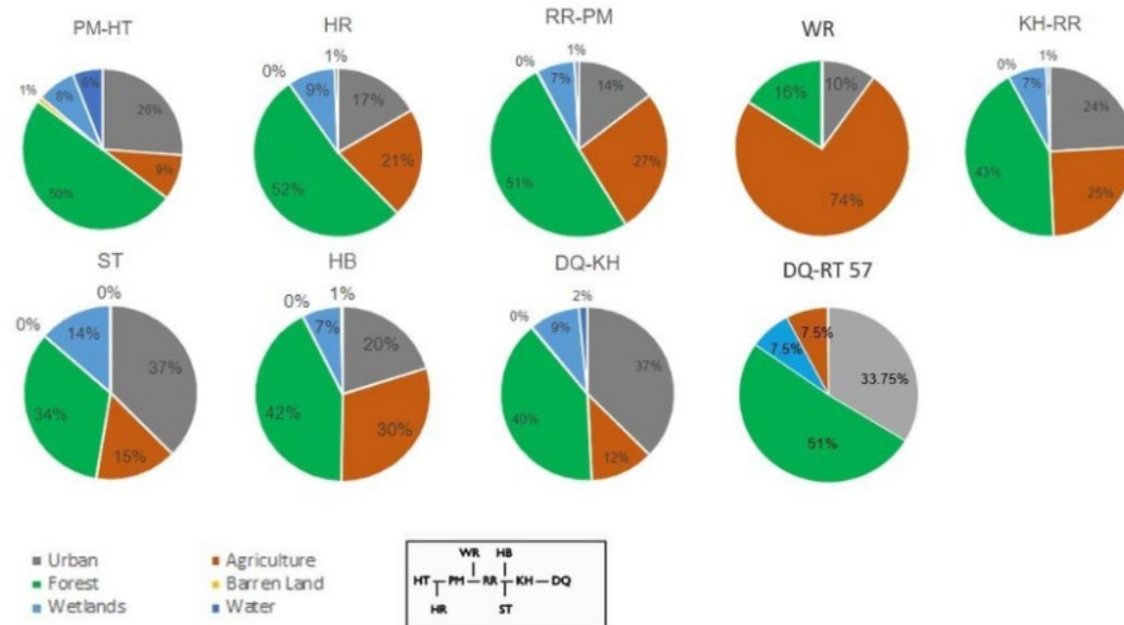


Table 6.2.1.q. Relation of wet weather events where *E. coli* threshold was exceeded vs total *E. coli* threshold exceedances across study period by site

Site	Wet weather exceedances/total exceedances	Percent exceedances
HT	8/11	73%
PM	8/10	80%
RR	7/9	78%
KH	6/9	67%
DQ	6/9	67%
HR	6/7	86%
WR	5/13	38%
ST	7/7	100%
HB	9/20	45%

Table 6.2.1.r. Further impacts of wet weather across study sites

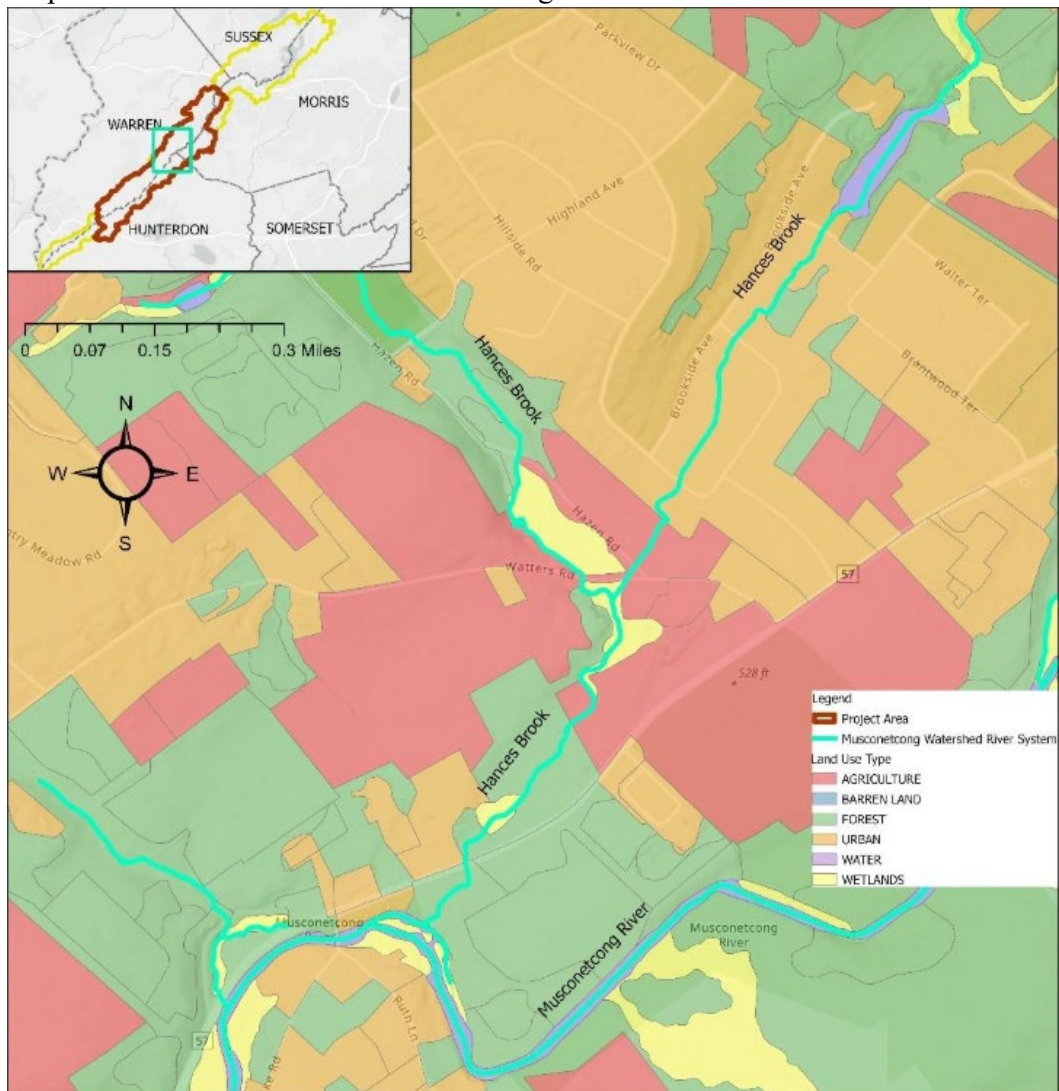
Parameter	Significant	p-value	Significant increase (+) or decrease (-)
Discharge	Y	<0.0001	+
pH	Y	<0.0001	-
DO	Y	0.0126	-

E. coli conc	Y	0.0075	+
E. coli loads	Y	<0.0001	+
TSS conc	Y	<0.0001	+
TSS loads	Y	<0.0001	+
TP conc	Y	<0.0055	+
TP loads	Y	<0.0001	+

Table 6.2.1.s. Provides background for historical bacterial monitoring to reveal trends

Bureau of Freshwater and Biological Monitoring Historical Data			
Site	Year	Fecal coliform – geomean (copies/100mL)	<i>E. coli</i> – geomean (copies/100mL)
BA162 - MUSCONETCONG R UNT ON RT 604 (WATERLOO RD)	2012	248	454
AN0067 - MINE BROOK RT 517	2017-2018	N/A	467
BA160 - MUSCONETCONG R OFF RT 604 ON MORRIS CANAL TRAIL	2012-2018	24	65
BFBM000118 - Lubbers Run On Route 206	2011	N/A	76
01457120 - Musconetcong River at Route 579 at Greenwich	2009	N/A	128
BA161 - MUSCONETCONG R AT END OF GLEN BK RD	2012-2018	73	93.35
01457400 - MUSCONETCONG RIVER AT RIEGELSVILLE	2009-2010	N/A	116

Map 6.2.1.a Hances Brook with surrounding land use



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights Hances Brook and the surrounding land use, to help identify the causes of elevated e. coli.

Sources: NJDEPGIS

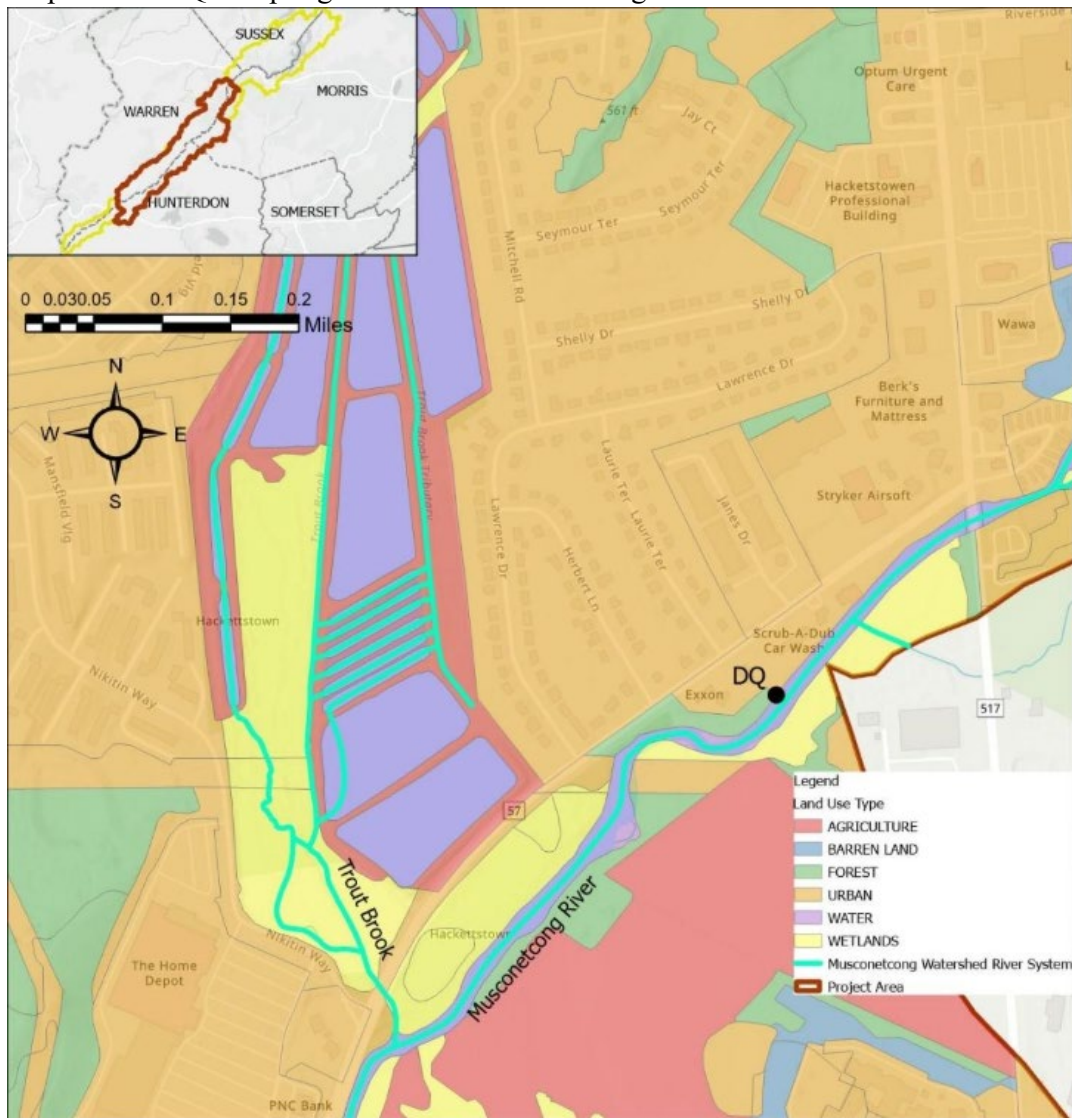


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ESRI, NASA, NGA, USGS, FEMA, Sources: ESRI, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: ESRI, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Delaware Geological Survey - New Jersey/Delaware boundary data through the Delaware River within the 12 mile circle centered on the old New Castle County Courthouse (Used prior to 1881).

New Jersey Department of Agriculture, State Agricultural Development Committee, Farmland Preservation Program - preserved farmland boundary data from property surveys New Jersey Department of Environmental Protection, Green Acres Program - open space.

Map 6.2.1.b DQ Sampling location and surrounding land use



**Musconetcong Watershed
Protection Plan: Hackettstown to
Hampton**

This map highlights the location of urban land
usage to the sampling location Dairy Queen
(DQ).

Sources: NJDEPGIS

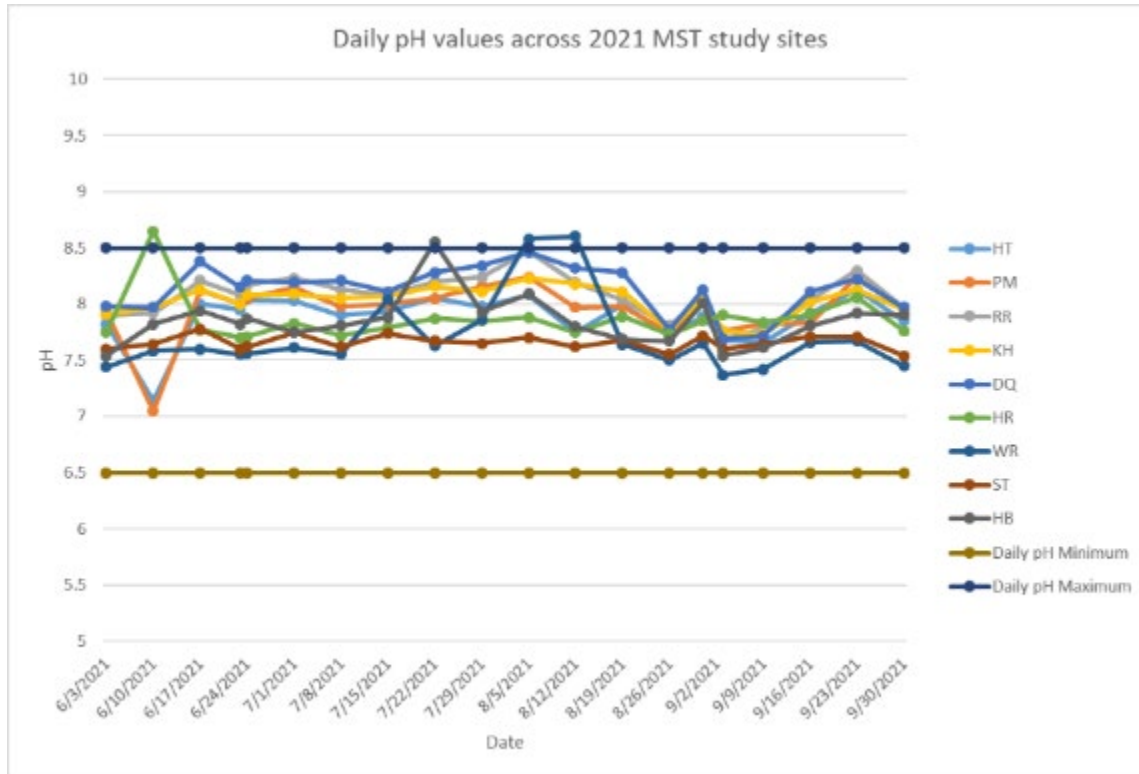


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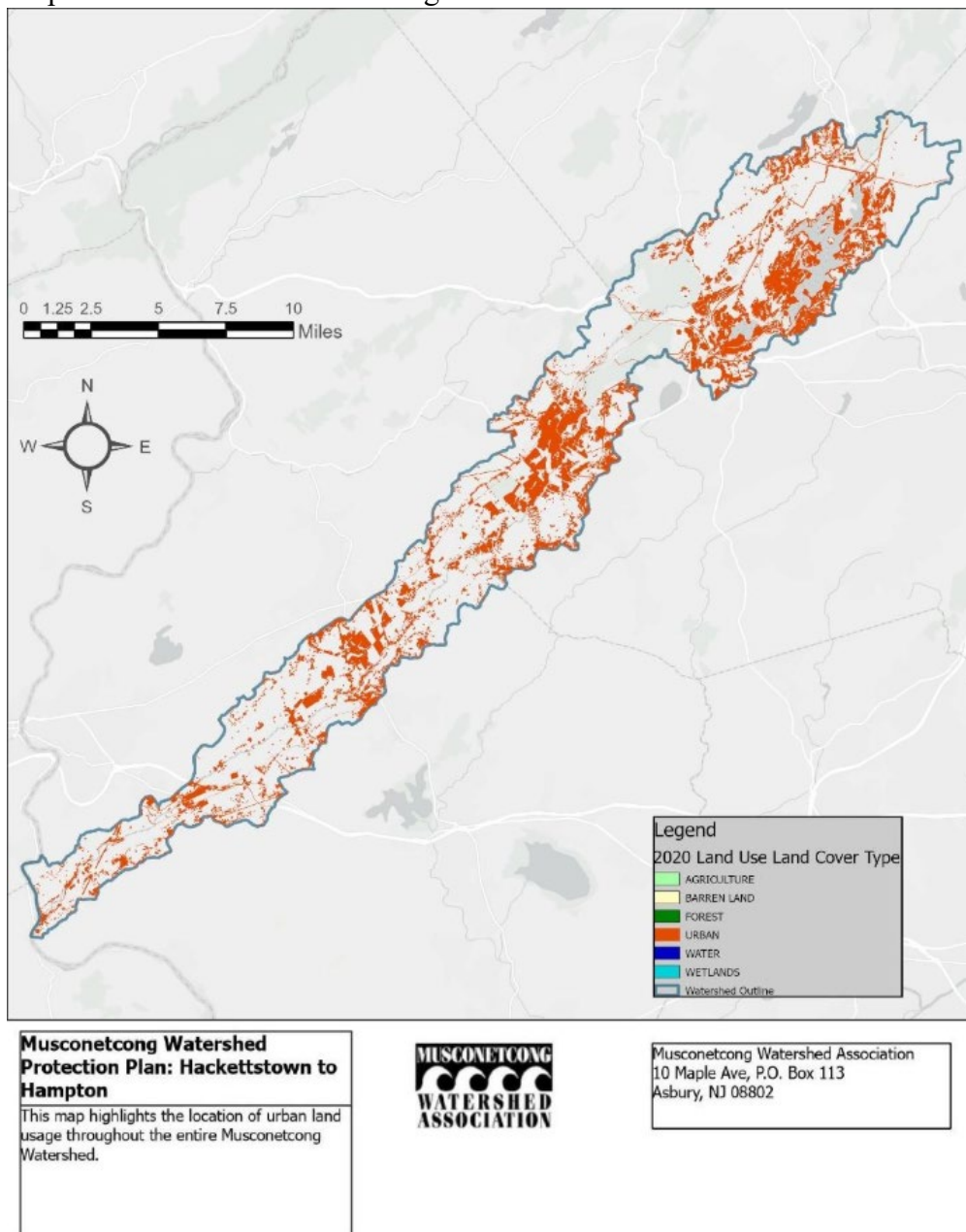
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Delaware Geological Survey - New Jersey/Delaware boundary data through the Delaware River within the 12 mile circle centered on the old New Castle County Courthouse (Used prior to 1881)

New Jersey Department of Agriculture, State Agricultural Development Committee, Farmland Preservation Program - preserved farmland boundary data from property surveys New Jersey Department of Environmental Protection, Green Acres Program - open space

Figure 6.2.1.c Daily pH values across sample sites from 2021 MST study.



Map 6.2.1.c Urban land use throughout the whole watershed



Biological Monitoring

The NJDEP conducts biological monitoring statewide through the Ambient Biomonitoring Network (AMNET), which has assessed benthic macroinvertebrate communities since the 1970s. Benthic macroinvertebrates—bottom-dwelling organisms common in freshwater systems—are effective indicators of stream health due to their limited mobility, differential sensitivity to

pollutants, and responsiveness to both chemical and physical stressors such as turbidity, siltation, eutrophication, and temperature changes (NJDEP, 2007). Their ubiquity and cost-effective sampling make them ideal for evaluating water quality consistent with the goals of the Clean Water Act.

Established in 1992, AMNET includes more than 800 sites across New Jersey's five major drainage basins (Upper and Lower Delaware, Northeast, Raritan, and Atlantic). Sites are sampled every five years using a modified USEPA Rapid Bioassessment Protocol II (NJDEP, 2007). Biological condition is evaluated through multiple community metrics, the protocol and formula can be found in Appendix O.

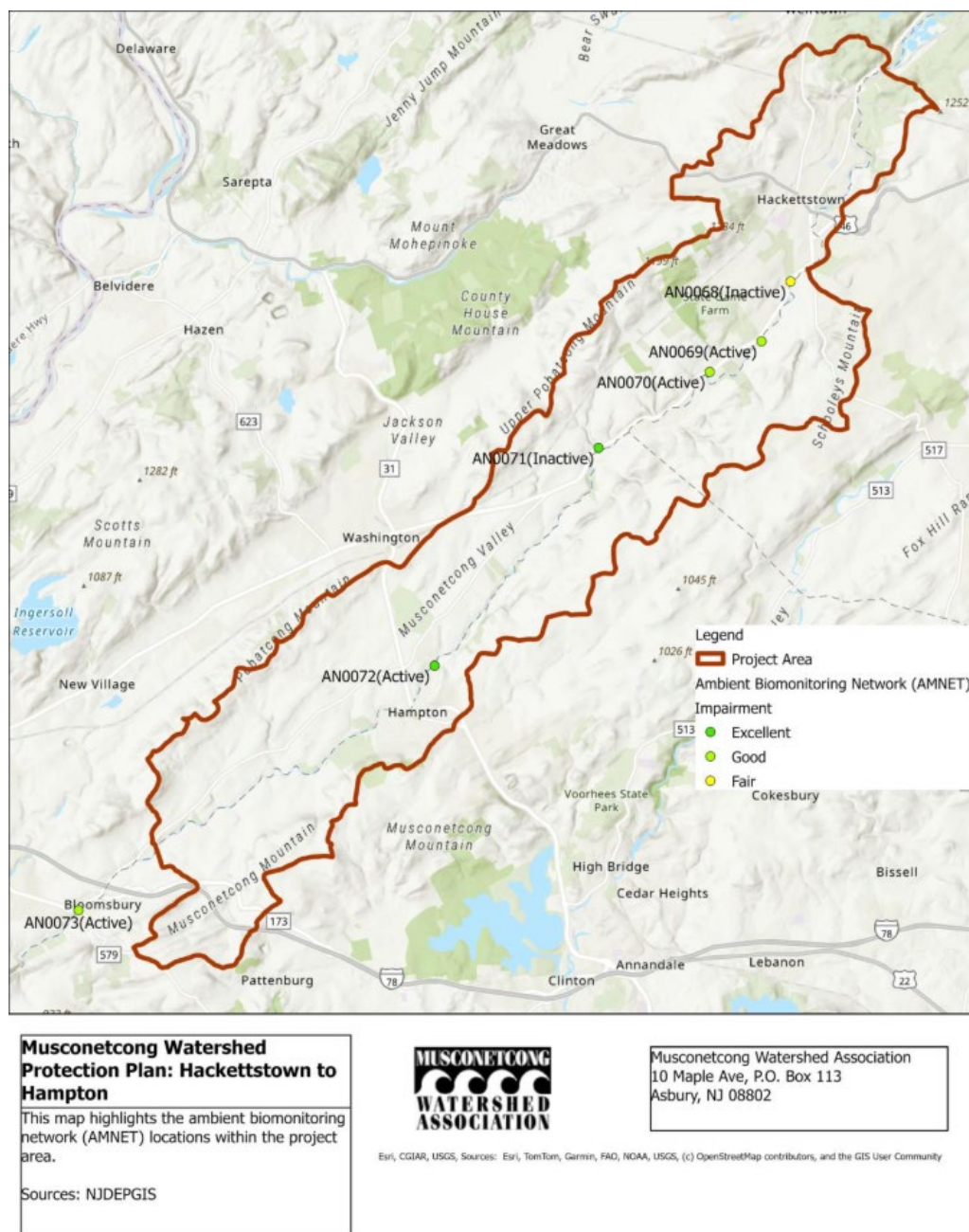
Table 6.2.1.t AMNET sites within Project Area

Site	Active or Inactive*	Impairment Score	Habitat Score	Habitat Rating
AN0068	Inactive	Fair	189	Optimal
AN0069	Active	Good	167	Optimal
AN0070	Active	Good	153	Suboptimal
AN0071	Inactive	Excellent	169	Optimal
AN0072	Active	Excellent	176	Optimal
AN0073	Inactive	Good	161	Optimal

**Inactive sites are showing the most recent data collected.*

Supplemental biological assessments conducted by Rutgers Cooperative Extension Water Resources Program in 2007 (Sites #1 and #10) confirmed non-impaired biological and optimal habitat conditions, consistent with NJDEP findings at AN0072 and AN0073 later that year. As no current impairments were identified, the USEPA Stressor Identification (SI) process (USEPA, 2000) was deemed unnecessary.

Map 6.2.1.d AMNET sampling location in Project Area



6.2.2 Monitoring Program for April 2022 - May 2023 (MWA Macro)

As an extension of the 2021 water quality and bacterial monitoring conducted through MSU, a secondary macroinvertebrate sampling QAPP was established. The monitoring was focused on identifying the benthic macroinvertebrate community composition and the physical riparian and in-stream habitat conditions, along with accompanying in-situ parameters of temperature, pH, dissolved oxygen and turbidity. This monitoring program was proposed to further investigate the

water quality conditions at the upper portion of the TMDL area and use bioassessment data as ecological health indicators. In this monitoring program, samples were collected by MWA staff and samples were sent to Cole Ecological to be processed, in accordance with the approved QAPP.

As a result of the conclusions from the ‘2012 Musconetcong River Restoration and Protection Plan – Hampton to Bloomsbury’ highlighting that the area of greatest urbanization in the watershed, upstream of Hampton, continues to impact downstream segments, primarily through stormwater runoff, it became evident that changes within the watershed necessitated an update and expansion of the plan. With the inclusion of four additional HUC14s, on top of the two previously studied HUC14s, the monitoring program for April 2022 to May of 2023, seeks to identify the sources of impairment for the ultimate purpose of de-listing this segment of the river from the 303(d) list.

MWA staff collected habitat data using USEPA Rapid Bioassessment protocol (See Appendix O) and macroinvertebrates were collected and preserved then analyzed in a certified lab by a Society of Freshwater Science Certified Taxonomist and according to quality assurance (Society for Freshwater Science, 2015). The biological and habitat data collected according to the approved QAPP should be considered by NJDEP as Tier 3 of the New Jersey Community Water Monitoring Tiered Data Quality Framework (NJDEP, 2021) and therefore will be submitted to WQX for use in the New Jersey Integrated Report. Results from the first year of this monitoring program are presented in Table 6.21, highlighting the overall Excellent and Sub-optimal conditions present within the study area.

Table 6.2.2.a Results from the 2022 Biological Monitoring Program

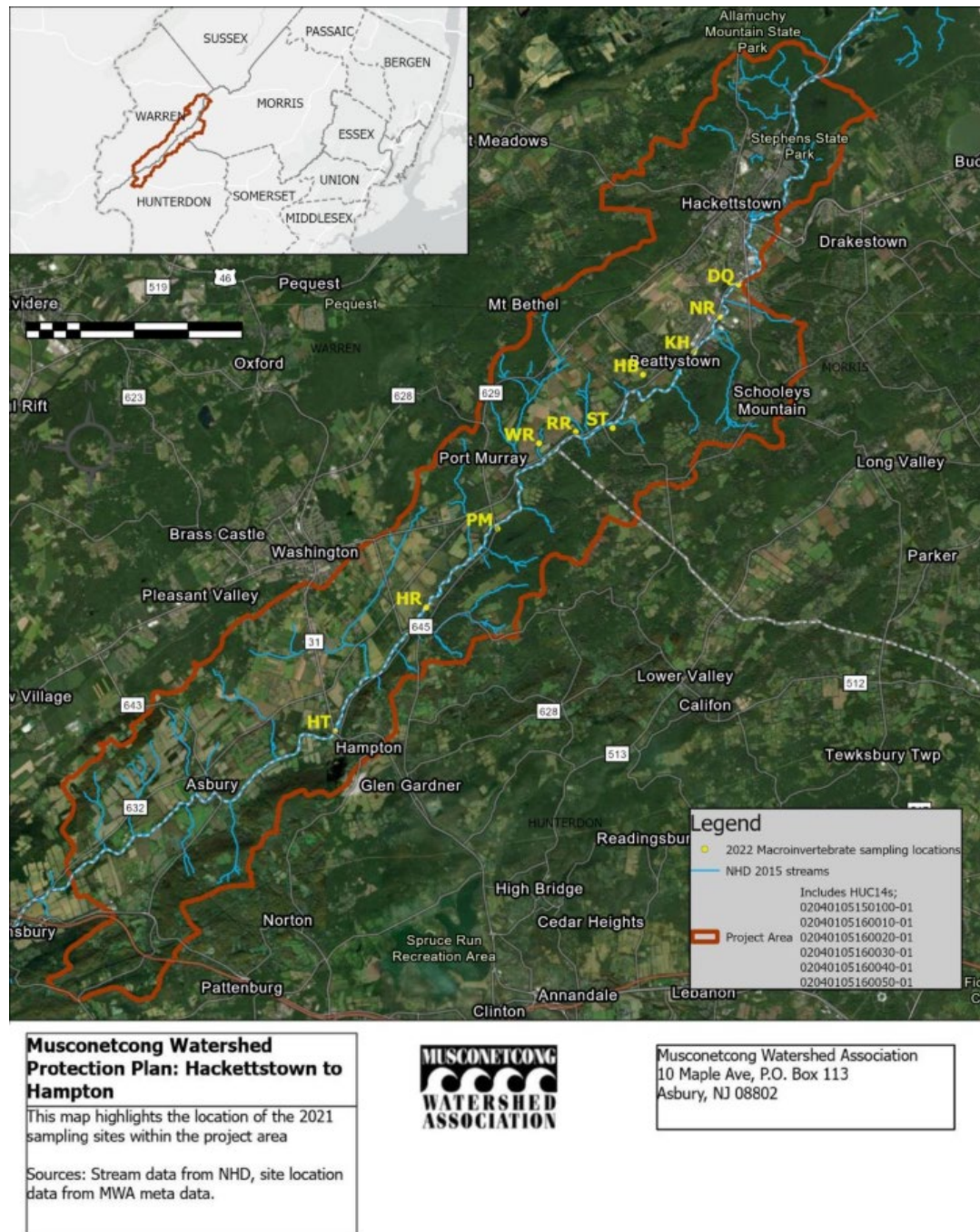
Date	Site	Macroinvertebrate rating	Habitat Assessment Score
7/14/21	Newburg Road (NR)	Excellent	112 – Sub-optimal
5/16/22	Watters Road (WR)	Excellent	144 – Sub-optimal
5/16/22	Hollow Road (HR)	Excellent	135 – Sub-optimal
5/18/22	Dairy Queen (DQ)	Excellent	151- Sub-optimal
5/18/22	Stephensburg Tributary (ST)	Excellent	124 – Sub-optimal
5/23/22	Hampton Park (HT)	Excellent	115 – Sub-optimal
5/23/22	Kings Highway (KH)	Good	137 – Sub-optimal
5/23/22	Point Mountain (PM)	Excellent	161 - Optimal
5/23/22	River Road (RR)	Good	157 – Sub-optimal
5/26/22	Hances Brook (HB)	Good	160 - Optimal

Table 6.2.2.b Results of 2022 Biological monitoring program highlighting species diversity

Site	Total # of genera	% of sensitive EPT	% of non-insect genera
Newburg Road (NR)	23	50	21.7
Watters Road (WR)	29	63	3.4
Hollow Road (HR)	32	70	6.3
Dairy Queen (DQ)	30	43	16.7
Stephensburg Tributary (ST)	35	51	11.4
Hampton Park (HT)	30	34	20
Kings Highway (KH)	20	28	10
Point Mountain (PM)	32	31	18.8
River Road (RR)	25	26	16
Hances Brook (HB)	25	28	16

The results of the 2022 Macroinvertebrate monitoring program highlight an overall Excellent score, but looking further into species diversity and specific classifications, a deeper conclusion can be drawn. Most sites in the project area presented with a diverse population, ranging from 20 to 35 different genera, however, the percentage of sensitive EPT or *Ephemeroptera*, *Plecoptera*, *Trichoptera* (mayflies, stoneflies and caddisflies) reveal a majority of sites below 50 percent. This is concerning because it means the majority of the sample population falls in the tolerant genera; species able to withstand pollution and therefore occurring more predominantly at impaired sites.

Map 6.2.2 2021 Bacteria and macroinvertebrate monitoring locations in Project Area



6.3 Point and Nonpoint Source Loadings

Significant achievements have been made nationally in regard to the protection and enhancement of water quality over the last three decades. However, the progress seen thus far has been a result of efforts focused primarily on point source pollution but as the data continues to show, nonpoint source pollution loads continue to present problems for achieving water quality goals and designated uses in many parts of the United States, the Musconetcong Watershed included. Nonpoint source is defined as any source of water pollution that does not meet the legal definition of point source as defined in Section 502(14) of the Clean Water Act which describes “point source” as any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged (This term does not include agricultural storm water discharges and return flows from irrigated agriculture). Categories of nonpoint source pollution affecting waterbodies include agriculture, atmospheric deposition, channelization, construction, contaminated sediment, contaminated ground water, highway maintenance/runoff, land development, recreational activities, removal of riparian vegetation to name a few. The vast multitude of categories leads to nonpoint source pollution, the designation by states, tribes and territories as the number one cause of water quality problems (USEPA, 2016).

6.3.1 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 twelve (12) surface water discharges within the watershed project area, 6 of which are existing and 6 have been terminated.

- **Asbury Graphite Mills Inc**

PTERMDATE: 12/31/1995

RECWATERS: Musconetcong R via Mill Run raceway

NJPDES: NJ0031208

PIPE: 003A

STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **Asbury Graphite Mills Inc**

PTERMDATE: 12/31/1995

RECWATERS: Musconetcong R via Mill Run raceway
NJPDES: NJ0031208
PIPE: 004A
STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **Asbury Graphite Mills Inc**

RECWATERS: Musconetcong R via Mill Run raceway
NJPDES: NJ0031208
PIPE: 002A
STAT CODE: E - Existing in the Point Source Permitting Regions

- **Asbury Graphite Mills Inc**

RECWATERS: Musconetcong R via Mill Run raceway
NJPDES: NJ0031208
PIPE: 001A
STAT CODE: E - Existing in the Point Source Permitting Regions

- **Asbury Graphite Mills Inc**

RECWATERS: Musconetcong R via Mill Run raceway
NJPDES: NJ0031208
PIPE: 005A
STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **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

- **Thomas & Betts – Elastimond Plant**

RECWATERS: Musconetcong R via unnamed tributary
NJPDES: NJ0004812
PIPE: 004A
STAT CODE: E - Existing in the Point Source Permitting Regions

- **Thomas & Betts – Elastimond Plant**

PTERMDATE: 8/31/2001
RECWATERS: Schooley's Mt Brook
NJPDES: NJ0004812

PIPE: 001A

STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **USR Optonix Inc**

PTERMDATE: 7/31/1996

RECWATERS: Musconetcong R via storm sewer

NJPDES: NJ0032247

PIPE: 001A

STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **Diamond Hill Estates Sewer Co**

PTERMDATE: 2/27/2006

RECWATERS: Hances Brook

NJPDES: NJ0028592

PIPE: 001A

STAT CODE: R - Revoked/Terminated - Pipe no longer permitted for discharge

- **Borealis Compounds Inc**

RECWATERS: Musconetcong R via unnamed tributaries & streams

NJPDES: NJ0028657

PIPE: 001A

STAT CODE: E - Existing in the Point Source Permitting Regions

- **Hackettstown MUA**

RECWATERS: Musconetcong River

NJPDES: NJ0021369

PIPE: 002A

STAT CODE: E - Existing in the Point Source Permitting Regions

Map A.5 of these point source locations can be found in Appendix E.

Information on these points was obtained from The New Jersey Department of Environmental Protection (NJDEP).

6.3.2 Nonpoint Sources

Common pollutants include but are not limited to: fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, road salts 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 in Hackettstown and Mansfield, the small borough of Hampton, the village of Asbury and Bethlehem Township. These areas, with the majority of Hackettstown being the only exception, rely solely on individual onsite wastewater disposal systems. A map of the most populated portions of the project area, highlighting sewer service areas can be found in Appendix F (Map A.6).

7.0 Criteria #1 – Causes and Sources of Pollution

Within this watershed, three primary sources of NPS fecal contamination were examined: livestock, septic systems, and wildlife. Factors contributing to this issue include environmental stressors such as increased water temperature, reduced dissolved oxygen, soil and streambank erosion, stormwater runoff, and declining water quality due to nonpoint source pollution.

Over the last 34 years, land use changes have had a significant impact on watershed hydrology. With the increase in urbanization, there has been a notable rise in impervious surfaces such as rooftops, driveways, additional roads, and parking lots, while conventional agricultural lands have decreased. In 1986, the project area experienced 16 percent coverage of impervious surface, however, from 1986 to 2020, the project area showed a 56 percent increase in impervious surface, resulting in 25 percent coverage by 2020 (Map 4.8). (NJDEP. Land Use/Land Cover of New Jersey 2020.,NJDEP. Land Use/Land Cover of New Jersey 1986). These shifts typically reduce infiltration and groundwater recharge while increasing surface runoff.

Table 7.0 Land Use Land Cover Comparison from 1986 to 2020

Land Use / Land Cover Type	Percent Coverage of Whole Watershed in 1986	Percent Coverage of Whole Watershed in 2020	Percent Change of Whole Watershed from 1986 to 2020	Percent Coverage of Project Area in 1986	Percent Coverage of Project Area in 2020	Percent Change of Project Area from 1986 to 2020
Agriculture	21.38%	15.03%	-30%	25.06%	27.60%	10%
Barren Land	0.73%	0.95%	30%	0.17%	0.49%	186%
Forest	45.58%	47.33%	4%	57.48%	39.90%	-31%
Urban	18.91%	24.63%	30%	13.52%	24.95%	85%
Water	2.89%	4.98%	72%	0.49%	0.94%	91%
Wetlands	10.51%	7.09%	-33%	3.28%	6.13%	87%

NJ Dept. Of Environmental Protection, Bureau of GIS- 1986, 2020, GIS Data Layer.

The development of urban and suburban areas necessitates additional infrastructure for stormwater management. In the past, this meant drainage pipes and ditches designed to swiftly divert stormwater away from properties. Similarly, some agricultural lands still employ tile drainage and swale infrastructure to quickly disperse runoff from fields. These developments contribute to flashy watershed hydrology, characterized by streamflow that quickly rises and falls in response to storm events. Consequently, this phenomenon leads to streambank erosion, unstable channel conditions, and increased sedimentation and habitat degradation within streams.

The priority in stormwater management has evolved over time. As stated above, initially, stormwater infrastructure was developed to quickly move water from unwanted areas, such as fields or parking lots, to streams, but this led to flooding hazards. Later, the focus shifted to attenuation, controlling the rate of stormwater release to streams, which still caused flooding in poorly managed areas and offered no water quality benefits. Now, the emphasis is on green stormwater infrastructure (GSI) and improving water quality, while still considering attenuation. This approach filters and cleans the stormwater while gradually moving it to groundwater and the nearest water body.

7.1 Pathogens

The presence of fecal coliform and *E. coli* serves as indicators of pathogens in waterways. Typically, both human and animal waste are sources of these pathogen indicators within water systems. The Musconetcong River is designated for primary contact recreation in all its lakes and streams. For primary contact, the SWQS were updated in December 2023.

Data collected in summer 2021 (20 consecutive weeks, 9 sites, both wet and dry weather) show persistent exceedances of these standards. All but one site failed the geometric mean criterion, and all sites exceeded the statistical threshold value. Tributary sites such as Hances Brook (HB) and Watters Rd (WR) were especially elevated, with geometric means over 1,000 cfu/100 mL and high frequency of excursions, resulting in all monitored sites failing to support recreational use (Section 6.2.1).

In addition to bacterial counts, MSU MST data was used to ascertain contamination sources. Results clearly indicated that human contributions were the most significant, far surpassing cows, with Canada geese contributing minimally. The primary source of human bacteria was determined to be on-site sewage disposal systems (septic systems). Factors include limited sewer coverage, aging infrastructure (25–30 year lifespan), and high system density near streams. The GWLF-E model estimates septic systems contribute ~10% of the total pathogen load, while farm animals account for ~80%, especially in the middle watershed. Hances Brook and Watters Rd tributary consistently showed both high *E. coli* and human MST markers, identifying them as hotspots for follow-up BMP implementation.

7.2 Temperature

While discrete in-situ temperature measurements did not indicate thermal stress, continuous data from live sensors revealed otherwise. Using the trout maintenance daily temperature standard as a benchmark, monitoring showed that thermal exceedances occur regularly under certain conditions. At Hampton Borough Park (EnviroDIY Station 16-4-HP), stream temperatures exceeded 25 °C on 83 days between June and September 2022, compared to only 4 days in 2023 and 23 days in 2024. These results indicate recurring thermal stress in portions of the watershed, particularly during dry, hot summers when baseflows are low and riparian shading is reduced. Increased impervious cover and diminished riparian buffers amplify these effects by directing warm stormwater into channels and allowing greater solar heating of the stream surface.

7.3 Sediment

Streambank erosion is the dominant contributor to sediment loads in the Musconetcong watershed, consistent with broader studies. Although some erosion is natural, increases in precipitation intensity and frequency of high-flow events have accelerated bank failure. In New Jersey, for example, model forecasts and State “Climate of the State” studies show a rising frequency of high-intensity storms, which are expected to increase runoff and erosion rates (Neverman et al., 2023; Rutgers Climate Institute, 2023; Tufekcioglu et al., 2024). Sediment movement is also strongly linked to agricultural practices, especially bare fields post-harvest.

Monitoring in 2021 found six exceedances of the FW2-TP/TM TSS criterion (25 mg/L). The downstream main stem site (HT) exceeded twice (>35 mg/L), and three tributary sites (HR, WR, ST) also exceeded, with WR influenced by culvert construction during the study. These findings underscore the need for targeted sediment management, even though sediment itself is not listed as an impairment upstream of the Delaware.

7.4 Nutrients

Phosphorus, though essential in small amounts, is a driver of eutrophication when excessive. In the Musconetcong watershed, most phosphorus loading is tied to sediment transport from bank erosion and bare soils. Hay/pasture lands are the largest land-use source, with urban runoff contributing about 5%. Malfunctioning septic systems add another ~4% to the annual load.

During the 2021 monitoring, phosphorus was measured weekly along with bacteria, TSS, and in-situ parameters. Concentrations correlated with sites experiencing sediment and pathogen issues,

indicating overlapping stressors. Tributary sites with agricultural and septic influences (e.g., WR, HB, HR) were especially elevated. These data confirm that phosphorus sources mirror those of sediment, reinforcing the need for integrated BMPs addressing both.

Table 7.4.a Loading for sediment and total phosphorus per land use classification

Land Cover	Total Phosphorus (TP) Load (lbs/acre/yr)	Total Suspended Solids (TSS) Load (lbs/acre/yr)
High, Medium Density Residential	1.4	140
Low Density, Rural Residential	0.6	100
Commercial	2.1	200
Industrial	1.5	200
Urban, Mixed Urban, other Urban	1	120
Agriculture	1.3	300
Forest, Water, Wetlands	0.1	40
Barren Land/Transitional Areas	0.5	60

Table 7.4.b Pollutant Loads for Project Area for Total Phosphorus and Total Suspended Solids

General Use Categories	Area (acres)	TP (lbs/yr)	TSS (lbs/yr)
Agriculture	11,902.55	15,473.32	3,570,765.00
Barren Land	209.63	104.82	12,577.80
Forest	17,209.62	1,720.96	688,384.80
Urban	10,760.91	11,837.00	1,366,635.57
Water	403.70	40.37	16,148.00
Wetlands	2,642.87	264.29	105,714.80
Totals	43,129.28	29,440.75	5,760,225.97

7.5 pH and Other Parameters

In addition to the pollutants of concern, pH, dissolved oxygen, and conductivity were tracked. pH limits for FW2 waters are 6.5–8.5. Historically, exceedances were acidic (<6.5), but in 2021, exceedances occurred on the alkaline side. HR recorded 8.65, WR exceeded twice, and HB measured 8.55. Potential sources include wastewater effluent, agricultural lime, or deteriorating infrastructure. While not as consistently elevated as pathogens or sediment, these readings warrant further investigation.

8.0 Criteria # 2 - Required Load Reductions

For all impaired streams throughout the United States, the U.S.EPA requires the development of a TMDL for each pollutant of concern. A TMDL establishes the maximum amount of a pollutant that a waterbody can receive and still meet applicable water quality standards and allocates that allowable load among point and nonpoint sources within the watershed.

The NJDEP has adopted and approved a TMDL for fecal coliform in the Musconetcong River. As a result, this parameter has been moved to Sublist 4a of the Integrated Report. The TMDL requires 93% reductions in nonpoint source fecal coliform loads from medium- and high-density residential, low-density and rural residential, commercial, industrial, mixed urban/other urban, and agricultural lands.

Because fecal coliform is often indicative of broader nonpoint source pollution, achieving these reductions will also contribute to improvements in other pollutants of concern, such as nutrients and sediment. To quantify potential pollutant reductions, a planning-level analysis was performed for key BMPs identified for implementation under this plan.

8.1 Load Reduction Estimation Approach

Reductions were derived from multiple technical sources, as no single reference provides comprehensive removal rates for all BMPs across agricultural, suburban, and urban land uses. Where possible, reductions were aligned with existing NJDEP-approved MapShed/GWLF-E model simulations and supplemented with removal efficiencies drawn from the NJDEP Stormwater Best Management Practices Manual (2024), PA Stormwater BMP Manual (2006), and the Minnesota Stormwater Manual (2023).

The NJDEP Stormwater BMP Manual provides robust data for TSS and TP, but limited data for bacteria. Therefore, phosphorus reductions were estimated directly where coefficients were available or inferred from corresponding TSS reduction rates when necessary. For fecal coliform, only those BMPs with published bacterial removal efficiencies were assigned reduction factors; other BMPs were noted as qualitative contributors toward achieving the TMDL target.

8.2 Baseline Loads and Land Use Assignments

Baseline annual pollutant export rates were calculated from the watershed's land use analysis, which identified total area and annual loadings by general category. Only Agriculture and Urban categories were used in the reduction calculations, as these represent the predominant anthropogenic sources targeted by implementation projects.

- **Agriculture baseline:** 0.0013 lb TP/ac/yr and 300 lb TSS/ac/yr

Urban baseline: 0.0011 lb TP/ac/yr and 127 lb TSS/ac/yr. Each BMP was linked to a corresponding baseline category based on its type and likely area of implementation—for

example, Cover Crops, Grazing Management, and Nutrient Management were assigned to Agricultural land use, while Rain Gardens, Bioswales, and Permeable Pavers were assigned to Urban land use. The Regional Composting Facility was left out of the load reduction calculation as it isn't a defensible, stand-alone percent reduction. In both MapSheds/GWLF-E and the Minnesota Agricultural BMP Handbook, a composting facility is treated as a source-reduction/manure-management action, not an edge-of-field treatment with a fixed TP/TSS "removal rate."

8.3 Standardization of BMP Units

To maintain consistency across BMPs, each practice was assigned a representative or "standard" design footprint or linear extent based on the NJDEP BMP Manual, design guidance, and field implementation experience within the Musconetcong watershed. These standardized assumptions are summarized below:

Table 8.3 Standardization of best management practices for unit calculations

BMP Type	Standard Unit	Conversion to Area (ft² / acres)
Rain Gardens	200 ft ² per unit	392 units = 78,400 ft ² (1.8 ac)
Roadside Ditch Retrofits	300 ft ² per unit	50 units = 15,000 ft ² (0.34 ac)
Detention Basin Retrofits	1,000 ft ² per unit	5 units = 5,000 ft ² (0.11 ac)
Permeable Pavers	2,500 ft ² per unit	50 units = 125,000 ft ² (2.87 ac)
Bioswales	1,000 ft ² per unit	12 units = 12,000 ft ² (0.28 ac)
Heavy Use Area Protection	3,900 ft ² per unit	2 units = 7,800 ft ² (0.18 ac)
Conservation Buffers on Agricultural Land	30-ft average width	12,451 linear ft = 373,530 ft ² (8.57 ac)
Vegetative Buffers on Developed Land	10-ft average width	55,236 linear ft = 552,360 ft ² (12.68 ac)
Livestock Access Control	30-ft corridor width	24,902 linear ft = 747,060 ft ² (17.15 ac)

Where BMPs were non-area based (e.g., Manure Management Systems, OSDS upgrades), reductions were calculated per treated system or described qualitatively due to limited quantifiable data.

8.4 Pollutant Removal Efficiencies

Each BMP was assigned a TSS, TP, and (where available) bacteria removal percentage using the midpoint of published ranges (Hsu, M. et al, 2019) to provide a conservative yet realistic planning-level estimate.

For example, a TSS range of 40–60% was standardized to 50%, and a TP range of 60–80% was standardized to 70%.

In cases where BMPs function in sequence (e.g., Parking Lot Diversions routed to a Bioswale and Naturalized Basin), a treatment train efficiency was calculated using the compounding formula:

$$\text{Overall Reduction} = 1 - (1 - R_1)(1 - R_2) \quad \{ \text{Overall Reduction} \} = 1 - (1 - R_1)(1 - R_2)$$

where R_1 and R_2 are the fractional removal rates of the individual BMPs. For example, a bioswale (85% TP) followed by a naturalized basin (60% TP) yields an overall TP reduction of 94%.

8.5 Implementation Goals

An analysis of each land use category was conducted, and with input from the Technical Advisory Committee, a balanced midpoint was established between aspirational targets and practical implementation capacity. The following table presents the total goal for each proposed BMP within its applicable land use type.

Table 8.5 Implementation goals for best management practices

Types of BMP Projects		Implementation Goal	
		%	Unit
1	Cover Crop	75	3905 acres
2	Prescribed Grazing	50	400 acres
3	Livestock Access Control	90	22412 ft
4	Nutrient Management	75	3905 acres
5	Conservation Buffers on Agricultural Land	50	12451 ft
6	No till	75	3905 acres
7	Regional Livestock Waste Storage and Composting Structure	100	1 unit
8	Manure Application Incorporation Technology	75	310 acres

9	Heavy Use Area Protection	66	2 units
10	Rain Gardens	50	392 units
11	Roadside Ditch Retrofitting	50	50 units
12	Detention Basin Retrofitting	50	5 units
13	Vegetative Buffers on Developed Land	40	55,236 ft
14	Permeable Pavers	50	50 units
15	Bioswales	50	12 units
16	Parking Lot Diversions	50	25 units
17	OSDS Inspection and Maintenance	80	2,600 units
18	Failed OSDS Retrofitting	40	65 units

8.6 Calculation of Load Reductions

Reductions were calculated using the following equation:

$$\text{Load Reduction (lbs/yr)} = \text{Area (acres)} \times \text{Baseline Load (lbs/ac/yr)} \times \text{Removal Efficiency (\%)} / 100$$

$$\text{Load Reduction (lbs/yr)} = \text{Area (acres)} \times \text{Baseline Load (lbs/ac/yr)} \times \frac{\text{Removal Efficiency (\%)}}{100}$$

Results represent annualized pollutant reductions expressed in pounds per year (lbs/yr). All values are planning-level estimates assuming proper design, installation, and maintenance.

Summary of Assumptions

- Areas and linear extents represent realistic planning-level implementation targets, not finalized engineering footprints.
- Midpoint removal efficiencies represent average expected performance based on literature and NJDEP manual values.
- Calculations do not adjust for overlapping benefits or background attenuation between BMPs.
- Results focus on manageable, anthropogenic sources, excluding reductions from natural or undeveloped areas.

Table 8.6.a Load reduction coefficients for BMPs and source of information

Best Management Practice	TSS Reduction %	TP Reduction %	Bacteria Reduction %	Source TSS	Source TP	Source Bacteria
Cover Crop	40-60	15		Minnesota Agricultural BMP Handbook (2017), Appendix B – Cover Crops	Minnesota Agricultural BMP Handbook (2017), Appendix B – Cover Crops	
Prescribed Grazing	75		80	Minnesota Agricultural BMP Handbook (2017), Appendix B – Prescribed Grazing		Peterson, Redmon & McFarland (2011b)
Livestock Access Control	75		≈99	Minnesota Agricultural BMP Handbook (2017), Appendix B – Fences & Use Exclusion		Minnesota Agricultural BMP Handbook (2017), Appendix B – Fences & Use Exclusion
Nutrient Management		35			Minnesota Agricultural BMP Handbook (2017), Appendix B – Nutrient Management	
Conservation Buffers on Agricultural Land	76	59	71	Minnesota Agricultural BMP Handbook (2017), Appx B/Table 13 – Buffers	Minnesota Agricultural BMP Handbook (2017), Appx B/Table 13 – Buffers	Minnesota Pollution Control Agency (2009) and Peterson et al. (2012b)
No till	78	69		Minnesota Agricultural BMP Handbook (2017), Appx B/Table 13 – No-till	Minnesota Agricultural BMP Handbook (2017), Appx B/Table 13 – No-till	
Regional Livestock Waste			97-99		Virginia Department of Environmental	

Storage and Composting Structure					Quality (2003) and Redmon, Wagner & Peterson (2012)	
Manure Application Incorporation Technology		≈93 (subsurface injection)			Minnesota Agricultural BMP Handbook (2017), Appx B/Table 13 – Manure subsurface injection	
Heavy Use Area Protection	80			Minnesota Agricultural BMP Handbook (2017), Appendix B – Heavy Use Area Protection		
Rain Gardens	80-90	85	60-90	New Jersey Stormwater Best Management Practices (BMP) Manual. Ch. 9.7 Small-Scale Bioretention; Ch. 10.1 Large-Scale Bioretention	PA -Chapter 6 “Water Quality Functions.” Also summarized in Appendix A Table A-4.	Minnesota Stormwater Manual – Bioretention performance
Roadside Ditch Retrofitting	≤50	50	30-70	New Jersey Stormwater Best Management Practices (BMP) Manual. Ch. 9.3 Grass Swales	PA-Appendix A Table A-4 (swales).	Minnesota Stormwater Manual – Vegetated swales
Detention Basin Retrofitting	Extended detention basin 40–60; Wet Pond: 50–90	60	40-60	New Jersey Stormwater Best Management Practices (BMP) Manual. Ch. 9.4 Extended Detention Basins; Ch. 9.11/10.5 Wet Ponds	PA- Appendix A Table A-4.	Minnesota Stormwater Manual – Wet sedimentation basins
Vegetative Buffers on Developed Land	60-80	20	50-70	New Jersey Stormwater Best Management Practices (BMP)	PA - Chapter 6 “Water Quality Functions” for	Minnesota Stormwater Manual – Filter strips

				Manual. Ch. 9.10 Vegetative Filter Strips	filter strips; also in Table A-4.	
Permeable Pavers	80	85	60-80	New Jersey Stormwater Best Management Practices (BMP) Manual. Ch. 9.6 (current) / archived Ch. 9.7 Pervious Paving	PA - Appendix A Table A-4 entry "Porous Pavement with Infiltration Bed."	Minnesota Stormwater Manual – Permeable pavement
Bioswales	80-90	85	50-80	New Jersey Stormwater Best Management Practices (BMP) Manual. Ch. 9.3 Grass Swales; Ch. 10.1 Bioretention	PA - Appendix A Table A-4.	Minnesota Stormwater Manual – Biofiltration swales
Parking Lot Diversions	if diverted to bioretention, use 80–90; to filter strip, use 60–80	if diverted to bioretention, use 80–90; to filter strip, use 60–81	Use receiving BMP	New Jersey Stormwater Best Management Practices (BMP) Manual. Use chapter for downstream BMP	New Jersey Stormwater Best Management Practices (BMP) Manual. Use chapter for downstream BMP	
OSDS Inspection and Maintenance					Modeled with GWLF-E	Modeled with GWLF-E
Failed OSDS Retrofitting					Modeled with GWLF-E	Modeled with GWLF-E

Table 8.6.b: Estimated Annual Load Reductions on Applicable Land for Implementation Goals for TP and TSS

Best Management Practice	Land Use	Area (acres)	TP reduction (lbs/yr)	TSS reduction (lbs/yr)
Cover Crop	Agriculture	3905.00	761.48	585750.00

Prescribed Grazing	Agriculture	400.00		90000.00
Livestock Access Control	Agriculture	17.15		3858.78
Nutrient Management	Agriculture	3905.00	1776.78	
Conservation Buffers on Agricultural Land	Agriculture	8.58	6.58	1955.12
No Till	Agriculture	3905.00	3502.79	913770.00
Manure Application Incorporation Technology	Agriculture	310.00	374.79	
Heavy Use Area Protection	Agriculture	0.18		42.98
Rain Gardens	Urban	1.80	1.68	194.29
Roadside Ditch Retrofitting	Urban	0.34	0.19	10.93
Detention Basin Retrofitting	Urban	0.12	0.08	9.48
Vegetative Buffers on Developed Land	Urban	12.68	2.79	1127.29
Permeable Pavers	Urban	2.87	2.68	291.55
Bioswales	Urban	0.28	0.26	29.74
Failed OSDS Retrofitting	Urban	NA	267.30	
Total			6,697.40	1,597,040.16

Table 8.6.c Estimated Load Reductions combined with projected Implementation Schedule (TP, TSS)

Pollutant	Year 2	Year 5	Year 10
Total TP (lbs/yr)	1,245.21	4,412.71	6,686.51
Total TSS (lbs/yr)	219,084.97	1,048,682.89	1,596,652.22

Table 8.6.d Estimated Bacterial Load Reductions

BMP	Area (acres)	Bacteria % midpoint	Est. Bacteria Reduction (cfu/yr)
Cover Crop	3905		
Prescribed Grazing	400	80	5.440e+12
Livestock Access Control	17.15	99	2.886e+11
Nutrient Management	3905		
Conservation Buffers on Agricultural Land	8.575	71	1.035e+11
No Till	3905		
Regional Livestock Waste Storage and Composting Structure		98	Per-system BMP; needs system- level baseline (cfu/system/yr).
Manure Application Incorporation Technology	310		Highly variable due to application timing
Heavy Use Area Protection	0.179		
Rain Gardens	1.8	75	3.510e+10
Roadside Ditch Retrofitting	0.344	50	4.477e+09
Detention Basin Retrofitting	0.115	50	1.492e+09
Vegetative Buffers on Developed Land	12.68	60	1.978e+11
Permeable Pavers	2.87	70	5.223e+10
Bioswales	0.275	65	4.656e+09
Parking Lot Diversions		81	Depends on BMPs used downstream

8.7 OSDS Loading and Reductions

To estimate bacteria loading from OSDS, a planning-level calculation was developed based on the estimated number of homes contributing to nonpoint fecal contamination within the focus area. It was assumed that approximately 5% of all homes in the study area have leaky or failing septic systems, resulting in an estimated 163 affected households. Each home was assumed to discharge an average of 200 gallons of wastewater per day, equivalent to approximately 276,000 liters per year. Septic effluent concentrations for *E.coli* were derived from published literature and NJDEP-supported microbial source tracking studies, which report effluent concentrations ranging from 10^5 to 10^7 cfu per 100 mL. A midpoint concentration of 10^6 cfu/100 mL (1×10^7 cfu/L) was used for planning purposes.

Table 8.7.a: Loading scenarios with a 5% leaky septic system assumption

% Bacteria reaching stream	Per-home load (mid, cfu/yr)	Per-home load (low, cfu/yr)	Per-home load (high, cfu/yr)	Total load for 163 homes (mid, cfu/yr)	Total load for 163 homes (low, cfu/yr)	Total load for 163 homes (high, cfu/yr)
15	4.15E+11	4.15E+10	4.15E+12	6.76E+13	6.76E+12	6.76E+14
40	1.11E+12	1.11E+11	1.11E+13	1.80E+14	1.80E+13	1.80E+15
80	2.21E+12	2.21E+11	2.21E+13	3.60E+14	3.60E+13	3.60E+15
100	2.76E+12	2.76E+11	2.76E+13	4.50E+14	4.50E+13	4.50E+15

Table 8.7.b: Reduction Scenario with 40% OSDS Retrofit

% Bacteria reaching stream	Baseline Delivered Load (cfu/yr)	Post-Implementation Delivered Load (cfu/yr)	Absolute Reduction (cfu/yr)	Percent Reduction of Baseline (%)
15	6.76E+13	4.33E+13	2.43E+13	35.9
40	1.80E+14	1.16E+14	6.47E+13	35.9
80	3.60E+14	2.31E+14	1.29E+14	35.9
100	4.50E+14	2.89E+14	1.62E+14	35.9

Pollutant Reduction Summary

Based on the compiled BMP implementation targets and modeled efficiencies, the proposed actions within the watershed are projected to achieve substantial pollutant load reductions across all parameters of concern. The cumulative TSS reduction goal is estimated at approximately 1,597,040 lbs per year or 799 tons. The TP reduction goal is estimated at 6,697 lbs per year.

For bacteria, the combined reductions from agricultural livestock exclusion, riparian buffer expansion, urban stormwater retrofits, and onsite wastewater (OSDS) improvements, including the retrofit of failing septic systems and implementation of inspection and maintenance programs, represent a total annual reduction on the order of 10^{15} cfu per year under midrange delivery conditions, according to modeling by MapSheds. These pollutant load reductions collectively demonstrate measurable progress toward achieving the watershed's restoration goals and meeting the fecal indicator bacteria TMDL targets established for the Musconetcong River.

9.0 Criteria #3 - Management Measures and Targeted Critical Areas

A range of management measures are recommended to reduce the impacts of pathogens, temperature, nutrients, and sediment on stream corridors and to restore watershed hydrology. Monitoring data and desktop analyses were used to delineate targeted critical areas where implementation of BMPs will most effectively address pollutant sources and achieve compliance with the New Jersey Surface Water Quality Standards and designated uses. Many of the BMPs described provide concurrent benefits across multiple pollutants of concern; however, each has been placed within the section where it offers the most direct and measurable improvement.

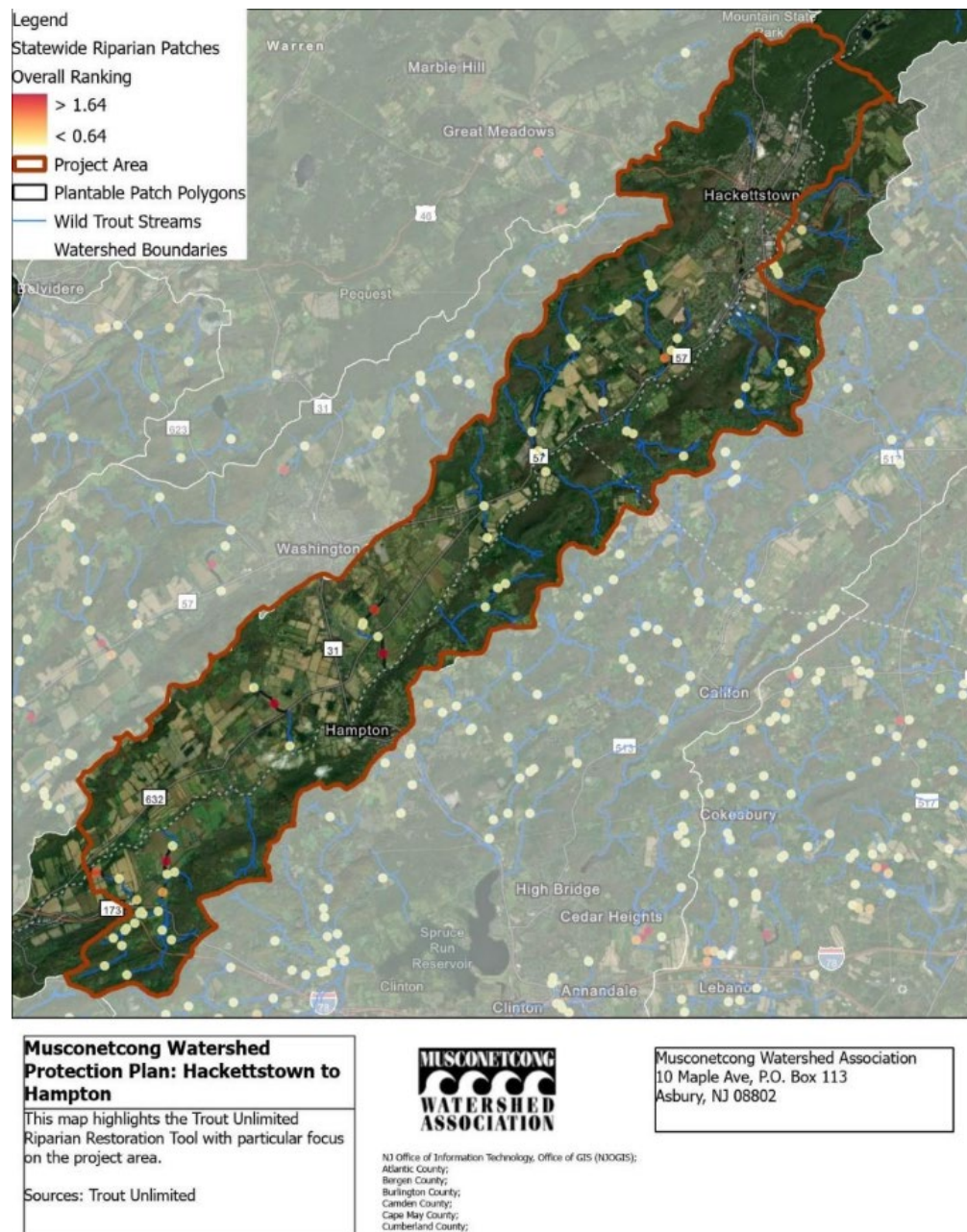
9.1 Temperature

Continuous in-stream sensors and discrete sampling were evaluated against trout maintenance standards. Elevated thermal conditions were linked to riparian canopy loss, reduced baseflow, and channel modification. In addition to monitoring data, Trout Unlimited (TU) developed a mapping tool to identify segments of New Jersey's 1,480 miles of trout production waters that may benefit from riparian buffer installation see Map 9.1 below. Buffers can reduce stream temperatures, decrease allochthonous inputs, and slow incoming runoff, which benefits our wild fish, especially in headwater streams.

TU's mapping tool identified potential planting patches within a 35ft stream buffer by intersecting 'restorable' land uses from NJ's 2015 land use/land cover dataset with low vegetation or barren cover types from the Delaware basin counties' fine-scale (1m) landcover dataset. TU then prioritized patches across the state, with larger patches and those with fewer landowners per patch ranking highest.

Patches were further assessed in the Delaware basin by reviewing patch imagery, position in the stream network, and anticipated benefit to wild trout. In all, 366 potential patches were narrowed in the Delaware to 46 candidate projects potentially impacting about 7 stream miles. In the entire Musconetcong Watershed, there is one "High-priority" and three "Medium-priority" projects identified. The "High-priority" project is an unnamed tributary that enters the Musconetcong River parallel to New Hampton Rd in Washington Twp, Warren County. Using this tool, we successfully advanced this "High-priority" project into implementation, completing a riparian buffer planting at the site as this plan was being developed.

Map 9.1 TU Riparian Restoration Tool



9.2 Bacteria

E. coli data were analyzed against the NJ SWQS for recreational use. Two subwatersheds exhibited chronic exceedances: Hances Brook and the Watters Road tributary. Both sites consistently exceeded the SWQS geometric mean and single-sample maximum criteria, as well as the STV, with Hances Brook producing “off-the-chart” values in multiple sampling events. These elevated concentrations suggest persistent nonpoint bacterial sources such as failing or poorly maintained septic systems, livestock access to streams, and insufficient riparian filtration along developed or agricultural

reaches. In addition to current monitoring results, historical data from previous NJDEP monitoring efforts, available through the Bureau of Freshwater and Biological Monitoring (BFBM) sampling inventory website, were also reviewed to help identify and refine critical areas within the focus area (NJDEP, Bureau of Freshwater and Biological Monitoring, 2024).

9.3 Total Suspended Solids (TSS)

Elevated TSS was co-located with high bacteria levels at Hances Brook and the Watters Road tributary, indicating sediment mobilization from eroding streambanks and upland runoff. Increased sediment loads can serve as bacterial transport mechanisms and contribute to habitat degradation.

9.4 Total Phosphorus (TP)

Total phosphorus concentrations were generally below threshold values for concern and are not currently a dominant impairment driver. However, continued monitoring will track nutrient dynamics to ensure that restoration activities do not inadvertently increase nutrient export. Adaptive management will incorporate nutrient controls if future data indicates upward trends.

9.5 Management Measures

9.5.1 Management Measures to Reduce Temperature

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

- Conservation buffers/Vegetative buffers - Planting native trees, shrubs, and grasses along riverbanks and stream corridors creates riparian buffers that provide shade, lowering water temperatures by blocking direct sunlight. These vegetated zones stabilize streambanks, reduce erosion and sedimentation, and filter pollutants and runoff before they enter the waterway. Together, riparian vegetation and streamside buffers improve water quality, regulate temperature, and enhance habitat along the river corridor.
- Detention Basin Retrofitting – The detention basin captures a large amount of stormwater runoff from medium and low density developed areas to temporarily capture and slowly release runoff, reducing peak flows and downstream flooding. When retrofitted or naturalized with vegetation, they promote infiltration, support groundwater recharge, and restore more natural hydrologic patterns. These basins also provide secondary benefits, such as lowering water temperature and improving water quality by allowing sediment and nutrients to settle before discharge. In addition, a properly designed detention basin retrofit can function like a bioretention basin or constructed wetland, reducing pathogen loads to streams, with bioretention retrofits capable of filtering up to 95% of bacteria (Minnesota Stormwater Manual, 2025). However, the watershed is heavily underlain with karst, and this BMP should be thoroughly examined before being considered. Reducing impervious surfaces- Reducing impervious surfaces in urban and suburban areas or replacing them with low-impact development (LID) practices such as pervious pavers, rain gardens, bioswales, parking lot diversions, and naturalized detention basins, helps reduce the volume and temperature of runoff reaching rivers and streams. These systems capture and infiltrate stormwater close to its source, filtering pollutants and minimizing thermal loading.

- Groundwater source protection- Identifying and protecting groundwater inputs into the river are crucial. By controlling land use activities within these areas, the risk of pollution, including thermal pollution, can be minimized.
- Restoring natural hydrology- Restoring natural flow patterns, such as reconnecting floodplains, reestablishing wetlands, and removing in-stream barriers, helps moderate water temperatures and improve overall watershed function by allowing cooler groundwater to recharge streams and rivers. BMPs that support this approach include dam removals, floodplain reconnection projects, culvert replacements designed for aquatic organism passage, and wetland or floodplain restoration using natural channel design. These practices enhance baseflow, reduce thermal and sediment stress, and restore habitat connectivity essential for fish migration and stream ecosystem resilience. In addition to large-scale restoration efforts, smaller-scale BMPs such as rain gardens, bioswales, vegetated buffers, and naturalized detention basins can also help restore more natural hydrologic patterns by increasing infiltration, promoting groundwater recharge, and reducing the volume and temperature of stormwater entering streams.
- Thermal discharge regulations- Thermal discharges from wastewater treatment plants and industrial facilities can elevate stream temperatures, affecting aquatic life and overall water quality. Existing regulations, including the New Jersey Surface Water Quality Standards (N.J.A.C. 7:9B), already establish temperature criteria that dischargers must meet to protect designated uses such as trout production and maintenance. This plan emphasizes identifying and assessing existing thermal discharges within the watershed to determine their contribution to temperature impairments. Where elevated temperatures are documented, data should be used to inform a TMDL or other enforcement actions under the NJPDES permitting process. Coordinating with NJDEP to evaluate effluent temperatures and encourage cooling or flow management practices at permitted facilities will help reduce localized thermal impacts and support attainment of water quality standards.

9.5.2 Management Measures to Reduce Bacterial Loads (*E. coli*)

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

- OSDS Management- Effective management of OSDSs will play a crucial role in reducing bacterial loading within the watershed. This aspect presents significant challenges, as septic systems are predominantly situated on private lands, often with subsurface issues that are difficult to detect externally. The density of septic systems and their proximity to waterways can exacerbate bacterial loading concerns. Despite the challenges, adopting basic stewardship practices can mitigate some of these issues. Regular inspections of tanks and leach fields, along with adherence to maintenance and best management practices such as routine pump outs, preventing field compaction, redirecting runoff from the system, and limiting vegetation to lawn grass, are essential. Moreover, avoiding septic system additives and refraining from disposing of non-degradable materials are critical measures. As systems in the watershed approach the end of their typical 25–30-year OSDS lifespan (EPA, 2005), repairs, replacements, and new construction must be prioritized and aligned with evolving septic design and placement rules to minimize impacts. Enhanced performance is achieved through the mandated use of

two-chamber tanks, while a robust permitting and review process is pivotal. Community education and outreach efforts are indispensable in promoting best management practices. While not directly part of septic management, expanding sanitary sewer services and detecting and addressing illicit discharges contribute significantly to controlling bacterial and nutrient loading associated with OSDSs.

- **Sewer Infrastructure Maintenance in Sewer Service Areas (SSAs)** – Proper management of sanitary sewer systems within designated Sewer Service Areas is essential to reducing bacteria and nutrient loading in the watershed. Leaks, overflows, and cross-connections can introduce untreated wastewater into surface waters, particularly during wet-weather events. Regular inspection, cleaning, and repair of collection lines, manholes, and pump stations are critical to maintaining capacity and preventing sanitary sewer overflows. Municipalities should maintain up-to-date asset management plans, conduct condition assessments using CCTV inspections, and implement inflow and infiltration (I/I) reduction programs through targeted lining, sealing, and rehabilitation. Coordination with MS4 programs ensures that illicit sanitary discharges to stormwater systems are identified and corrected through mapping, dry-weather screening, and dye or smoke testing. Preventive maintenance schedules and documentation of completed repairs help meet both NJPDES and Tier A MS4 permit requirements. Long-term planning should include evaluating system capacity to support growth, prioritizing upgrades in areas with recurring SSO or I/I issues, and ensuring consistency with local Water Quality Management Plans. Collectively, these actions prevent untreated wastewater releases, protect receiving waters, and support overall compliance with state water quality standards.
- **Stormwater Management-** Stormwater management encompasses a diverse array of techniques and structures aimed at effectively handling runoff from both permeable and impermeable surfaces while enhancing water quality to mitigate pollutant discharge into surface waters. Stringent regulation of stormwater management exists at both the State and local levels, enforced through various programs, laws, and ordinances. This regulatory focus is particularly pronounced in redevelopment or new development projects, emphasizing the utilization of Low Impact Development (LID) techniques to minimize stormwater loading from the outset. In areas with existing development or identified stormwater management issues, efforts concentrate on rectifying concerns by implementing a range of structural BMPs or retrofitting existing systems to enhance performance. Key performance metrics typically include reductions in solids, nutrients, bacteria, total flow, and peak rate. Major categories of stormwater management designs encompass stormwater ponds, wetlands, infiltration practices, filtering methods (vegetative buffers), permeable pavers and water quality swales.
- **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** – This plan calls for complete exclusion of livestock from the streams and the immediate riparian areas from pastureland with technical assistance and financial funding support. The exclusion of livestock primarily focuses on streams that pass directly through or are currently included in pastureland and shall not apply to temporary stream crossings for livestock.
- **Wildlife Management** – MST data from the 2021 study indicate that wildlife contributes only minimally to pathogen contamination in the watershed compared to other sources. This 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. This plan supports coordination with ongoing state and county wildlife management programs, including those led by the New Jersey Division of Fish and Wildlife, county Mosquito and Wildlife Control divisions, and local park agencies, to align population control and habitat management strategies with watershed goals. BMPs for wildlife management will focus on minimizing congregation and defecation in riparian zones and stormwater conveyances. Recommended practices include: installing vegetative buffers or taller native plantings along streambanks and detention basins to discourage geese from loafing; maintaining limited access to mowed turf near waterways; and using deterrents such as fencing, trained canines, or visual and acoustic repellents in areas of chronic congregation. For deer, targeted fencing, reforestation, and native shrub planting can reduce browsing pressure and minimize soil disturbance and vegetation loss that increase sediment transport.
- **Conservation or Vegetative Buffer** - Vegetated filter strips and riparian buffers help mitigate waste from livestock, pets, and wildlife by intercepting and filtering stormwater runoff before it enters waterways. On both agricultural and developed lands, these buffers reduce bacteria, sediment, and nutrient loads while stabilizing streambanks and moderating water temperature. Native grasses, shrubs, and trees should be used where feasible, with buffers at least 35 feet wide in accordance with NRCS and NJDEP guidance. Properly designed and maintained buffers can remove up to 70–90 percent of suspended solids and associated bacteria from runoff, providing measurable improvements in water quality.

9.5.3 Management Measures to Reduce Sediment (TSS)

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

- **Conservation Buffers** - Conservation buffers have multiple water quality benefits and reduce nutrient and 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. A recent trend of using a multi-functional

riparian buffer has emerged to incentivize their installation. These buffers incorporate a variety of vegetation types, including trees, shrubs, and grasses, to enhance their functionality beyond traditional erosion control and water quality improvement, including being another source of income. Types of products are: agroforestry (nuts, berries, pussy willows), non-timber forest products (mushrooms, syrups), forage and livestock products, and ecosystem services (carbon credits).

- No-till Agriculture - No-till agriculture significantly reduces soil erosion and sediment runoff by maintaining a permanent soil cover and minimizing soil disturbance. This practice helps to preserve soil structure, improve water infiltration, and increase organic matter in the soil. By avoiding plowing or tilling, no-till farming reduces the likelihood of soil particles being washed into streams during rainfall events.
- 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.
- Heavy Use Protection Areas (HUPAs) - HUPAs are stabilized zones in high-traffic locations such as livestock feeding, watering, or equipment areas where soil compaction and erosion are common. By using materials like gravel, concrete, or geotextile fabric, HUPAs prevent mud and sediment from entering nearby waterways. These areas reduce sediment and nutrient runoff, protect water quality, and improve site drainage and animal health.
- 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 must 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.

9.5.4 Management Measures to Reduce Nutrients

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

Integrated Crop Nutrient Management – Integrated Crop Nutrient Management (ICNM) ensures that fertilizers and soil amendments are applied at agronomic rates that meet crop needs while minimizing nutrient loss to surface and groundwater. Fertilizer applications should be based on realistic crop yield goals and site-specific soil nutrient analyses determined through annual soil testing. This data-driven approach helps prevent over-application of nitrogen and phosphorus, two key contributors to water quality degradation. Technical assistance programs within the watershed should promote soil testing, adaptive nutrient budgeting, and precision application methods such as split applications, incorporation of manure or fertilizers, and use of cover crops to capture residual nutrients. Farmers should be encouraged to participate in NRCS and NJRC&D programs that support nutrient management planning, recordkeeping, and certification. Implementing these practices will reduce nutrient runoff, improve soil health, and enhance long-term agricultural productivity while protecting local water resources.

- **No-Till Agricultural** - No-till agriculture is an effective practice for reducing nutrient pollution by maintaining a permanent soil cover and minimizing soil disturbance. This approach helps to retain soil nutrients, reduce runoff, and prevent nutrient loss. By avoiding plowing or tilling, no-till farming decreases the likelihood of nutrients, such as nitrogen and phosphorus, being washed into streams and water bodies during rainfall events.
- **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 ICNM 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** - This is a system that helps agricultural producers 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 nonpoint sources.

- Nutrient Management for Lawn Care – The Fertilizer Control Law, enacted in 2011, 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.

9.5.5 Management Measures to Restore Hydrology and Streamflow

Land use changes and associated stormwater infrastructure have significantly altered the hydrology of the Musconetcong River Watershed. 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 and improve water quality in the Musconetcong River Watershed.

- Bio-retention Systems – Bio-retention systems such as rain gardens, bioswales, and naturalized detention basins capture and treat stormwater close to its source, allowing pollutants to settle and infiltrate through vegetated soil media. These systems reduce runoff volume, improve water quality, and promote groundwater recharge. Converting traditional mowed or riprapped detention basins and wet ponds into naturalized basins planted with native vegetation enhances pollutant removal, moderates water temperature, and provides valuable habitat while reducing maintenance needs. Integrated across developed areas, these practices restore more natural hydrology and increase the watershed's overall resilience.
- 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.

- **Dam removals and Floodplain Restoration** - Removing obsolete or failing dams restores natural river flow, sediment transport, and aquatic habitat connectivity. Dam removal projects lower stream temperatures, reestablish natural sediment dynamics, and allow the river to reconnect with its floodplain, improving groundwater exchange and reducing flood risk. Associated floodplain restoration, through re-grading, native plantings, and wetland reconnection, enhances water storage and filtration during high-flow events. These combined actions moderate peak discharges, support baseflow, and promote a self-sustaining channel form. Strategic dam removals within the watershed will be prioritized where ecological benefits, sediment management, and community safety can all be achieved.
- **Constructed Wetlands** - Constructed wetlands are engineered systems designed to mimic the functions of natural wetlands by capturing, storing, and treating stormwater runoff. These systems slow flow, promote sedimentation, and remove nutrients and pathogens through biological and physical processes. Constructed wetlands also provide flood attenuation and create valuable wildlife and pollinator habitat. When sited near floodplains or at stormwater outfalls, they help restore more natural hydrologic patterns by enhancing infiltration and evapotranspiration. Properly designed wetlands planted with native wetland vegetation can achieve high pollutant removal rates while improving both ecological and aesthetic value within the watershed.
- **Culvert Replacements** - Undersized or perched culverts can obstruct fish movement, alter stream hydrology, and cause upstream flooding and erosion. Replacing these structures with appropriately sized, embedded, or open-bottom culverts restores natural stream gradients, improves flow conveyance, and maintains sediment continuity. Design standards should follow the New Jersey Department of Environmental Protection's *Stream Crossing Guidelines* and the U.S. Fish and Wildlife Service's *Aquatic Organism Passage* design criteria. Prioritization should focus on locations that reconnect the greatest length of upstream habitat, reduce localized flooding, and increase resilience to storm events while meeting transportation and infrastructure needs.

10.0 Criteria #4 Estimate Technical and Financial Assistance Needed

Table 10.0.a summarizes the scope and cost of the BMP projects recommended for achieving the water quality goals established for the watershed. Due to the scope, size, and complexity of the overall plan, not all management measures outlined under Criterion #3 are included in this cost analysis. Instead, this section focuses on the priority BMPs that are most feasible to implement within the current planning horizon and funding capacity. There are nine types of agricultural BMP projects, seven types of stormwater BMP projects and two types of OSDS BMP projects. The first column lists the recommended BMPs for various projects. The second column gives the amount of applicable area, length or units to which the BMP could be applied. The third column is the unit application cost of BMPs including installation, maintenance and other costs estimated

by the project team based on the best available sources and experiences of implementing those BMPs in the watershed and surrounding regions. The fourth column is the life span for each BMP, which is used to calculate the annual costs of BMP projects. The second to last column is the total cost of the recommended BMP project when it is applied to all applicable units in the watershed, which equals the product of the applicable unit and the unit cost. The last column is the annualized cost, which is the total cost divided simply by the life span.

The cost estimates and implementation lifespans presented in this table are planning-level approximations intended to represent typical unit costs and expected maintenance cycles for each BMP. Actual project costs will vary based on site-specific conditions, design complexity, permitting requirements, material and labor rates at the time of construction, and available funding sources. Estimates do not include administrative or contingency costs unless noted. Funding opportunities such as the New Jersey Water Bank, 319(h) Nonpoint Source Program, NRCS programs, and American Rescue Plan Act (ARPA)-derived infrastructure allocations may offset a portion of these costs, pending eligibility and program availability. Final budgets will be refined during project design and procurement phases.

The total cost for implementing the nine types of agricultural BMP projects is approximately \$5.9 million. These costs can be reduced when combined with multiple management practices, such as cover crops, nutrient management, and no-till agriculture, are used together. The total cost of all stormwater BMP projects is estimated at \$7.8 million. Retrofitting for stormwater should be performed in the “treatment train” approach to maximize water quality benefits. This approach starts with source control measures, such as permeable pavements and green roofs, to reduce runoff generation. After source control measures, a series of conveyance controls like bioswales and bioretention areas which, unlike their concrete-lined counterparts, promote infiltration and the steady movement of water through the system. It then includes end-of-pipe treatments such as constructed wetlands or detention basins to further treat the water before it is discharged into natural water bodies. By combining these varied practices, the treatment train approach effectively enhances water quality, reduces flood risks, and promotes the sustainable management of stormwater. The total cost of establishing the comprehensive OSDS inspection and maintenance programs and eliminating the failing OSDSs in the watershed is \$7.5 million. Implementing all recommended BMP projects is expected to achieve and even exceed the load reduction targets for TP, sediment and pathogens as specified in Table 12.0.a and restore the watershed hydrology in the Musconetcong River Watershed. Total implementation cost is estimated to be \$21 million.

Table 10.0.a Recommended BMP Projects for the Musconetcong River Watershed and associated costs

Types of BMP Project	Applicable Unit*	Unit Cost (\$/unit)	Life span (years)	Total Cost (\$)	Annualized Cost (\$/year)
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1. Cover Crop	5,207 acres	440	3	\$2,291,080.00	\$763,693
2. Prescribed Grazing	801 acres	563	5	\$450,963.00	\$90,193
3. Livestock Access Control	24,902 feet	15	10	\$373,530.00	\$37,353
4. Nutrient Management	5,207 acres	150	3	\$781,050.00	\$260,350
5. Conservation Buffers on Agricultural Land	24,902 feet	5	15	\$124,510.00	\$8,301
6. No Till	5,207 acres	32	3	\$166,624.00	\$55,541
7. Regional Livestock Waste Storage and Composting Structure	1 Unit	1,000,000	10	\$1,000,000.00	\$100,000
8. Manure Application Incorporation Technology	401 acres	198	1	\$79,398.00	\$79,398
9. Heavy Use Protection Area	3 Units	200,000	5	\$600,000.00	\$120,000
<i>A. Subtotal for Agricultural BMP Projects (1-9)</i>				\$5,867,155.00	\$1,514,829
10. Rain Gardens	785 Units	1,000	15	\$785,000.00	\$52,333
11. Roadside Ditch Retrofitting	100 Units	30,000	15	\$3,000,000.00	\$200,000
12. Detention Basin Retrofitting	10 Units	35,000	15	\$350,000.00	\$23,333
13. Vegetative Buffers on Developed Land	138,091 feet	5	15	\$690,455.00	\$46,030
14. Permeable Pavers	100 Units	25,000	25	\$2,500,000.00	\$100,000
15. Bioswales	25 Units	5,800	15	\$145,000.00	\$9,667
16. Parking Lot Diversions	50 Units	6,650	15	\$332,500.00	\$22,167
<i>B. Subtotal for Stormwater BMP Projects (9-16)</i>				\$7,802,955.00	\$453,530

17. OSDS Inspection and Maintenance	3,250 Units	800	2	\$2,600,000.00	\$1,300,000
18. Failed OSDS Retrofitting	163 Units	30,000	20	\$4,890,000.00	\$244,500
<i>C. Subtotal for OSDS Projects (16-17)</i>				\$7,490,000.00	\$1,544,500
<i>D. Total (A + B + C)</i>				\$21,160,110.00	\$3,512,859

*Due to the varying standard sizes of BMPs, certain assumptions were necessary to perform cost estimates. These assumptions are as follows:

- **Regional Livestock Waste Storage and Composting Structure:** Considered as one unit because it's a regional facility, and only one is needed in the watershed due to size variability.
- **Heavy Use Protection Area:** Heavy Use Protection Areas average 3,900 sq ft at \$51 per square foot, covering concrete and gravel application.
- **Rain Gardens:** Estimated at \$5 per square foot, with an average size of 200 sq ft, resulting in \$1,000 per unit.
- **Roadside Ditch Retrofitting:** Defined as a unit of 3 ft wide by 100 ft long (300 sq ft) at \$100 per sq ft, totaling \$30,000 per unit.
- **Detention Basin Retrofitting:** Calculated as \$35,000 per unit, with each unit covering 1,000 sq ft at \$35 per sq ft.
- **Permeable Pavers:** Installation averages \$10 per sq ft, with a typical unit being a sidewalk area of 2,500 sq ft, totaling \$25,000.
- **Bioswales:** One unit is 100 ft long and 9-16 ft wide, costing \$58 per sq ft, equating to \$5,800 per unit.
- **Parking Lot Diversions:** Average unit size is 70 sq ft at \$95 per sq ft, resulting in \$6,650 per unit.
- **OSDS Inspection and Maintenance:** Costs an average of \$800 for both inspection and maintenance.
- **Failed OSDS Retrofitting:** Replacement costs average \$50,000, with repairs at \$10,000, averaging \$30,000 for retrofitting.

Although all BMP projects are recommended, they vary in terms of cost, pollutant-removal performance, feasibility, and partner readiness. Therefore, BMPs in this plan are prioritized based on their demonstrated effectiveness in reducing pollutant loads, alignment with monitoring data, the availability of willing partners, overall project cost, and current grant funding opportunities. Table 10.0.b summarizes the resulting priority rankings. These rankings reflect a balanced consideration of both watershed needs and implementation practicality.

Table 10.0.b Summary of BMP and their priority ranking for each parameter

Types of BMP Project	Priority Rank in Reducing		
	Pathogen	Sediment	TP
1. Cover Crop		3	4
2. Prescribed Grazing	5	9	11
3. Livestock Access Control	3	6	5
4. Nutrient Management	8		2
5. Conservation Buffers on Agricultural Land	6	2	1
6. No-till	9	1	3
7. Regional Livestock Waste Storage and Composting Structure	6		13
8. Manure Application Incorporation Technology	4		10
9. Heavy Use Protection Area	10		12
10. Rain Gardens		10	14
11. Roadside Ditch Retrofitting		5	9
12. Detention Basin Retrofitting	11	8	6
13. Vegetative Buffers on Developed Land	7	4	7
14. Permeable Pavers			18

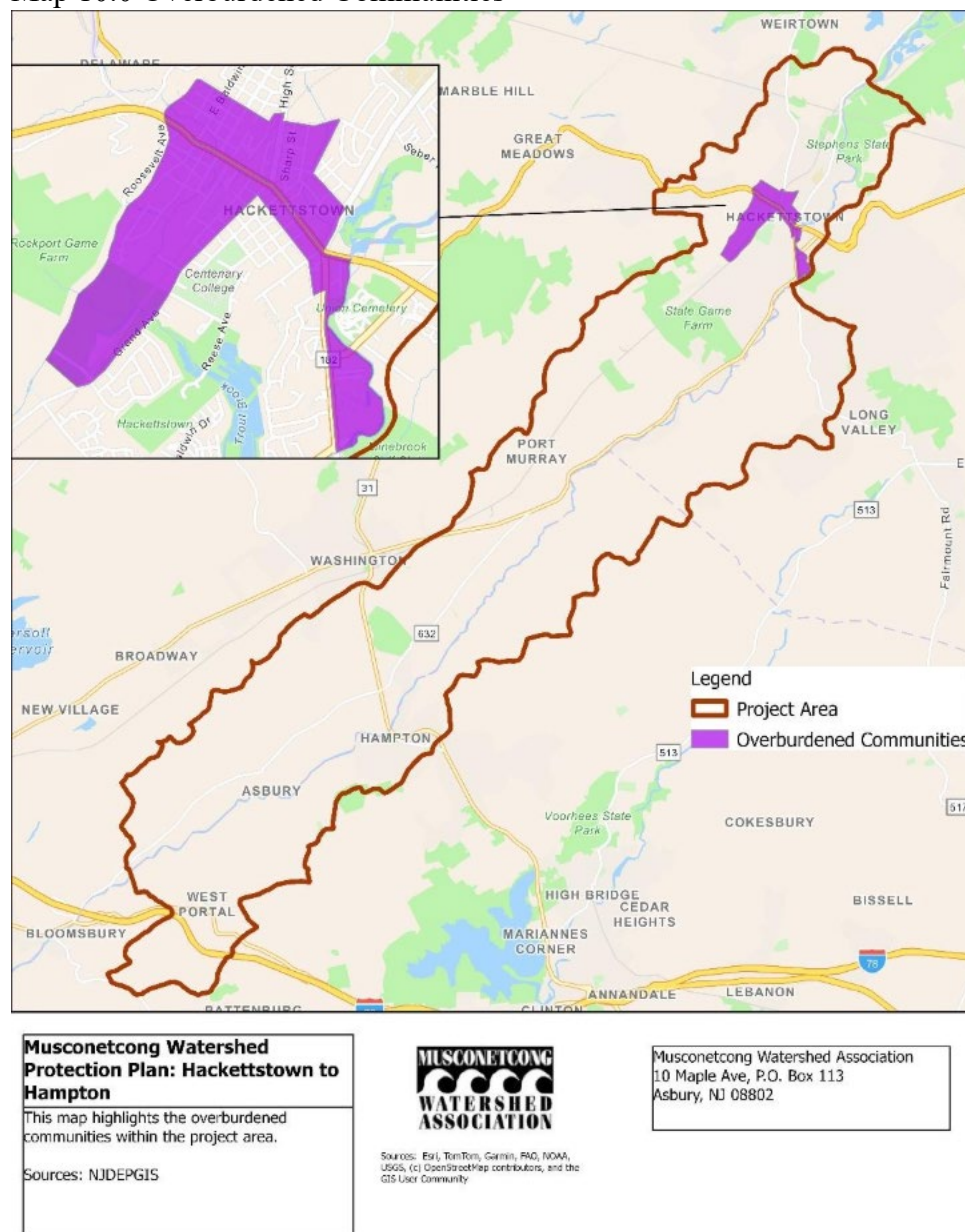
15.Bioswales	12	7	8
16.Parking Lot Diversions		11	15
17.OSDS Inspection and Maintenance	2		16
18.Failed OSDS Retrofitting	1		17

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

As indicated in Table 10.0.a, the total cost for achieving implementation on all available land in the Project Area is about \$21,160,110. That cost can be broken down into two different implementation categories: agricultural and urban. Of the \$5,867,155 of agricultural implementation costs, \$4,400,366 can be covered through USDA, while the remaining \$1,466,789 must be funded by the stakeholder or other grant sources. Of the \$7,802,955 of urban implementation costs, \$6,242,364 can be covered under ARPA while the remaining \$1,560,591 must be funded by the stakeholder or other grant sources. Tables 10.0.c and 10.0.d summarize the potential sources of funding for implementation of BMP projects.

It is important to note that the inclusion of Overburdened Communities (OBCs) opens additional funding opportunities. Implementation costs can often be covered or further subsidized when projects are located in or adjacent to an OBC. As shown in Map 10.0, the Hackettstown area is identified as an OBC. Projects centered on these communities are given higher priority in programs such as the Clean Water State Revolving Fund (CWSRF), which can provide ranking advantages, principal forgiveness, or other subsidies. Similarly, NJDEP's 319(h) Nonpoint Source Pollution Grants incorporate environmental justice considerations, giving stronger weight to projects that directly benefit OBCs. Together, these programs increase both the competitiveness and affordability of green infrastructure and restoration projects in Hackettstown and neighboring areas.

Map 10.0 Overburdened Communities



Funding available for BMP implementation depends on the project type and the nature of costs. Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) support installation of agricultural BMPs through outreach, technical assistance and cost-sharing of installation costs. There are revolving and one-time funding opportunities for the implementation of stormwater BMPs, however, few of them have the revenue capacity or one-time flux of funds to support anything more than small capital projects or ancillary programs (Environmental Financial Advisory Board - EFAB).

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, e.g. upkeep and watering for installed rain gardens. Second, a majority 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 10.0.c Funding Sources for Agricultural BMPs

Types of BMP Projects		Total Cost \$	Stake-holders share \$	USDA (75%)	Other Possible Funding Sources*
1	Cover Crop	\$2,291,080.00	\$572,770.00	\$1,718,310.00	Act Now (NRCS), AgAssist (NJRC&D), Conservation Stewardship Program (CSP) (NRCS)
2	Prescribed Grazing	\$450,963.00	\$93,382.00	\$338,222.00	CSP (NRCS), AgAssist (NJRC&D)
3	Livestock Access Control	\$373,530.00	\$93,382.00	\$280,148.00	CSP (NRCS), Agricultural Management Assistance (AMA) (NRCS)
4	Nutrient Management	\$781,050.00	\$195,262.00	\$585,788.00	CSP (NRCS), AMA (NRCS)
5	Conservation Buffers on Agricultural Land	\$124,510.00	\$31,128.00	\$93,382.00	CSP (NRCS), CREP (USDA), AMA (NRCS),
6	No till	\$166,624.00	\$41,656.00	\$124,968.00	Act Now (NRCS), CSP (NRCS)

7	Regional Livestock Waste Storage and Composting Structure	\$1,000,000.00	\$250,000.00	\$750,000.00	AgAssist (NJRC&D)
8	Manure Application Incorporation Technology	\$79,398.00	\$19,850.00	\$59,548.00	CSP (NRCS), AgAssist (NJRC&D)
9	Heavy Use Area Protection	\$600,000.00	\$150,000.00	\$450,000.00	CSP (NRCS), AMA (NRCS)

Table 10.0.d Funding Sources for Urban/Suburban Stormwater BMPs and Wastewater BMPs

Types of BMP Projects		Total Cost	Stakeholder	Stormwater Resilience - ARPA (80%)	Other Possible Funding Sources*
10	Rain Gardens	\$392,000	\$78,400	\$313,600	CRR (Arbor Day Foundation), WFPO (NRCS), NJ Water Bank, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP), 319(h) (NJDEP)
11	Roadside Ditch Retrofitting	\$1,500,000	\$300,000	\$1,200,000	Watershed Protection and Flood Prevention Operations (WFPO) (NRCS), 319(h) (NJDEP)
12	Detention Basin Retrofitting	\$175,000	\$35,000	\$140,000	WFPO (NRCS), 319(h) (NJDEP)

13	Vegetative Buffers on Developed Land	\$276,180	\$55,236	\$220,944	WFPO (NRCS), CRR (Arbor Day Foundation), 319(h) (NJDEP)
14	Permeable Pavers	\$1,250,000	\$250,000	\$1,000,000	WFPO (NRCS), NJ Water Bank, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP), 319(h) (NJDEP)
15	Bioswales	\$69,600	\$ 13,920	\$55,680	WFPO (NRCS), NJ Water Bank, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP), 319(h) (NJDEP)
16	Parking Lot Diversions	\$166,250	\$33,250	\$ 133,000	WFPO (NRCS), NJ Water Bank, MS4 Programs – I-Bank (NJEIFP), 319(h) (NJDEP)
17	OSDS Inspection and Maintenance	\$2,080,000	\$416,000	\$1,664,000	WFPO (NRCS), NJWB (NJDEP), Clean Water State Revolving Fund (CWSRF) (USEPA), 319(h) (NJDEP)
18	Failed OSDS Retrofitting	\$1,950,000	\$390,000	\$1,560,000	WFPO (NRCS), NJWB (NJDEP), CWSRF (USEPA), 319(h) (NJDEP)

*Other Possible Funding Sources are not an all-inclusive list, and some grants may be on a rolling basis while others may be one-time submissions.

Table 10.0.e Cost out for BMPs over Implementation Goals, 2-5-10 year time frames

BMP	Units (2 yrs)	Cost (2 yrs)	Units (5 yrs)	Cost (5 yrs)	Units (10 yrs)	Cost (10 yrs)
Cover Crop	521 ac	\$229,240	2,604 ac	\$1,145,760	3,905 ac	\$1,718,200
Prescribed Grazing	80 ac	\$45,040	200 ac	\$112,600	400 ac	\$225,200
Livestock Access Control	2,490 ft	\$37,350	12,451 ft	\$186,765	22,412 ft	\$336,180
Nutrient Management	1,302 ac	\$195,300	2,604 ac	\$390,600	3,905 ac	\$585,750
Conservation Buffers (Ag)	2,490 ft	\$12,450	6,226 ft	\$31,130	12,451 ft	\$62,255

No-Till	521 ac	\$16,672	2,604 ac	\$83,328	3,905 ac	\$124,960
Regional Livestock Composting Structure	0	\$0	0	\$0	1 unit	\$1,000,000
Manure Incorporation Tech	40 ac	\$7,920	200 ac	\$39,600	301 ac	\$59,598
Heavy Use Area Protection	0	\$0	2 units	\$400,000	2 units	\$400,000
Agricultural Totals		\$543,972		\$2,389,783		\$4,512,143
Rain Gardens	78 units	\$78,000	196 units	\$196,000	392 units	\$392,000
Roadside Ditch Retrofits	10 units	\$300,000	20 units	\$600,000	50 units	\$1,500,000
Detention Basin Retrofits	1 unit	\$35,000	2 units	\$70,000	5 units	\$175,000
Vegetated Buffers on Developed Land	6,905 ft	\$34,525	27,618 ft	\$138,090	55,236 ft	\$276,180
Permeable Pavers	10 units	\$250,000	20 units	\$500,000	50 units	\$1,250,000
Bioswales	1 unit	\$5,800	5 units	\$29,000	12 units	\$69,600
Parking Lot Diversions	3 units	\$19,950	12 units	\$79,800	25 units	\$166,250
Stormwater Totals		\$723,275		\$1,612,890		\$3,829,030
OSDS Inspection & Maintenance	650 units	\$520,000	1,625 units	\$1,300,000	2,600 units	\$2,080,000
Failed OSDS Retrofitting	8 units	\$240,000	33 units	\$990,000	65 units	\$1,950,000
OSDS Totals		\$760,000		\$2,290,000		\$4,030,000
Totals		\$2,027,247		\$6,292,673		\$12,371,173

11.0 Criteria #5 – Develop an Informational and Educational Component

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 solve them. Education is the key to enhancing stakeholder understanding and interest as well as affecting 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
- Rain Barrel Build Workshop
- Sustainable Jersey TM
- Detention Basin Retrofits
- Agriculture Mini-Grant Program
- Soil Testing Program
- Stewardship of Open Space (SOS)
- Greening of Department of Public Works
- River Watcher at MWA
- Watershed Allies Training (WAT)

11.1 River-Friendly Programs

The River-Friendly Programs engage residents, schools, businesses, and golf courses in voluntary actions that reduce nonpoint source pollution. Through certifications and site evaluations, participants learn to manage stormwater on-site, reduce fertilizer and pesticide use, and protect riparian buffers. This program directly supports BMP adoption across developed areas and builds public stewardship for long-term watershed health.

11.2 Rain Garden Program

The Rain Garden Program through MWA, educates homeowners, municipalities, and community groups on how to design, install, and maintain rain gardens that capture and infiltrate stormwater. Workshops, demonstration sites, and design assistance promote the use of bio-retention systems that reduce runoff, filter pollutants, and recharge groundwater.

11.3 Rain Barrel Workshop

The Rain Barrel Workshop through MWA and Raritan Headwaters Association, teaches residents how to construct, install, and maintain rain barrels for capturing roof runoff. These

workshops build community awareness of stormwater management while providing a practical tool that reduces runoff, conserves water and decreases the load on local drainage systems during storm events.

11.4 Sustainable Jersey™

Sustainable Jersey™ provides a certification framework for municipalities to implement sustainability and resiliency actions. Participation encourages towns to adopt local policies aligned with watershed goals—such as green infrastructure planning, stormwater ordinance updates, and environmental education—while accessing grant funding to implement these measures.

11.5 Detention Basin Retrofit Program

This program works with municipalities, homeowner associations, and schools to identify and convert conventional detention basins into naturalized bio-retention systems. Educational outreach and design support help local partners understand the benefits of vegetated systems that improve water quality, reduce maintenance, and enhance habitat. Detention basin retrofit programs in New Jersey are most often led by Rutgers Cooperative Extension Water Resources Program (RCE-WRP), in partnership with municipalities, county planning departments, and nonprofits.

11.6 Agriculture Mini-Grant Program

The Agriculture Mini-Grant Program provides cost-share and technical assistance to farmers implementing conservation practices such as cover crops, livestock exclusion fencing, and nutrient management. Through targeted outreach and partnerships with NJRC&D and NRCS, the program educates producers and advances BMP adoption in agricultural critical areas.

11.7 Soil Testing Program

This program promotes annual soil testing among farmers, landscapers, and homeowners to encourage precise fertilizer application based on actual nutrient needs. By linking test results to integrated crop nutrient management plans, it helps reduce nutrient runoff and supports the long-term fertility and productivity of agricultural and developed lands. New Jersey's main soil testing resource is the Rutgers Soil Testing Laboratory, part of Rutgers Cooperative Extension (RCE).

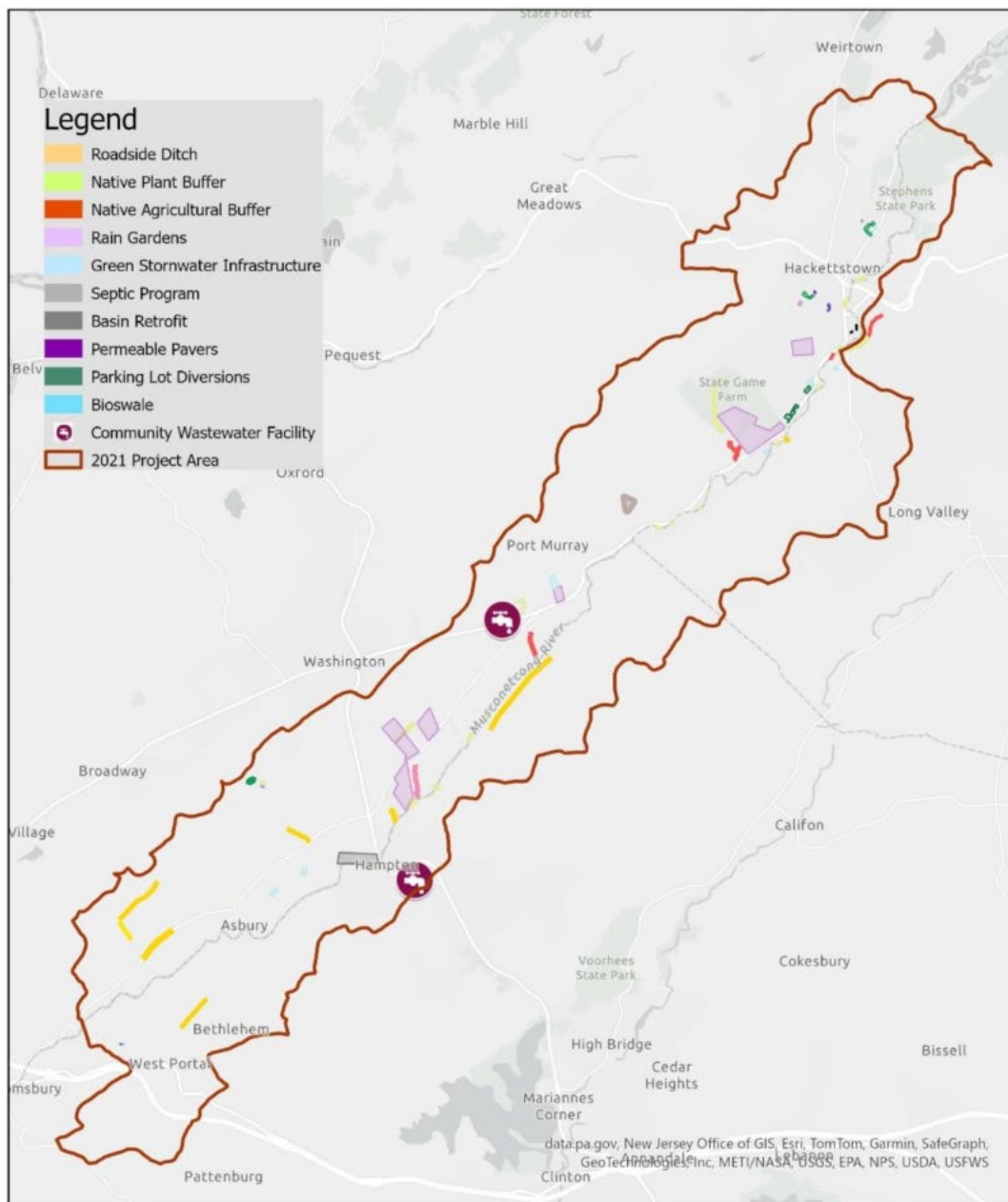
11.8 Stewardship of Open Space (SOS)

The Stewardship of Open Space (SOS) program supports local governments, land trusts, and community groups in the active management of preserved lands to enhance ecological function. Funded through the New Jersey Department of Environmental Protection's Green Acres Program, SOS provides competitive grants for activities such as invasive species removal, reforestation, forest stand improvement, and stream buffer restoration. These stewardship actions help ensure that preserved lands continue to deliver water quality protection, habitat enhancement, and long-term watershed benefits, while complementing municipal and regional efforts to meet stormwater management and watershed protection goals.

11.9 Greening of Department of Public Works (DPW)

The Greening of DPW initiative promotes sustainable operations in municipal maintenance yards and facilities. Training and BMP implementation—such as proper salt storage, equipment washing practices, and stormwater retrofits—reduce pollutant runoff from public works operations and demonstrate municipal leadership in watershed stewardship. The program in New Jersey is coordinated by Sustainable Jersey™, in partnership with the NJDEP and RCE WRP. Map 11.9 below highlights locations within the project area where stormwater retrofits could be implemented.

Map 11.9 Potential Stormwater Infrastructure Retrofit locations



This map highlights the stormwater management infrastructure that has been identified as area's which can be retrofitted using Green Infrastructure tactics.



Musconetcong Watershed Association
10 Maple Ave, P.O. Box 113
Asbury, NJ 08802

11.10 River Watchers Program

The River Watchers Program is the Musconetcong Watershed Association's long-standing community science initiative that engages volunteers in monitoring water quality, habitat, and biological conditions throughout the watershed. Participants are trained to collect field data such as bacteria, temperature, and macroinvertebrate samples following NJDEP and NJ Watershed Watch Network protocols. The program builds local capacity for watershed stewardship, provides valuable data to assess BMP effectiveness, and fosters public awareness of how individual actions influence stream health.

11.11 Watershed Allies Training Program

Musconetcong Watershed Association has developed a public education program, Watershed Allies Training, to train residents with real skills that they can implement within their communities or in their own homes. To date, a training series has been created for DIY Septic Inspection, How to Make Your Public Comment Count and DIY Solutions for Sustainable Stormwater Management. The goal of education programs is to improve stakeholder awareness and to promote behavior changes that will be beneficial to achieving watershed restoration and protection.

11.12 Outreach

11.12.1 Flow Together Outreach Meetings

A series of outreach sessions were conducted, in two phases, to gain public input on various aspects of nonpoint source pollution. The initial phase was more focused on overall BMP comprehension and understanding, while the second phase was aimed at getting feedback regarding implementation. Overall, there were 8 sessions (5 Phase One and 3 Phase Two) as well as two different, phase focused surveys which were distributed at each session.

11.12.2 Flow Together Outreach Feedback

The feedback from the Phase One sessions can be broken down into three different buckets; What makes your community special? What are your perceived water quality/quantity concerns? And what are the challenges your community faces? Phase Two sessions could be broken down into three buckets as well; What are your thoughts on septic BMPs? What are your thoughts on stormwater BMPs? And what are your thoughts on the MWA's Vision Plan and the WRPP? The feedback from the outreach sessions has been summarized and those reoccurring themes throughout each session have been highlighted and are as follows:

The community's identity is richly defined by its cherished river access, open spaces, and historic value. These special features form the foundation of what makes the community unique and beloved by its residents.

In addressing water quality and quantity concerns, the highest priority is ensuring safe drinking water, which is critical for the health and safety of the residents. Equally important are recreational opportunities such as swimming, fishing, and boating in the river, which significantly enhance the community's lifestyle and well-being. Urgent attention is needed for issues like flooding and failing or improperly maintained septic systems to prevent environmental degradation and health risks. Because most residents rely on private wells, the critical connection between surface water and groundwater must also be recognized, as contamination in rivers and streams can directly affect the quality of groundwater resources used for drinking water.

Maintaining and enhancing riparian buffer zones and controlling overdevelopment are essential to preserving the ecological balance and preventing erosion. Addressing non-point source pollution, educating the community on environmental stewardship, and managing invasive species are also vital for long-term sustainability. Additionally, while they are lesser perceived priorities compared to the aforementioned concerns, maintaining ash trees, increasing tree cover, and promoting biodiversity are also seen as important.

Community challenges are multifaceted, with education requiring significant focus and resources as the top priority. Navigating political issues and preserving historic value are also crucial, necessitating careful consideration and action. Mitigating the problem of impervious pavement, which exacerbates flooding and pollution, is seen as essential.

Overdevelopment remains a recurring theme, underscoring the need for improved municipal planning, including better zoning, transportation, and walking paths. A strong emphasis on working together and gaining community buy-in is crucial for the success of various initiatives. Effective resource management and updating aging infrastructure are imperative to support sustainable growth and development.

Enhancing recreational opportunities can further improve community life. Addressing agricultural economics, overcoming regulatory rigidity, and increasing civic engagement are necessary for the community's prosperity. Managing trash and navigating political landscapes are ongoing challenges that must be addressed to maintain the community's quality of life.

To support community health and environmental sustainability, addressing septic system issues is critical. The highest priority here is extensive outreach and education to inform residents about proper septic system maintenance and its importance to overall water quality. Offering discounted maintenance services can help overcome cost barriers that many residents face. Addressing the fear of the unknown and the high density of septic systems in certain areas is also

crucial. Mitigating concerns about ordinances and the political climate, which can hinder the implementation of necessary regulations, is important. Demonstrating the public benefit of maintaining septic systems and providing data on septic failure rates will help build community support for these initiatives.

In managing stormwater, outreach and education are paramount to inform the community about BMPs. Changing perspectives to see stormwater management as a public benefit and involving municipal authorities in the process are essential steps. Successful implementation of these BMPs requires cooperation and understanding from all community members and stakeholders.

The community's input on the MWA's Vision Plan and the WRPP emphasizes collaboration to achieve shared goals. This effort is supported by extensive education and outreach to keep everyone informed and engaged. Smart development practices are essential to balance growth with environmental protections, particularly for water and farmland. Linking these efforts to personal benefits for residents makes the vision plan relevant to their daily lives. Adaptability to changing circumstances and new information is a key component of the plan's success. Sharing information widely and ensuring that all stakeholders are informed and engaged will help the community achieve its long-term goals.

By addressing these priorities and challenges with a cohesive and collaborative approach, the community can ensure a sustainable and prosperous future while preserving the unique characteristics that define its identity.

11.12.3 Flow Together Outreach Survey Responses

During the Flow Together outreach sessions, surveys were used to understand how well the community understands, engages with, and is open to BMPs. The responses gave detailed insights, particularly in line with existing wastewater management data. The surveys showed that 69% of respondents rely on septic systems, 27% are connected to the municipal sewer system, and 4% did not respond.

In Phase One (see Appendix I for Phase One survey), 50% of participants showed a willingness to adopt all suggested behavior changes (e.g. Supporting a reduction of paved surfaces, reduced fertilizer use, and proper car maintenance). Notably, there was a unanimous agreement (100%) on incorporating native plants, especially in rain gardens or along streamside buffers. Additionally, 65% expressed a strong interest in learning more about outdoor passive and active recreational opportunities.

In Phase Two (see Appendix J for Phase Two survey), participants uniformly demonstrated a visual preference for Green Infrastructure, easing the earlier concerns from Phase One. While about 50% fully understood the benefits of rain gardens and bioretention swales. On a scale of 1 to 10, participants were most willing to spend money on native plants (average score: 9.2), followed by rain gutter detachment (average score: 6.5). However, there was less interest in installing solar panels (average score: 5.4) and replacing paved driveways with maintained gravel or pervious pavement (average score: 4.4).

12.0 Criteria #6 - Implementation Schedule

Although all eighteen types of BMP projects are recommended, it is not achievable 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 a variety of reasons, some farmers or landowners may have different priorities or constraints that influence whether recommended implementation approaches are pursued. For example, cover crop is applicable on all 5,207 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 12.0.a Implementation targets for the recommended BMP projects in the Musconetcong River Watershed

Types of BMP Projects	Implement ation Goal	Unit	Reduction Goal			Cost for Implementation
	%		TP (lbs./yr)	TSS (lbs./yr)	Bacteria % reduction (applicabl e land)	
1 Cover Crop	75	3905 acres	761.48	585750	NA	\$ 1,718,200
2 Prescribed Grazing	50	400 acres	NA	9000	80%	\$ 225,200
3 Livestock Access Control	90	22412 ft	NA	3858.78	99%	\$ 336,180
4 Nutrient Management	75	3905 acres	1776.78	NA	NA	\$ 585,750
5 Conservation Buffers on Agricultural Land	50	12451 ft	6.58	1955.12	71%	\$ 62,255
6 No till	75	3905 acres	3502.79	913770	NA	\$ 124,960
7 Regional Livestock Waste Storage and Composting Structure	100	1 unit	NA	NA	98%	\$ 1,000,000
8 Manure Application Incorporation Technology	75	310 acres	374.79	NA	70-90%*	\$ 61,380

9	Heavy Use Area Protection	66	2 units	NA	42.98	NA	\$ 400,000
10	Rain Gardens	50	392 units	1.8	1.68	75%	\$ 392,000
11	Roadside Ditch Retrofitting	50	50 units	0.34	0.19	50%	\$ 1,500,000
12	Detention Basin Retrofitting	50	5 units	0.12	0.08	50%	\$ 175,000
13	Vegetative Buffers on Developed Land	40	55,236 ft	12.68	1127.29	60%	\$ 276,180
14	Permeable Pavers	50	50 units	2.87	291.55	70%	\$ 1,250,000
15	Bioswales	50	12 units	0.28	29.74	65%	\$ 69,600
16	Parking Lot Diversions	50	25 units	NA	NA	45%	\$ 166,250
17	OSDS Inspection and Maintenance	80	2,600 units	NA	NA	50%	\$ 2,080,000
18	Failed OSDS Retrofitting	40	65 units	267.3**	NA	90%	\$ 1,950,000
Total				6,697.40	1,597,040.16		\$ 12,372,955
	*Highly dependent on application timing i.e. rain events ** Assumes 250 gpd, a 90% removal rate efficiency and 6 mg/L per unit load						

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 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 12.0.a. Note that TP levels did not exceed SWQS in the monitoring effort in 2021, and the waters in the project area are not impaired for TP.

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 12.0.b 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 12.0.b 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	521 acres	50	2,604 acres	75	3,905 acres
2	Prescribed Grazing	10	80 acres	25	200 acres	50	400 acres
3	Livestock Access Control	10	2,490 ft	50	1,2451 ft	90	22,412 ft
4	Nutrient Management	25	1,302 acres	50	2,604 acres	75	3,905 acres
5	Conservation Buffers on Agricultural Land	10	2,490 ft	25	6,226 ft	50	12,451 ft
6	No till	10	521 acres	50	2,604 acres	75	3,905 acres
7	Regional Livestock Waste Storage and Composting Structure	0	0	0	0	100	1 unit
8	Manure Application Incorporation Technology	10	40 acres	50	200 acres	75	301 acres
9	Heavy Use Area Protection	0	0	33	2 units	66	2 units
10	Rain Gardens	10	78 units	25	196 units	50	392 units
11	Roadside Ditch Retrofitting	10	10 units	20	20 units	50	50 units
12	Detention Basin Retrofitting	10	1 unit	20	2 units	50	5 units
13	Vegetative Buffers on Developed Land	5	6,905 ft	20	27,618 ft	40	55,236 ft
14	Permeable Pavers	10	10 units	20	20 units	50	50 units
15	Bioswales	5	1 unit	20	5 units	50	12 units
16	Parking Lot Diversions	5	3 units	20	12 units	50	25 units

17	OSDS Inspection and Maintenance	20	650 units	50	1,625 units	80	2,600 units
18	Failed OSDS Retrofitting	5	8 units	20	33 units	40	65 units

Table 12.0.c BMP Schedule with cost out for 2-5-10 year goals

BMP	Units (2 yrs)	Cost (2 yrs)	Units (5 yrs)	Cost (5 yrs)	Units (10 yrs)	Cost (10 yrs)
Cover Crop	521 ac	\$229,240	2,604 ac	\$1,145,760	3,905 ac	\$1,718,200
Prescribed Grazing	80 ac	\$45,040	200 ac	\$112,600	400 ac	\$225,200
Livestock Access Control	2,490 ft	\$37,350	12,451 ft	\$186,765	22,412 ft	\$336,180
Nutrient Management	1,302 ac	\$195,300	2,604 ac	\$390,600	3,905 ac	\$585,750
Conservation Buffers (Ag)	2,490 ft	\$12,450	6,226 ft	\$31,130	12,451 ft	\$62,255
No-Till	521 ac	\$16,672	2,604 ac	\$83,328	3,905 ac	\$124,960
Regional Livestock Composting Structure	0	\$0	0	\$0	1 unit	\$1,000,000
Manure Incorporation Tech	40 ac	\$7,920	200 ac	\$39,600	301 ac	\$59,598
Heavy Use Area Protection	0	\$0	2 units	\$400,000	2 units	\$400,000
Rain Gardens	78 units	\$78,000	196 units	\$196,000	392 units	\$392,000
Roadside Ditch Retrofits	10 units	\$300,000	20 units	\$600,000	50 units	\$1,500,000
Detention Basin Retrofits	1 unit	\$35,000	2 units	\$70,000	5 units	\$175,000
Vegetated Buffers on Developed Land	6,905 ft	\$34,525	27,618 ft	\$138,090	55,236 ft	\$276,180
Permeable Pavers	10 units	\$250,000	20 units	\$500,000	50 units	\$1,250,000
Bioswales	1 unit	\$5,800	5 units	\$29,000	12 units	\$69,600

Parking Lot Diversions	3 units	\$19,950	12 units	\$79,800	25 units	\$166,250
OSDS Inspection & Maintenance	650 units	\$520,000	1,625 units	\$1,300,000	2,600 units	\$2,080,000
Failed OSDS Retrofitting	8 units	\$240,000	33 units	\$990,000	65 units	\$1,950,000

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 hand 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.

13.0 Criteria #7 – Describe Interim, Measurable Milestone

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 to prioritize protecting hydrologically sensitive areas from future development.
- Develop and adopt a 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 necessary 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 12.0.c above are estimated to cost \$2,027,247 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 1,245 pounds of the TP load, which is close to 20 percent of the required load reduction in TP;
- Reduce 219,085 pounds of the sediment load, which is equivalent to 16 percent of the total load reduction in sediment; and
- Reduce 15% of the required 93% load reduction in pathogens.

The completion of the 10-year implementation of the BMP projects as indicated in Implementation schedule (Table 12.0.c) is estimated to cost \$12,371,173 and achieve the following milestones toward the pollutant reduction goals and the attainment of the water quality standards:

- Improvement and protection of water quality and watershed hydrology;
- Reduce 6,686 pounds of annual TP load, which is equivalent to 80 percent of the required annual load reduction in TP;
- Reduce 1,596,652 pounds of annual sediment load, which exceeds the required annual load reduction in sediment;
- Achieve the required annual load reduction of 93 percent in annual pathogen loads and attain the water quality standards in pathogens.

14.0 Criteria #8 – Identify Indicators to Measure Progress

Progress toward achieving the watershed restoration and protection goals will be evaluated through both implementation and outcome indicators, as outlined in Section 2.176 of the EPA's guidelines. These indicators assess changes in land use management practices as well as measurable improvements in water quality and habitat conditions within the watershed.

The first set of indicators focuses on implementation and behavioral change, evaluating the extent to which BMPs have been adopted and maintained by agricultural producers, landowners, and municipalities. These may include the number of agricultural acres under nutrient management plans, the length of exclusion fencing installed, the number of retrofitted detention basins, or the area of riparian buffers restored. MWA will support these efforts through education, outreach, and coordination with technical service providers such as NRCS, local Soil Conservation Districts, and Rutgers Cooperative Extension. Tracking these changes provides valuable insight into the effectiveness of outreach, education, and incentive programs across the watershed.

The second set of indicators measures environmental outcomes, evaluating how BMP implementation translates into improvements in stream health and water quality. This includes monitoring parameters such as TP, TSS, *E. coli*, and temperature at long-term sampling sites, as well as macroinvertebrate community indices (HGMI) to assess ecological response. Comparing

pre- and post-implementation data, supported by continuous and grab-sample monitoring, will demonstrate whether pollutant load reductions and hydrologic restoration goals are being met. Together, these two sets of indicators—management practice adoption and environmental condition trends—provide a comprehensive framework for evaluating project success. The Musconetcong Watershed Association will continue to coordinate with local, state, and federal partners to ensure consistent monitoring, data management, and reporting practices, allowing for adaptive management and refinement of implementation strategies over time.

Table 14.0 – Indicators to Measure Progress

Indicator Type	Metric	Frequency	Data Source / Method	Responsible Party
Implementation Indicators	Acres under nutrient management or cover crop adoption	Annual	NRCS reports, landowner self-reporting, and Soil Conservation District records	NRCS, Hunterdon/Warren SCDs, NJ RC&D Landowners
	Linear feet of livestock exclusion fencing installed	Annual	Field verification and contractor documentation	NRCS, SCDs, NJRC&D Landowners
	Number of stormwater BMP retrofits (e.g., basins, bioswales, rain gardens)	Annual	Municipal stormwater reports, site inspections	Municipal Engineers, MWA (support)
	Area of riparian buffers restored or enhanced	Annual	GIS mapping, field GPS verification	NRCS, SCDs, MWA (support)
	Public outreach participation (trainings, River Talks, volunteer events)	Annual	Event records, surveys	MWA Staff
Outcome Indicators	Reduction in pollutant concentrations (TP, TSS, E. coli, temperature)	Quarterly to seasonal	MWA long-term monitoring program, NJDEP WQX data	MWA Laboratory

	Improvement in macroinvertebrate community indices (HGMI)	Biennial	Bioassessment following NJDEP protocols	MWA River Watchers, NJDEP
	Streambank stability and riparian vegetation cover	Annual	Photo-point monitoring and visual assessments	MWA Field Staff, Environmental consultants
	Community perception and stewardship behavior	Every 3–5 years	Stakeholder surveys and interviews	MWA, Partner Organizations

Review and Adaptive Management

Indicators will be reviewed annually by a Technical Advisory Committee (TAC) to assess progress toward load reduction goals, identify barriers to implementation, and refine strategies as needed. This iterative approach ensures that management actions remain effective, data-driven, and responsive to changing watershed conditions.

15.0 Criteria #9 - Monitoring Program

A monitoring program can 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 Generalized Watershed Loading Functions Enhanced model (GWELF-E/MapSheds). This database could be integrated into NJ GeoWeb or the new web tool, Watershed NJ;
- MWA has been monitoring water quality in the watershed for many years and has become a NJDEP Office of Quality Assurance Certified Laboratory. MWA monitoring programs are guided by approved QAPPs for biomonitoring, field and laboratory parameters. This water quality data will be analyzed to monitor the success of BMP implementation on improving water quality in the Musconetcong River watershed.
- Continue comprehensive stream flow, and water quality program at the EnviroDIY live sensor stations and 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 at four biological monitoring stations within the project area 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 EPA's Rapid Habitat Assessment to assess physical changes in the streams and their riparian zones.

16.0 Regulations and Ordinances

16.1 Stormwater Management Regulations

The strongest water protection in the project area comes from the state, not the county or municipality levels of government. In 2008, the NJDEP classified the project area of the river as a Category One waterbody under N.J.A.C. 7:8, Stormwater Management Regulations, protecting it from any measurable change to water quality characteristics. Category One waters are identified 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 NJDEP upgraded this 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 entire study area, from its beginning in Hackettstown downstream to Valley Station Road in Bethlehem Township Hunterdon County is classified as a Category One river 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, was upgraded to 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

16.1.1 Municipal Stormwater Regulation Program (MS4)

The Municipal Stormwater Regulation Program was created in response to the USEPA's Phase II rules from December 1999. The Department issued the NJPDES stormwater rules on February 2, 2004, including four general permits for stormwater discharges from Tier A and Tier B municipalities, Public Complexes, and Highway Agencies that discharge from municipal separate storm sewer systems (aka "MS4s"). In 2023, all former Tier B municipalities were changed to Tier A, so that the Tier A permit covers all municipalities in New Jersey. Public Complexes include large public colleges, prisons, hospitals, and military bases. Highway Agencies include county, state, interstate, or federal government agencies operating highways. These permits are routinely renewed.

The MS4 permitting process requires a regional Watershed Improvement Plan (WIP), to be developed within the current five-year cycle. MS4 permits require permittees to develop or participate in WIPs to address water quality and quantity issues in their subwatersheds. The municipalities in the project area should incorporate information from this WRPP into their WIPs.

The WIP aims to improve water quality, reduce pollutants in impaired waterbodies with TMDLs, and address stormwater flooding. New Jersey has 958 subwatersheds (HUC14s) with various impairments, such as Fecal Coliform, Total Phosphorous, Total Suspended Solids, Dissolved Oxygen, *E. coli*, Nitrogen, pH, Total Dissolved Solids, Temperature, Turbidity, PCBs, VOCs, and metals, affecting fish, drinking water intakes, and recreational waters. Every town in the state has a TMDL or impairment, often both. The Department acknowledges that some pollution and flooding sources, like farmland or federal properties, are beyond a permittee's control, but this process will help identify those sources.

The WIP has three phases:

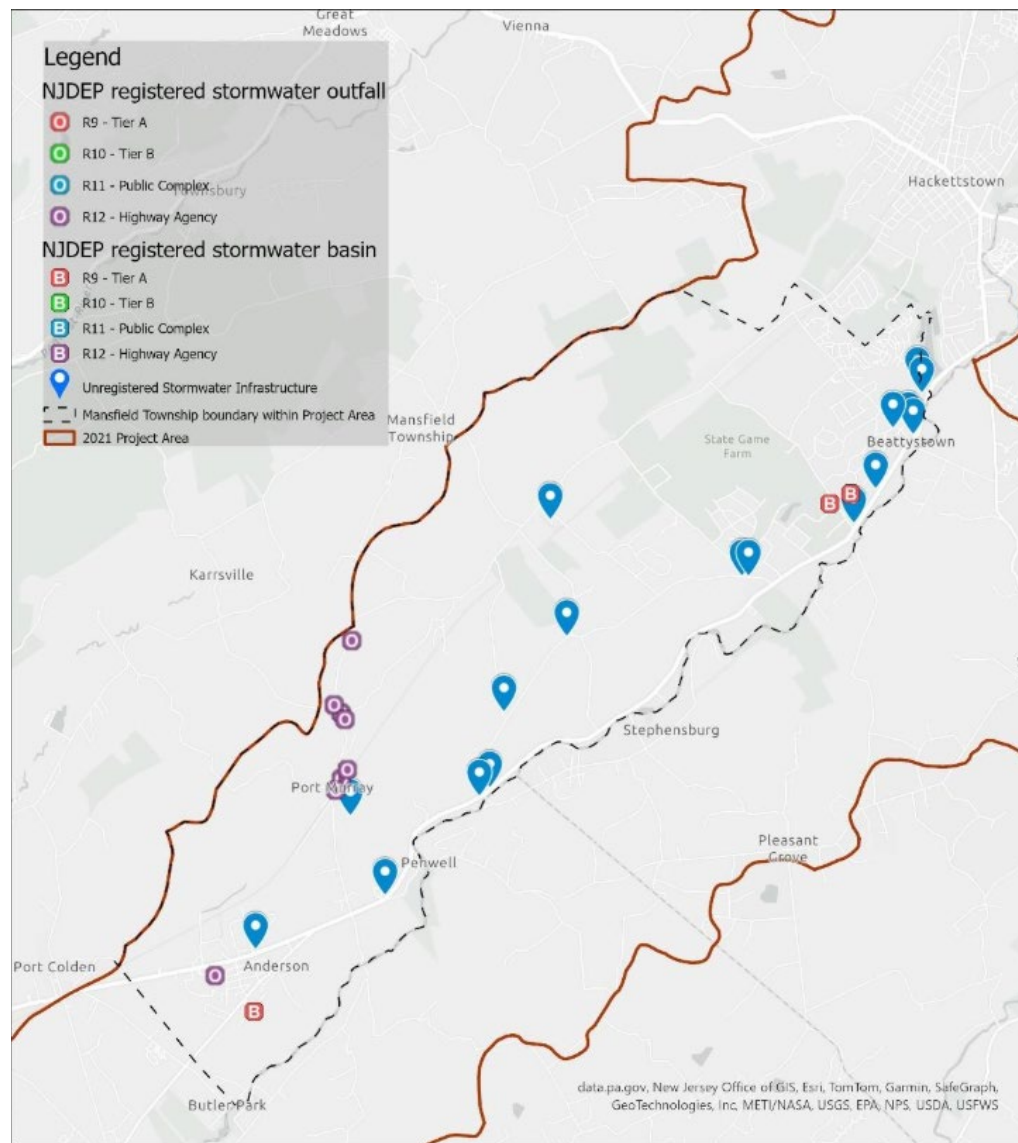
1. Phase 1: Stormwater inventory and mapping.
2. Phase 2: Evaluation of the inventory to identify potential improvement projects.
3. Phase 3: Selection and scheduling of improvement projects.

More information on permits, municipal stormwater mapping and inventory assistance can be found at <https://dep.nj.gov/njpdes-stormwater/municipal-stormwater-regulation-program/>.

Map 16.1.1 below showcases the MS4 inventoried stormwater infrastructure within Mansfield township compared to the ground truthed stormwater infrastructure in the area. To create this map, desktop exercises were conducted to identify the stormwater infrastructure registered with NJDEP for their MS4 permitting, then MWA staff went out into the field to ground truth the desktop data. While in the field, staff uncovered a number of stormwater infrastructure that had not been documented in the desktop exercises, thus leading to the creation of a map to showcase these differences. The current assessment of stormwater infrastructure (SI) (Map A.8 in Appendix H) reveals a significant gap between inventoried and non-inventoried systems, with most SI not being registered. This lack of registration poses a risk when it comes to the

maintenance and management of these critical infrastructures and can be seen across municipalities.

Map 16.1.1 Registered and Unregistered Stormwater Infrastructure



This map highlights the stormwater management infrastructure that has been identified through NJDEP relating to MS4 permitting versus the ground truthed stormwater infrastructure found throughout Mansfield township - it is important to note that no registered culverts were identified in this area.
Data Layer Source: SI layer from NJDEP website



Musconetcong Watershed Association
10 Maple Ave, P.O. Box 113
Asbury, NJ 08802

Although the deadline for completing the inventory and mapping of SI is not until the end of 2026, these findings indicate an urgent need to begin addressing these gaps now. By taking proactive steps to inventory and map all stormwater infrastructure ahead of the deadline,

municipalities can ensure they are better equipped to maintain and manage these systems effectively, reducing the risk of future issues.

To support this effort, the Center for Watershed Protection created a worksheet for each major land category (urban, rural, etc.) to help communities evaluate and revise local development regulations. The goal is to encourage site developers to minimize impervious cover, conserve natural areas, and implement runoff reduction practices for stormwater management. The worksheet, titled *The Code and Ordinance Worksheet: A Tool for Evaluating the Development Rules in Your Community*, is available for free download at <http://owl.cwp.org> and was published in 2017.

16.2 Highlands Act/Highlands Regional Master Plan

Another state regulation superseding some municipal water protections is the Highlands Water Protection and Planning Act, signed on August 10, 2004. The rules incorporate required standards for various land uses, water resources, and environmental protection. The Highlands Act splits the Highlands region into two areas: the Preservation Area and the Planning Area.

The Preservation Area is defined by the Act as containing lands essential to generating drinking water, leading to stringent state development restrictions to protect water. Additionally, 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)."

Planning Area lands also contribute to water generation but in many cases are already developed, so both further growth and compliance with the regional plan in general are left to individual municipalities in the area.

The entire study area is within the Highlands area. Lebanon, Hampton Borough and Bethlehem, in Hunterdon County, are all in the Preservation Area. Washington and Franklin, in Warren County, are in the Planning Area.

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
Watershed & Land Management
Office of Policy and Technical Development
Water Quality Management Planning Unit

501 E. State Street
Mail Code 501-01A
P.O. Box 420
Trenton, New Jersey 08625-0420
(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

16.3 Stream Buffers

Buffers are vegetated areas adjacent to waterways that provide critical protection to water quality by filtering pollutants, stabilizing streambanks, reducing erosion, and maintaining habitat connectivity. Historically, buffer widths were established through local ordinances, resulting in inconsistent protections across municipalities. Under New Jersey's Stormwater Management rules and the Special Water Resource Protection Area (SWRPA) standards applied to Category One (C1) waterbodies, all C1 waterways within the study area must be protected by a 300-foot buffer, measured from the top of each bank. No municipality in the study area currently enacts an ordinance that exceeds this statewide requirement.

Waterbodies located within municipalities in the Highlands Preservation Area (including Hackettstown, Allamuchy, Mount Olive, Washington Township [Morris], Independence, Mansfield, Washington Township [Warren], Lebanon, Hampton Borough, and Bethlehem Township) are also protected by 300-foot riparian buffers under the Highlands Water Protection and Planning Act, which restricts development, vegetation removal, and land disturbance within Riparian Protection Zones.

In addition to these requirements, NJDEP regulates activities within stream buffers through several key permitting programs, including:

- Flood Hazard Area Control Act Rules (N.J.A.C. 7:13), which establish Riparian Zones of 50, 150, or 300 feet depending on stream classification and regulate any disturbance—including vegetation clearing, construction, grading, or placement of fill—within those zones. More information is available at: <https://www.nj.gov/dep/landuse/fha.html>
- Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), which regulate wetlands and associated transition areas (wetland buffers). Widths vary from 0 to 150 feet depending on wetland resource value and may overlap with riparian buffer requirements. More information is available at: <https://www.state.nj.us/dep/landuse/wetlands.html>

Together, these regulatory frameworks—stormwater rules, Highlands protections, flood hazard regulations, and wetland transition-area requirements—establish a multilayered system of riparian buffer management throughout the Musconetcong River Watershed. Municipalities must comply with all applicable NJDEP rules when reviewing development applications or adopting ordinances related to riparian areas, and property owners must secure the appropriate NJDEP permits before undertaking regulated activities within these buffers.

16.4 Agriculture

Eight municipalities that run along the banks of the Musconetcong River in the focus area have a Right to Farm Ordinance. Right to Farm ordinances confer the rights to:

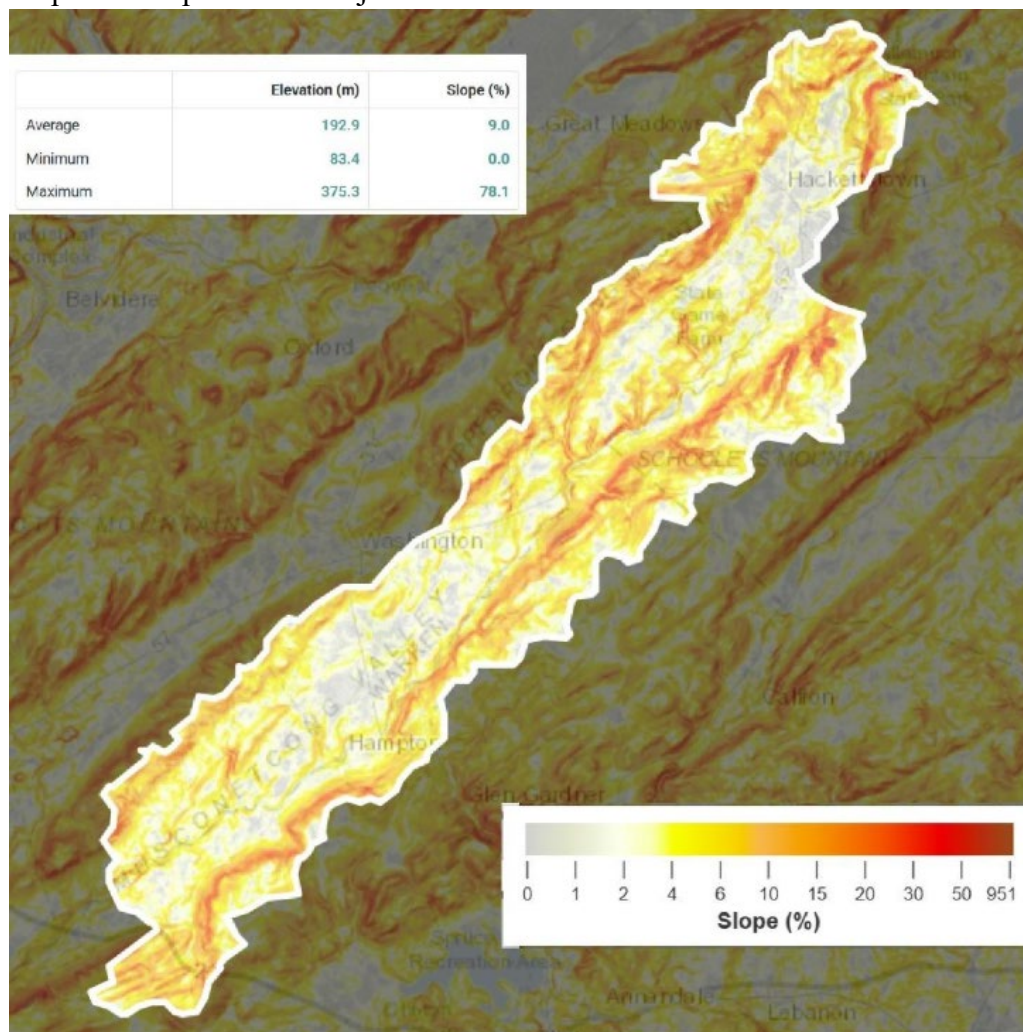
- Clear woodlands using open burning and other accepted techniques and install and maintain vegetative and terrain alterations and other physical facilities for water and soil conservation and surface water control in wetland areas.
- Use irrigation pumps and equipment, aerial and ground seeding and 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.

Hackettstown does not have a Right to Farm ordinance. In Allamuchy, Manfield, Independence, 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.

16.5 Steep Slopes

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. Nine of the eleven municipalities that run along the banks in the study area of the Musconetcong River have a steep slope ordinance. Hampton Borough and Hackettstown do not have a steep slope ordinance.

Map 16.5 Slopes of the Project Area



**Musconetcong Watershed
Protection Plan: Hackettstown to
Hampton**

This map highlights the slope and elevation of
the project area.

Sources: ModelMyWatershed



Musconetcong Watershed Association
10 Maple Ave, P.O. Box 113
Asbury, NJ 08802

16.6 Septic System Maintenance

The septic systems in the project area are typically managed at the county rather than the local level. County Boards of Health or Health Departments are responsible for septic system design review, site inspections, installation inspections, compliance investigations, certifications, and

repair guidance. Most of the municipalities in the study area do not have specific ordinances regulating the maintenance or inspection of septic systems.

Only Mount Olive requires septic systems to be enrolled in their License to Operate Septic System Program. Licenses to operate septic systems expire every 3 years and can be renewed once property owners provide either:

1. Evidence the septic system has been pumped by a licensed septic hauler
2. A septic system inspection report from a licensed professional engineer indicating the system has been maintained and doesn't yet need to be pumped.

A model ordinance can be found in Appendix M.

16.7 NJ Wild and Scenic Rivers

The National Wild and Scenic Rivers System was established by the Wild and Scenic Rivers Act of 1968. Designation as a Wild and Scenic River is reserved for rivers with outstanding natural, cultural, and recreational values in a free-flowing condition. The Act preserves these rivers for “the enjoyment of present and future generations.”

In 2006, the U.S. Congress passed the Musconetcong Wild and Scenic Rivers Act, which designates portions of the Musconetcong River as a Wild and Scenic River. The project area 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 to guide cooperative management of the Musconetcong River as a component of the National Wild and Scenic River System. It recognized the importance of the various roles of landowners, as well as those in government, business and industry, in the protection of the river corridor.

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. The goals of the River Management Plan would be served by the successful implementation of this WRPP.

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.

The Musconetcong RMP also calls for the formation of a Musconetcong River Management Council (MRMC), which meets bimonthly. 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.

Each municipality in the project area has appointed a representative to the MRMC and is party to a 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 RMP under their jurisdiction or for which they assume responsibility.

17.0 Specific Restoration Projects

The site-specific green infrastructure retrofit concepts presented in this section are intended as potential on-the-ground projects for future implementation and as examples of the types of projects that could be implemented at similar sites throughout the watershed. It is important to note that these concepts are examples of potential opportunities and do not reflect site-specific project designs. Individual project proponents, such as municipalities, private property owners, and developers, are responsible for assessing the feasibility, design, and permitting of these and similar site-specific concepts. An effort was made to identify examples within each of the generalized management categories, including stormwater management, agricultural BMPs, stream bank stabilization and riparian enhancement, OSDS management and wildlife management.

17.1 Project Name: Hackettstown Medical Center and Willow Grove Medical Plaza

Location: 651-657 Willow Grove St, Hackettstown, NJ. 40.86187, -74.81521

Priority: Medium

Recommended BMPs: Permeable pavers, parking diversions, rain gardens, bioswales and other GSI as identified as a best fit by a consultant.

Current Condition: This project is comprised of three facilities occupying one medical “campus”. The campus covers 19.6 acres, of which 62% is impervious cover (Figure B, High/Med Intensity Development), most of which is parking lots. The entire property has soil group D-very slow infiltration (Figure A).

Issues and Concerns: This medical campus, located in the heart of Hackettstown, occupies a large area and has outdated grey stormwater infrastructure that channels untreated pollutants to pipes leading to the Musconetcong River, less than a quarter of a mile away. The impervious parking lots and flat black rooftops contribute to the urban heat island effect and thermal water pollution.



Figure A: Hackettstown Medical Facilities with soil group (D- Very slow infiltration)



Figure B: Hackettstown Medical Facilities Land Use/Cover, Medium Intensity = 41.94%, High Intensity = 23.66%. Totalling 12.15 acres of impervious coverage.

Proposed Solutions: A combination of urban BMPs to create a “treatment train” approach is best suited to a large campus like this. This starts with the permeable pavers and parking diversions, then to bioswales and rain gardens. Creating a layered or staged system that progressively captures, treats, and infiltrates stormwater enhances water quality benefits. The bioswales and rain gardens will create channels in the slow infiltration soil (D) to allow for more groundwater recharge. Ultimately, this will reduce TSS and nutrient runoff to meet load reduction targets.

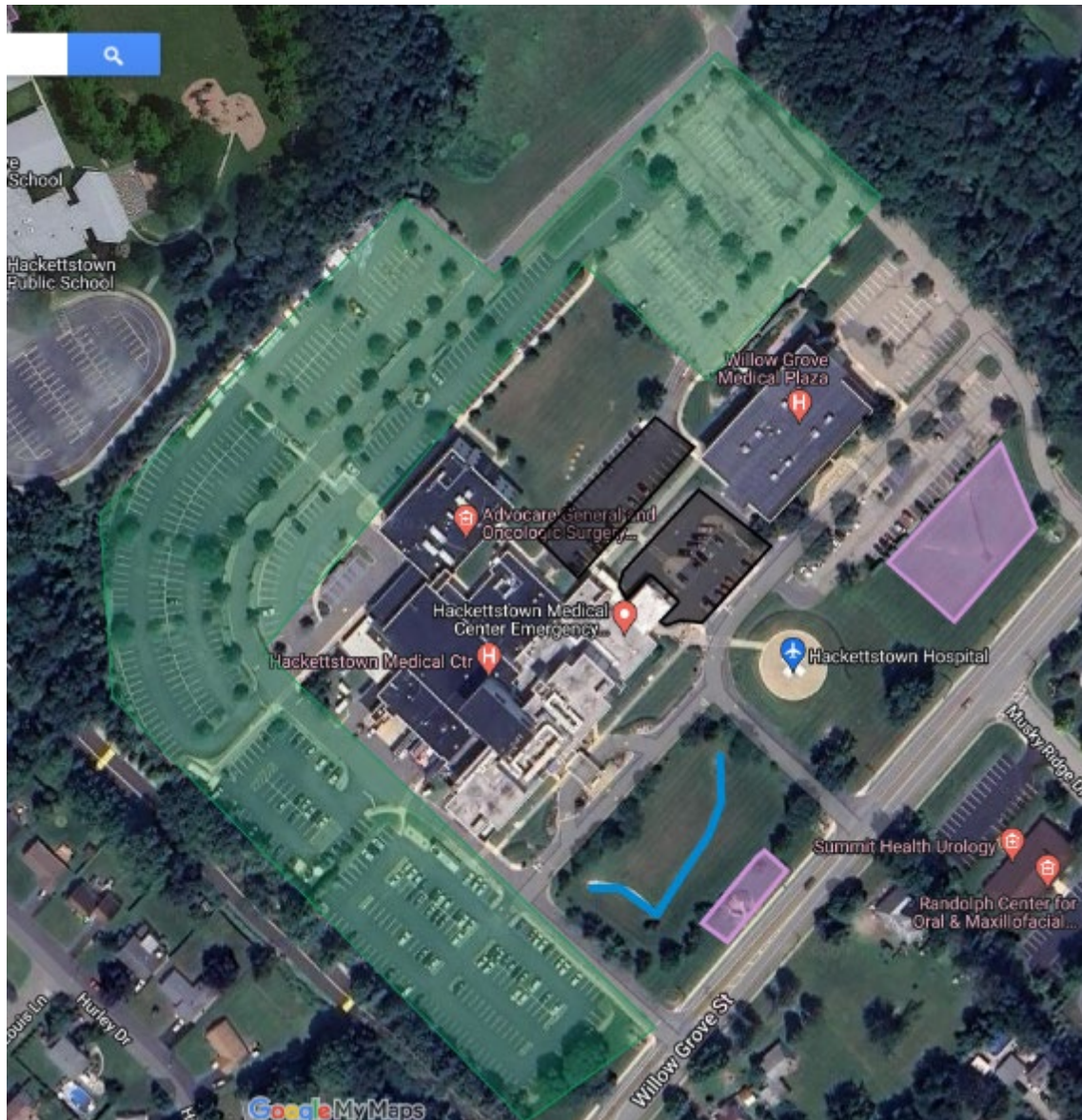


Figure C: Hackettstown Medical Facility complex.

Pink – Rain gardens

Blue – Bioswale

Black – Permeable Pavers

Green – Parking Diversions

Anticipated Benefits: This approach will manage stormwater on-site, reducing runoff volumes and nonpoint source pollution. For a campus of this size, adding plants and trees will help mitigate the urban heat island effect and reduce thermal pollution. The roots of native plants will create channels in the soil, enhancing water infiltration and improving groundwater recharge. The health and well-being benefits of this project are also significant. Green spaces and natural environments have been shown to reduce stress and promote well-being. Access to nature can improve the mental and physical health of patients, staff, and visitors, creating a more healing

and pleasant environment. Additionally, the inclusion of native plants will provide habitat for wildlife and pollinators.

Anticipated Issues: The property has multiple owners, which, despite being on a single campus, could present challenges for implementing a unified project across the entire area. Operations and maintenance procedures will need to be updated, including the development of a new training program for grounds management. This is especially important for maintaining the permeable pavers during winter months. New equipment and specialized training will require buy-in and proper instruction for the staff. Additionally, during the construction phase, parking may become a concern, requiring arrangements for overflow parking at other locations while diversions and pavers are being installed.

Possible Partners/Stakeholders: Hackettstown Business Improvement District

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), NJ Water Bank, American Rescue Plan (ARPA)

17.2 Project Name: Hackettstown Lowes Detention Basin Naturalization

Location: 215-225 Mountain Ave, Hackettstown, NJ. 40.83932, -74.8213

Priority: High

Recommended BMPs: Detention basin naturalization, parking diversions and other GSI identified by a consultant.

Current Condition: This property, owned by Hackettstown Interstate LLC, is directly adjacent to the Musconetcong River. It contains 2 big box stores, a fast-food restaurant and fast casual restaurant. It is a high traffic location on one of the main streets in the center of the town. The 2 detention basins are wet basins that gather and release stormwater to the Musconetcong River. The property sits on 25.54 acres 71.78% of which is impervious surface.

Issues and Concerns: This site is in a high-traffic, highly developed area of Hackettstown, directly adjacent to the river. As a result, any pollutants accumulated on-site are discharged into the river. The wet basins exacerbate water quality issues by holding and heating stormwater, which can promote the growth of harmful algae and attract nuisance Canada geese. The presence of Canada geese contributes to bacterial contamination. Additionally, the outfall pipe from the basins discharges onto the riverbank, leading to erosion and increased TSS. The large amount of impervious cover on the site contributes to the urban heat island effect, which heats stormwater and increases thermal pollution. The entire development also sits on Soil group D – very slow infiltration (Figure A), so a naturalized basin will assist with creating more channels for groundwater recharge.

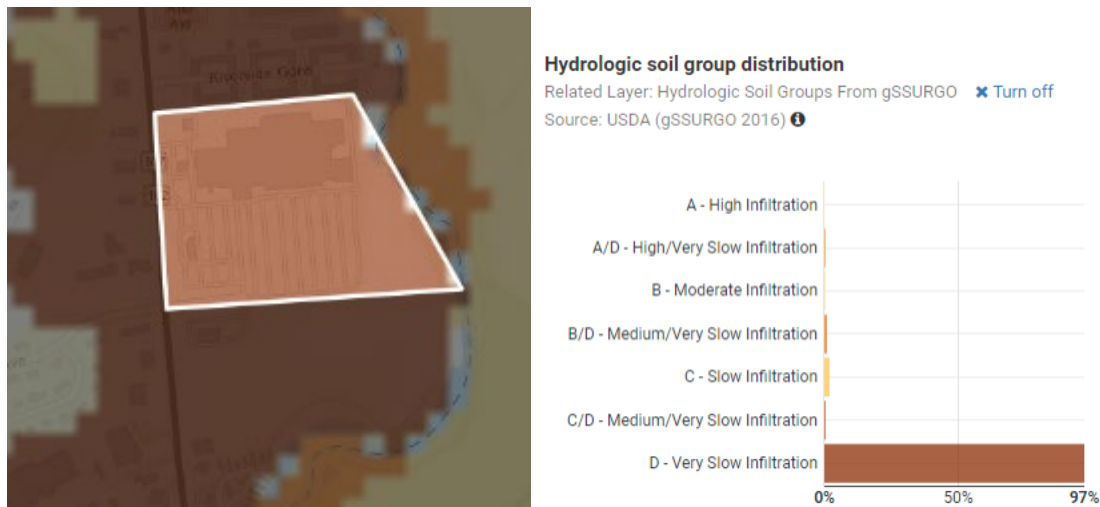


Figure A: Hackettstown Lowes complex, underlain by Soil group D.

Proposed Solutions:



Figure B: Hackettstown Lowes complex, adjacent to Musconetcong River.

Green – Parking Diversions

Yellow – Naturalized Detention Basins

Anticipated Benefits: Naturalized basins feature a diverse array of plant species that absorb and filter pollutants, including nutrients, heavy metals, and sediments. The increased vegetation and shaded areas help cool stormwater, reducing thermal pollution often associated with

conventional wet detention basins. These basins are effective at removing nutrients like nitrogen and phosphorus, which can lead to algal blooms and eutrophication in downstream water bodies. The diverse root systems in these areas enhance soil structure, promote infiltration, reduce surface runoff, and contribute to groundwater recharge. Additionally, naturalized basins provide habitats for various wildlife, including birds, amphibians, and beneficial insects, while supporting local ecosystems and promoting biodiversity. They also discourage nuisance species like Canada geese, thus helping to attain the 93% reduction for fecal coliform called for in the TMDL. As part of a treatment train approach, parking diversions will filter and direct stormwater to these naturalized areas, enhancing water quality. The increased presence of trees and plants will help mitigate the urban heat island effect and create a more green and aesthetically pleasing environment.

Anticipated Issues: Operations and maintenance of the naturalized detention basins will be vastly different than the current wet basins. There will be a learning curve for the maintenance crew and training will need to be administered. The parking diversions should not pose any issues, as the lot is large enough to accommodate a rotational construction schedule that does not impede business to the stores.

Possible Partners/Stakeholders: Hackettstown Business Improvement District

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), NJ Water Bank, American Rescue Plan (ARPA)

17.3 Project Name: Hances Brook – left branch

Location: Located in Mansfield Twp, at 40.805016, -74.860074

Priority: High

Recommended BMPs: Native plantings (buffers and successional reforestation), grazing management, livestock access control, and heavy use protection areas

Current conditions: The project will focus on Hances Brook's left branch, a priority tributary with an approximate drainage area of 2,200 acres, which flows into the Musconetcong River. Located downstream from the urban hubs of Hackettstown and Mansfield, Hances Brook's two branches* traverse a former pheasant farm and a residential neighborhood before converging on agricultural lands. The right branch features a maximum elevation of 375.8 meters and a slope of 48.8%, combined with soil types that are predominantly moderate to slow in infiltration, Hances Brook experiences consistently elevated levels of TSS and *E. coli*. Therefore, it should be considered a high-priority restoration area.

*Hances Brook's right branch will be discussed in a separate project so that BMPs and associated recommendations can be discussed in full.

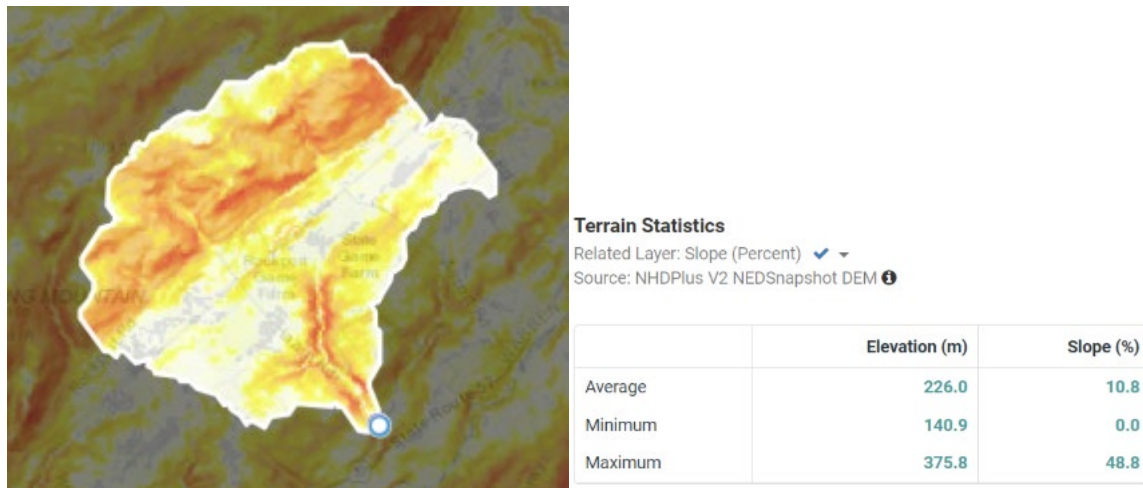


Figure A: Hances Brook's left branch with highly elevated terrain situated upstream from more of the agricultural lands, highlighting the impact agricultural lands will have on the surface water's ability to infiltrate before entering the tributary.



Figure B: Highlights the lack of streamside buffers and heavy use protection areas within the pastureland as well as the slope directly into the tributary on its right bank.

Issues and Concerns: The terrain and land use result in flash flood conditions unimpeded by stormwater infrastructure which carry with them nonpoint source pollutants in the form of excess nutrients and sediment. *E. coli* is one of the most notable pollutants entering the stream from a variety of sources such as cows in the tributary and legacy manure from the defunct pheasant farm. These conditions are compounded moving downstream, resulting in a TMDL which requires a 93% reduction in fecal coliform.

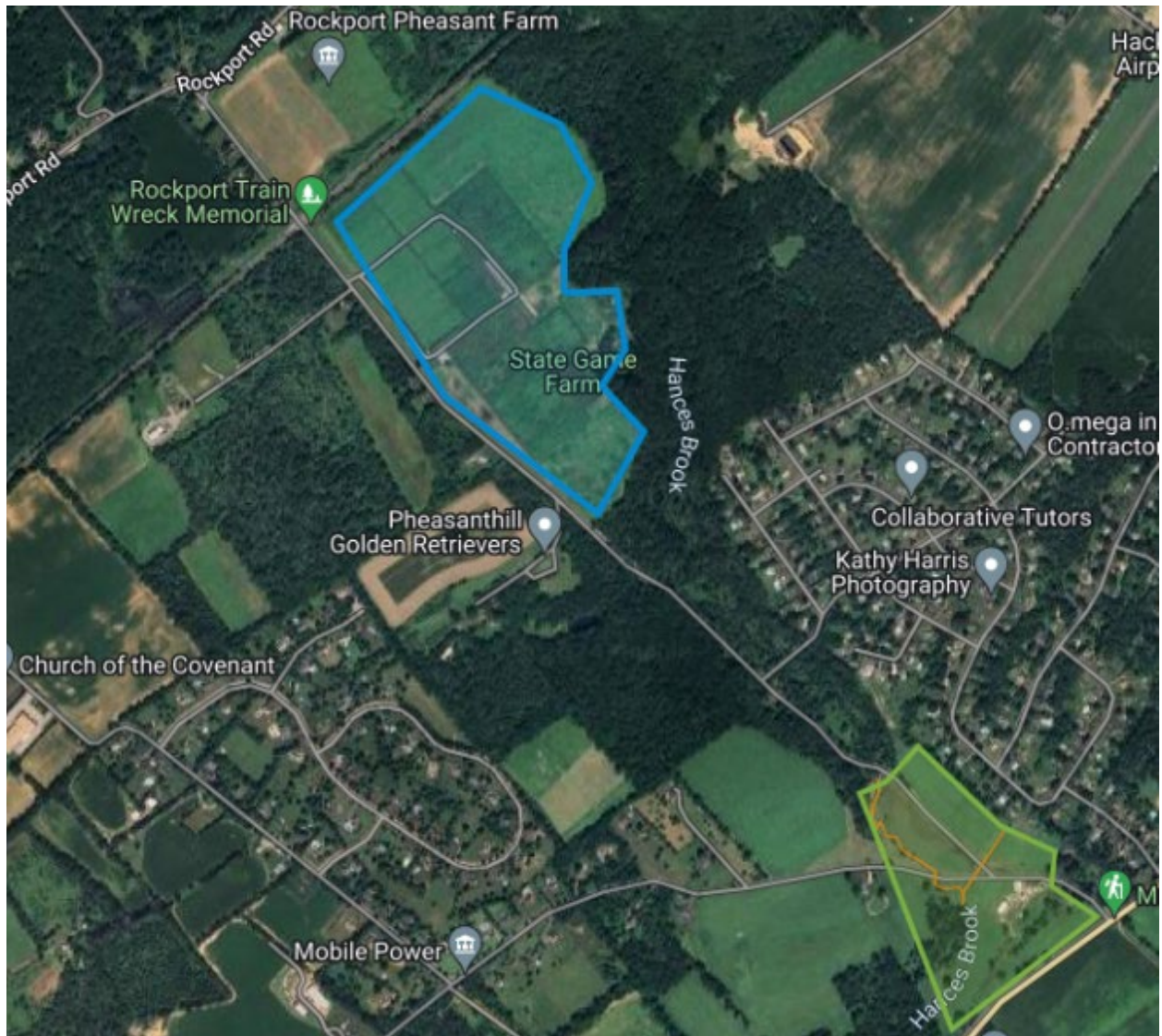


Figure C: Hances Brook with satellite base layer showing expanse of state game land and agricultural land and associated recommended BMPs.

Blue – Native successional forest planting

Green – Grazing management and livestock access control

Orange – Buffer planting

Proposed Solutions: A large-scale native planting (Figure A, blue polygon) where the defunct pheasant farm is, restoring it to a native forest through successional plantings; first by starting with native grasses and meadow species and then allowing it to succeed into a native forest. A

secondary native planting effort (orange line), along the agricultural section of the tributary will further enhance filtration/infiltration and reduce erosion. The final proposed solution (green polygon) would be various agricultural practices such as native buffers, grazing management, livestock access control and heavy use protection areas. These agricultural BMPs will lessen nutrient and bacterial inputs and sediment.

Anticipated Benefits: All the proposed BMPs will slow and filter stormwater from the surrounding land uses or prevent excess sediments from entering the stream through access control or protection areas like those around feedlots. By doing this, the number of nonpoint source pollutants making their way to the tributary will be dramatically reduced, leading to improved water quality. The surrounding properties will also see a decrease in erosion and thus a decrease in sediment making its way to the tributary as well as any pollutants which may affix themselves to sediment.

Anticipated Issues: Being that Hances Brook flows through a variety of state- and privately-owned lands, coordinating with all the stakeholders to implement the treatment train of BMPs will require an establishment of trust between stakeholders and staff members. This poses a challenge due to any preconceived notions on Green Infrastructure and the nature of people to adhere to traditional/conventional practices.

Possible Partners/Stakeholders: private landowners, Mansfield Township, NJF&W

Funding Sources: EQIP, 319(h) grants from NJDEP, American Rescue Plan (ARPA), CSP (NRCS), AMA (NRCS), CREP (USDA)

17.4 Project Name: Hances Brook – right branch

Location: Located in Mansfield Twp, at 40.805016, -74.860074

Priority: High

Recommended BMPs: Rain gardens, permeable pavers, roadside ditch retrofits, bioswales, native buffers and cover crops.

Current conditions: The project will focus on Hances Brook's right branch, a priority tributary with an approximate drainage area of 404 acres, which flows into the Musconetcong River. Located downstream from the urban hubs of Hackettstown and Mansfield, Hances Brook's two branches traverse a former pheasant farm and a residential neighborhood before converging on agricultural lands. The right branch begins on cropland before flowing through medium to low density neighborhood and then makes its way onto pastureland where it converges with the left branch before joining with the mainstem river. With a maximum elevation of 208 meters and a slope of 26.8%, combined with the various land uses, Hances Brook experiences consistently elevated levels of TSS and *E. coli*. Therefore, it should be considered a high-priority restoration area.

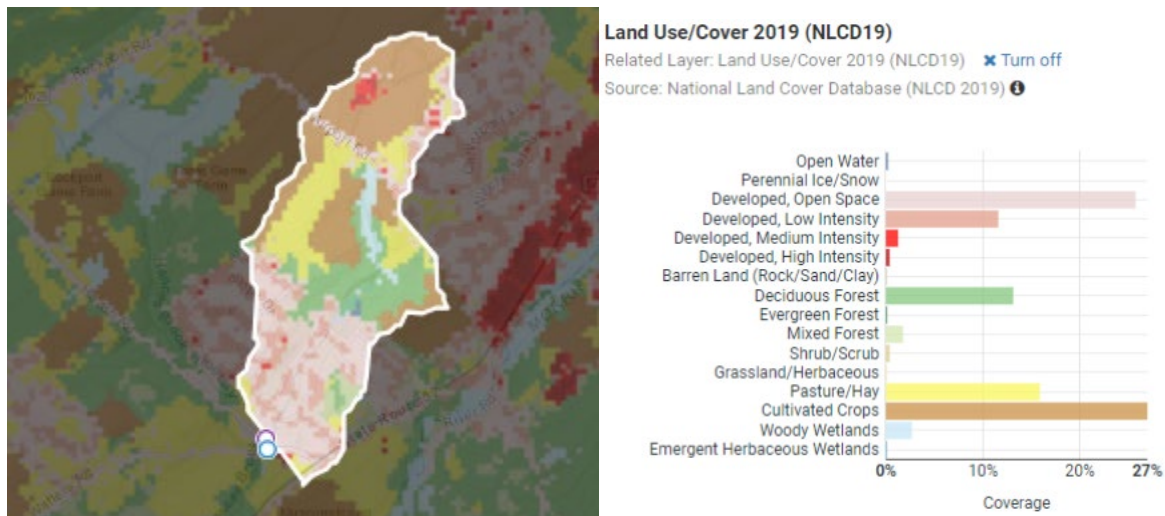


Figure A: Hances Brook's right branch with Land Use/Cover data showing cropland, developed land and pasture/hay land being the dominant land uses.



Figure B: Showcases the right branch flowing from the residential neighborhood and through the agricultural pastureland and the lack of stormwater infrastructure on the way.

Issues and Concerns: The terrain and land use result in flash flood conditions unimpeded by stormwater infrastructure which carry with them nonpoint source pollutants in the form of excess nutrients and sediment. The nutrients and sediment carried from the agricultural land can sheet over the landscape due to moderate to slow infiltration class soils and grey stormwater

infrastructure. These conditions are compounded moving downstream, resulting in a TMDL which requires a 93% reduction in fecal coliform.



Figure C: Hances Brook's right branch with satellite base layer showing expanse of residential land and agricultural land and recommended BMPs.

Light Blue – Agricultural BMPs: cover crops and native buffers

Pink – Rain Gardens, permeable pavers, retrofitted roadside ditches and bioswales

Proposed Solutions: The polygon at the bottom (pink) highlights the residential neighborhood the tributary flows through where rain gardens, permeable pavers, retrofitted roadside ditches and bioswales can be implemented. The retrofitted stormwater infrastructure and rain gardens will not only provide environmental benefits but also provide an aesthetic appeal in the

neighborhood. The other proposed solution (light blue polygon) would be various agricultural practices such as cover cropping and native buffer plantings. These agricultural BMPs will lessen nutrient inputs as well as sediment.

Anticipated Benefits: All proposed BMPs will slow and filter stormwater from the surrounding land uses. By doing this, the number of nonpoint source pollutants making their way to the tributary will be dramatically reduced, leading to improved water quality. The surrounding properties will also see a decrease in erosion and thus a decrease in sediment making its way to the tributary. Rain gardens, retrofitted roadside ditches and bioswales not only aid in the above-mentioned benefits, but they also provide native pollinators habitat, strengthening biodiversity.

Anticipated Issues: Being that Hances Brook flows through a variety of state- and privately-owned lands, coordinating with all the stakeholders to implement the treatment train of BMPs will require an establishment of trust between stakeholders and staff members. This poses a challenge due to any preconceived notions on Green Infrastructure and the nature of people to adhere to tradition/traditional practices.

Possible Partners/Stakeholders: private landowners, Mansfield Township, HOAs

Funding Sources: EQIP, 319(h) grants from NJDEP, American Rescue Plan (ARPA), ACT NOW (NRCS), AqAssist (NJRC&D), CSP (NRCS)

17.5 Project Name: Mansfield Municipal Building and adjacent recreational area

Location: Mansfield Township, 100 Port Murray Rd, Port Murray, NJ. 40.77866, -74.91473.

Priority: Medium

Recommended BMPs: Rain gardens, bioswales, permeable pavers and other GSI as identified as a best fit by a consultant.

Current Condition: The Mansfield Municipal building sits on 15.13 acres in a mostly rural area of southern Mansfield Township, Warren County. The outdated stormwater management system fails to allow infiltration and groundwater recharge in addition to the 19% impervious coverage. Compacted, mowed depressions collect stormwater and channel it downhill to the road. The recreational area includes a baseball diamond, several soccer/football fields, and an old basketball court. The maximum slope is 10%, with a series of berms and depressions designed to slow stormwater flow, but there are no native plants, natural swales, or rain gardens to aid in filtration of TSS and nutrients and infiltration of water.

Issues and Concerns: Retrofitting the current swales and basin into a more naturalized setting should be straightforward. Geologically, it has minor limestone (Figure A, dark pink) at the property's southern end that should be considered.

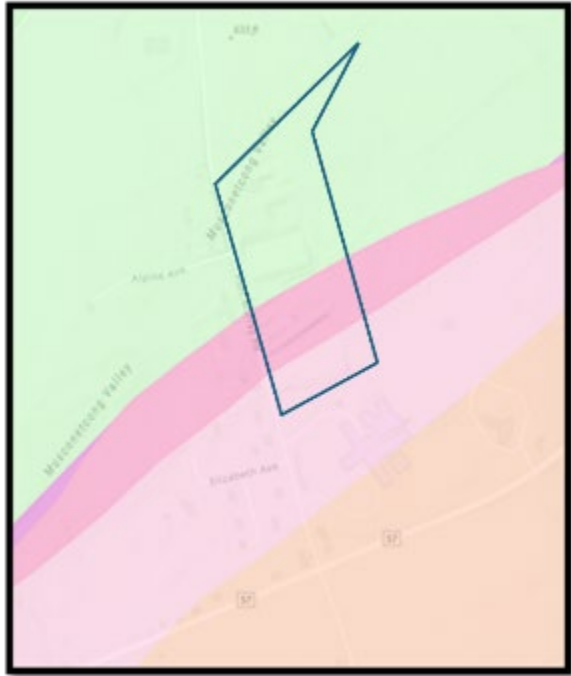


Figure A – Bedrock geological map overlain with Mansfield Municipal building property boundary.

Green: shale, slate, less abundant siltstone, and minor dolomite lens

Dark Pink: dolomite and minor limestone

Light Pink: dolomite and minor limestone

Orange: dolomite, and less abundant quartzite and shale

Proposed Solutions: Installing a series of rain gardens (Figure B, pink polygons) and bioswales (Figure B, blue lines) will help intercept and filter TSS, *E. coli*, and phosphorus from nearby farm fields and lawns. The deep root systems of native plants will create soil channels, enhancing water infiltration into the aquifer. This "treatment train" approach not only improves water quality but also provides habitats for pollinators and wildlife. Permeable pavers (Figure B, Black polygon) will restore a deteriorating parking lot and basketball court. They will enable water to filter into the ground, reducing runoff that carries nonpoint source pollutants to the road and eventually to a storm drain that leads to the river.

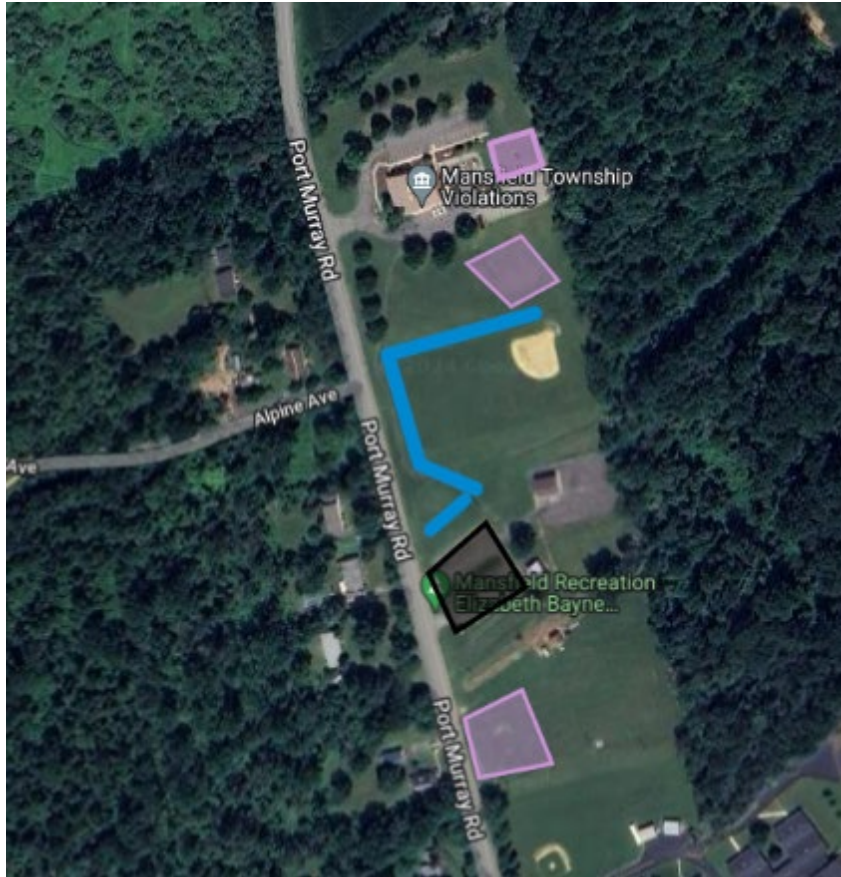


Figure B: Mansfield Municipal building and adjacent recreational area.

Pink – Rain gardens

Blue – Bioswale

Black – Permeable Pavers

Anticipated Benefits: All proposed BMPs will slow and filter stormwater from the property, allowing for improved infiltration. This will allow for groundwater recharge and attenuation through a more naturalized setting and therefore less NPS pollutants will enter the stream, additionally it will help reduce temperature plumes. The rain garden will also enhance the habitat for wildlife, especially pollinators, which can aid in fostering biodiversity.

Anticipated Issues: Rain gardens, permeable pavers, and bioswales require ongoing maintenance to ensure they function properly. This includes regular inspection, cleaning, weeding, and replacing plants as needed. New equipment and training will require acceptance by the staff. The second impediment is aesthetics, this detention basin handles drainage for the neighborhood's stormwater runoff. Because of this the officials may resist the project because they prefer the basin's look with mowed turf grass and landscaped shrubs over a more natural look proposed in this project.

Possible Partners/Stakeholders: Mansfield Township

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), NJ Water Bank, American Rescue Plan (ARPA)

17.6 Project Name: Mansfield Elementary School

Location: Mansfield Township, 50 Port Murray Rd, Port Murray, NJ. 40.77466, -74.91222

Priority: Low

Recommended BMPs: Rain gardens, bioswales and other GSI as identified as a best fit by a consultant.

Current Condition: Mansfield Elementary School sits on 22.19 acres in a mostly rural area of southern Mansfield Township, Warren County. Impervious cover is approximately 30% and the rest of the grounds are mostly maintained lawns, playgrounds and fields.

Issues and Concerns:

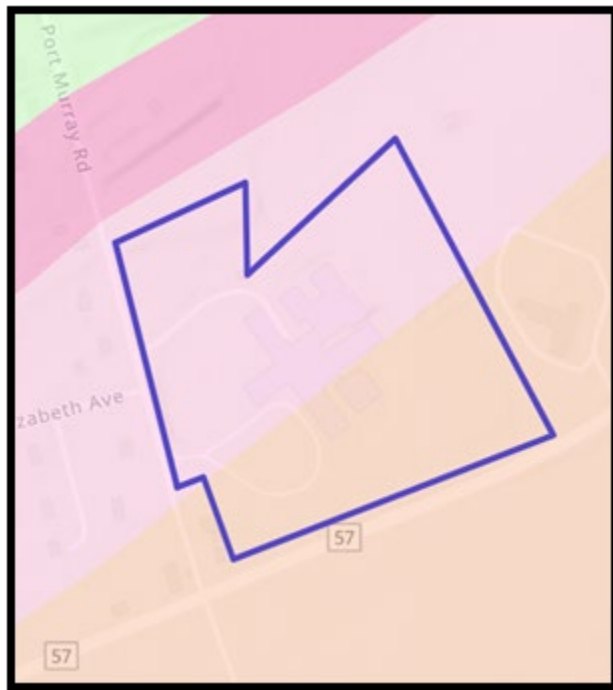


Figure A: Bedrock geological map overlain with Mansfield Municipal building property boundary.
Green: shale, slate, less abundant siltstone, and minor dolomite lens
Dark Pink: dolomite and minor limestone
Light Pink: dolomite and minor limestone
Orange: dolomite, and less abundant quartzite and shale

Proposed Solutions: The installation of a bioswale (Figure B, blue) that follows the contour of the property down the gradient will allow for filtration and infiltration of the stormwater that moves across the land from the municipal building up-slope. The bioswale then leads to a low spot on the property where a rain garden (Figure B, pink) would be most effective at continuing the infiltration of the stormwater, reducing runoff that carries nonpoint source pollutants to the main stem of the Musconetcong River, which is only 1/3 of a mile down the road.



Figure B: Mansfield Elementary School with proposed BMPs.

Blue – Bioswale

Pink – Rain garden

Anticipated Benefits: These BMPs will slow and filter stormwater from the property, enhancing infiltration and allowing for better groundwater recharge. This naturalized setting will reduce nonpoint source pollutants entering the stream. Additionally, the native plants and their pollinators will offer benefits for wildlife habitat and provide an educational opportunity for the students and community.

Anticipated Issues: Switching from a mowed lawn to a native swale and rain garden will require new operations and maintenance protocols. Like the municipal building next door, this will

involve regular inspection, cleaning, weeding, and plant replacement as needed. Staff will need new equipment and training to manage these changes effectively.

Additionally, signage and education for teachers will be necessary. This will enable teachers to explain the purpose of the new "garden" to the children, ensuring they understand the importance of not running through and disturbing the new plantings.

Possible Partners/Stakeholders: Warren County Board of Education, Mansfield Township

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), American Rescue Plan (ARPA)

17.7 Project Name: Pilot Septic Pumping and Maintenance program & stormwater infrastructure retrofit

Location: In Mansfield Township there is an isolated neighborhood with 14 homes surrounded by agricultural lands between Watters Rd and Washburn Rd, center at approximately 40.79652, -74.89114.

Priority: High

Recommended BMPs: Septic inspection and maintenance program, rain garden or bioswale

Current Condition: The 2021 water quality study showed high *E.coli* counts, and the MST data showed that most of the contribution was human sourced, second to that, cow manure. This residential development was installed in the 2000's and all homes are on septic systems. A concrete stormwater channel (Figure A, light blue polygon) funnels untreated runoff to a pipe that directs the flow towards the tributary without any treatment for water quality.

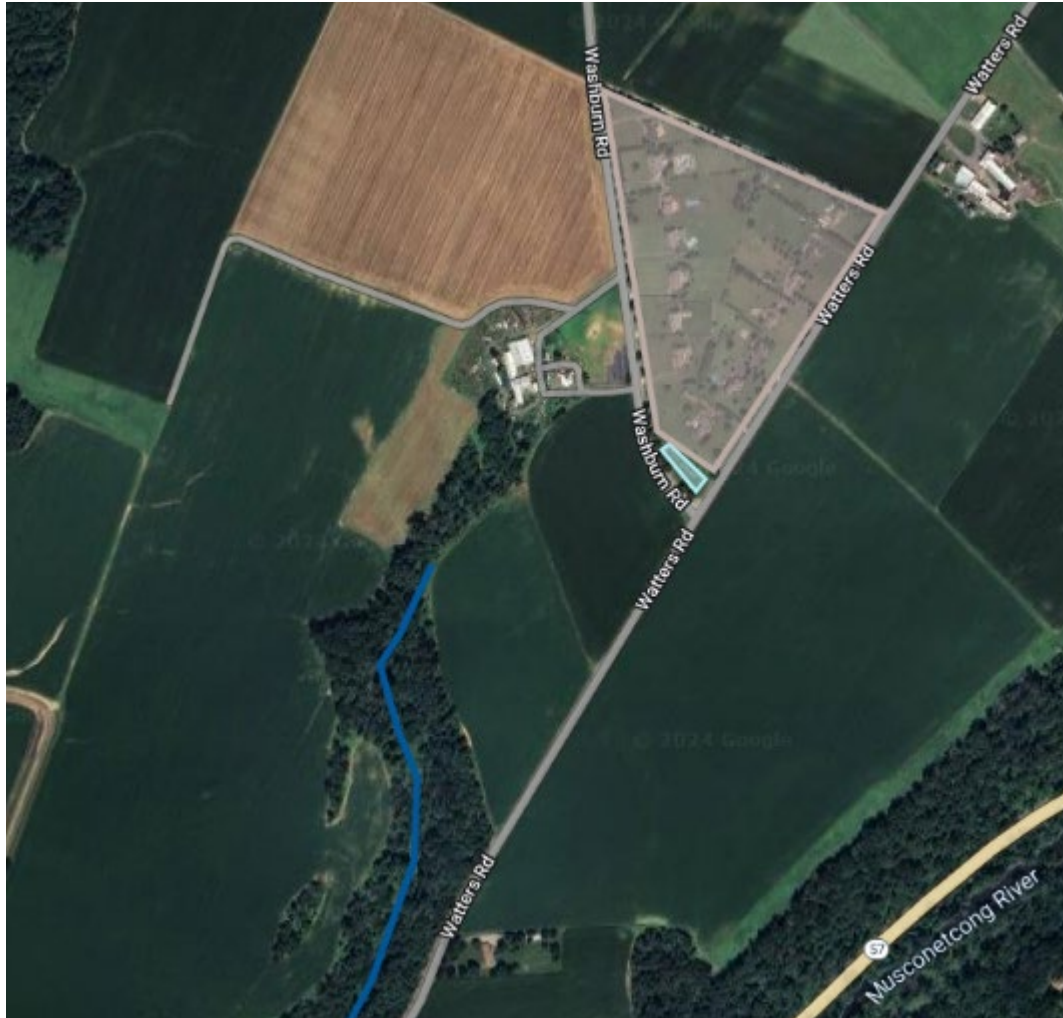


Figure A: Watters Rd neighborhood with the satellite base layer.

Grey polygon – 13 residential homes

Light Blue polygon – Concrete stormwater control mechanism

Blue line – tributary to Musconetcong River

Issues and Concerns: High levels of *E.coli*, particularly from human sources, are the primary concern. In a 2021 study, this tributary was identified as the highest contributor of human-sourced *E.coli*. Apart from two farmhouses, the area is an isolated residential neighborhood (Figure A, grey polygon) with a concrete stormwater control mechanism that directs stormwater into the tributary. Additionally, this tributary has exceeded SWQS for TSS. Addressing both bacterial and sediment issues is essential.

Proposed Solutions: Engage all residents (Figure A, grey polygon) in a pilot program to inspect, pump, and maintain septic systems to evaluate the effectiveness of this recommendation on a larger scale. Replace the concrete stormwater channel with a rain garden or bioswale to enhance infiltration, slow and filter water, and reduce TSS and *E.coli* contributions.

Anticipated Benefits: This project offers two key benefits. Firstly, it will educate residents about proper septic system maintenance, including when and how to service them. Secondly, by providing pumping and inspection services, faulty or leaking systems will be identified and repaired, reducing fecal contamination of surface and groundwater. Replacing the concrete structure with green stormwater infrastructure (GSI) will enhance stormwater infiltration, filter pollutants, and reduce runoff before it reaches the tributary.

Anticipated Issues: When dealing with private property and many individuals, there is always a chance that complete buy-in will not be achieved. Some people would rather not know of potentially expensive problems, especially when out of sight. The education program will be of paramount importance.

Partners/Stakeholders: Mansfield Environmental Commission and DPW

Funding Sources: Private pay for septic maintenance and pumping, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), NJ Water Bank, American Rescue Plan (ARPA)

17.8 Project Name: Lebanon Township Ditch Retrofits or Installations

Location: Lebanon Township, Musconetcong River Rd, right side when facing NE between Hollow Rd and Mountain Top Rd.

Priority: Medium

Recommended BMPs: Retrofit or installation of roadside ditches

Current Condition: This road runs parallel to the Musconetcong River. It has points of flooding in low spots and exists at the bottom of steep slopes. Most of the roadside does not have any ditches and the ones that do exist only pipe water under driveways or to small tributaries in isolated areas. The roadway sits along moderate infiltration soils, group B.

Issues and Concerns: Since this roadway is adjacent to the river, it shuttles stormwater across the pavement and down the slope. Flooding occurs at multiple pockets along the roadway and causes hazardous conditions. Since it sits at the bottom of a 38-degree slope, it accumulates sediment, nutrients and bacteria.

Proposed Solutions: The location and width of the shoulder lend this project to a French drain-style ditch.

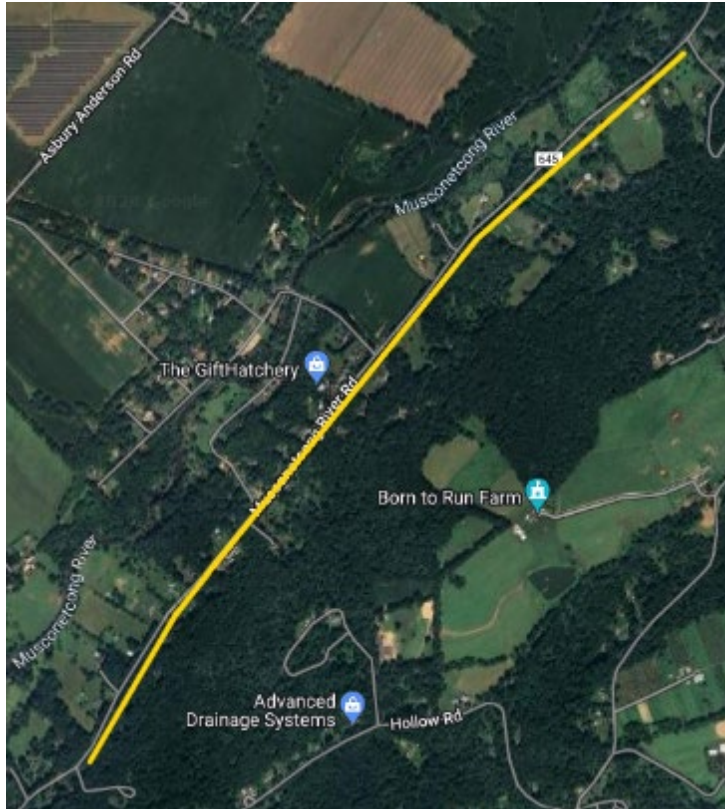


Figure A: Lebanon Township, Musconetcong River Rd site for ditch installation or retrofit in yellow.

Anticipated Benefits: The ditch will provide efficient stormwater management and reduce flooding, offering a low-maintenance and cost-effective solution for improving water quality. It will help prevent erosion along the roadway, thereby prolonging the road's lifespan and reducing maintenance and repair costs. Additionally, the ditch will facilitate infiltration and groundwater recharge. The filtration process will assist in reducing sediment, nutrients, and fecal coliform levels, contributing to progress toward meeting the TMDL requirements of 93% reduction.

Anticipated Issues: This road is sinuous and the main route for some commuters and will impede traffic while installation is taking place, but as the drains are easy to install, this should be a minor inconvenience for a short duration.

Possible Partners/Stakeholders: Lebanon Township

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), NJ Water Bank, American Rescue Plan (ARPA)

17.9 Project Name: Changelwater Rd tributary

Location: Washington Township, Warren County. Neighborhood east of Springtown Rd at approximately 40.74079, -74.96222.

Priority: High

Recommended BMPs: Rain gardens and riparian buffers

Current Condition: The unnamed tributary to the Musconetcong River has exceptional fisheries value, as evidenced by the presence of over a hundred native brook trout found during a 2021 electroshocking effort by NJF&W. However, it is being degraded by buffer loss and stormwater pulses. The areas upstream of Springtown Rd lack sufficient buffers and have degraded streambanks due to erosion. Most homes in the Springtown and Saddlebrook neighborhoods have manicured lawns and ornamental shrubs instead of native vegetation. The farm fields have small buffer zones, but they are not wide enough to mitigate the stormwater runoff from the fields. The culvert that runs under Springtown Rd is silted in and severs aquatic connectivity in low flow periods (Figure A).

Issues and Concerns: This tributary is a cold, groundwater-fed stream capable of supporting a native fishery but has been flagged by the NJDEP for temperature violations as it crosses Asbury Anderson Rd. The adjacent golf course maintains a minimum 100-foot buffer along the stream, so the stormwater issues originate upstream and from the roadway itself. Trout Unlimited has identified this tributary as a high-priority restoration site. It is crucial for the resident fish population and supplies cold water to the Musconetcong River. Over 150 trees are being planted in the riparian area downstream of Asbury Anderson Rd to stabilize streambanks and provide shade and ecological benefits. The upstream portion above Springtown Rd is a source of sediment, temperature pollution, nutrients, and bacteria.



Figure A: Culvert on Springtown Rd. The water depth under the culvert is 3” at the deepest point and turbidity exceeds criteria limits with no disturbance or rain, demonstrating a high amount of suspended sediment in the stream. Dozens of fish (mixed species) were observed in the scour pool downstream of the culvert, trapped on both sides by point bar formation.

Proposed Solutions: Installing a series of rain gardens within the neighborhoods (Figure B, pink polygons) and riparian buffers (Figure B, yellow line) will help intercept and filter TSS, *E. coli*, and phosphorus from nearby farm fields and lawns and stabilize the streambanks. The deep root systems of native plants will create soil channels, enhancing water infiltration into the aquifer.

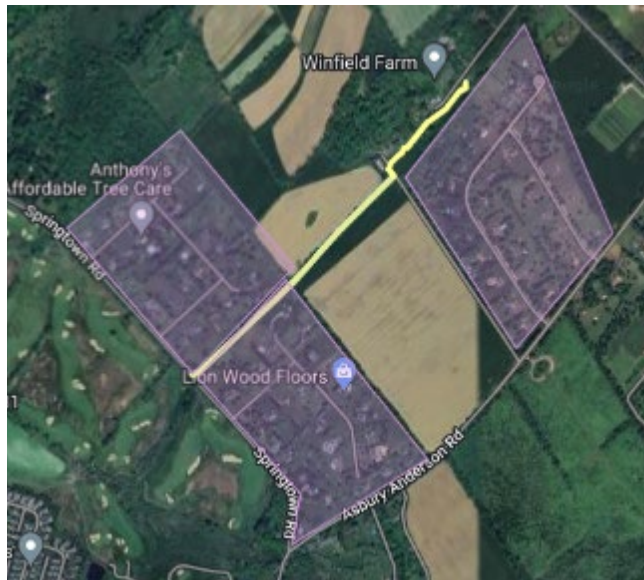


Figure B: Area in Washington Township (Warren County) between Springtown Rd and Changelogwater Rd, north of Asbury Anderson.

Pink – Rain Gardens

Yellow – Riparian Buffers

Anticipated Benefits: Adding rain gardens and a riparian buffer to the neighborhoods and adjacent farm fields offers significant environmental and community benefits. Rain gardens manage stormwater by capturing and infiltrating rainwater, reducing runoff, and filtering pollutants. They also recharge groundwater, create habitats for wildlife, and enhance the neighborhood's aesthetic appeal. Riparian buffers improve water quality by filtering pollutants, stabilize streambanks to prevent erosion, and provide critical wildlife habitat. They help regulate water temperatures and mitigate local flooding. Together, these green infrastructure solutions promote biodiversity, engage the community in sustainable practices, and protect the local ecosystem.

Anticipated Issues: Implementing rain gardens throughout the neighborhood will require significant outreach and buy-in from individual property owners, which can be challenging, especially if there is an HOA with restrictions on yard plantings. Establishing riparian buffers on

agricultural land will depend on the farmer's willingness to take land out of production and their ability to secure funding or assistance.

Possible Partners/Stakeholders: NRCS, NJRC&D, NJ Audubon, Washington Twp

Funding Sources: 319(h) grants from NJDEP, American Rescue Plan (ARPA), CREP (USDA), CRR (Arbor Day Foundation), CCGP (Inflation Reduction Act), WFPO (NRCS)

17.10 Project Name: Blue Army Shrine (BAS)

Location: BAS is in Asbury NJ at 40.72981, -75.00746.

Priority: Low

Recommended BMPs: Parking lot diversion or permeable pavers, vegetative buffers and rain garden.

Current Conditions: BAS covers 35.3 acres, and most of the property is covered by impervious surface and maintained lawn. It's at a maximum elevation of 741 ft and a maximum slope of 17.4%. The entirety of the property has soil group D-very slow infiltration. It is adjacent to an unnamed tributary to the Musconetcong River that regularly returns results of high TSS and *E. coli*. The property has grown over the years and the stormwater management has not been upgraded to reflect the change in use.

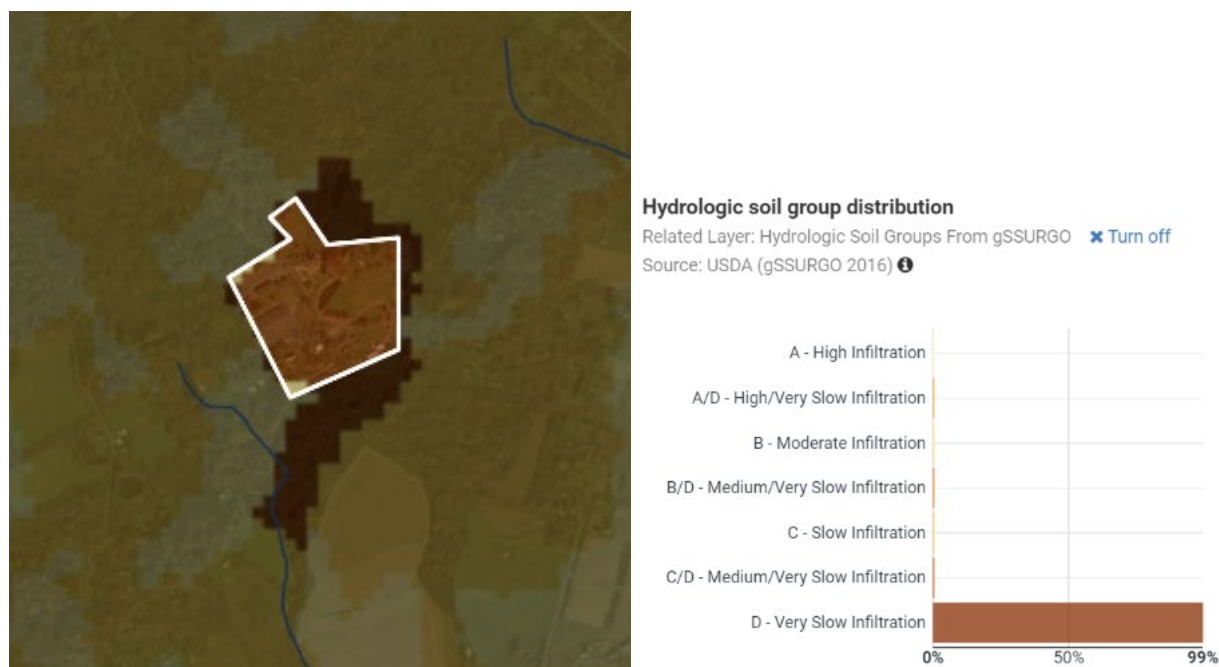


Figure A: Blue Army Shrine with soil group (D- Very slow infiltration) situated upstream and upslope from unnamed tributary to the Musconetcong River, aka Shurts Tributary.

Issues and Concerns: Steep slopes, undersized stormwater infrastructure, and extensive maintained lawns concentrate stormwater discharge into the tributary, causing flashy conditions. These conditions lead to bank erosion on the downstream farm property. This erosion further exacerbates downstream stream conditions, washing manure and fertilizer from farm fields into the stream. Because of these issues, the TMDL requires a 93% reduction in fecal coliform.



Figure B: Blue Army Shrine with satellite base layer showing expanse of mowed lawn and recommended BMPs.

Pink – Parking diversions/permeable pavers

Yellow – Native planting

Blue – Detention basin retrofit

Proposed Solutions: An herbaceous/grassed buffer (Figure A, yellow line) along the sloped lawn perimeter will slow and filter stormwater approaching the tributary. Replacing the current dry retention basin with a rain garden (pink polygon) at the property's base will enhance infiltration, allow for transpiration, and filter sediment through root channels in the soil. Parking diversions or permeable pavement (green polygon) will allow for runoff from the impervious surface to be treated and more infiltration for groundwater recharge. It will also help reduce the temperature of the water in summer months, whether through infiltration or attenuation.

Anticipated Benefits: All proposed BMPs will slow and filter stormwater from the property, allowing for more/better infiltration. This will allow for groundwater recharge, attenuation to decrease the flashiness and flooding of downstream land and therefore less NPS pollutants will enter the stream. It will also decrease the intensity of the stormwater within the stream, reducing bank erosion. The rain garden will also enhance the habitat for wildlife, especially pollinators.

Anticipated Issues: The BSA is a religious organization that may face resistance from stakeholders regarding property alterations. Ensuring a commitment to maintain the BMPs and enforcing an O&M plan could also be challenging. Additionally, promoting the use of native plants might be difficult due to existing traditional landscape aesthetics and the common perception of native plants as "weeds."

Possible Partners/Stakeholders: Franklin Township, Blue Army Shrine

Funding Sources: NJDEP 319(h) grants, MS4 Programs – I-Bank (New Jersey Environmental Infrastructure Financing Program (NJEIFP)), American Rescue Plan (ARPA)

Project Prioritization

Section 17 provides detailed information about implementing individual BMPs at specific sites within the watershed. Prioritization of BMPs is essential to address water quality issues effectively within the watershed. High-priority BMPs were identified based on monitoring data that revealed violations of surface water quality standards. These violations highlight critical areas where immediate intervention is needed to mitigate pollutants and improve water quality.

Out of ten proposed projects, each was assigned a priority level—high, medium, or low—based on the severity and frequency of SWQS violations, the potential for pollutant load reduction, and the feasibility of implementation. High-priority projects are those with the most significant impact on reducing pollutants and are slated for immediate action. Medium-priority projects are essential but less urgent, while low-priority projects are beneficial but can be deferred until resources are available. This prioritization ensures that efforts are focused on the areas where they will have the most substantial impact on the watershed's health and compliance with water quality standards.

18.0 Summary

Non-point sources of pollution within the watershed study area are numerous and sporadic, significantly impacting water quality. Failing commercial and home septic systems are a major contributor, introducing bacterial and nutrient contamination into the watershed. Additionally, agricultural practices contribute to organic enrichment, nitrate-nitrite, nutrients, phosphorus, and pathogenic bacteria. The destruction of riparian zones by unrestricted livestock access and farming in riparian areas, as well as urban development, further exacerbates these issues.

Residential and commercial development has expanded from central cities into rural areas, leading to habitat and flow alterations, sediment and nutrient importation into tributaries. These land use changes, notably the increase in urban land and decrease in agricultural lands over the past few decades, have significantly affected watershed hydrology. Urbanization has increased impervious surfaces, reduced infiltration, and groundwater recharge while increasing surface runoff. This rapid runoff contributes to streambank erosion, unstable channel conditions, and increased sedimentation and habitat degradation.

Efforts to manage stormwater have shifted from prioritizing volume and velocity attenuation to focusing on water quality. This change underscores the importance of mitigating pollutants and contaminants carried by stormwater runoff to protect the watershed's health and ecosystem.

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. 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

2. 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

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

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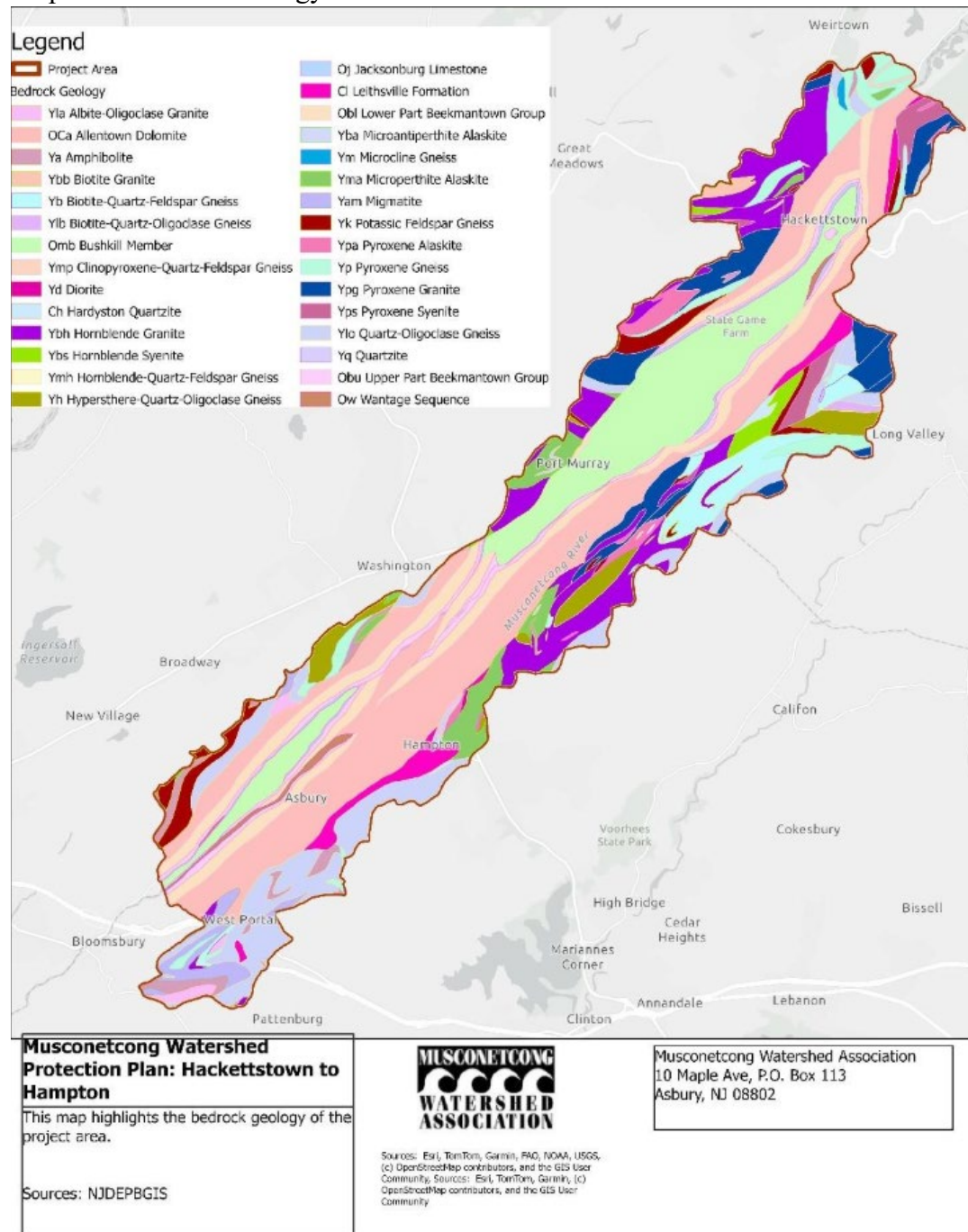
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Appendices

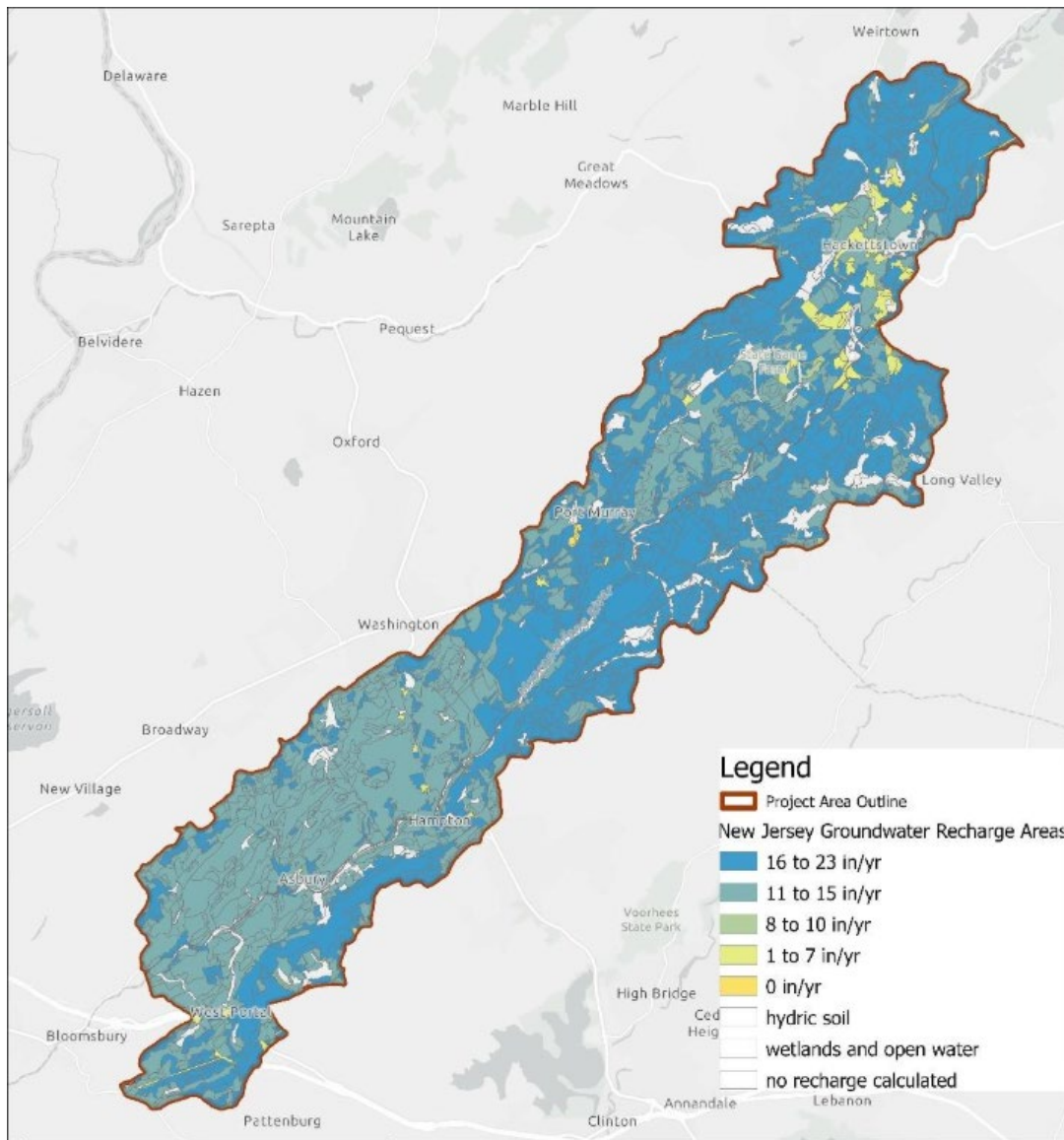
A. Bedrock Geology

Map A.1 Bedrock Geology



B. Groundwater Recharge

Map A.2 Groundwater Recharge



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the groundwater recharge areas within the project area.

Sources: NJ Highlands Council

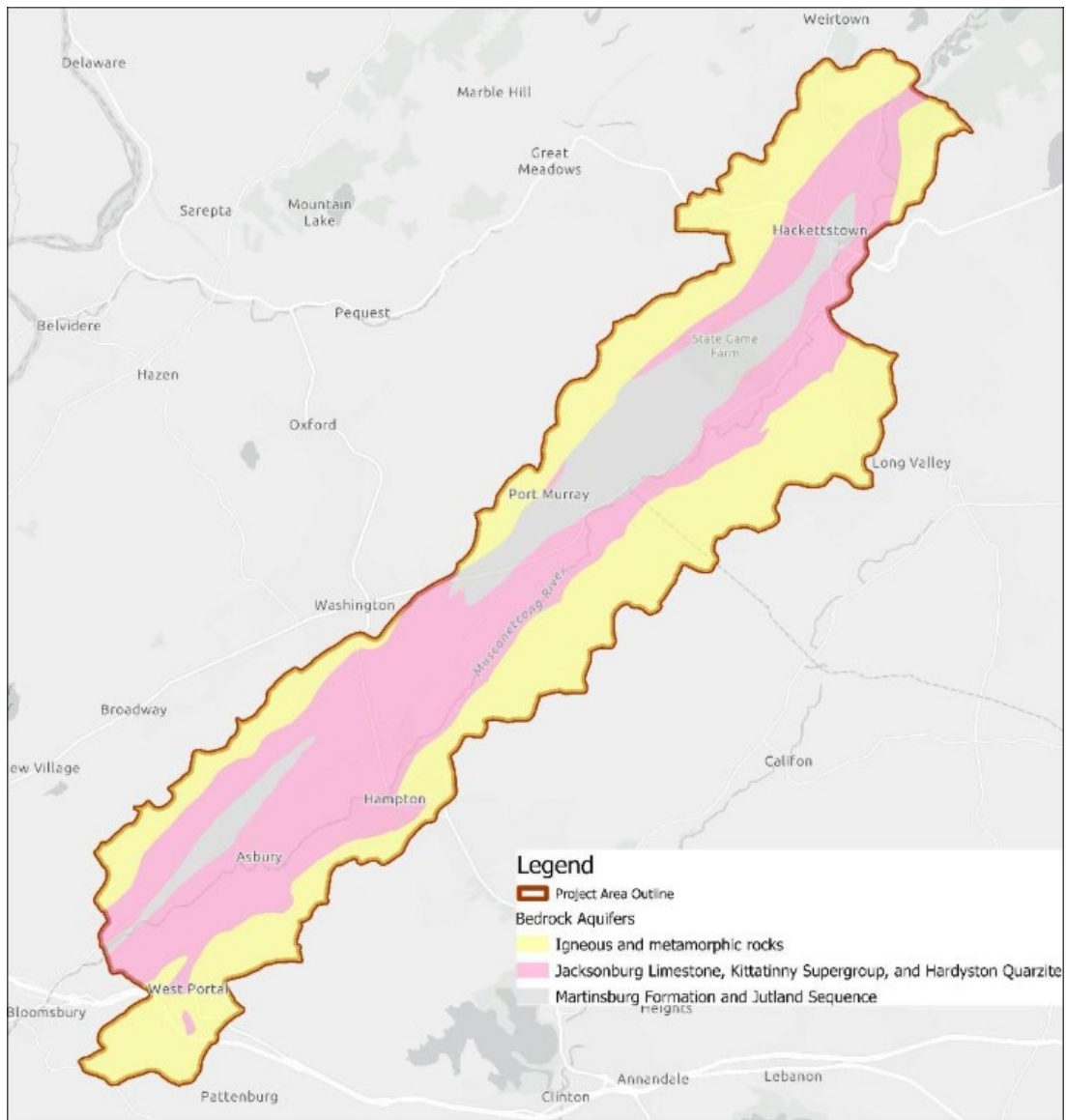


Sources: Esri, TomTom, Garmin, FAD, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community

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C. Bedrock Aquifer

Map A.3 Bedrock Aquifer



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the bedrock aquifers within the project area.

Sources: NJDEPBGIS

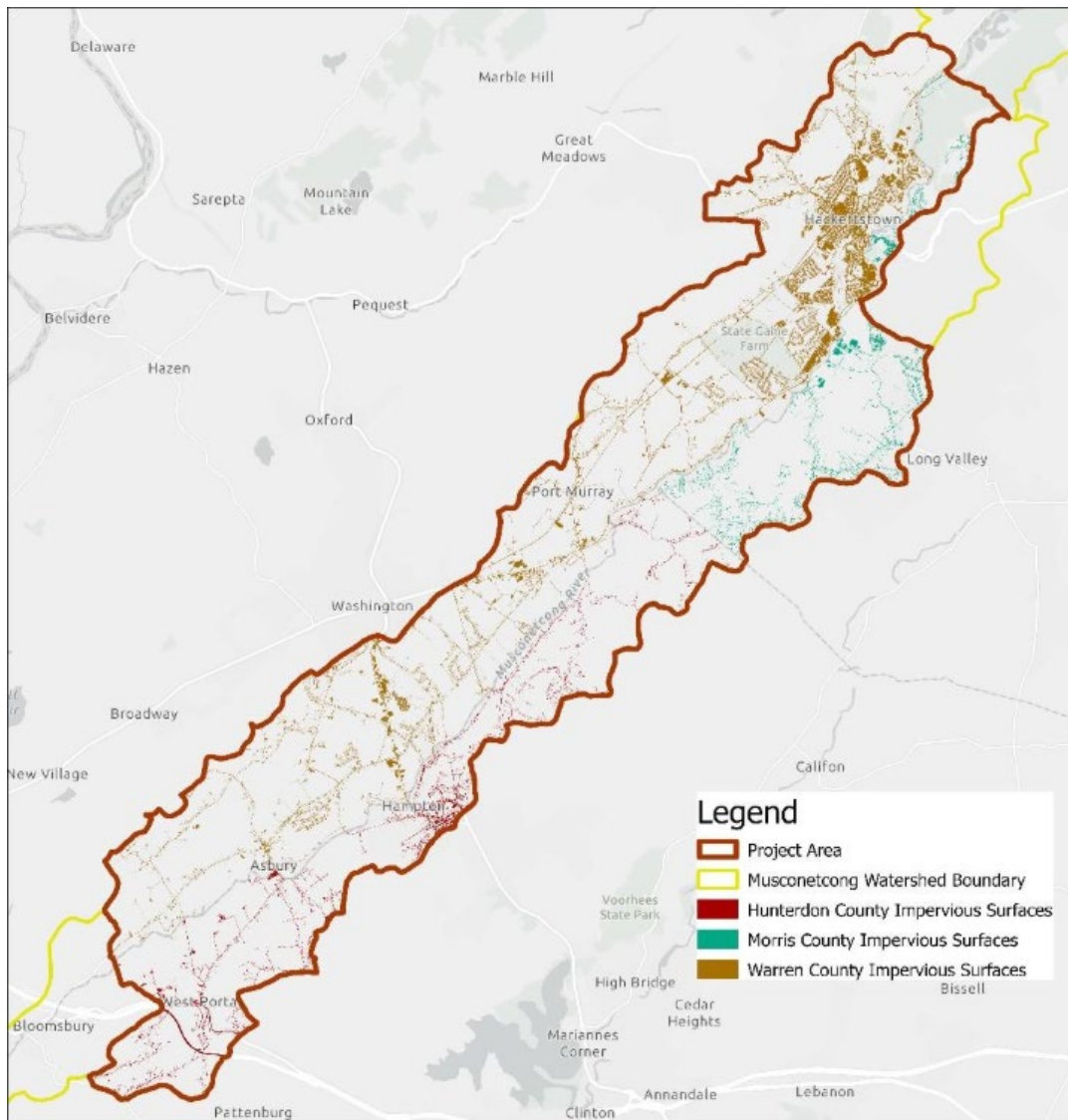


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D. Impervious Surfaces

Map A.4 Impervious Surfaces



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the impervious surfaces (buildings, roads and other) broken up by County within the Project Area.

Sources: NJGIN

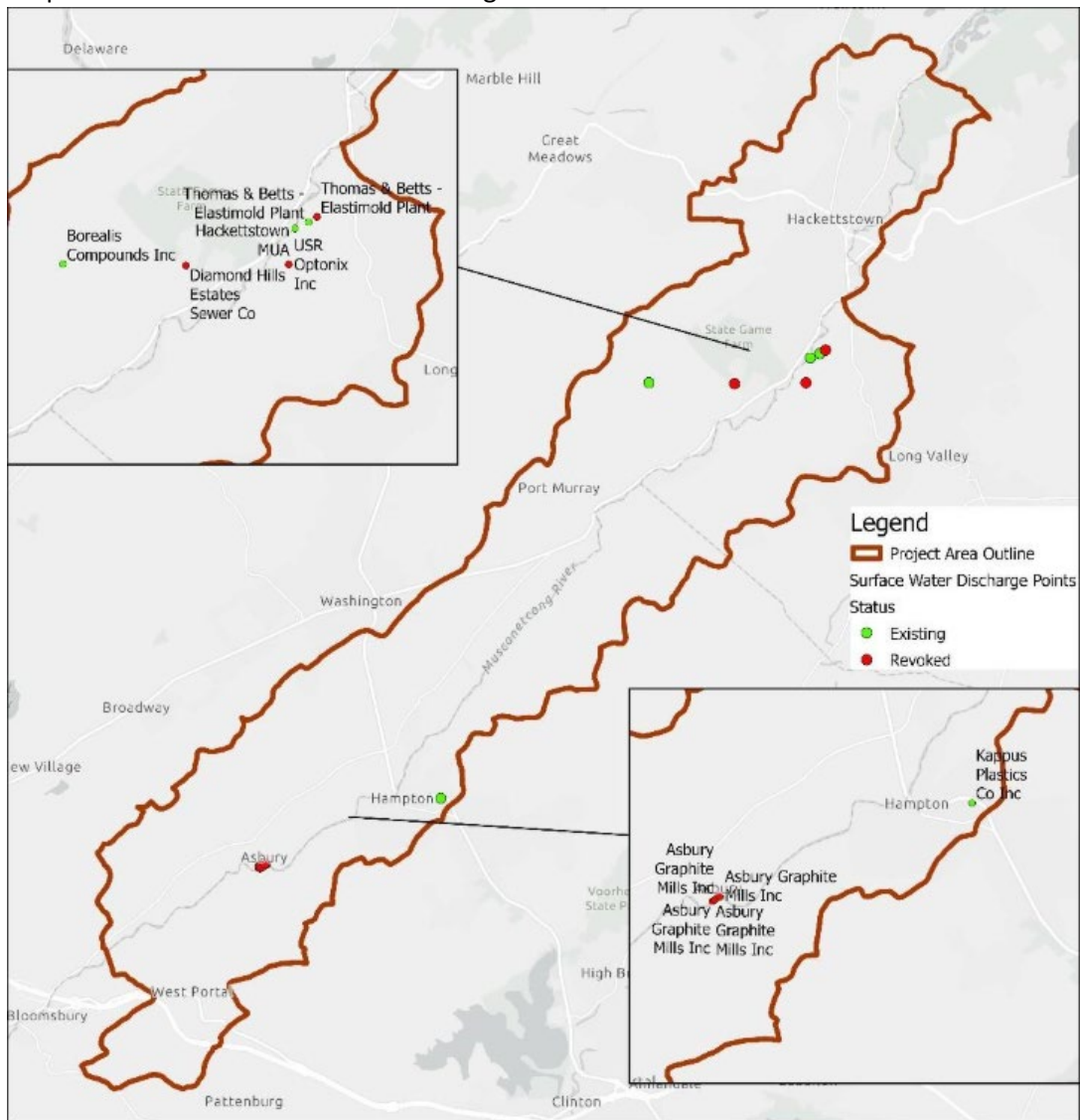


Sources: Esri, TomTom, Garmin, FAD, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community.

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E. Point Source Permitted Discharges

Map A.5 Point Source Permitted Discharges



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the surface water discharge locations within the project area, with a focus on the locations with existing and revoked permits.

Sources: NJDEPBGIS - 2024

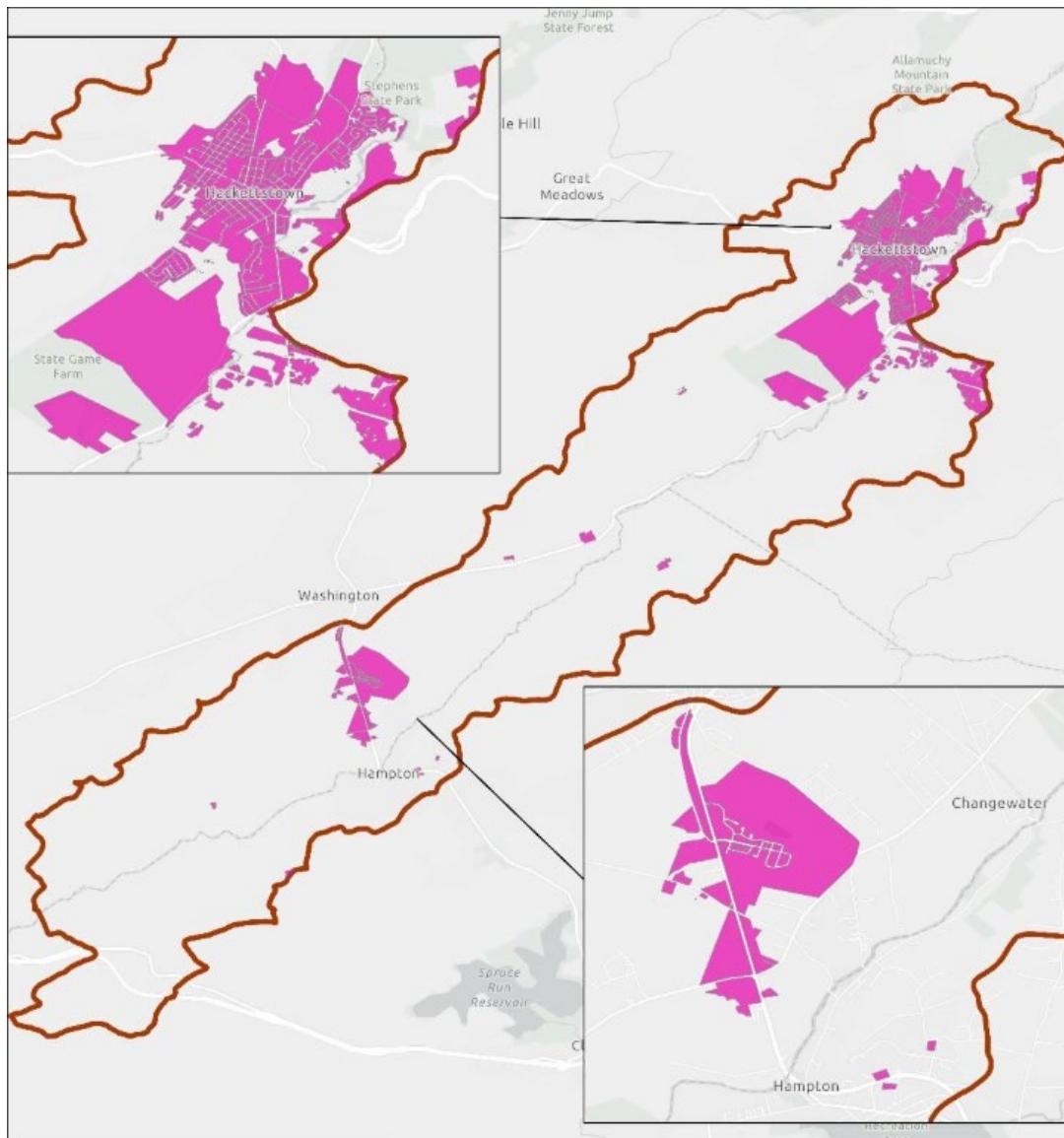


Sources: Esri, TomTom, Garmin, FAD, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community.

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F. Sewer Service

Map A.6 Sewer Service Areas



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights sewer service areas within the project area.

Sources: NJDEPBGIS

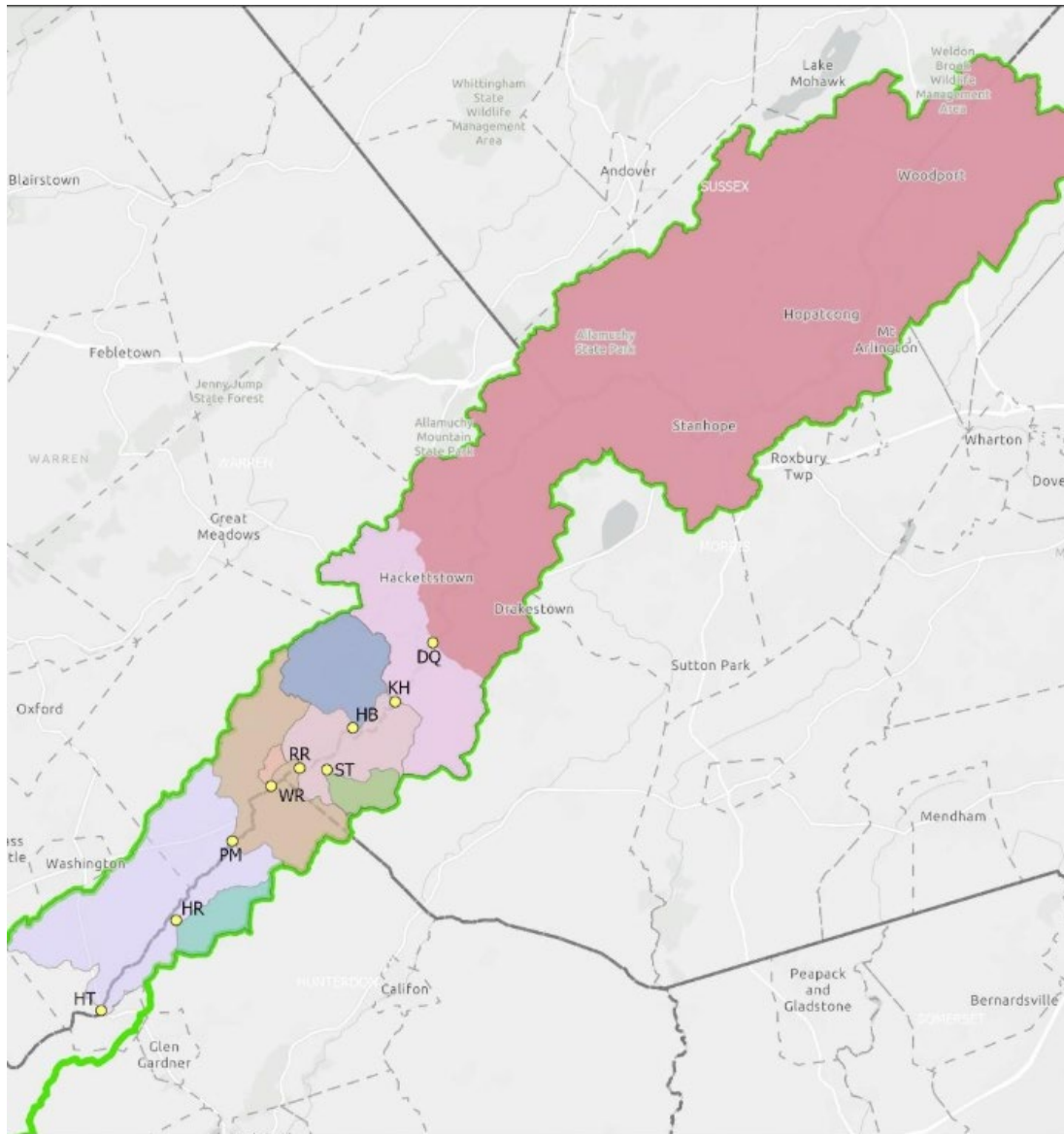


Sources: Esri, TomTom, Garmin, FMO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community

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G. Drainage Basins

Map A.7 Drainage Basins



Musconetcong Watershed Protection Plan: Bloomsbury to Hackettstown

This map highlights the drainage basins
associated with the 2021 project sampling
locations.

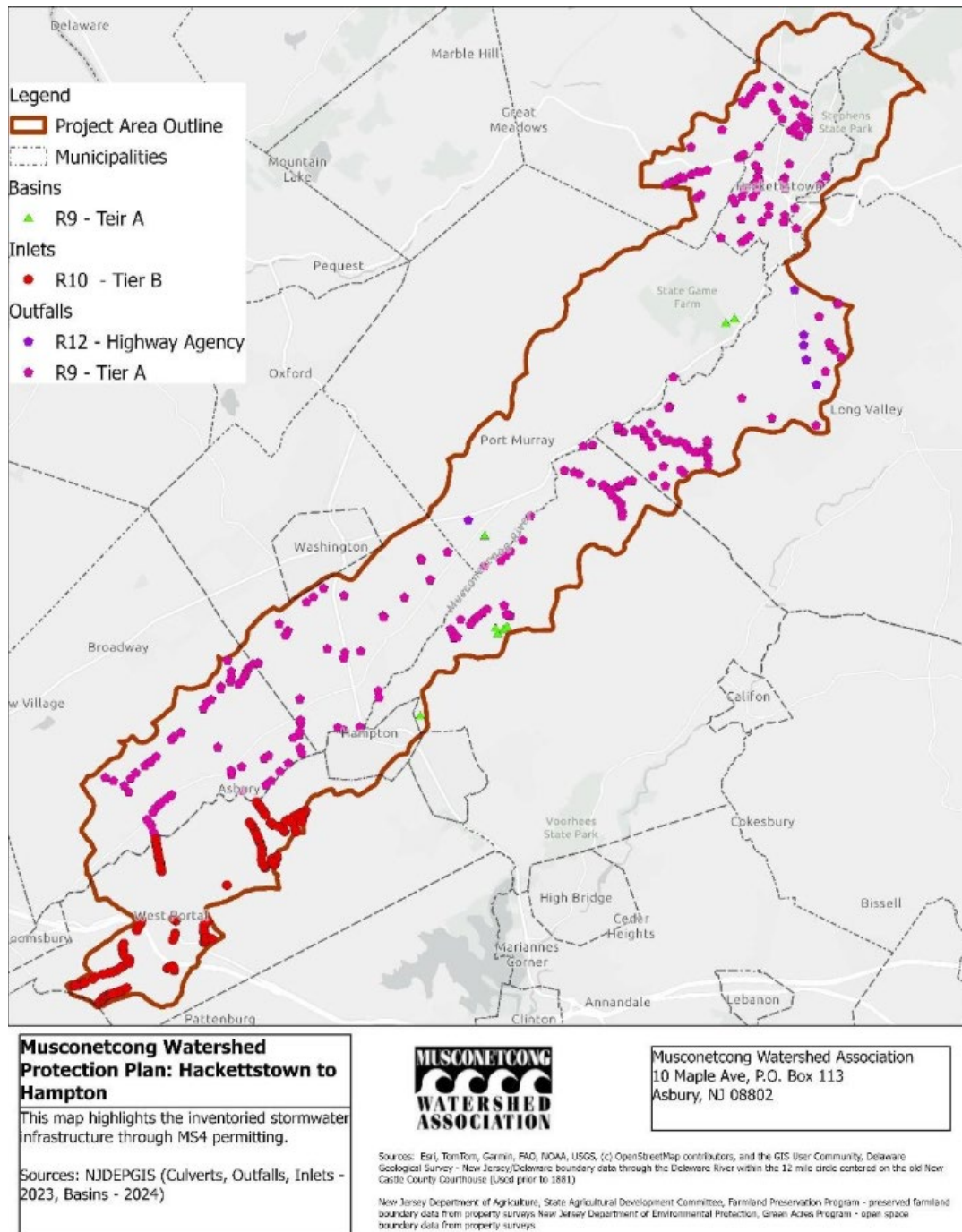
Sources: Drainage basin data is from Montclair
State University, 2021 MST study.



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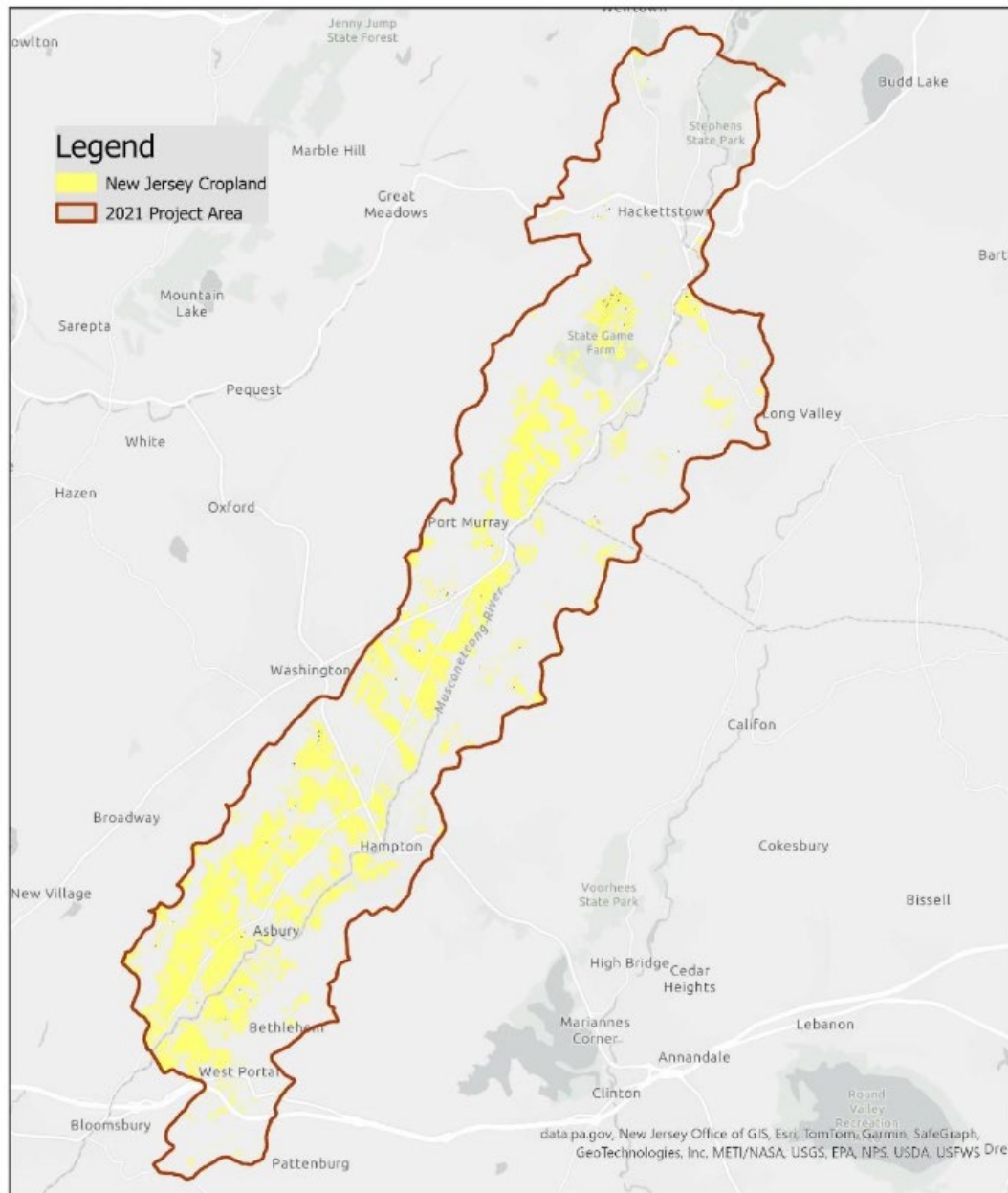
H. Stormwater Infrastructure

Map A.8 Stormwater Infrastructure



I. Potential Cover Cropping Locations

Map A.9 Potential Cover Cropping Locations



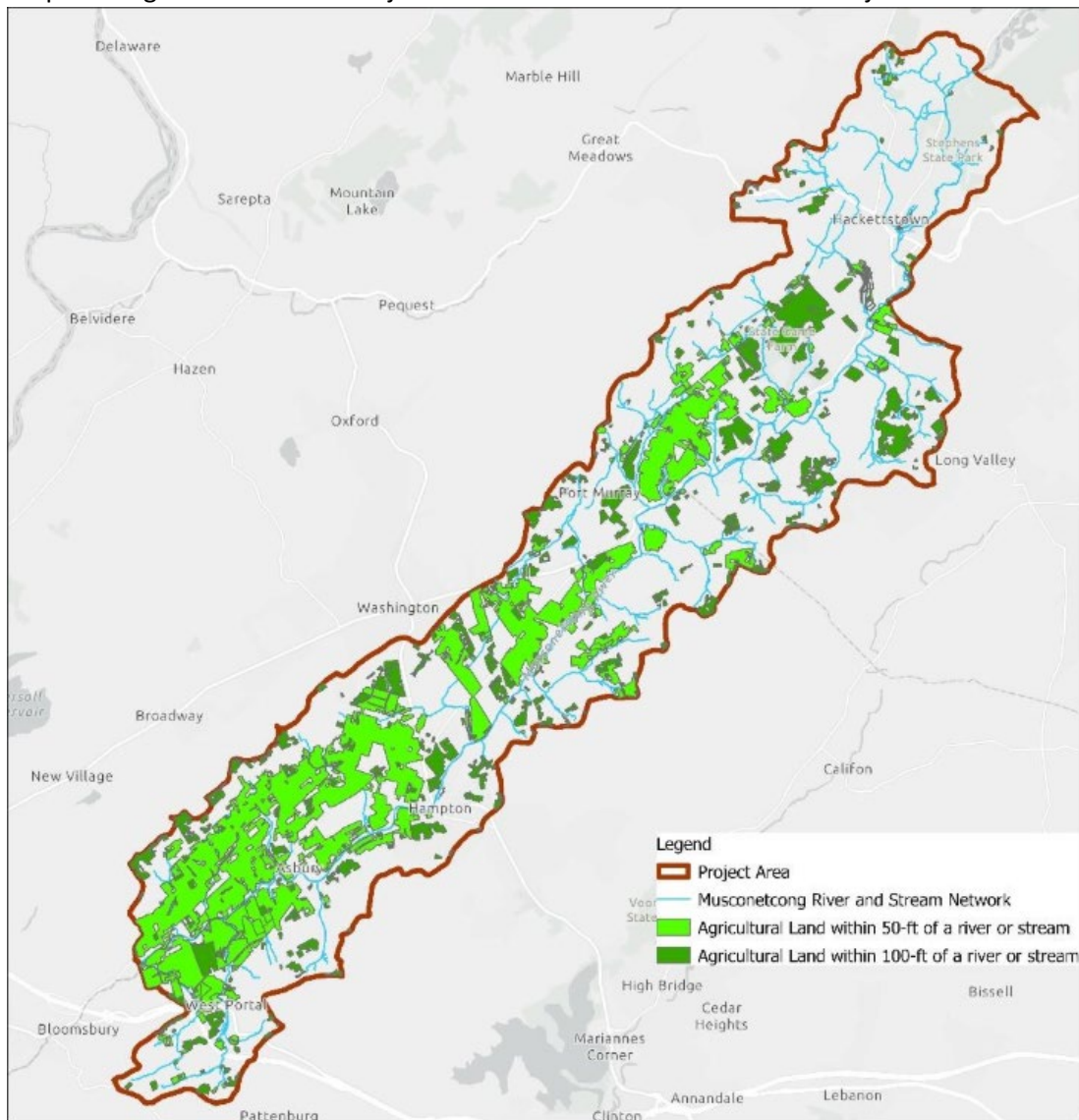
This map highlights the cropland available to implement cover cropping and nutrient management best management practices
Data Layer Source: USDA



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J. Agricultural Parcels Adjacent to a River or Stream

Map A.10 Agricultural Parcels adjacent to a river or stream within the Project Area



Musconetcong Watershed Protection Plan: Hackettstown to Hampton

This map highlights the farmland adjacent to a the river or stream. It is important to note that all of the agricultural parcels within the project area are within 100-ft of a river or stream.

Sources: NJDEPGIS



Sources: Esri, TomTom, Garmin, FAD, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community. Sources: Esri, TomTom, Garmin, (c) OpenStreetMap contributors, and the GIS User Community.

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K. Flow Together Phase One Survey

Flow Together Survey

This survey has been created by the Musconetcong Watershed Association to better grasp the community's understandings of stormwater run-off and it's impacts on the watershed. The goal is to take the information gathered and apply it to future best management practices, in the hopes of capturing the consideration of the whole community in which they impact. Your personal information will not be shared to other organizations.

Fun Fact:

Everyone lives in a watershed. The U.S. Geological Survey has divided the Nation into approximately 160,000 watersheds with an average size of 40 square miles. (USGS.gov)

What's your Hydrologic Unit Code (HUC-14)?

HUC stands for the Hydrologic Unit Code of a watershed (or part of a watershed) in the national Watershed Boundary Dataset. Think of it like a watershed zip code!

1. Take your phone out
2. Scan this QR code ----->
3. Click the Search button, enter your address
4. Click the light blue polygon your address is in and an informational window will pop up showing your HUC 4, 6, 8, 11, and 14
5. Record your HUC - 14 below!



Which best describes your race or ethnicity? (Select all that apply)

Asian / Southeast Asian / Asian American	Native
Black or African American	White
Hispanic / Latino	Two or More Races
Native American / Pacific Islander / Alaska	Prefer not to say

What is your age group?

5-15 years old
15-25 years old
25-35 years old
35-45 years old
45-60 years old
60+ years old

Do you own or rent your home?

1-Own
2-Rent

3-Other / Please Describe: _____

My property _____:

1-Is linked to the town sewer line

2-Is on septic

3- I don't know

4-Other / Please describe: _____

Are you involved with any local environmental commissions or other environmentally focused non-profits? If so, list here:

Are you familiar with the work of the Musconetcong Watershed Association?

Yes

No

If you answered yes to the previous question, what is your affiliation with the Musconetcong Watershed Association? (select all that apply)

Board Member

Supporter

Donor

Regularly attend MWA events

Former employee

Volunteer

Not affiliated at all

Other: _____

Have you ever heard of the term stormwater run-off?

Yes, and I understand what it means.

Yes, but I don't understand what it means.

No, I have never heard that word before.

If you answered "Yes" to the previous question: Where did you hear about stormwater run-off? (Select all that apply)

A friend/colleague

The news

Facebook

Instagram

Meet-Up

Snapchat

Tik-Tok

Twitter

WhatsApp

Other: _____

If you answered "No" or "Yes, but I don't understand what it means" to the previous question: Stormwater runoff is generated from rain and/or snowmelt that flows over land or paved surfaces such as paved streets, parking lots and building rooftops, and it does not soak into the ground resulting in large-scale flooding and pollution, especially in urban settings. Runoff can also pick up and deposit harmful pollutants such as trash, chemicals and dirt/sediment into streams, lakes and groundwater (US EPA, 2023).

I could see myself making these changes in my behavior to help support a resilient Watershed against stormwater runoff (Select all that apply):

- ☐ Support a reduction of paved surfaces and an increase in rain gardens and native plantings.
- ☐ Reduce the use of fertilizers, pesticides and other chemicals from gardens and homes.
- ☐ Avoid using excess soap while washing my car.
- ☐ Maintain my car to ensure it isn't leaking oil, grease, metals or coolants.
- ☐ Properly dispose of animal waste
- ☐ If I live river/stream side I will keep an appropriate native, streamside plantings.

I would be interested in learning more about (check all that apply):

Adaptive Reuse	Green Building Techniques	Remaining economically competitive on state and national levels	Opportunities for passive and active recreation
 1. Kearny Point (WXY) 2. Pennington St / New London, CT	 1 / Passive House	 1/ Green manufacturing jobs 2/ helping farmers & agriculture industry workers	 1. Natural Playground 2. Dog park

L. Flow Together Phase Two Survey

Flow Together Survey Phase II

This survey has been created by the Musconetcong Watershed Association to serve as a follow up to the initial survey from Phase I of this outreach series. In this survey, best management practices are identified, and participants are asked to give their input on such best management practices in order to better prioritize strategies that will not only be effective but a good fit for the communities in which they are implemented. Your personal information will not be shared with other organizations.

Do you have a comfortable understanding of what a best management practice (BMP) is in terms of stormwater?

Yes No

If no, a best management practice is a practice or combination of practices considered to be the most effective means (including technological, economic, and institutional considerations) of preventing or reducing the amount of pollution by nonpoint sources to a level compatible with water quality goals (USEPA).

In your own words can you describe what best management practices mean to you?

Looking at these images which would you consider more visually appealing?



Completely paved parking lot

or



Parking lot with vegetative zone



Concrete swale

or



Grass swale

For this section circle all options that apply:

Rain gardens provide what benefits:

Reduce mosquito breeding.
Filter runoff pollution.
Reduce garden maintenance.
Increase beneficial insects and eliminate pest insects.
Recharge local groundwater.
Improve water quality, removing up to 50% total suspended solids.
Reduce potential of home flooding.

Bioretention basin retrofits* provide what benefits:

Reduce noise pollution.
If decentralized, bioretention areas are less costly than conventional stormwater technologies.
Can remove up to 75% of phosphorus and nitrogen.
Can remove up to 95% of metals.
Can remove up to 90% of organics, bacteria, and total suspended solids.

For this next section, rate your willingness to implement a BMP on a scale from 1-10 with 1 being extremely unlikely and 10 being extremely likely.

Detach rain gutter from downspout to stop the concentrated flow of rainwater from gutters to street, to allow for infiltration into ground.

1 2 3 4 5 6 7 8 9 10

Spend \$200 on **native plants*** to replace current household landscaping to help reduce incidences of flooding inside your home.

1 2 3 4 5 6 7 8 9 10

Spend an average of \$1.50 per square foot to replace a paved driveway with gravel to reduce impervious surfaces on your property and increase infiltration, reducing not only pollution to the river but also reduce risk of flooding on your property.

1 2 3 4 5 6 7 8 9 10

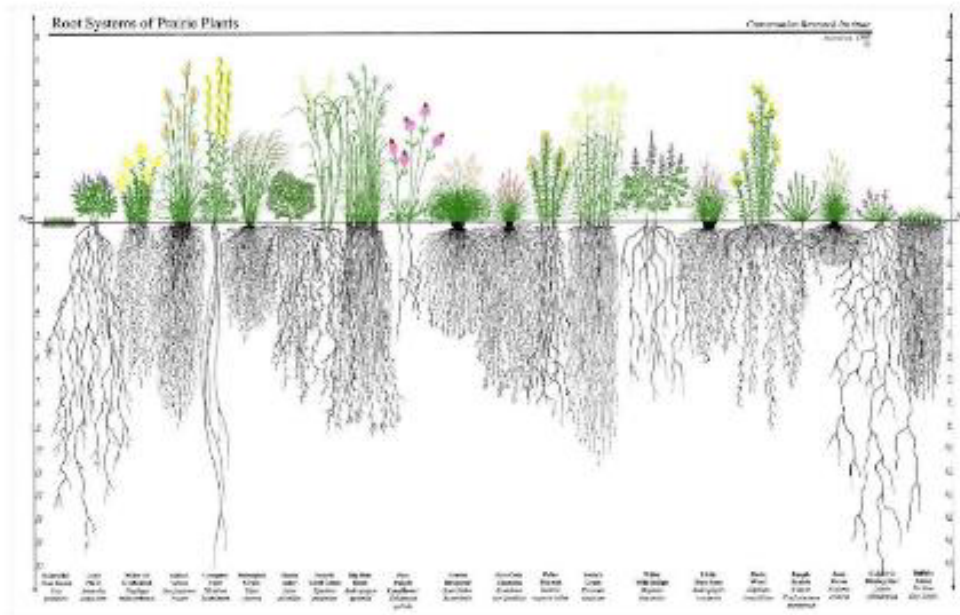
Spend an average of \$16,000 to install **solar panels***, knowing in the future (~10 years) electricity gained will be sold back to the grid and eventually, you'll be able to run your household solely on solar power.

1 2 3 4 5 6 7 8 9 10

For this final section, please indicate any barriers to BMP implementation (Please continue on the back of the second sheet if necessary).

Bioretention basin retrofit* - Taking an existing stormwater basin, either concrete or grass lined, and replacing it with a more landscape approach by putting a sand bed, organic layer and then plant material to allow for more efficient infiltration and pollutant filtering.

Native plants and reduced flooding* - Many native plants have deeper root systems which can significantly increase soil's capacity to store water. These deep root systems not only help increase soil's water storage capacity, but they also help prevent erosion by locking the soil in-place, further reducing the impacts of major storm events.



Solar panel benefits* - Not only does going solar help save you money in the long run, but it also allows the owner to become more resilient to power outages and if current weather regimes persist, grid outages may become increasingly more common. In the same vein, by providing self-resilience and reliance, the grid will become less stressed with development, thus taking some of the stress off the growing burden placed on the grid.

M. Model Ordinance Septic Maintenance and Pumping

Model Ordinance for Septic Pumping and Maintenance

Municipality of [Your Municipality Name]

Ordinance No. [Ordinance Number]

An Ordinance to Regulate the Pumping and Maintenance of Septic Systems

WHEREAS, the Municipality of [Your Municipality Name] is committed to protecting public health, safety, and the environment; and

WHEREAS, proper maintenance of septic systems is essential to prevent system failures, protect groundwater and surface water quality, and ensure the effective operation of wastewater treatment systems; and

WHEREAS, regular pumping and maintenance of septic systems are necessary to achieve these goals;

NOW, THEREFORE, BE IT ORDAINED** by the governing body of the Municipality of [Your Municipality Name], County of [County Name], State of New Jersey, as follows:

Section 1. Purpose

This ordinance establishes regulations for the regular pumping and maintenance of septic systems to protect public health, safety, and the environment.

Section 2. Definitions

For the purpose of this ordinance, the following terms shall have the meanings ascribed to them herein:

- Septic System: A system for the disposal of sewage that consists of a septic tank and a soil absorption system or other method of wastewater treatment.
- Septic Tank: A watertight receptacle that receives the discharge of sewage from a building and allows the settling and digestion of solid wastes.
- Property Owner: The person or entity that owns the property served by the septic system.

Section 3. Mandatory Septic System Pumping and Inspection

A. Pumping Frequency: All septic systems in the Municipality of [Your Municipality Name] shall be pumped at least once every three (3) years by a licensed septic system service provider.

B. Inspection: At the time of pumping, the septic system shall be inspected by the licensed service provider to ensure proper operation and identify any necessary repairs or maintenance.

****Section 4. Record Keeping and Reporting****

A. Service Report: The licensed septic system service provider shall provide the property owner with a service report detailing the pumping and inspection results. This report shall include the date of service, the condition of the septic system, and any recommended maintenance or repairs.

B. Submission to Municipality: Property owners shall submit a copy of the service report to the Municipality of [Your Municipality Name] Health Department within thirty (30) days of the service date.

****Section 5. Non-Compliance and Penalties****

A. Notice of Non-Compliance: The Municipality of [Your Municipality Name] Health Department shall issue a notice of non-compliance to any property owner who fails to comply with the pumping and reporting requirements of this ordinance.

B. Penalties: Property owners who fail to comply with the provisions of this ordinance shall be subject to fines as follows:

- First Offense: A fine of \$100.
- Second Offense: A fine of \$250.
- Subsequent Offenses: A fine of \$500 for each offense.

C. Additional Remedies: In addition to the penalties outlined above, the Municipality of [Your Municipality Name] may pursue any other remedy available at law or equity to enforce compliance with this ordinance.

****Section 6. Severability****

If any section, paragraph, sentence, clause, or phrase of this ordinance shall be declared invalid for any reason, the remaining provisions shall continue in full force and effect.

****Section 7. Effective Date****

This ordinance shall take effect upon final passage and publication as required by law.

****Introduced:**** [Date]

****Adopted:**** [Date]

****Attest:****

[Municipal Clerk]

[Mayor's Name]

Mayor, Municipality of [Your Municipality Name]

This ordinance ensures that septic systems are regularly maintained to prevent environmental contamination and protect public health.

N. Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers

This project utilized the Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish developed by the US EPA. The high gradient habitat assessment form utilizes 10 different characteristics using a scale of 0-20 (with 0 being the lowest score and 20 being the highest or most favorable) to help visually assess the integrity of a waterbody. The scores of the assessment are summed together and produce an overall habitat score which is then divided into 4 different categories optimal, sub-optimal, marginal and poor. The high gradient habitat assessment form's characters are as follows:

1. Epifaunal Substrate/Available Cover: Focuses on favorable substrate for epifaunal colonization and fish cover (e.g., snags, submerged logs, undercut banks, cobble or other stable habitat).
2. Embeddedness: Focuses on percent of fine sediment surrounding gravel, cobble and boulders (e.g., 0-25% surrounded by fine sediment, 25-50% surrounded, 50-75% or 75-100% surrounded).
3. Velocity/Depth Regime: Focuses on a reach's velocity/depth regimes (e.g., slow-deep, slow-shallow, fast-deep, fast-shallow)
4. Sediment Deposition: Focuses on sediment deposition causing the formation of islands or point bars (e.g., less than 5% affected by sediment deposition, 5-30% affected, 30-50% affected, and 50 or more % affected).
5. Channel Flow Status: Focuses on whether water reaches base of both lower banks and the amount of substrate exposed (e.g., water reaches both banks with minimal amount of substrate exposure, water fills >75% of available channel or <25% of channel substrate is exposed, water fills 25-75% of available channel or riffle substrates are mostly exposed, and very little water in channel and mostly standing pools present).
6. Channel Alteration: Focuses on the streams pattern (e.g., channelization absent or dredging absent and stream is within a normal pattern, some channelization present usually in areas of bridge abutments or evidence of past channelization, channelization may be extensive and embankments or shoring structures present on both banks with 40-80% reach channelized/disrupted, or banks shored with gabion or cement and 80% of reach channelized).
7. Frequency of Riffles (or bends): Frequency is calculated by taking the ratio of riffles divided by the width of the stream while also focusing on variety of habitat; boulder placement or large, natural obstruction location (e.g., frequent riffles with a ratio of 5 to 7, riffles infrequent with a ratio of 7 to 15, occasional riffle or bend with a ratio of 15 to 25, generally flat water or shallow riffles with a ratio of >25).
8. Bank Stability (each bank is scored individually from 0-10): Focuses on evidence of erosion or bank failure (e.g., stable banks <5% effected with little potential for future problems, moderately stable with 5-30% experiencing erosion, moderately unstable with 30-60% eroded, and unstable with 60-100% of bank erosional scars).

9. Bank Vegetative Protection (each bank is scored individually from 0-10): Focuses on the immediate riparian zone's levels of native vegetative protection from trees to shrubs and macrophytes (More than 90% covered by native vegetation and plants are allowed to grow naturally, 70-90% of the streambank surfaces covered or diverse representation is beginning to decline, 50-70% of the streambank surfaces are covered with obvious disruption and patches of bare soil or cropped vegetation, less than 50% of the streambank surfaces covered with remaining vegetation removed to 5 centimeters or less in average stubble height).
10. Riparian Vegetative Zone Width (each bank is scored individually from 0-10): Focuses on the proximity of the stream reach to human activities (e.g., width of riparian zone .18 meters away from human activities, 12-18 meters away from human activities, 6-12 meters away from human activities and <6 meters or no riparian vegetation due to human activities).

The high gradient habitat assessment 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 required consistency of assessors among all of the sites, in doing so the high gradient habitat assessments were conducted by audited Musconetcong Watershed Association staff and audited and by NJDEP to confirm consistency with NJDEP conventions and passed.

O. USEPA Rapid Bioassessment Protocol II

USEPA Rapid Bioassessment Protocol II (NJDEP, 2007).

1. Total number of genera: Describes the total number of different taxonomic classes at the genus level.
2. % non-insect genera: Measures the percent of non-insect genera compared to the total number of genera collected.
3. % sensitive EPT (excluding *Hydropsychidae*, including *Diplectrona*): 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. Number of scraper genera: Scraper genera are those macroinvertebrates who remove algae from rocks and other benthic substrate, such as caddisflies and mayflies. This metric measures the total number of scraper genera collected.
5. Hilsenhoff Biotic Index: is an estimate of the overall tolerance of the community sampled. This metric is weighted by the relative abundance of each taxonomic group, where organisms are assigned a tolerance number from 0 to 10 reflecting that groups known sensitivity to pollutants with 0 being most sensitive and 10 being most tolerant (USEPA, 2007).
6. Number of attribute 2 genera: This metric measures the highly sensitive and uncommon taxa.
7. Number of attribute 3 genera: This metric measures the sensitive and common taxa.

The former New Jersey Impairment Score (NJIS) has been replaced by the High Gradient Macroinvertebrate Index (HGMI), which improves precision through genus-level identification (NJDEP, 2008). HGMI integrates community metrics into four water quality categories—Excellent, Good, Fair, and Poor—based on biological integrity. Excellent sites resemble reference streams, while Fair or Poor sites are dominated by tolerant taxa. The HGMI scoring

system uses weighted formulas for each metric, producing total assessment scores: ≥ 63 (Excellent), 42–62 (Good), 21–41 (Fair), and < 21 (Poor).

Beginning with AMNET’s second sampling round, habitat assessments were added to complement biological evaluations. Following USEPA RBP II methods, ten habitat parameters (e.g., substrate cover, embeddedness, sediment deposition, bank stability, riparian vegetation) are visually scored and summed to classify conditions as *optimal* (160–200), *suboptimal* (110–159), *marginal* (60–109), or *poor* (< 60) (NJDEP, 2007). These findings help interpret biological results and identify constraints on ecological potential.

Table O. Scoring formula for NJ High Gradient Macroinvertebrate Index

Metric	Formula (with X being the corresponding metric)
1. Number of genera	$100 * X / 31$
2. % non-insect genera	$100 * (60 - X) / 55$
3. % sensitive EPT	$100 * X / 69$
4. Number of scraper genera	$100 * X / 11$
5. Hilsenhoff Biotic Index	$100 * (7.2 - X) / 4.6$
6. Number of attribute 2 genera	$100 * X / 8$
7. Number of attribute 3 genera	$100 * X / 8$

P. Best Management Practices (BMPs)

The following Best Management Practices (BMPs) are recommended for implementation throughout the Musconetcong River Watershed to address nonpoint source pollution from agricultural, urban, and wastewater sources. Each BMP includes background information, implementation approaches, cost considerations, expected benefits, and practical recommendations suitable for inclusion in a 319(h) watershed-based plan.

Agricultural Best Management Practices

Agricultural BMPs included in this plan: No-Till and Residue Management, Conservation (Vegetative) Buffers, Cover Crops, Nutrient Management, Heavy Use Protection Areas, Prescribed Grazing, Exclusion Fencing, and Regional Composting for Manure Management.

No-Till and Residue Management Program

Description: No-till minimizes soil disturbance and maintains plant residue year-round while limiting soil-disturbing activities to those necessary for nutrient placement and seeding. Specialized equipment drills seed through residue and injects fertilizer with minimal disturbance.

Benefits: Reduces erosion and sedimentation; increases soil organic matter, carbon sequestration, and moisture retention; lowers fertilizer needs; and enhances drought resilience.

Cost Considerations: Upfront equipment costs are the primary barrier. Financial and technical assistance are available through NRCS programs such as EQIP and CSP, and support from NJ RC&D.

Implementation Notes: Adoption is crop- and site-specific and may require trials. Pairing no-till with nutrient management and cover crops maximizes return on investment, particularly in NWQI areas.

Recommendation: Promote no-till, strip-till, mulch-till, and ridge-till systems with targeted education, demonstrations, and cost-share enrollment.

Conservation (Vegetative) Buffers

Description: Strips of grasses, shrubs, and/or trees planted between fields and waterways to intercept sheet flow, slow velocities, promote infiltration, and trap bacteria, sediment, and nutrients.

Current Conditions: Six HUC14s in the project area are impaired for E. coli; two for pH and one for temperature. Agricultural runoff from pastures and manured cropland is a significant source.

Implementation: MWA and North Jersey RC&D will coordinate site identification, design, funding, installation, and periodic inspections. Buffers must maintain sheet flow to function effectively.

Multifunctional riparian buffers (e.g., agroforestry, non-timber forest products) can provide economic incentives for landowners.

Maintenance: Inspect quarterly and after >1" storms for debris, clogging, erosion, unwanted growth, and excess ponding; mow as appropriate; address vegetation deficiencies using low-input methods (Semple et al., 2004).

Cost: Varies with vegetation type and complexity. Warm-season grass buffers are generally lower cost than woody/multi-tier buffers.

Prioritization: Target subwatersheds with the highest estimated fecal loading first.

Expected Results: Literature indicates 74–91% bacteria removal with concurrent TSS and nutrient reductions.

- Recommendation: Install conservation buffers watershed-wide as primary stormwater BMPs.
- Recommendation: Provide outreach to small farms on benefits, costs, and funding options.

Cover Crops

Description: Grasses, legumes, and forbs established for seasonal cover and conservation. Cover crops reduce erosion, capture residual nutrients, improve soil structure, and suppress weeds.

Cost: Approx. \$61–\$100 per acre (NRCS EQIP 2024). Cost-share available; savings accrue via reduced fertilizer and improved soil health.

Implementation & Prioritization: Integrate where fields are fallow or between rotations. Stack with no-till and nutrient management. Prioritize cropland proximal to streams and on steeper slopes.

- Recommendation: Launch an education/assistance program to accelerate adoption and optimize species mixes by soil and management goal.

Nutrient Management

Description: Strategic, data-driven application of fertilizers and soil amendments to optimize yield while minimizing off-site transport. Core practices include soil testing, precise rate/timing/placement, crop rotation, and cover crops.

Cost: Initial costs include soil testing and potential precision ag tools; often offset by lower fertilizer use and improved yields. EQIP FY2024 lists Adaptive Nutrient Management plans and per-acre support (e.g., manure incorporation technology).

Implementation: Develop field-specific plans; emphasize incorporation/placement, timing relative to rainfall, and setbacks from waterways.

Potential Locations: Agricultural fields identified for stacking with no-till and cover crops.

- Recommendation: Provide training on soil testing and application techniques; enroll producers in NJ RC&D AgAssist for eligibility and applications.

Livestock Access Control – Exclusion Fencing

Description: Fencing livestock out of streams eliminates direct deposition of manure, reduces bank trampling and erosion, and enables riparian recovery.

Design: Typically set back ≥ 35 ft from stream banks (site-specific). Fencing type depends on livestock and site conditions; provide off-stream water sources as needed.

Cost: Approx. \$5.48/linear ft (NRCS), with potential cost-share up to ~75% for fencing and associated practices (e.g., watering).

- Recommendation: Install exclusion fencing at all livestock-access stream segments with technical support from NRCS and partners to ensure durability and effectiveness.

Prescribed Grazing

Description: Planned livestock grazing to meet ecological and production goals by managing timing, intensity, and duration across paddocks.

Implementation: Assess soils/forage/water; set stocking rate and rotation; install needed infrastructure (fencing, water, shelter); monitor forage and soil conditions; adapt as needed.

Cost: Varies with scale and infrastructure; typically offset by improved forage production, animal health, and reduced feed costs.

- Recommendation: Engage producers through programs such as the Grazing Lands Conservation Initiative and CRP; pair with exclusion fencing and buffers.

Regional Composting Facility

Description: Composting raw manure into a stable organic product to reduce pathogen and phosphorus mobility, especially where on-site land application is limited or operations are overstocked.

Siting/Design: Windrows or static piles at least 50 ft from property lines and 250 ft from occupied dwellings; avoid floodplains unless protected; design runoff controls; maintain C:N ratio and aerobic temperatures.

Cost: Broad range (~\$0.27–\$24.72/sq ft, NRCS EQIP 2024). Cost-share may be available for facilities, but not typically for equipment (e.g., tractors, windrow turners).

Prioritization: Target operations with high manure generation near waterways or with limited land base for safe utilization; prioritize subwatersheds with high combined fecal bacteria and phosphorus loads.

- Recommendation: Coordinate with NRCS and local solid waste authorities; provide operator training and O&M support.

Heavy Use Protection Area (HUPA)

Description: Stabilized areas for concentrated livestock activities (feeding, watering, loafing) that reduce erosion, mud, and contaminated runoff while improving animal health and operational efficiency.

Implementation: Select well-drained sites; stabilize with concrete, gravel, or geotextile composites; integrate runoff controls, buffers, and manure containment; connect to composting or storage.

Cost: ~\$2.28/sq ft (gravel on geotextile with site prep) to ~\$23.48/sq ft (concrete slab with curb and retaining wall) per NRCS EQIP 2024; costs vary with slope and access.

- Recommendation: Assess all grazing operations for HUPA opportunities; offer trainings and farm tours to encourage adoption.

Urban Stormwater Best Management Practices

Urban BMPs recommended in this plan include Rain Gardens, Roadside Ditch Retrofits, Detention Basin Retrofits, Vegetated Buffers on Developed Land, Pervious/Permeable Pavers, Bioswales/Grassed Waterways, and Parking Lot Diversions.

Rain Gardens

Description: Shallow, vegetated depressions that intercept, treat, and infiltrate the water-quality storm (typically 1.25 inches) at the source to capture the first-flush of pollutants. Applicable on residential lots and within rights-of-way for roadway retrofits.

Design/Implementation: Size to treat contributing impervious area (e.g., ~10×20 ft by 6 in depth for 1,000 sq ft roof/driveway). Integrate soil amendments and underdrains where needed. Follow Rutgers Rain Garden Manual design guidance (http://water.rutgers.edu/Rain_Gardens/RGWebsite/RainGardenManualofNJ.html).

Maintenance: Inspect quarterly and after >1" storms; remove debris/sediment; control weeds; evaluate drain time—must drain within 72 hours per NJDEP (Semple et al., 2004; NJDEP BMP Manual, 2021).

Prioritization: Focus on subwatersheds with highest bacteria loading; target residential and commercial areas willing to maintain installations.

Expected Results: When properly designed and maintained, rain gardens typically achieve 80–90% pollutant reduction for treated runoff (NJDEP BMP Manual, 2021) and reduce flashy hydrology by promoting infiltration.

- **Recommendation:** Conduct education, outreach, and demonstration projects; pair with habitat certification programs to increase adoption.



Figure P.1 – Residential rain garden in Ocean County NJ. Photo Credit - <https://soildistrict.org/>



Figure P.2 -Rain Garden on Main Street in Asbury, NJ. A trench captures runoff and pipes it into the rain garden. Photo credit – MWA



Figure P.3 – End of pipe into Rain Garden bed. Photo credit - MWA

Roadside Ditch Retrofits

Description: Retrofit existing drainage ditches—often narrow, unvegetated, and designed for rapid conveyance—with energy-dissipating and infiltration-enhancing features to reduce velocities, encourage settling, and improve water quality.

Design Alternatives:

- Stone-filled gabion basket check dams installed periodically to reduce velocity and promote settling/infiltration.
- Exposed French-drain segments (stone-filled trenches) bounded by gabions to provide longer flow paths, storage, and vehicle crossings.
- Weirs (e.g., cinder block with notches) to control stage-discharge where finer flow control is needed.

Implementation: Verify right-of-way width and depth to groundwater (≥ 2 ft separation); test infiltration every ~500 ft or soil change; regrade, install flow controls, stabilize soils, and establish vegetation.

Maintain quarterly via drive-by inspections for standing water, debris, and erosion.

Prioritization: Sequence projects by bacteria loading in contributing subwatersheds.

Expected Results: Acting similarly to filter strips/bioretention, literature suggests bacteria removal in the 74–99% range for treated flows; load reductions will vary by contributing area and retrofit density.

- **Recommendation:** Retrofit ditches with native vegetation and structural flow controls; coordinate funding with county/municipal highway departments (e.g., NJDEP 319(h)).

Detention Basin Retrofits

Description: Conventional detention basins primarily control peak flow and often provide minimal water-quality treatment. Retrofitting basins to function like bioretention systems—e.g., replacing low-flow concrete channels with vegetated or rip-rap channels, adding amended soils, and native vegetation—improves pollutant removal and reduces maintenance.

Karst Considerations: In areas underlain by karst, include qualified professionals (hydrogeologist, PG/Geotech, soil scientist, water resources engineer); avoid concentrating infiltration directly to subsurface voids; maintain ≥ 2 ft of natural soil/media before infiltration; develop contingency and rapid-response plans for subsidence; increase inspection frequency.

Design Alternatives:

- Small/Large-scale bioretention retrofits with amended soils and native vegetation.
- Low-flow vegetated channel (0.1% side slope; slope $\leq 3\%$; 18 in bioretention media over 6 in clean stone) replacing concrete gutters.
- Low-flow rip-rap channel designed to infiltrate the water-quality storm within 48 hours; remove concrete channels during retrofit.

Maintenance: Inspect at least quarterly and after major storms; manage vegetation with low-mow regimes; monitor for excess ponding and correct promptly (Semple et al., 2004).

Prioritization: Retrofit basins in subwatersheds with highest bacteria loading first.

Expected Results: Treating the 1.25-inch water-quality storm ($\approx 90\%$ of annual events) yields substantial reductions in bacteria, TSS, and nutrients via settling, filtration, plant uptake, and infiltration.

- **Recommendation:** Retrofit basins with native vegetation and amended soils; follow karst guidance to prevent sinkholes and protect groundwater.



Figure P.4 – Wet detention basin in Hackettstown NJ. This basin is overrun by algae and has many Canada Geese in residence (not in picture). It drains directly into the mainstem of the Musconetcong River. Photo Credit – MWA

Bioretention System Basics - Profile View

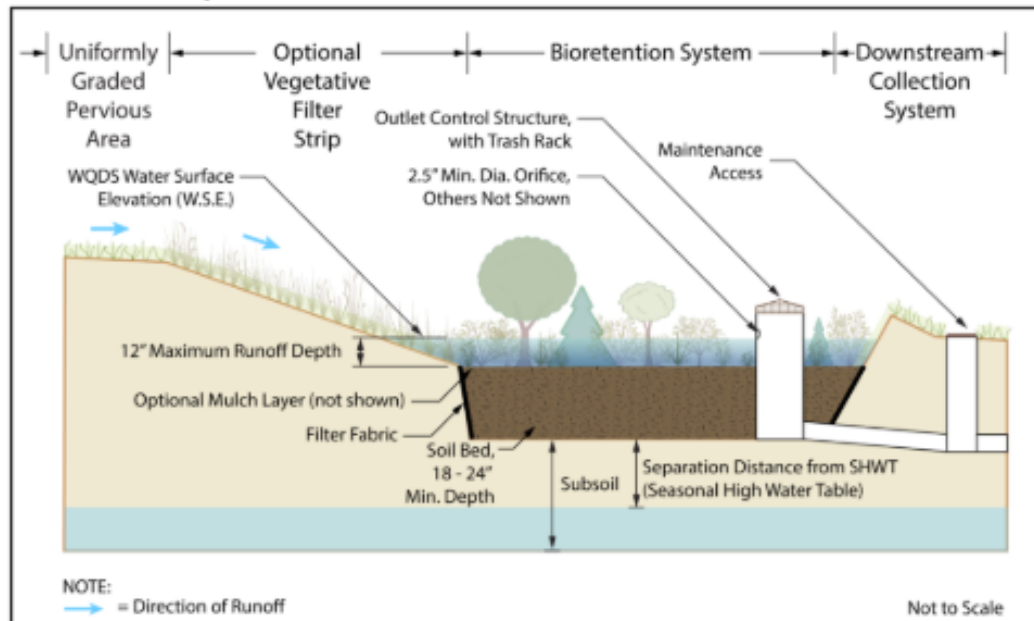


Figure P.6 – Profile of typical bioretention basin retrofit. Image - <https://dep.nj.gov/stormwater/bmp-manual/>



Figure P.7 – Low flow concrete channels directing all stormwater to one area. Turf grasses shallow roots are not able to soak up much water or create channels in the soil for water to infiltrate.



Figure P.8 – 24 hours after a storm and the stormwater is spread out and native vegetation is allowing the water to naturally infiltrate and recharge the groundwater, instead of being piped to surface water streams. Images - <https://pecpa.org/>

Vegetated Buffers on Developed Land

Description: Vegetated strips along developed land/water interfaces to remove solids and associated pollutants from stormwater via sheet flow. Vegetation types include turf-to-native grasses, shrubs, and trees; sheet flow is essential for treatment.

Implementation: Identify sites using NJDEP land use data, aerials, and field reconnaissance; engage businesses, homeowners (via MWA Watershed Allies Training), and municipalities (MS4 grants) to design, install, and maintain buffers consistent with the NJ BMP Manual (Feb 2004, Ch. 7; updated 2021).

Maintenance & Cost: Similar to agricultural buffers—quarterly inspections, mowing/vegetation care, debris/sediment removal. Costs vary with width, plant palette, and site grading needs.

Prioritization & Expected Results: Prioritize by subwatershed loading; literature indicates 74–91% bacteria removal for treated sheet-flow runoff.

- **Recommendation:** Implement buffers broadly across developed corridors; provide homeowner/business outreach and native plant resources.

Pervious/Permeable Pavers

Description: Durable, permeable surface systems over an open-graded aggregate storage bed that infiltrate or underdrain the water-quality storm. When designed to NJDEP standards, they achieve an 80% TSS removal rate.

Design Criteria: Surface course must support loads with a tested infiltration rate ≥ 6.4 in/hr; include choker course and clean open-graded storage bed sized for WQDS without overflow.

Implementation: Applicable for businesses, homeowners, municipalities (MS4), and campuses. Replace or retrofit driveways, sidewalks, plazas, and parking stalls.

Maintenance: Vacuum sweep (not power sweep) $\geq 4 \times$ /year; annual surface inspections; spring infiltration testing (ASTM C1701/C1781).

Cost & Prioritization: Costs vary by system (e.g., interlocking units vs. cast-in-place). Prioritize subwatersheds with high pollutant loads and high-density impervious cover.

Expected Results: Significant reductions in runoff volume and 80% TSS removal where systems are maintained.

- Recommendation: Implement a demonstration project at a municipal complex or school and train O&M staff.

Bioswales / Grassed Waterways

Description: Vegetated linear channels that slow, infiltrate, and filter runoff from roads, lots, and rooftops. Effective as part of a stormwater treatment train paired with detention basin and rain garden retrofits (NJDEP BMP Manual, 2021).

Expected Results: Typical pollutant reductions approach ~50% for suspended solids and meaningful reductions in nutrients and pathogens when properly designed and maintained.

- Recommendation: Install bioswales strategically along transportation corridors and within large parking complexes; provide design training and funding guidance to municipalities and institutions.

Parking Lot Diversions (Vegetative Filter Strips)

Description: Stable, evenly graded vegetated areas receiving sheet flow from parking lots to remove pollutants by filtration and uptake. Applicable in commercial centers, campuses, and hospital grounds; especially promising in Mansfield and Hackettstown (upper focus area).

Design Criteria: Maintain sheet flow; vegetation density $\geq 85\%$; length 25–100 ft; slope limits per soil/vegetation; apply criteria per NJDEP BMP Manual (Mar 2021).

Maintenance: Annual structural checks; regular mowing and trimming; bi-weekly inspections during establishment; ensure designed drain time is met.

Expected Results: 60–80% TSS removal depending on vegetation and maintenance.

- Recommendation: Prioritize large plazas along Route 57/Main Street and Centenary University lots; MWA can liaise among owners and contractors.

Wastewater Best Management Practices

On-Site Disposal Systems (OSDS) – Maintenance, Inspection, and Pumping

Description: Regular pumping and inspection of septic systems prevent failures that release pathogens and nutrients to groundwater and surface waters. With proper maintenance, typical systems last ~20–30 years; without it, failure rates rise markedly (commonly 5–20% in aging areas).

Implementation:

- Pumping Frequency: At least once every 3 years by a licensed provider.
- Inspection at Pumping: Evaluate tank, baffles, distribution box, and drainfield; document findings.
- Recordkeeping: Owners maintain service records and recommendations.

Cost: Typical NJ ranges—Inspection \$300–\$500; Pumping \$250–\$500; combined \$500–\$1,000 (varies by tank size and access).

Education & Incentives: Utilize MWA Watershed Allies Training (DIY Septic Inspections).

Municipalities may consider ordinances if voluntary compliance is insufficient; see model ordinance in Appendix K.

Expected Results: Reduced pathogen and nutrient loads from failing systems and improved public health protection.

- Recommendation: Adopt watershed-wide maintenance schedules; pair with homeowner education and optional water-quality screening incentives.

Retrofitting Failed or Outdated OSDS

Description: MST data indicate human sources are primary contributors of bacteria; GWLF-E/MapShed modeling suggests 5–10% of systems are failing. Repairs and upgrades reduce pathogen and nutrient discharges.

Implementation Steps: Thorough inspection and diagnosis; develop repair plan and cost estimate; secure permits; implement using qualified professionals; conduct post-repair inspection to verify performance.

Cost: Repairs typically \$10,000–\$30,000; full replacement up to ~\$50,000. Assistance may be available through grants/loans such as the Clean Water State Revolving Fund (CWSRF).

Support Measures: Provide technical assistance, homeowner workshops, and referral networks for financing and design.

- Recommendation: Target clusters of suspected failures for coordinated retrofit campaigns to maximize load reductions.

Wildlife Management

Description: Resident geese and overabundant deer contribute pathogens, damage vegetation, and exacerbate runoff impacts—especially in winter when ground cover is low.

Geese Management: Plant dense ground cover; use deterrents (noise, dogs, mylar tape); install buffers to intercept droppings; consider USFWS resident Canada goose egg-addling/nest destruction permits (via USDA Wildlife Services; NJ Fish & Wildlife permits for farmers Apr 1–Aug 31).

Deer Management: Overpopulation (often exceeding biological carrying capacity) degrades forest health and increases collision risks. Strategies include fencing (NJDA programs), habitat management, and regulated hunting in coordination with NJ agencies.

- Recommendation: Identify nuisance wildlife hotspots near streams and implement integrated control and exclusion measures; pursue funding for deer exclusion fencing through NJDA.