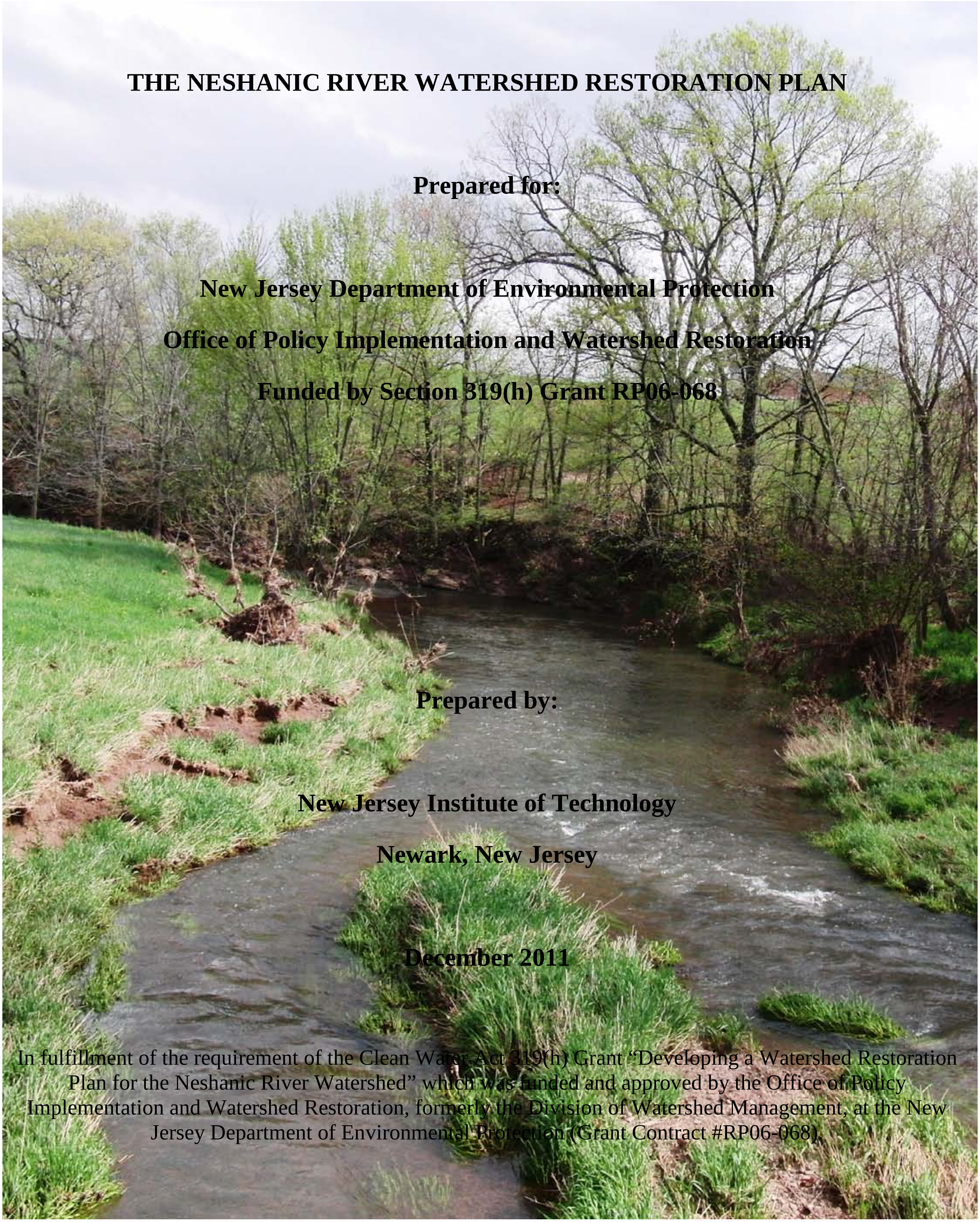


THE NESHANIC RIVER WATERSHED RESTORATION PLAN

Prepared for:

New Jersey Department of Environmental Protection

Office of Policy Implementation and Watershed Restoration

Funded by Section 319(h) Grant RP06-068

Prepared by:

New Jersey Institute of Technology

Newark, New Jersey

December 2011

In fulfillment of the requirement of the Clean Water Act 319(h) Grant "Developing a Watershed Restoration Plan for the Neshanic River Watershed" which was funded and approved by the Office of Policy Implementation and Watershed Restoration, formerly the Division of Watershed Management, at the New Jersey Department of Environmental Protection (Grant Contract #RP06-068).

Table of Contents

List of Project Task Reports

(Reports Provided Separately)

A. Water Quality Monitoring Report

B. Stream Visual Assessment Report

C. Stormwater Infrastructure Inventory Report

D. Stormwater Best Management Practices and Prioritization Report

E. Agricultural Best Management Practices Report

F. SWAT Modeling Analysis for the Neshanic River Watershed Report

G. Walnut Brook Riparian Restoration Project Report

List of Figures

List of Tables

List of Maps

List of Acronyms

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

PIG – Planning Incentive Grant
PCR – Polymerase Chain Reaction
RC&D – Resource Conservation and Development Council
RCE – Rutgers Cooperative Extension
ROW – Right of Way
RTMUA – Raritan Township Municipal Utilities Authority
SADC – State Agriculture Development Committee
SBWA – South Branch Watershed Association
SSA – Sewer Service Area
SSURGO – Soil Survey Geographic
STEPL – Spreadsheet Tool for Estimating Pollutant Load
SVAP – Stream Visual Assessment Protocol
SWAT – Soil and Water Assessment Tool
SWQC – Surface Water Quality Criteria
TMDL – Total Maximum Daily Loads
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids
USDA – U.S. Department of Agriculture
USGS – U.S. Geological Survey
VSA – Variable Source Area
WHIP – Wildlife Habitat Incentive Program

1. Acknowledgements

Funding for this project was provided by the Office of Policy Implementation and Watershed Restoration, formerly the Division of Watershed Management, at the New Jersey Department of Environmental Protection (NJDEP) through the Clean Water Act's Section 319(h) program (Grant Contract #RP06-068). Additional in-kind contributions to the project are provided by New Jersey Institute of Technology, Hunterdon County Soil Conservation District and the New Jersey Water Supply Authority. The following individuals from the respective agencies contributed to the completion of the project:

New Jersey Department of Environmental Protection

Nick Zripko, Project Manager: Grant administration and communication with various divisions at NJDEP

New Jersey Institute of Technology

Zeyuan Qiu, Ph.D., Associate Professor: Project Director, and Plan Document Author and Editor
Lizhong (George) Wang, Ph.D., former Postdoctoral Research Associate: Soil and Water Assessment Tool (SWAT) modeling and Primary Author of the SWAT Modeling Report
Tina Bologna, Part-time Research Associate: Watershed assessment and characterization
Shashin Fitter, Research Assistant: Website development
Steven Watkins, Research Assistant: Data collection and processing
Florencio Balestores, Jr., Graduate Research Assistant: Data collection and processing

Rutgers Cooperative Extension Water Resource Program

Christopher C. Obropta, Ph.D., P.E., Associate Extension Specialist and Associate Professor: Water quality monitoring and stormwater Best Management Practices (BMPs) and the primary author of the water quality monitoring and stormwater BMPs reports
Lisa Galloway Evrard, Senior Program Coordinator, Water quality monitoring and assessment
Sean Walsh, Program Associate: Stormwater BMP assessment
Katie Buckley Giacalone, former Program Associate: Stream Visual Assessment Protocol (SVAP)

Hunterdon County Soil Conservation District

William E. Engisch, Manager: Administrative support and report review
Chris Testa, Former Special Project Manager: Stormwater Infrastructure Inventory and the Primary Author of the Stormwater Infrastructure Inventory Report
Zach Oliver, former Intern: Stormwater infrastructure mapping
Kevin Milz, Agricultural Specialist: Agricultural practices and BMPs

New Jersey Water Supply Authority

Kathy Hale, Principal Watershed Protection Specialist: SVAP training, project committee and report review
Rick Anthes, Assistant Watershed Protection Specialist: Report review
Jen (Yongzhen) Zhang, Watershed Protection Specialist: GIS data support
Kenneth Klipstein, Director of Watershed Protection Programs: Project support
Dan Van Abs, Ph.D., former Director of Watershed Protection Programs: Planning

North Jersey Resource Conservation and Development Council
Patrick Natale, Agricultural Outreach Specialist: Agricultural practices and BMPs; Primary Author of Agricultural BMP Report
Abigail Jones, former Agricultural Outreach Specialist: Agricultural practices and BMPs
Dana Ronyack, former Agricultural Outreach Specialist: Agricultural practices

South Branch Watershed Association
Bill Kibler, Executive Director: SVAP and the Primary Author of SVAP Report
Tom Southard, former Watershed Project Manager: SVAP and communication with municipalities
Ellen Cronan, former Watershed Project Manager: SVAP

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

New Jersey Department of Agriculture
Dave Clapp, Agricultural Specialist: Agricultural practices and BMPs

Raritan Township
Marianne Rampulla, Appointed Municipal Representative
Fred Copolla, Town Engineer: Stormwater BMPs

Delaware Township
Kathy Klink, Appointed Municipal Representative

Flemington Borough
Lois Stewart, Appointed Municipal Representative

East Amwell Township
Dee Kellogg, Appointed Municipal Representative

2. Executive Summary

2.1. Background

The Neshanic River Watershed is located in Hunterdon County and encompasses Raritan, Delaware and East Amwell Townships and Flemington Borough and is a headwater watershed of the Raritan River Basin in Central New Jersey. The watershed includes Walnut Brook, First, Second and Third Neshanic Rivers, and the Neshanic River main branch. Water quality impairments in Neshanic streams have been a constant subject in various reports and among the watershed management professionals in the region. According to the U.S. Geological Survey (USGS), the Neshanic River is one of the water bodies with the worst overall water quality in the Raritan River Basin (Reiser, 2004). The Neshanic River was listed in the 2008 New Jersey Integrated Water Quality Monitoring and Assessment Report as impaired for aquatic life and nonpoint source pollution (NPS) from bacteria, phosphorus and total suspended solids (NJDEP, 2008). It is generally recognized that agriculture, rapid urban development and wildlife cause water quality contamination in the watershed. In addition to the water quality problems, there is a concern about increasing occurrence of no/low streamflow in the Neshanic River in late summer (Reiser, 2004).

In the Spring of 2005, a group of water resource professionals from various agencies, namely the New Jersey Institute of Technology (NJIT), the New Jersey Water Supply Authority (NJWSA), the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA), the North Jersey Resource Conservation and Development Council (RC&D), the Rutgers Cooperative Extension (RCE), the South Branch Watershed Association (SBWA) and the Hunterdon County Soil Conservation District (HCSCD) assembled to discuss conducting a systematic study of water quality problems and developing a roadmap for restoring water quality in the Neshanic River Watershed. A proposal for a Neshanic River Watershed Restoration Plan was developed after a series of discussions with NJIT as the lead and all other agencies as collaborators. The proposal was submitted to the Clean Water Act Section 319 (h) program administered by the former Division of Watershed Management at the New Jersey Department of Environmental Protection (NJDEP). In 2006, the NJDEP awarded a grant to NJIT and its collaborators (RP06-068) to develop the Neshanic River Watershed Restoration Plan (Plan).

The Plan details the management measures needed to achieve the desired reduction in bacteria and attain water quality standards for total phosphorus (TP) and total suspended solids (TSS), and to reduce aquatic life impairments to a non-impaired level and outline the actions needed to restore the base flow of the Neshanic River. Because a similar effort was conducted in the lower part of the Neshanic River Watershed, including the Back Brook and its drainage area, the Neshanic River Watershed Restoration Plan focuses on the 31 square mile upper part of the Neshanic River Watershed, which includes Walnut Brook, First, Second and Third Neshanic Rivers and the Neshanic River main branch immediately above the Back Brook confluence with the Neshanic River.

2.2. Sources and Root Causes

Water quality and quantity issues in the Neshanic River Watershed are the result of substantial land use changes in the watershed. According to the historical land use data developed and maintained by NJDEP, land use changes in the watershed include increases in urban land uses and decreases in agricultural lands due to rapid suburbanization during the last two decades. The percentage of urban land in the watershed increased from 16.6 percent in 1986 to 25 percent in 1995, and was 31.2 percent in 2002 and 35.1 percent in 2007. The increases in urban land resulted primarily from the loss in agricultural land in the watershed. Agricultural lands in the watershed decreased from 51.4 percent in 1986 to 43 percent in 1995, and rose to 36.4 percent in 2002 and 35 percent in 2007. Other land uses were relatively steady with forest around 20-21 percent, wetlands at 10-11 percent, water at 0.2-0.5 percent and barren at 0.3-1.6 percent.

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

Water quality and quantity are affected by not only quantitative changes in land use, but also the nature of the land use changes and where those changes occur on the landscape. Many intensive land uses, such as agriculture and urban development, took place in hydrologically sensitive areas, hydric soils and riparian areas of the streams, which intensifies the water quality and quantity issues in the watershed. Other sources of water quality degradation include: intensive uses of fertilizer and pesticides in agricultural production and lawn management; livestock production, such as cattle and horses; failing on-site wastewater treatment systems, such as on-site sewage disposal systems (OSDSs); animal manure mismanagement; and deposition of excrement of wildlife, such as deer and geese. The SWAT watershed model was used to improve understanding of how various sources of water quality degradation affect water quality in the watershed. SWAT is a continuous, daily time-step, spatially distributed hydrological river basin scale model that simulates water, sediment, nutrient, chemical and bacteria transport in a watershed resulting from the interaction of weather, soil, stream channel, vegetation and crop growth, and land management practices, and calculates various pollutant loads from landscape and point sources (Arnold et al., 1994; Neitsch et al., 2005). SWAT divides a watershed into hydrologic response units (HRUs) that consist of specific land use, soil and slope characteristics that represent spatial heterogeneity in terms of land cover, soil type and slope class within a watershed. The model estimates relevant hydrologic responses, such as evapotranspiration, surface runoff, peak rate of runoff, groundwater flow, sediment and pollutant loads from each HRU to streams due to the changing climate and land use conditions. Based on the SWAT modeling results, the sources and root causes of water quality degradation are discussed in detail for three categories of water pollutants: sediment; nutrients; and pathogens.

2.2.1. Pathogens

Both fecal coliform and *Escheria coli* (E. coli) in water are indicators of pathogen contamination. In general, human and animal wastes are sources of pathogens in Neshanic streams. Failing OSDSs, which are the largest source of pathogens in the watershed, contribute 46 percent of the pathogen loads in the Neshanic streams. The second largest source is manure that is applied to the field for row-crop production, which accounts for 31 percent of the annual load of pathogens in the Neshanic streams. Livestock in the watershed is a significant contributor of pathogens to streams, including animals grazed on pasture and/or animals that enter streams. Livestock account for 19 percent of annual pathogen loads in the watershed, which make it the third largest contributor to pathogen loads. Another minor contributor is wildlife, such as geese and deer.

2.2.2. Nutrients

Nutrients include total nitrogen (TN) and TP. Water quality monitoring efforts by USGS, NJDEP and the project team indicate that TP is a significant source and TN is an insignificant source of water pollution in the watershed. The SWAT assessment shows that 229,119 pounds of TN and 12,282 pounds of TP leave the watershed through streamflow each year. The primary source of nutrients in the Neshanic River Watershed is agricultural land that is used for row-crop production, pasture and hay, accounting for 76 percent of the TN and 60 percent of the TP loads in the watershed. Fertilizers on urban lands are the second largest sources of nutrients, contributing 11 percent of the TN load and 29 percent of the TP load.

2.2.3. Sediment

Sediment in streamflow is measured by TSS. Results of the SWAT model indicate that, each year, streamflow carries 1,715 tons of sediment out of the watershed. Streams are the primary source of sediments and contribute 1,021 tons of sediment per year, which accounts for 60 percent of the total annual sediment load. The source of sediments from the streams is soil eroded from the streambanks and resurfaced from the deposited sediments in the stream bed due to the high energy streamflow. The remaining 40 percent of sediments, roughly 694 tons, come from various land uses in the watershed, including row-crop agriculture (i.e., corn, soybean, wheat and rye production), which accounts for almost 57 percent of the sediment, urban land (27 percent) and other agricultural lands, such as pasture and hay (15 percent).

2.3. **Required Load Reductions**

The NJDEP (2010a) designated the Neshanic River and its tributaries as FW2-NT. According to this designation from the New Jersey Surface Water Quality Standards (NJAC 7:9B) amended January 4, 2010 (42 N.J.R. 68a), the following surface water quality standards are applicable to the pollutants of concern in the Neshanic River and its tributaries:

- *E. coli* shall not exceed a geometric mean of 126 counts per 100 milliliter (mL) or a single sample maximum of 235 counts per 100 mL;

- Fecal coliform shall not exceed a geometric average of 200 counts per 100 mL, nor shall more than 10 percent of the total samples taken during any 30-day period exceed 400 counts per 100 mL;
- TP shall not exceed 0.1 mg/L;
- TSS shall be less than 40 mg/L; and
- TN shall be below 10 mg/L.

For all impaired streams, the U.S. Environmental Protection Agency (EPA) requires the development of Total Maximum Daily Loads (TMDLs) for the pollutants of concern. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

The NJDEP approved and adopted a TMDL for fecal coliform for the Neshanic River, which requires a 87 percent reduction in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands (NJDEP, 2003). A nutrient TMDL for the Raritan Basin was developed and is still under review by NJDEP. However, the adopted fecal coliform TMDL and the nutrient TMDL are based on the water quality monitoring data at the USGS Reaville Gage Station, and therefore cover only the upper portion of the Neshanic River Watershed. The project team developed its own load reduction targets for the pollutants of concern that enable the streams in the Neshanic River Watershed to meet the water quality standards for their designated uses. This project uses a more robust load duration curve method for setting TMDL targets. A duration curve is a graph representing the percentage of time during which the value of a given parameter (e.g. flow, load) is equaled or exceeded.

The load reduction target for the Neshanic River Watershed is defined as the total pollutant load reductions that are required to satisfy the water quality standards for the non-trout FW2 streams in the watershed as defined by NJDEP. A 10 percent margin of safety (MOS) and less than 10 percent exceedance threshold were adopted to determine the pollutant load reduction targets. The 10 percent MOS indicates the more stringent water quality targets at the 90 percent of the regulatory water quality standards. For example, the TN target is 9 mg/L instead of 10 mg/L when considering the MOS. Given the stochastic nature of water contamination, it is not practical to require the water quality standard to be achieved daily. The less than 10 percent exceedance threshold requires a frequency of violating the water quality standards and their MOS of less than 10 percent.

Three sets of load duration curves were developed for the watershed. Each set contains five load duration curves for TSS, TN, TP, fecal coliform and *E. coli*. The first set of load duration curves is based on observed streamflow and water quality data at the USGS Reaville Gage Station (N1 Station), above which is the upper portion of the watershed. Both TSS and TN satisfy the TMDL water quality goals at the N1 Station. The load reduction targets of 48, 90 and 91 percent for TP, fecal coliform and E. coli, respectively, are required to achieve the specified TMDL goals including MOS and the threshold for the frequency of exceedance at the N1 Station. The second set of load duration curves are based on the streamflow and water quality results simulated by the SWAT watershed model at the N1 station. To satisfy the TMDL requirements, the load reduction targets are 48 percent for TP, 90 percent for fecal coliform and 91 percent for *E. coli*. It is not necessary to reduce TN and TSS at the N1 station. These pollutant load reduction targets are essentially the same as those based on the monitoring data at the same station. Since there is no observed streamflow and water quality data at the watershed outlet, the third set of load duration curves are based on the streamflow and water quality results simulated by the SWAT model. The load reduction targets required to meet the TMDL goals at the watershed outlet are 9 percent for TSS, 49 percent for TP and 89 percent for both fecal coliform and *E. coli*.

2.4. **Management Measures**

Different management measures are recommended to reduce pathogen, nutrients and sediment loads from various sources to the streams and to restore watershed hydrology.

2.4.1. Management Measures to Reduce Pathogenic Loads

The following management measures are recommended to reduce pathogenic loads to the streams:

- OSDS Education and Management – The Plan calls for a comprehensive education campaign on OSDS operation and maintenance, a three-year inspection and certification program, and technical assistance and financial incentive programs to retrofit the failing OSDSs in the watershed.
- Animal Manure Management – In addition to implementing 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 calls for the operation of five small scale regional manure composting and storage facilities and the development and implementation of manure incorporation technology when applying manure as fertilizer in row-crop and hay production.
- Livestock Access Control – The Plan calls for the complete exclusion of livestock from the streams and their immediate riparian areas from pasture and offers technical assistance and financial support as incentives. The exclusion primarily focuses on the streams that pass through pasture and does not apply to temporary stream crossings for livestock.
- Sewer Infrastructure Maintenance in Sewer Service Areas (SSAs) – The Plan calls for periodic assessments of the conditions and capacity of all sewer infrastructures in SSAs and planned updates and/or improvement in the sewer infrastructure in the watershed.
- Wildlife Management – Currently, wildlife is a minor contribution to pathogen contamination in the watershed as compared to other sources. The Plan calls for the active participation in various wildlife management programs implemented at the state and county levels and implementation of various BMPs to disrupt habitats for deer and geese along the streams.
- Detention Basin Retrofitting – The detention basins capture a large amount of stormwater runoff from medium and low density urban development where pathogen sources could exist. There is no existing empirical study indicating how much retrofitting detention basins would reduce pathogen loads. Depending on the final design of the detention basin, a retrofitted detention basin can function like a bio-retention basin or a constructed wetland that removes pathogen loads to the streams.

2.4.2. Management Measures to Reduce Nutrient Loads

The following management measures are recommended to reduce nutrient loads to the streams:

- Integrated Crop Nutrient Management – The amount of fertilizers applied to crops should be based on reasonable crop yield goals and available nutrients in soils as determined by soil testing. Technical assistance for soil test-based integrated crop management (ICM) should be offered to farmers in the watershed.
- Conservation Buffers – Conservation buffers are planned vegetative mixtures of trees, shrubs and grasses placed in landscapes to influence ecological processes and enhance ecosystem goods and services. There are many types of conservation buffers, such as contour buffer strips, field borders, grassed waterways, filter strips and riparian forest buffers. Optimal placement of buffers in the watershed is essential for maximizing their efficiency in reducing nutrient loads.
- Cover Crop – Cover crops are grasses, legumes, forbs or other herbaceous plants established for seasonal cover and other conservation purposes. Cover crops reduce soil erosion, help maintain soil moisture and improve nutrient and organic content of soils. Other potential benefits of cover crops include decreased farm operation costs, reduced tillage, less herbicide use and better overall soil health. Farmers should be offered technical assistance and financial incentives to encourage the use of cover crops on fields that are not farmed for all or part of a year.
- Manure Management – Cropland should not be used as a dumping ground for animal manure. Manure application should be rotated among numerous fields to avoid concentrating manure in a limited area based on an ICM plan or nutrient management plan. To protect water resources and promote crop growth and soil health, manure should be tested for nutrient content and applied according to crop needs.
- Prescribed Grazing – Prescribed grazing is a system that helps agricultural producers to manage grazing and browsing of animals to ensure adequate ground cover and proper livestock nutrition. A prescribed grazing plan can include reducing the number of livestock in a given pasture, more frequent rotation of livestock across pastures, and using temporary fencing to exclude livestock from pastures recovering from past grazing activity. Prescribed grazing helps to maintain healthy and productive pastures. Healthy pastures protect soil from erosion and the resultant phosphorus and fecal runoff. In addition, an actively growing pasture takes up more nutrients, improves water infiltration and reduces runoff and NPS.
- Nutrient Management for Lawn Care – The newly enacted Fertilizer Control Law establishes standards for certain fertilizer applications, requires certification of professional fertilizer applicators and regulates labeling and sale of certain fertilizers. As with agricultural fertilizer application, lawn fertilizer application rates should be based on soil testing in order to promote healthy lawns and reduce nutrient loads to streams.

2.4.3. Management Measures to Reduce Sediment Loads

The following management measures are recommended to reduce sediment loads to the streams:

- Contour Farming – Contour farming uses ridges and furrows formed by tillage, planting and other farming operations to change the direction of runoff from directly downslope to around the hill slope. Contour farming reduces sediment from gully erosion, surface water runoff, and the transport of phosphorus and other contaminants to streams.
- Conservation Buffers – Conservation buffers have multiple water quality benefits and reduce both sediments and nutrient loads to streams. As runoff flows through a conservation buffer, dense vegetation in the buffer acts as a filter, blocking sediments and sediment-absorbed nutrients, pesticides and pathogens and preventing them from entering streams. To maximize their efficiency in improving water quality, conservation buffers should be placed in the optimal locations in a watershed.
- Livestock Access Control – Livestock access control not only reduces the pathogen loads into streams, but also eliminates livestock disturbances to streambanks and maintains streambank stability. A stable streambank results in less soil erosion and, therefore, less TSS load to the streams in the watershed.
- Cover Crop – Cover crops reduce soil erosion, help maintain soil moisture and improve soil nutrients and organic content. Farmers should be offered technical assistance and financial incentives to encourage the use of cover crops on fields that farmed for all or part of a year.
- Prescribed Grazing – Prescribed grazing helps to maintain healthy and productive pastures. Healthy pastures have lower soil erosion rates, lower phosphorus and fecal matter in runoff, greater absorption of nutrients, and higher water infiltration.
- Roadside Ditch Retrofitting – The roadside ditches in the watershed are actively eroding, thus adding sediment to stormwater that flows through them. Roadside ditch retrofitting can transform ditches into bio-retention systems that are very similar to constructed wetlands.
- Streambank stabilization – Streambank erosion contributes significantly to TSS in streams in this watershed. Streambank stabilization is effective in reducing streambank erosion, improving water quality and enhancing stream ecology. Although streambanks can be temporarily stabilized through various streambank stabilization measures, permanent stabilization can only be achieved by controlling the amount and velocity of stormwater runoff in the watershed. Stabilizing streambanks requires prohibiting any land use activities that disturb the streambank.

2.4.4. Management Measures to Restore Watershed Hydrology and Streamflow

Land use changes and associated stormwater infrastructure have significantly altered the hydrology of the Neshanic 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 Neshanic River Watershed.

- Bio-retention Systems – Traditional stormwater infrastructure is designed to quickly deliver stormwater from the sources to the streams. Bio-retention systems are BMPs that are designed to retain the stormwater first and then discharge it to the stormwater systems and/or the stream if necessary. These systems are designed to treat the retained stormwater to achieve substantial water quality benefits through various biological processes embedded in the system. The stormwater retained in those systems could also be infiltrated though the soils to recharge groundwater, thus reducing the amount of stormwater entering streams. Bio-retention systems should include a series of bio-retention facilities that are maintained under different situations and include rain gardens in residential and commercial properties and along the roadsides.
- Conservation buffers – Conservation buffers provide both water quantity and quality benefits. They achieve runoff reduction through evapotranspiration by plants and promote groundwater recharge through multiple biological and hydrological processes.
- Conservation Planning and Ordinances – Land use changes, especially suburban development, substantially alter watershed hydrology and cause many water quality problems in the Neshanic River Watershed. As suburban development continues in the watershed, conservation planning and ordinances should be reviewed, developed, implemented, and enforced to alleviate harmful land use activities and protect the water resources in 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 development, 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 expanded to protect critical source areas (CSAs) from intensive land use activities and disturbances and prevent water resources from being degraded at their sources.

2.5. **Recommended Projects**

Table 2.1 summarizes the scope and cost of the BMP projects recommended for achieving the water quality goals established for the watershed. There are eight types of agricultural BMP projects, four 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 the total cost divided simply by the life span. The total cost for implementing the eight types of agricultural BMP projects is about $9.5 million of which more than half is for conservation buffers on agricultural lands. The total cost of all stormwater BMP projects is estimated at $39.4 million. Retrofitting roadside swales and ditches in the watershed accounts for half of the total cost of stormwater BMPs. The total cost of establishing the comprehensive OSDS inspection and maintenance programs and eliminating the failing OSDSs in the watershed is $7.6 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 Section 2.3 and restore the watershed hydrology in the Neshanic River Watershed. Total implementation cost is estimated to be $56.5 million.

Table 2.1: Recommended BMP projects for the Neshanic River Watershed

Types of BMP Project	Applicable Unit	Unit Cost ($/unit)	Life span (years)	Total Cost ($)	Annualized Cost ($/year)
1. Cover Crop	4,011 acres	315	3	1,263,180	421,060
2. Prescribed Grazing	892 acres	444	5	396,226	79,245
3. Livestock Access Control	24,663 feet	11.54	10	284,512	28,451
4. Contour Farming	1,846 acres	117	3	215,267	71,756
5. Nutrient Management	9,645 acres	117	3	891,548	297,183
6. Conservation Buffers on Agricultural Lands	988 acres	6,027	15	5,955,005	397,000
7. Regional Animal Waste Storage and composting Structure	5 units	90,000	10	450,000	45,000
8. Manure Application Incorporation Technology	330 acres	156	1	51,480	51,480
A. Subtotal for Agricultural BMP Projects (1-8)				*$9,507,219*	*$1,391,175*
9. Rain Gardens	3,545 units	4,150	15	14,711,750	980,783
10. Roadside Ditch Retrofitting	853 units	23,500	15	20,045,500	1,336,367
11. Detention Basin Retrofitting	153 units	29,500	15	4,513,500	300,900
12. Vegetative Buffers on Developed Lands	27,603 feet	4.84	15	133,657	8,910
B. Subtotal for Stormwater BMP Projects (9-12)				*$39,404,407*	*$2,626,960*
13. OSDS Inspection and Maintenance	1,490 units	600	3	894,000	298,000
14. Failed OSDSs Retrofitting	447 units	15,000	15	6,705,000	447,000
C. Subtotal for OSDS BMP Projects (13-16)				*$7,599,000*	*$633,250*
D. Total (A + B + C)				*$56,510,626*	*$4,763,136*

Although all BMP projects are recommended, they differ in terms of their cost and effectiveness in reducing pollutant loads. Table 2.2 summarizes the priority ranks of all BMP projects according to their cost-effectiveness of BMPs in reducing TP, sediment and pathogen in the Neshanic River Watershed. Cost-effectiveness measures the average reduction in the loading of pollutant achieved by a BMP per dollar spent on implementing that BMP. It equals the annual pollutant load reduction divided by the annual cost of full implementation of the BMP project in the watershed. For example, spending $1,000 on cover crops would reduce TP by 1.86 pounds and spending $1,000 on livestock access control would reduce TP by 32.08 pounds. The BMP with the highest cost-effectiveness has a priority rank of one, which means it should be implemented first. The top five ranked BMPs for reducing TP loads in order of ranking are livestock access control, nutrient management, conservation buffers in agricultural lands, contour farming and prescribed grazing. The top five ranked BMPs for reducing sediment in order of ranking are vegetative buffers in developed lands, livestock access control, contour farming, conservation buffers in agricultural lands and detention basin retrofitting. The top five ranked BMPs for reducing pathogen loads to the streams in order of ranking are livestock access control, livestock waste storage and composting structures, OSDS inspection and maintenance, manure application incorporation technology, and failed OSDS retrofitting.

Table 2.2: Priority ranks for all BMP projects in the Neshanic River Watershed

Type of BMP Project		Priority Rank in Reducing		
		TP	Sediment	Pathogen
1	Cover Crop	8	7	
2	Prescribed Grazing	5	6	6
3	Livestock Access Control	1	2	1
4	Contour Farming	4	3	
5	Nutrient Management	2		9
6	Conservation Buffers in Agricultural Lands	3	4	10
7	Livestock Waste Storage and Composting Structure	12		2
8	Manure Application Incorporation Technology	11		4
9	Rain Garden	10	9	
10	Road Ditches	9	8	11
11	Detention Basin Retrofitting	7	5	7
12	Vegetative Buffers in Developed Lands	6	1	8
13	OSDS Inspection and Maintenance	13		3
14	Failed OSDS Retrofitting	14		5

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

2.6. **Implementation Schedule**

Although 14 types of BMP projects are recommended, it is not necessary to implement all BMPs on all applicable lands or at applicable facilities in order to achieve the pollutant reduction targets in the Neshanic River Watershed. There are some practical limits on implementing BMP projects at their applicable units in full scale. Natural resource conditions may restrict the kinds of BMPs that can be implemented on applicable lands. For various reasons, some farmers or landowners may resist implementation of any BMPs on their lands. For example, cover crop is applicable on all 4,011 acres of row-crop fields in the watershed, but it is not realistic to expect all farmers in the watershed to use cover crop on their cropland. An implementation plan should balance the physical restrictions related to natural resource conditions, stakeholders' willingness and ability to act, and financial feasibility. The implementation plan details the types of BMPs being selected for implementation and the scope of how much or how many of the selected BMPs will be implemented in the watershed in terms of implementation acreage and the number of retrofitted stormwater infrastructure that achieve the required pollutant load reduction targets. Table 2.3 presents the implementation targets for all of the recommended BMP projects. Targets are described in terms of the percentage and physical dimensions of the applicable units for the BMP projects (implementation goal) and the amount or reduction achieved (reduction goal). They are based on the cost-effectiveness of those BMPs, the feasibility of implementation and the pollutant reduction requirements. The expected annual load reductions for the implementation plan are 6,632 pounds of TP and 324 tons of sediment, which is sufficient to achieve a 49 percent reduction in TP and greater than 9 percent of reduction in TSS. The expected cost of the implementation plan is $14.6 million. Of this amount, 52 percent is for inspecting and maintaining OSDSs and retrofitting the failing OSDSs in the watershed and 20 percent is for installing conservation buffers on 494 acres of agricultural lands.

Table 2.3: Implementation targets for the recommended BMP projects in the Neshanic River Watershed

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
		%	Unit	TP (lbs)	Sed. (tons)	$	%
1	Cover Crop	50	2,006 acres	392	40	631,590	4.3
2	Prescribed Grazing	50	446 acres	190	8	198,113	1.4
3	Livestock Access Control	100	24,663 feet	913	52	284,512	2.0
4	Contour Farming	75	1,385 acres	380	55	161,451	1.1
5	Nutrient Management	75	5,734 acres	2,608		668,661	4.6
6	Conservation Buffers in Agricultural Lands	50	494 acres	1,850	125	2,977,503	20.5
7	Livestock Waste Storage and Composting Structure	100	5 units			450,000	3.1
8	Manure Application Incorporation Technology	75	248 acres			38,610	0.3
9	Rain Garden	1	35 units			147,118	1.0
10	Road Ditches	1	9 units	2		200,455	1.4
11	Detention Basin Retrofitting	25	39 units	277	35	1,135,750	7.8
12	Vegetative Buffers on Developed Lands	50	13,802 feet	19	10	66,828	0.5
13	OSDS Inspection and Maintenance	100	1,490 units			894,000	6.1
14	Failed OSDS Retrofitting	100	447 units			6,705,000	46.1
Total				6,632	324	$14,559,591	100.0

The estimated reduction in TP is on the conservative side for several reasons. First, almost all BMP projects for reducing pathogen loads also reduce TP loads, but the reductions from some BMPs are difficult to quantify and are not included in the calculation. Second, the implementation of the newly enacted Fertilizer Control Law and the municipal low-phosphorus ordinances for lawn care should substantially reduce TP loads from the urban lands that contribute 28 percent of TP loads to the streams in the watershed. Third, targeting the application of BMP projects in the critical pollution source areas should reduce pollutant loads much more than the average reduction rates used in this estimation in Table 2.3. The quantification of pathogen load reduction is difficult. It is expected that the required 89 percent reduction in pathogen (both fecal coliform and *E. coli*) can be achieved by eliminating the failing OSDSs, improving manure application and completely excluding livestock access to streams in the watershed.

The implementation plan also considers how the BMP projects are implemented in the watershed over space and time. The implementation plan is discussed in terms of a 10-year planning horizon. Table 2.4 presents the implementation schedule within 2, 5 and 10 years in terms of the 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 the high priority areas identified in the project.

Table 2.4: BMP implementation schedule in the Neshanic River Watershed

Types of BMP Projects		In 2 Years		In 5 Years		In 10 Years	
		%	Unit	%	Unit	%	Unit
1	Cover Crop	10	401 acres	25	1,003 acres	50	2,006 acres
2	Prescribed Grazing	10	89 acres	25	223 acres	50	446 acres
3	Livestock Access Control	25	6,166 feet	50	12,332 feet	100	24,663 feet
4	Contour Farming	25	462 acres	50	923 acres	75	1,385 acres
5	Nutrient Management	25	1,911 acres	50	3,823 acres	75	5,734 acres
6	Conservation Buffers in Agricultural Lands	10	99 acres	25	247 acres	50	494 acres
7	Livestock Waste Storage and Composting Structure	20	1 unit	60	3 units	100	5 units
8	Manure Application Incorporation Technology	25	83 acres	50	165 acres	75	248 acres
9	Rain Garden	0.1	4 units	0.5	18 units	1	35 units
10	Road Ditches	0.1	1 unit	0.5	4 units	1	9 units
11	Detention Basin Retrofitting	5	8 units	15	23 units	25	39 units
12	Vegetative Buffers in Developed Lands	10	2,760 feet	25	6,901 feet	50	13,802 feet
13	OSDS Inspection and Maintenance	25	373 units	10 0	1,490 units	100	1,490 units
14	Failed OSDS Retrofitting	25	112 units	50	224 units	100	447 units

The assumption of a 10-year planning horizon does not mean it takes 10 years to achieve the required pollutant load reduction targets. Depending on funding availability and the stakeholders' willingness to act, many recommended BMPs can be implemented at a much faster pace. However, attaining the required pollutant load reduction targets does not guarantee the restoration of water quality and biological integrity of the streams in the watershed because it takes time for reductions in pollutant loads to affect water quality.

2.7. **Measurable Milestones**

During the first two years after the Plan is adopted, the four municipalities in the watershed should:

- Educate the residents, farmers, and businesses on the water quality status of the Neshanic River and responsible stewardship in land use and management;
- Where applicable, establish concrete steps for implementing the New Jersey State Rules for improving water quality and/or preventing water quality from continuous deterioration. These rules includes New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program rules (N.J.A.C. 7:14A), the Stormwater Management Rules (N.J.A.C. 7:8), the Flood Hazard Area Control Act rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Criteria and Standards for Animal Waste Management(N.J.A.C. 2:91), and the newly enacted Fertilizer Control Law for commercial and residential lawn care and management.
- Refine their open space and farmland preservation plan for protecting hydrologically sensitive areas from future development.
- Develop the municipal ordinance for OSDS inspection, maintenance and operation that requires a 3-year certification program.
- Work with federal, state, county governmental agencies, universities, non-governmental and non-profit agencies and local environmental consulting firms to apply for and secure the necessary funding and technical assistance and begin implementation of the proposed BMP projects in the watershed.

The implementation of the BMP projects for the first two years as indicated in Table 2.4 are estimated to cost $3.4 million 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 annual TP load by 1,770 pounds, which is close to 30 percent of the required annual load reduction for TP;
- Reduce annual sediment load by 75 tons, which is equivalent to 50 percent of the required annual load reduction for sediment; and
- Reduce annual load of pathogens by 5 percent.

Implementation of the BMP projects during the first five years as indicated in Table 2.4 are estimated to cost $8 million and achieve the following milestones toward the pollutant reduction goals and the attainment of the water quality standards:

- Improve water quality and watershed hydrology;
- Reduce annual TP load by 3,800 pounds, which is equivalent to 60 percent of the required annual load reduction in TP;
- Reduce annual sediment load by 175 tons, which exceeds the required annual load reduction for sediment; and
- Reduce annual load of pathogens by 60 percent.

The completion of the 10-year implementation of the BMP projects as indicated in Table 2.4 is estimated to cost $14.6 million and achieve the following milestones toward the pollutant reduction goals and the attainments of the water quality standards:

- Improve the water quality and restore watershed hydrology;
- Reduce annual TP load by 6,000 pounds, which exceeds the required annual load reduction in TP and attains the water quality standard for TP;
- Reduce annual sediment load by 324 tons, which exceeds the required annual load reduction for sediment and achieves the water quality standard for TSS;
- Achieve an 89 percent annual load reduction for pathogens and attain the water quality standard for pathogens.

2.8. **Funding and Technical Assistance**

As indicated in Table 2.3, the total cost for achieving implementation targets is about $14.5 million. That cost can be broken down into three components: (1) outreach and technical assistance costs for reaching out to stakeholders and designing BMP implementation plans, and obtaining the necessary permits to install the BMPs; (2) BMP installation costs for related materials, labor, equipment and other items; and (3) BMP maintenance costs that ensure proper operation of BMPs. Of the $14.6 million of implementation costs, $1.5 million is for outreach and technical assistance, $10.9 is for installation and $2.2 million is for maintenance.

The funding available for BMP implementation depends on the types of BMPs and the nature of the costs. USDA NRCS and Farm Service Agency (FSA) support installation of agricultural BMPs (1-8) through outreach, technical assistance and cost-sharing of installation costs. There are no consistent funding sources for implementing stormwater BMPs and no public funding sources available to support the OSDS inspection and maintenance and retrofitting because OSDSs are generally viewed as private properties.

The funding and technical assistance for the implementation plan are based on the following recommendations. First, all maintenance costs for installed BMPs should be the responsibility of stakeholders. For example, homeowners should pay for the maintenance cost for installed rain gardens. Local homeowners associations should be responsible for maintaining retrofitted detention basins in their neighborhoods. Residents should be responsible for operating their own OSDSs. Second, 50 percent of the outreach and technical assistance and installation costs for agricultural BMPs (1-8) 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). Third, to jump start the comprehensive OSDS certification and maintenance program and completely eliminate water pollution from the failing OSDSs, the implementation plan should consider funding the OSDS inspection and cost-share the retrofitting cost for failing OSDSs in the watershed.

Table 2.5 summarizes the potential sources of funding for implementation of BMP projects. Stakeholders, such as farmers and residents, could pay $5.4 million of the total implementation costs. Of this amount, 50 percent is for retrofitting failing OSDSs and OSDS inspection and maintenance. The remaining stakeholders' costs are for the time and labor required for maintenance of installed BMPs. The USDA could contribute $2.25 million for agricultural BMPs. An additional $7 million is needed from other sources, of which $6.1 million is for BMP installation and $0.88 million is for outreach and technical assistance.

Table 2.5: Potential sources of funding for implementation of BMP projects

	Types of BMP Projects	Total Cost	Stake-holders	USDA	Other Sources	
					BMP Inst.	Tec. As.
1	Cover Crop	631,590	0	315,795	299,622	16,173
2	Prescribed Grazing	198,113	0	99,057	71,182	27,875
3	Livestock Access Control	284,512	49,326	117,593	70,733	46,860
4	Contour Farming	161,451	0	80,725	62,303	18,423
5	Nutrient Management	668,661	0	334,330	258,031	76,299
6	Conservation Buffers in Agricultural Lands	2,977,503	617,500	1,180,001	751,868	428,133
7	Livestock Waste Storage and Composting Structure	450,000	250,000	100,000	100,000	
8	Manure Application Incorporation Technology	38,610	0	19,305	19,305	
9	Rain Garden	147,118	53,175		58,493	35,450
10	Road Ditches	200,455	63,975		110,890	25,590
11	Detention Basin Retrofitting	1,135,750	288,750		654,500	192,500
12	Vegetative Buffers in Developed Lands	66,828	10,896		45,036	10,896
13	OSDS Inspection and Maintenance	894,000	670,500		223,500	
14	Failed OSDS Retrofitting	6,705,000	3,352,500		3,352,500	
Total		14,559,591	5,356,622	2,246,807	6,077,962	878,200

Other sources of funding for BMP projects include:

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

In addition to the standard funding that could be provided by the above agencies, there are alternative funding sources that can be developed for watershed restoration, such as the stormwater mitigation fund implemented in Raritan Township, the stormwater utility and water quality trading being implemented in many other communities in the U.S., and the low-interest or no-interest loan or subsidy for OSDS retrofitting patterned after the New Jersey Clean Energy program.

2.9. **Criteria and Monitoring Program**

Two criteria can be used to evaluate whether watershed restoration is successful. The first criterion relates to changes in land use management practices. This criterion evaluates whether: (1) the proposed BMP projects are implemented in the watershed; (2) stakeholders are more aware of the impacts of their land use and management decisions; and (3) stakeholders continue to practice environmentally friendly BMPs after initial BMP funding ends. The second criterion relates to the outcomes observed in streams and their riparian areas. This criterion evaluates whether such things as: (1) water quality and biological conditions in streams improve over time; and (2) stream channels become stabilized.

Based on these two criteria, a monitoring program can be used to determine the success of watershed restoration efforts. Such a program would involve the following elements:

- Establish a database to document the BMPs being implemented in different locations of the watershed and estimate their water quality impacts using quantitative models and tools, such as Spreadsheet Tool for Estimating Pollutant Load (STEPL) model;
- Continue the comprehensive streamflow, water quality and biological monitoring program at the USGS Reaville 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 the long-term biological monitoring in four biological monitoring stations in the watershed to determine long-term changes in biological conditions in the Neshanic streams; and
- Use volunteers to periodically conduct stream visual assessment using SVAP to assess physical changes in the streams and their riparian zones.

2.10. **Education**

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

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

The ultimate goal of education is to improve stakeholders' awareness and promote behavior changes that are beneficial in achieving watershed restoration.

3. Project Background, Purpose and Partnership

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

3.1. Background

The Neshanic River Watershed is located in Hunterdon County and encompasses Raritan, Delaware and East Amwell Townships and Flemington Borough. It is part of the Raritan River Basin in Central New Jersey. Figure 3.1 shows the general location of the watershed.

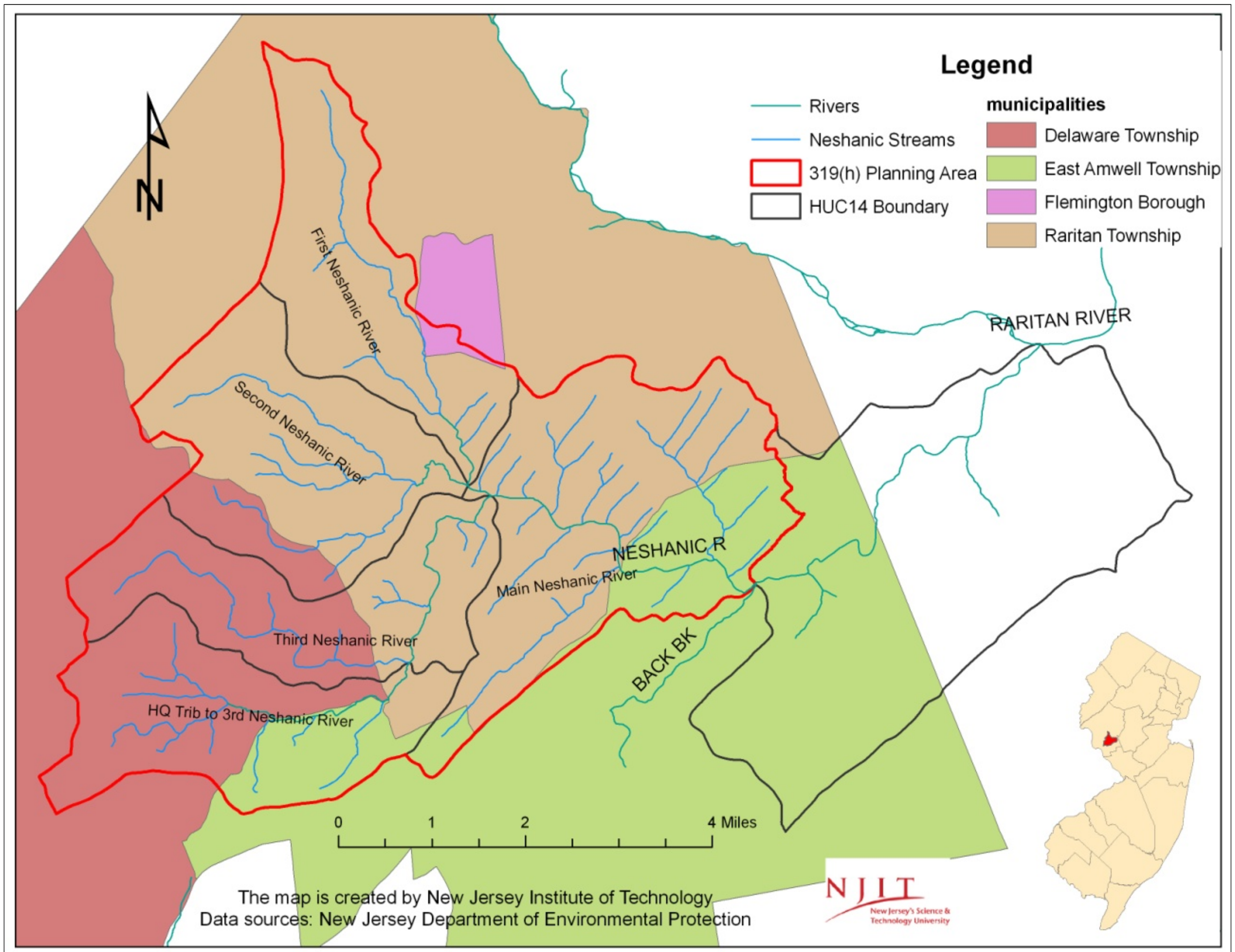


Figure 3.1: Neshanic River Watershed, New Jersey

The broad Neshanic River Watershed includes Walnut Brook, First, Second and Third Neshanic Rivers, Back Brook and the Neshanic River main branch. A similar watershed planning effort was conducted for the Back Brook and its drainage area. Therefore, the Neshanic River Watershed Restoration Plan focused on the 31 square mile upper part of the Neshanic

River Watershed and includes Walnut Brook, First, Second and Third Neshanic Rivers and the Neshanic River main branch immediately above the Back Brook confluence with the Neshanic River. The planning area covers four HUC14s including First Neshanic River (02030105030010), Second Neshanic River (02030105030020), HQ Trib to Third Neshanic River (02030105030030), Third Neshanic River (02030105030040), and two-fifths of the HUC14 Main Neshanic River (02030105030060).

Numerous monitoring sources, including the NJDEP Ambient Biomonitoring Network, the USGS/NJDEP water quality monitoring network and the Metal Recon Program, indicate the Neshanic River and its branches are severely impaired. The Neshanic River was listed in the 2008 New Jersey Integrated Water Quality Monitoring and Assessment Report for impaired aquatic life, and NPS from bacteria, phosphorus, and TSS (NJDEP, 2008). According to USGS, the Neshanic River was one of the water bodies with the worst overall water quality in the Raritan River Basin (Reiser, 2004). A TMDL for fecal coliform was approved and adopted for the Neshanic River in 2003 by NJDEP (2003). This TMDL requires an 87 percent reduction in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest and agricultural lands. Additionally, a TMDL for total nutrients in the Raritan Basin was developed by NJDEP; it has not been released. Another concern in the watershed is the increasing occurrence of no/low baseflow in the Neshanic River in the late summer (Reiser, 2004). Although available data clearly show that the Neshanic River is impaired, the specific sources and causes of these impairments are not known. Although the TMDL for the Neshanic River requires an 87 percent reduction in nonpoint source fecal coliform loads for all non-natural land uses, the TMDL does not identify specific sources or management measures to achieve that reduction. Both natural causes and human activities could contribute to the increasing occurrence of low/no base water flow in recent years. No study has been done to investigate the dynamic nature of this issue and no actions have been taken to restore the baseflow.

3.2. **Purpose of the Plan**

The project developed a watershed restoration plan that describes the management measures needed to achieve the needed reduction in fecal coliform and attain water quality standards for TP and TSS, reduce aquatic life impairments to a non-impaired level and assess the potential for restoring the base flow of the Neshanic River in the 31 square mile watershed.

3.3. **Partnership**

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

Administrative Agency

<u>New Jersey Department Environmental Protection (NJDEP)</u>
Contact Information: Nick Zripko
NJ Department of Environmental Protection
Office of Policy Implementation and Watershed Restoration
P. O. Box 420
Trenton, NJ 08625-0420

(609) 633-2201
http://www.nj.gov/dep/

Lead Agency

New Jersey Institute of Technology (NJIT)
Contact Information: Dr. Zeyuan Qiu
Department of Chemistry and Environmental Science
Newark, NJ 07039
(973) 596-5357
http://www.njit.edu

Collaborative Agencies

Hunterdon County Soil Conservation District
Contact Information: William E. Engisch
687 Pittstown Road
Frenchtown, NJ 08825
(908) 788-9466
http://hcscd.weebly.com/

Natural Resources Conservation Service (NRCS)
Contact Information: Christine Hall
54 Old Highway 22, Suite 201
Clinton, NJ 08809-1389
(908) 735-0733
http://www.northjerseyrcd.org

New Jersey Water Supply Authority (NJWSA)
Contact Information: Kathy Hale
74 East Main Street
Somerville, NJ 08876-2312
(908) 685-0315
http://www.raritanbasin.org

North Jersey Resource Conservation & Development (RC&D) Council
Contact Information: Patrick Natale
P.O Box 5113
Clinton, NJ 08809-0113
(908) 441-9191
http://www.northjerseyrcd.org

Rutgers Cooperative Extension (RCE)
Contact Information: Dr. Chris Obropta
14 College Farm Road, DES
New Brunswick, NJ 08901
(732) 932-9011
http://www.water.rutgers.edu

South Branch Watershed Association (SBWA)
Contact Information: Bill Kibler
Lechner House; 41 Lilac Drive
Flemington, NJ 08822
(908) 782-0422
http://www.sbwa.org

Raritan Township
Contact Information: Marianne Rampulla
5 Fairfax Court
Flemington, NJ 08822
(908) 806-2933

Delaware Township
Contact Information: Kathy Klink
155 Ferry Road
Flemington, NJ 08822
(609) 397-3179 X133; kklink@dtsk8.org

Flemington Borough
Contact Information: Lois Stewart,
26 Spring Street,
Flemington, NJ 08822
(908) 782-4342

East Amwell Township
Contact Information: Dee Kellogg
49 Dutch Lane
Ringoes, NJ 08551
(908) 782-2413; KelloggDS@cdm.com

The Plan was developed by two entities: the Neshanic River Watershed Restoration Plan Project Team; and the Neshanic River Watershed Restoration Planning Committee. The project team consisted of representatives from NJDEP, NJIT, HCSCD, RC&D, NJWSA and SBWA with NJIT as the project lead. The project team developed the Plan by carrying out ten tasks as identified in the contract scope of work. Regular project team meetings were held to discuss progress being made and coordinate project activities. The planning committee included the project team members described above, representatives of four townships in the watershed, related agency personnel and other stakeholders, such as local residents, businesses and farmers in the watershed. Three public planning committee meetings were held during the course of the project. The first planning committee meeting was held on March 28, 2007 to introduce the public to the project, the project team, the methodology being used in the project, and to seek project volunteers as well as public input on the water quality problems and their solutions in the watershed. The second planning committee meeting was held on March 30, 2009 to communicate preliminary project results and findings to the general public and seek their input on the development of the Plan. The third planning committee meeting was held on March 16, 2011 to present the Neshanic River Watershed Restoration Plan and seek public input to revise and refine the Plan and identify opportunities for implementing the Plan.

4. Watershed Characterization

4.1. Physical Characteristics

4.1.1. Geography and Topography

The Neshanic River Watershed is located in Hunterdon County, New Jersey and encompasses Raritan, Delaware, and East Amwell Townships and Flemington borough as shown in Figure 4.1.

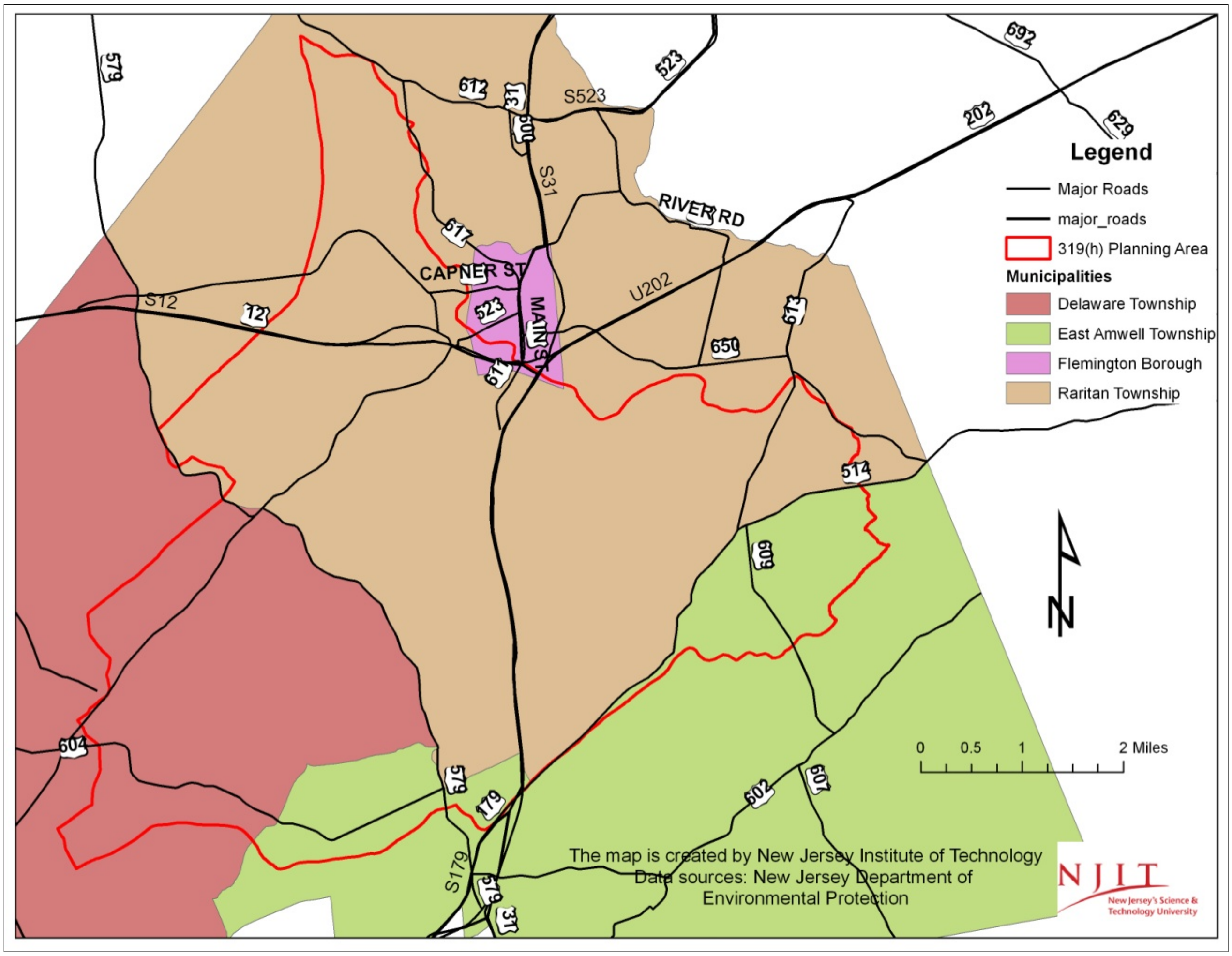


Figure 4.1: Transportation network in the Neshanic River Watershed

Interstate highway US202 is a major east-west thoroughfare passing through the watershed. State highway NJ12 runs from the Uhlerstown-Frenchtown Bridge at the Delaware River border between New Jersey and Pennsylvania, crosses the watershed in the north and intersects with US202 and Route31 at the Flemington Circle in Flemington just outside of the watershed in the east. There are also several county routes (CR) that connect the highways and communities in the watershed, including CR514 (from US202 in East Amwell Township to Bayway Avenue in Elizabeth), CR 609 (from CR602 in E. Amwell Township to CR514 in East Amwell Township), CR613 (from CR514 in Raritan Township to US202 in Readington

Township), CR579 (from John Fitch Parkway, namely US29, in Trenton to US173 in Greenwich Township), CR523 (from Main Street, namely US29, in Stockton to Hillside Avenue, namely US 202, in Bedminster Township), CR 604 (from CR 519 in Delaware Township to CR 579 in East Amwell Township) and Old Croton Road (Old US12).

Figure 4.2 shows the spatial distribution of elevation in the watershed. Elevation in the Neshanic River Watershed ranges from 101 to 689 feet above sea level. Areas with higher elevation are located along the northwestern ridge of the watershed, mostly in Raritan Township. Areas with lower elevation are located in the eastern portion of the watershed, mostly along the main Neshanic streams. The elevation of the southern ridge of the watershed generally exceeds 200 feet above sea level. Slopes in the watershed range from 0 to 85 percent. However, the watershed is generally flat. Only 5 percent of the watershed has a slope greater than 15 percent. The steeply sloped areas are located inside the southwestern to northern ridges in upland areas of the watershed and along the tributaries to the Neshanic River main stream in the lower part of the watershed.

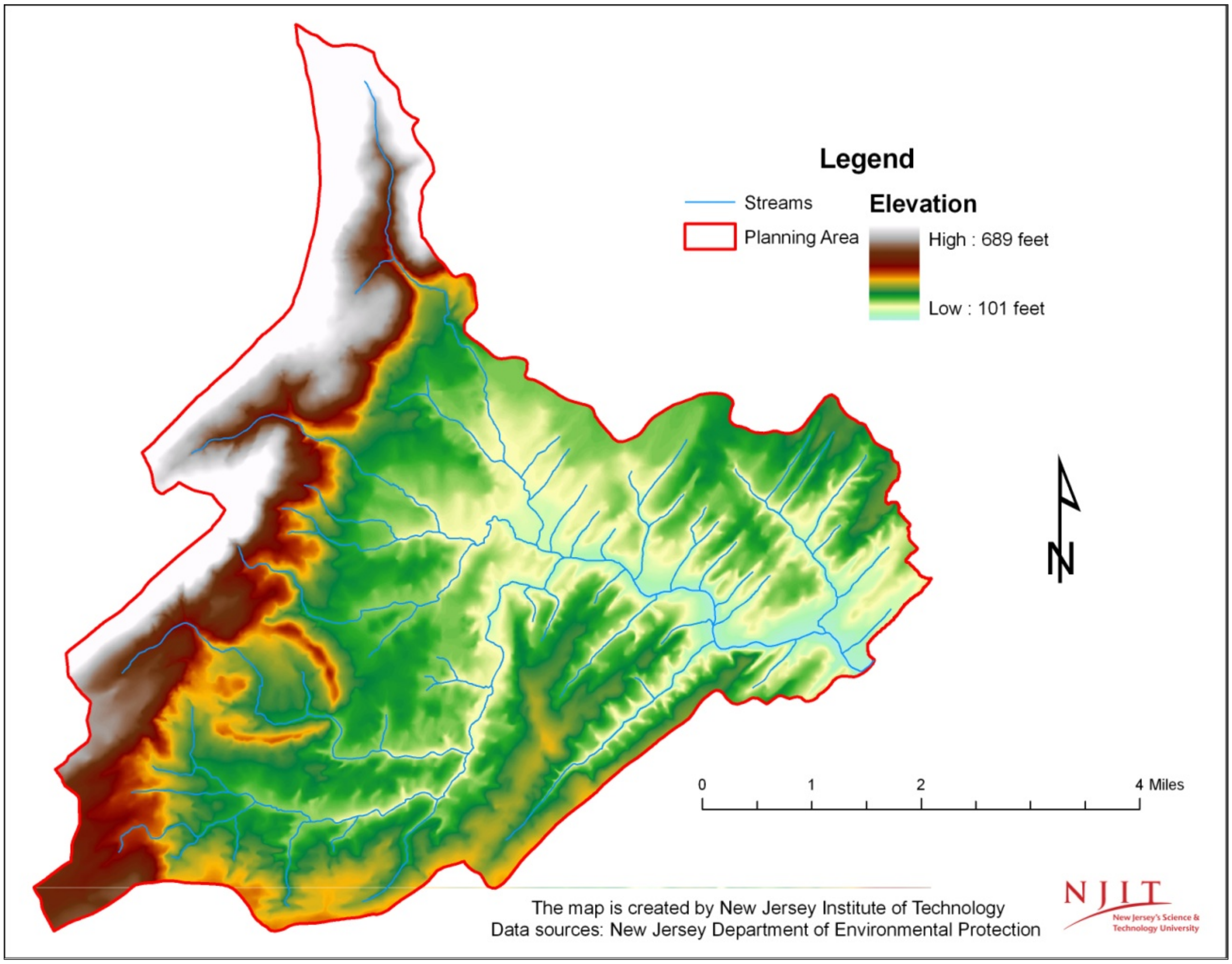


Figure 4.2: Topography in the Neshanic River Watershed

4.1.2. Demographics

Table 4.1 presents the total area, area in the watershed, population and population density of each of the four municipalities. Raritan Township has an area of 37.75 mi^2, which equates to 50 percent of the township located in the watershed. East Amwell Township only has 14 percent of its area in the watershed. Although Flemington Borough is the smallest municipality in the watershed, it has the highest population density of 3,888 people per mi^2 in 2000, which is more than seven times higher than for Raritan Township. The latter is the second most densely populated municipality in the watershed based on the 2000 U.S. Census. Population growth is quite different among the four municipalities. During the 1980s and 1990s, there was substantial population growth in Raritan Township and almost no growth in Flemington Borough. Both Delaware and East Amwell Townships experienced large population growth in the 1980s and almost no growth in the 1990s. Population growth in the 1980s and 1990s was primarily driven by a suburbanization process (i.e., the migration of corporations out of traditional urban centers). Firms like Exxon, Foster Wheeler and Merck established their corporate offices in Hunterdon County, attracting more people to the neighboring communities in the county (NJDLWD, 2006).

Table 4.1: Area, population and population density of municipalities in the Neshanic River Watershed

Municipality	Area (mi^2)	In watershed		Population			2000 Pop. density (people/mi^2)
		mi^2	percent	2000	1990	1980	
Raritan Township	37.75	19.02	50.38	19,809	15,616	8,292	524
Delaware Township	36.99	7.82	21.14	4,478	4,512	3,816	121
Flemington Borough	1.08	0.16	14.81	4,200	4,047	4,132	3,888
East Amwell Township	28.64	4.00	13.97	4,455	4,332	3,468	155

As indicated by the U.S. 2000 Census, the population in Delaware Township was 4,478 and 98 percent of the population was white. There were about 1,889 households in the township. The median household income was $76,523 in 2000, with 3.4 percent of the population and 2.3 percent of families below the poverty level. Of the total number of people living in poverty, 1.2 percent were under the age of 18 and 12.2 percent were 65 or older.

Raritan Township had a population of 19,809 in 2000 and 93 percent of the population was white. There were about 6,937 households in the township. Median household income in 2000 was $87,766, but grew to $109,477 in 2007. About 1.2 percent of families and 2 percent of the population were below the poverty level. Of the total number of people living in poverty, 1.6 percent were under the age of 18 and 2.9 percent were above the age of 65.

For East Amwell Township, the population in 2000 was 4,455 and 97 percent of the population was white. There were about 1,584 households in the township. Median household income was $85,664 in 2000. About 1.8 percent of families and 1.7 percent of the population were below the poverty level. Of the total number of people living in poverty, 2.2 percent were under the age of 18.

For Flemington Borough, the population in 2000 was 4,200 and 88 percent of the population was white. There were about 1,804 households in the borough. Median household income was $39,886 in 2000. About 5.0 percent of families and 6.9 percent of the population were below the poverty level. Of the total people living in poverty, 7.5 percent were under the age of 18 and 3.0 percent were above the age of 65.

This information is for 276 census blocks that are completely or partially in the watershed. Total population in the watershed was about 13,338 in 2000, with 6,515 males and 6,823 females. The race of the population was 12,523 whites, followed by 396 Asians, 347 Hispanic, 175 multi-racial and 155 black. Age wise, 1,039 were under the age of 5, 2,970 were between the ages of 5 and 17, 374 between 18 and 21, 791 between 22 and 29, 2,335 between 30 and 39, 2,748 between 40 and 49, 1,925 between 50 and 64, and 1,156 65 or older. Median age was 37 for the entire total population, 36.4 for males and 37.3 for females. There were about 4,623 households in the watershed.

Demographic characteristics have changed dramatically during the last decade. Unlike the population growth in the 1980s and 1990s that was primarily driven by the migration of corporations to the suburbs, population growth in the 2000s was driven primarily by exurbanization (i.e., the migration of people out of the traditional population centers into rural areas) (Nelson, 1992; Davis, et al., 1994). Such exurbanization increases low density, rural residential development. The 2010 Census results in Table 4.2 indicate that Raritan Township and Flemington Borough experienced high population growth during the period 2000-2010. Although there was a small increase in population in Delaware Township, the population of East Amwell Township declined between 2000 and 2010. The number of dwelling units in Raritan and Delaware Townships increased over 13 percent during the period 2000-2010.

Table 4.2: Changes in population and number of dwelling units for municipalities in the Neshanic River Watershed, 2000-2010

Municipality	Population			Number of Dwelling Units		
	2000	2010	Change	2000	2010	Change
Raritan Township	19,809	22,185	+12.0 %	7,094	8,288	+16.8%
Delaware Township	4,478	4,563	+1.9%	1,701	1,927	+13.3%
Flemington Borough	4,200	4,581	+9.1%	1,876	1,926	+2.7%
East Amwell Township	4,455	4,013	-9.9%	1,624	1,580	-2.7%

4.1.3. Climate

The climate of the region is humid subtropical, with typically hot and humid summers and cold winters. According to the weather data for the period 1955 – 2008 in the Flemington Weather Station located at 40.56°N 74.88°W maintained by the National Climate Center, the average high air temperatures in summer (June to August) were in the range 81 – 86 °F and the average low temperatures in summer were in the range 55 – 61 °F. On average, 19 days each summer had air temperatures that exceeded 90 °F. It was rare for the summer temperature to exceed 100 °F. The average high temperature in winter (December to February) was in the range 37 – 41 °F and average low temperature in winter was in the range 19 – 29 °F. For brief interludes, winter temperature fell in the range 10 – 20 °F and 50 – 60 °F. Spring and autumn can exhibit wide temperature variations, ranging from chilly to warm, although they usually have milder temperatures and lower humidity than in summer.

Mean annual precipitation of the watershed was about 48 inches during the period 1955-2008. It rained, on average, 104 days a year. Rain days were uniformly spread throughout the year. Snowfall in winter season varies from year to year and ranged from 5 to 30 inches. For some years, nor'easters occurred in winter and early spring, which are capable of causing blizzards or flooding. Drought and rain-free periods can last for weeks. Hurricanes and tropical storms, such as Hurricane Floyd in 1999, are rare.

4.1.4. Geology

The Neshanic River Watershed is located wholly within the Piedmont Plain physiographic province of New Jersey, which has rolling hills with wide, shallow valleys. It belongs to the broader geological region known as the Newark Rift Basin, which contains Triassic and Jurassic rocks deposited in a large sedimentary basin that formed during the breakup of Pangea, the giant continent that existed about 200 to 250 million years ago. Figure 4.3 depicts the spatial distribution of bedrock in the watershed.

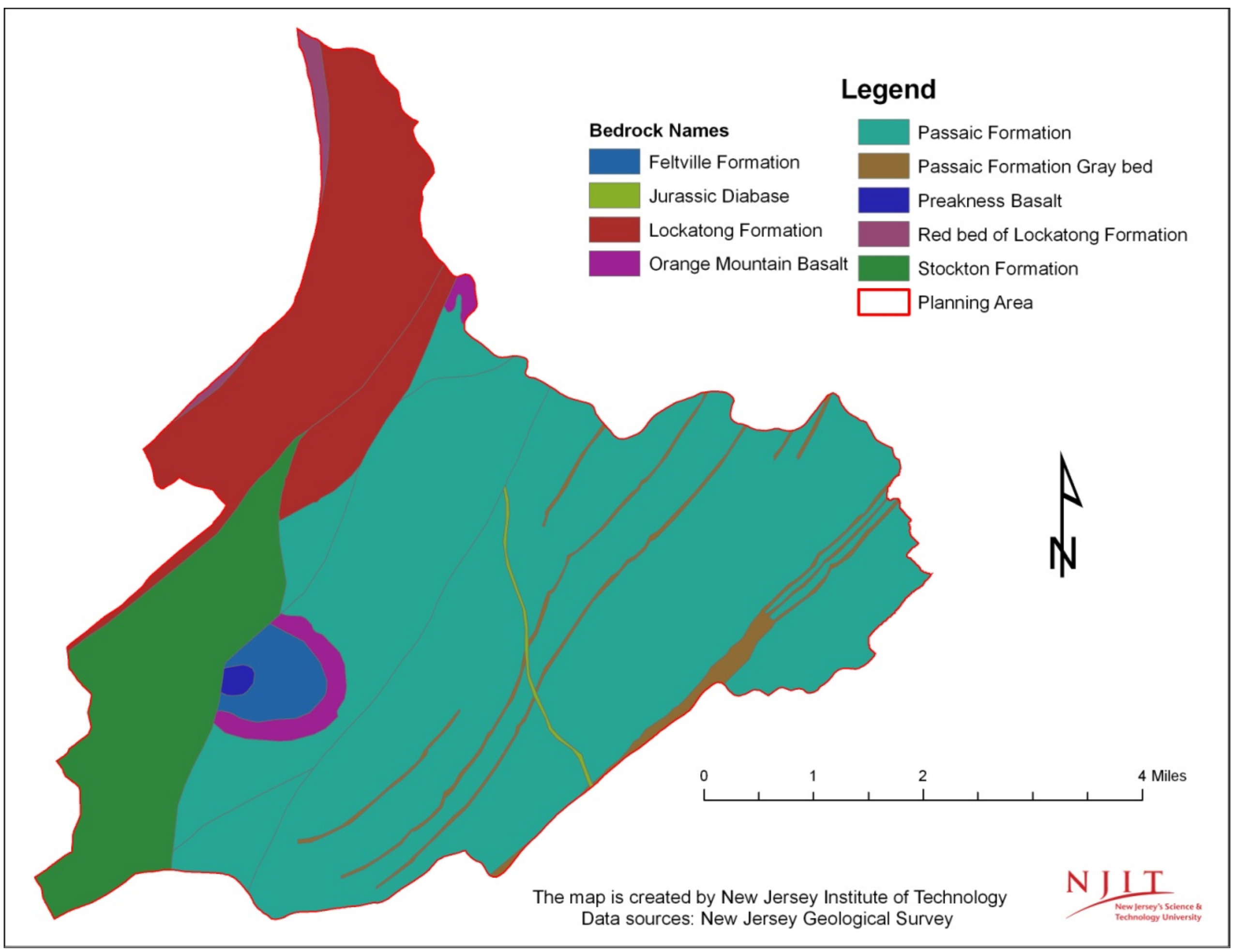


Figure 4.3: Spatial distribution of bedrock in the Neshanic River Watershed

The dominant bedrock in the watershed includes the Stockton Formation (13 percent of the watershed), Lockatong Formation (17 percent of the watershed) and Passaic Formation (63 percent of the watershed), which are the three oldest formations in Newark Rift Basin (Schlische, 1992). The Passaic Formation is located in the lower part of the watershed whereas the Lockatong and Stockton Formations are distributed along the western edge of the watershed. Water movement in these consolidated rocks is primarily through joints, bedding planes and fractures, that were created by the original deposition and weathering of the rock formations. This type of flow allows relatively limited movement of water through aquifers.

4.1.5. Soils

The Neshanic River Watershed has relatively uniform soils of the Brunswick formation developed from Triassic red shale. In non-wetland areas the soils are characteristically shallow, well-drained and loamy. Texturally, all of the watershed soils are silt-loams (USDA, 1974). The soil information for the watershed was derived from the Soil Survey Geographic (SSURGO) Database for Hunterdon County, New Jersey, which was obtained from the NRCS and the U.S. Department of Agriculture. There are 52 different types of soils in the watershed excluding Water and ROPF (rough broken land, shale). Figure 4.4 illustrates the spatial distribution of soil types in the watershed. Each soil type has a distinct map unit symbol (MUSYM) name.

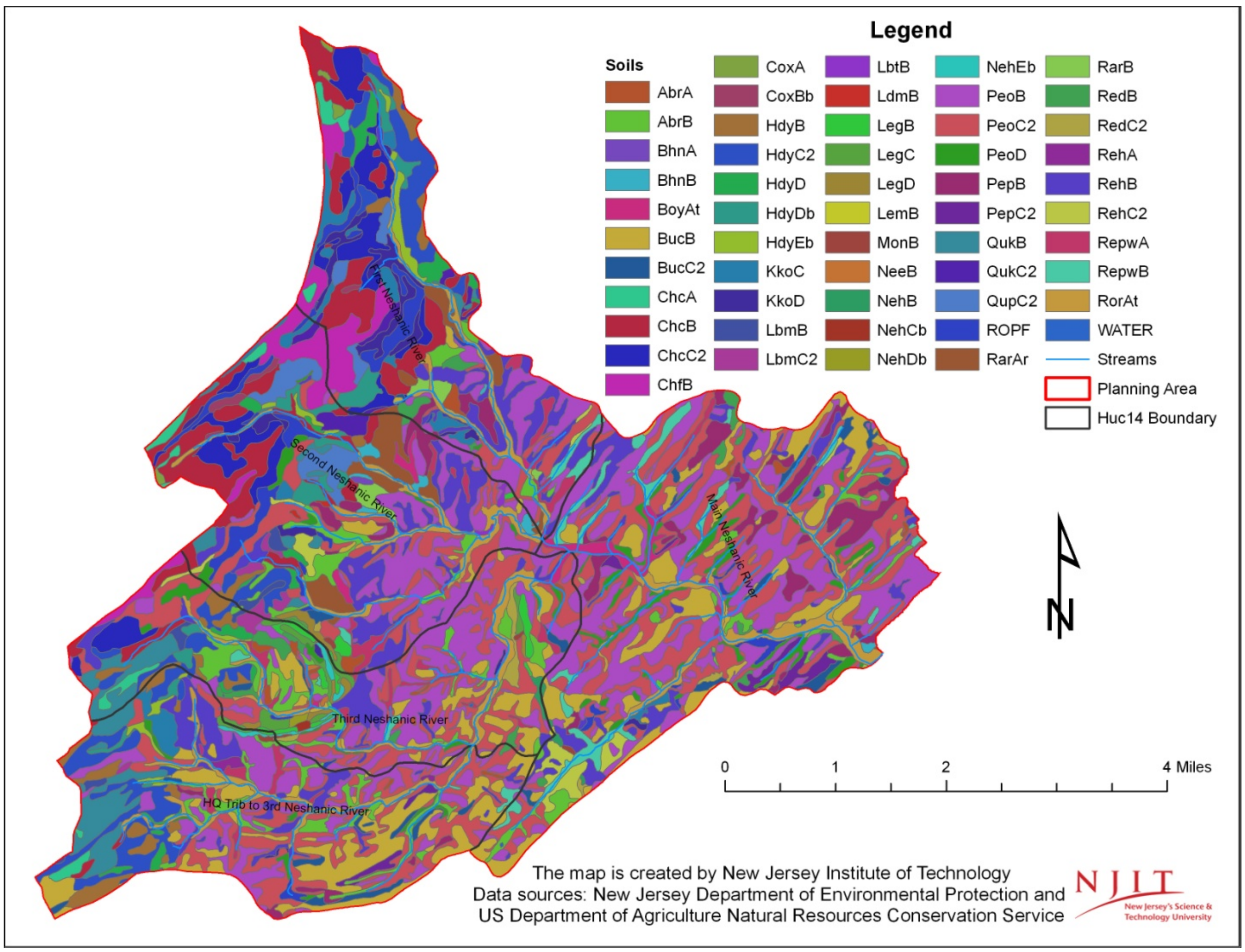


Figure 4.4: Distribution of soil types in the Neshanic River Watershed

Major soils types in the watershed are: Penn channery silt loam with 6 to 12 percent slopes, eroded (PeoC2 with 16.6 percent); Penn channery silt loam with 2 to 6 percent slopes (PeoB with 16.4 percent); Bucks silt loam, 2 to 6 percent slopes (BucB with 8.1 percent); Reaville silt loam, 2 to 6 percent slopes (RehB with 6.8 percent); Chalfont silt loam, 2 to 6 percent slopes (ChcB with 4.7 percent); Rowland silt loam, 0 to 2 percent slopes, frequently flooded (RorAt with 4.5 percent); Hazleton channery loam, 6 to 12 percent slopes, eroded (HdyC2 with 3.8 percent); and Abbottstown silt loam, 2 to 6 percent slopes (AbrB with 3.6 percent). These soil types cover 64.6 percent of the area of the watershed. Table 4.3 presents the acreage and area distribution of each soil type in the watershed by MUSYM. The Neshanic River Watershed has soils that are very suitable for agriculture. According to NRCS, 82.8 percent of the watershed is underlain by soils classified as either Prime Farmland (33.3 percent) or Farmland of Statewide Importance (49.5 percent). Prime Farmland soils are generally soils that are best suited for food, feed, forage, fiber and oilseed crops. Farmlands of statewide importance include soils that do not meet the criteria as Prime Farmland, but are nearly Prime Farmland and economically produce high yields of crops when treated and managed according to acceptable farming methods. Crop yields in Farmland of Statewide Importance soils can be as high as crop yields in Prime Farmland soils if conditions are favorable. The prime farmland designation is also given in Table 4.3. Given such natural resource conditions, it is not surprising that agriculture predominates historical use of the watershed until the last three decades when rapid urbanization occurred.

Table 4.3: Area distribution and farmland designation of soils in the Neshanic River Watershed

MUSYM	Soil Name	Acres	Percent
AbrA[1]	Abbottstown silt loam, 0 to 2 percent slopes	94.20	0.5
AbrB[1]	Abbottstown silt loam, 2 to 6 percent slopes	709.69	3.6
BhnA[2]	Birdsboro silt loam, 0 to 2 percent slopes	7.95	0.0
BhnB[2]	Birdsboro silt loam, 2 to 6 percent slopes	48.16	0.2
BoyAt[1]	Bowmansville silt loam, 0 to 2 percent slopes, frequently flooded	153.06	0.8
BucB[2]	Bucks silt loam, 2 to 6 percent slopes	1601.24	8.1
BucC2[1]	Bucks silt loam, 6 to 12 percent slopes, eroded	200.30	1.0
ChcA[1]	Chalfont silt loam, 0 to 2 percent slopes	143.03	0.7
ChcB[1]	Chalfont silt loam, 2 to 6 percent slopes	932.21	4.7
ChcC2[1]	Chalfont silt loam, 6 to 12 percent slopes, eroded	577.50	2.9
ChfB[1]	Chalfont-Quakertown silt loams, 0 to 6 percent slopes	417.51	2.1
CoxA[1]	Croton silt loam, 0 to 2 percent slopes	24.84	0.1
CoxBb	Croton silt loam, 0 to 6 percent slopes, very stony	35.11	0.2
HdyB[1]	Hazleton channery loam, 2 to 6 percent slopes	308.73	1.6
HdyC2[1]	Hazleton channery loam, 6 to 12 percent slopes, eroded	755.20	3.8
HdyD	Hazleton channery loam, 12 to 18 percent slopes	174.98	0.9
HdyDb	Hazleton channery loam, 6 to 18 percent slopes, very stony	228.71	1.2
HdyEb	Hazleton channery loam, 18 to 40 percent slopes, very stony	113.93	0.6
KkoC	Klinesville channery loam, 6 to 12 percent slopes	264.83	1.3
KkoD	Klinesville channery loam, 12 to 18 percent slopes	214.15	1.1
LbmB[2]	Lansdale loam, 2 to 6 percent slopes	63.37	0.3

LbmC2[1]	Lansdale loam, 6 to 12 percent slopes, eroded	66.12	0.3
LbtB[1]	Lansdowne silt loam, 2 to 6 percent slopes	11.81	0.1
LdmB[2]	Lawrenceville silt loam, 2 to 6 percent slopes	5.71	0.0
LegB[2]	Legore gravelly loam, 2 to 6 percent slopes	92.41	0.5
LegC[1]	Legore gravelly loam, 6 to 12 percent slopes	92.39	0.5
LegD	Legore gravelly loam, 12 to 18 percent slopes	54.17	0.3
LemB[1]	Lehigh silt loam, 2 to 6 percent slopes	1.99	0.0
MonB[2]	Mount Lucas silt loam, 2 to 6 percent slopes	15.48	0.1
NeeB[2]	Neshaminy gravelly loam, 2 to 6 percent slopes	7.89	0.0
NehB[2]	Neshaminy silt loam, 2 to 6 percent slopes	24.74	0.1
NehCb	Neshaminy silt loam, 6 to 12 percent slopes, very stony	6.31	0.0
NehDb	Neshaminy silt loam, 12 to 18 percent slopes, very stony	7.96	0.0
NehEb	Neshaminy silt loam, 18 to 35 percent slopes, very stony	35.39	0.2
PeoB[2]	Penn channery silt loam, 2 to 6 percent slopes	3262.31	16.4
PeoC2[1]	Penn channery silt loam, 6 to 12 percent slopes, eroded	3299.31	16.6
PeoD	Penn channery silt loam, 12 to 18 percent slopes	373.27	1.9
PepB[2]	Penn-Bucks complex, 2 to 6 percent slopes	537.57	2.7
PepC2[1]	Penn-Bucks complex, 6 to 12 percent slopes, eroded	118.70	0.6
QukB[2]	Quakertown silt loam, 2 to 6 percent slopes	442.38	2.2
QukC2[1]	Quakertown silt loam, 6 to 12 percent slopes, eroded	106.70	0.5
QupC2[1]	Quakertown-Chalfont silt loams, 6 to 12 percent slopes, eroded	214.42	1.1
ROPF	Rough broken land, shale	355.24	1.8
RarAr[2]	Raritan silt loam, 0 to 3 percent slopes, rarely flooded	265.12	1.3
RarB[2]	Raritan silt loam, 3 to 8 percent slopes	68.37	0.3
RedB[2]	Readington silt loam, 2 to 6 percent slopes	165.74	0.8
RedC2[1]	Readington silt loam, 6 to 12 percent slopes, eroded	59.90	0.3
RehA[1]	Reaville silt loam, 0 to 2 percent slopes	21.70	0.1
RehB[1]	Reaville silt loam, 2 to 6 percent slopes	1350.82	6.8
RehC2[1]	Reaville silt loam, 6 to 12 percent slopes, eroded	164.68	0.8
RepwA	Reaville wet variant silt loam, 0 to 2 percent slopes	304.02	1.5
RepwB	Reaville wet variant silt loam, 2 to 6 percent slopes	330.66	1.7
RorAt	Rowland silt loam, 0 to 2 percent slopes, frequently flooded	897.05	4.5
Water	Water	12.26	0.1
Total		19841.31	100.0

Note: 1. NRCS designated "Farmland of Statewide Importance"
2. NRCS designated "Prime Farmland"

4.1.6. Vegetation

The watershed contains agricultural lands, forests, wetlands and urban lands that contain vegetation that is typical of the Raritan River Basin and New Jersey Piedmont Plain Region. The agricultural lands are devoted to row crop production, including corn, soybeans, wheat, rye, hay, warm season grass, such as alfalfa and timothy, and pasture with fescue and various cool-season and warm-season grasses. Typical forest species in the New Jersey Piedmont Plain are red oak (*Quercus rubra*), white oak (*Quercus alba*) and black oak (*Quercus velutina*). Other less abundant canopy species include hickory (*Carya* spp.), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), tulip tree (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), black cherry (*Prunus serotina*), black birch (*Betula lenta*), American elm (*Ulmus americana*) and Green Ash (*Fraxinus Americana*). The understory of the forest is dominated by flowering dogwood (*Cornus florida*) and includes saplings of canopy species. Viburnums (*Viburnum acerifolium*, *V.prunifolium, V. dentatum*), spicebush (*Lindera benzoin*), American hornbeam (*Carpinus caroIiniana*) and witch hazel (*Hamamelis virginiana*) are major shrub-layer species while two cherry species (*Prunus serotina*, *P. avium*) are commonly associated with the forest edge (Robichaud and Anderson, 1994). Just outside of the watershed, the Herrontown Woods Preserve in Princeton, N.J. and Rutgers University's Hutcheson Memorial Forest in Franklin Township are well-studied woodlands that are analogous to what mesic Piedmont forests with limited human disturbance resemble. In the Hutcheson Memorial Forest, the average tree age is over 230 years old on ground that reportedly has never been plowed (Forman and Elfstrom, 1975, Robichaud and Anderson, 1994). In contrast, the younger stand at Herrontown was last timber-harvested in 1920. Also, there are larger forested areas close to the watershed on the Sourlands Mountain to the south and on Cushetunk Mountain. Both areas are hilly volcanic uplands that rise above the adjacent piedmont (Cantlon, 1953).

Historically, agriculture and urban development have been the major threats to the diverse vegetation in the forest and wetlands. In recent years, deer and invasive and exotic species have become major threats to the diversity of vegetation. Deer have a significant negative impact on the abundance, growth, regeneration and diversity of 700-800 native plant and animal species in New Jersey. In areas having high deer populations, deer consume ground cover and shrubs, affecting birds and other animals that rely on this vegetation; their populations decrease and may eventually disappear locally due to loss of habitat (New Jersey Audubon Society, 2005). Recent surveys have estimated deer density in Hunterdon County at over 180 per square mile. The Hunterdon County Board of Agriculture concluded that deer have caused severe damage to agricultural crops. Within the county, the reported deer harvest has declined by 27 percent, from a peak of 14,700 in 1999 to 10,700 in 2006.

In the absence of native ground cover, aggressive exotic plants, many introduced from Asia as ornamentals, begin to take over the forest floor, limiting the ability of native plants and dependent birds and animals to recover. 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 in the watershed include:

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

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

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

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

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

Vegetation in the Neshanic River Watershed is visibly stressed by deer browse and by invasive species, such as Multiflora rose (*Rosa multiflore),* Barberry (*Berberis thunbergii)* and Autumn olive (*Elaegnus umbellata*), which are less palatable to deer (C. Testa, personal communication). Non-native invasive species suppress the regeneration of native vegetation because they can grow without regard to competition. Autumn olive and multiflora rose shade the herb layer, limiting the growth of lower level vegetation which holds soil and provides protection from erosion. Notable exposure of soil in forests is common within the watershed.

4.1.7. Wildlife and Wildlife Habitat

The NJDEP Division of Fish and Wildlife classified the watershed into the Southern Highlands Zone when discussing the New Jersey Wildlife Action Plan (NJDEP, 2008b). This region supports two federal endangered and threatened species, six state endangered, 11 state threatened species, and 57 special concern and regional priority wildlife species, in addition to six game species of regional priority and six nongame fish species currently without state or regional status. The Bog turtle is the federally threatened species. The red-shouldered hawk, northern harrier, short-eared owl, upland sandpiper, vesper sparrow, green floater and Appalachian grizzled skipper are state endangered species. State threatened wildlife include the barred owl, Cooper's hawk, long-eared owl, osprey, bobolink, grasshopper sparrow, savannah sparrow, wood turtle, long-tailed salamander, tidewater mucket and yellow lampmussel. Special concern wildlife includes cavity-nesters, colonial waterbirds, forest passerines, freshwater wetland birds, grassland birds, raptors and scrub-shrub birds. Latin names of all species can be found in the New Jersey Wildlife Action Plan (NJDEP, 2008b).

Like the rest of the Southern Highlands Zone, the watershed is dominated by agricultural fields of cropland and pastures, which are generally poor habitats for wildlife. However, if properly managed, pastures can be good habitat for wildlife. The forest in the watershed is highly fragmented and exists primarily as small patches interspersed by development and agriculture. Encroaching development, disturbance, habitat loss, fragmentation and degradation threaten wildlife. Use of pesticides, mowing and other agricultural practices endanger grassland birds and their habitats (NJDEP, 2008b).

4.1.8. Threatened and Endangered Species

The Endangered and Nongame Species Program within the Division of Fish & Wildlife at NJDEP has developed the "Critical Habitats" project (also known as the Landscape Project) that identifies critical habitats for endangered and threatened forested, forested wetland, emergent wetland and grassland species. Table 4.4 lists those species of concern supported by the Neshanic River Watershed and the habitat priority ranks in the NJ Landscape Project.

Table 4.4: List of endangered species and their habitat priority in the Neshanic River Watershed

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

The habitat priority ranking is based on the conservation status of the species and 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 list of endangered and threatened species; 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 that do not intersect with any confirmed occurrences of such species (Niles et al., 2008). Although the Neshanic River Watershed supports many concerned species, it does not provide an ideal habitat for those species since 2 and 3 are the most dominant habitat priority rankings.

4.1.9. Streams

The watershed contains 62.6 miles of streams including Walnut Brook, First, Second and Third Neshanic Rivers and a part of the Neshanic River main branch immediately above the Back Brook confluence with the Neshanic River. The Neshanic River is a tributary to the South Branch of the Raritan River which drains to the Atlantic Ocean. The Neshanic River and its tributaries are classified as FW2-NT, or freshwater (FW) non-trout (NT) in the newly released 2010 New Jersey Surface Water Classification Standards. “FW2” refers to: water bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. “NT” indicates freshwaters that have not been designated as trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical or biological characteristics, but can support other fish species (NJDEP 2010a).

4.1.10. Groundwater Recharge

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 baseflow and wetlands. In 2004, New Jersey Geological Survey (NJGS) estimated the groundwater recharge in New Jersey using the NJGS methodology developed by Charles et al. (1993). NJDEP 1995 land-use/land-cover update, 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 six types of state ranks in the watershed. There are 8,535 acres (43 percent of the watershed) in State Rank C with the groundwater recharge ranging from 8 to 11 inches per year. Thirty-eight percent of the watershed is in State Rank B with the groundwater recharge ranging from 11 to 15 inches per year. Table 4.5 presents the area distribution of all state ranks.

Table 4.5: Area distribution of groundwater recharge in the Neshanic River Watershed

Groundwater Recharge		Area	
State Rank	Description	Acres	Percent
A	16-23 inches per year	321.13	1.6
B	11-15 inches per year	7607.65	38.3
C	8-11 inches per year	8534.67	43.0
D	1-7 inches per year	499.85	2.5
L	Hydric soils	156.92	0.8
W	Wetlands and open water	2721.09	13.7
Total		19841.31	100.0

Figure 4.5 presents the spatial distribution of the groundwater recharge based on the state ranking.

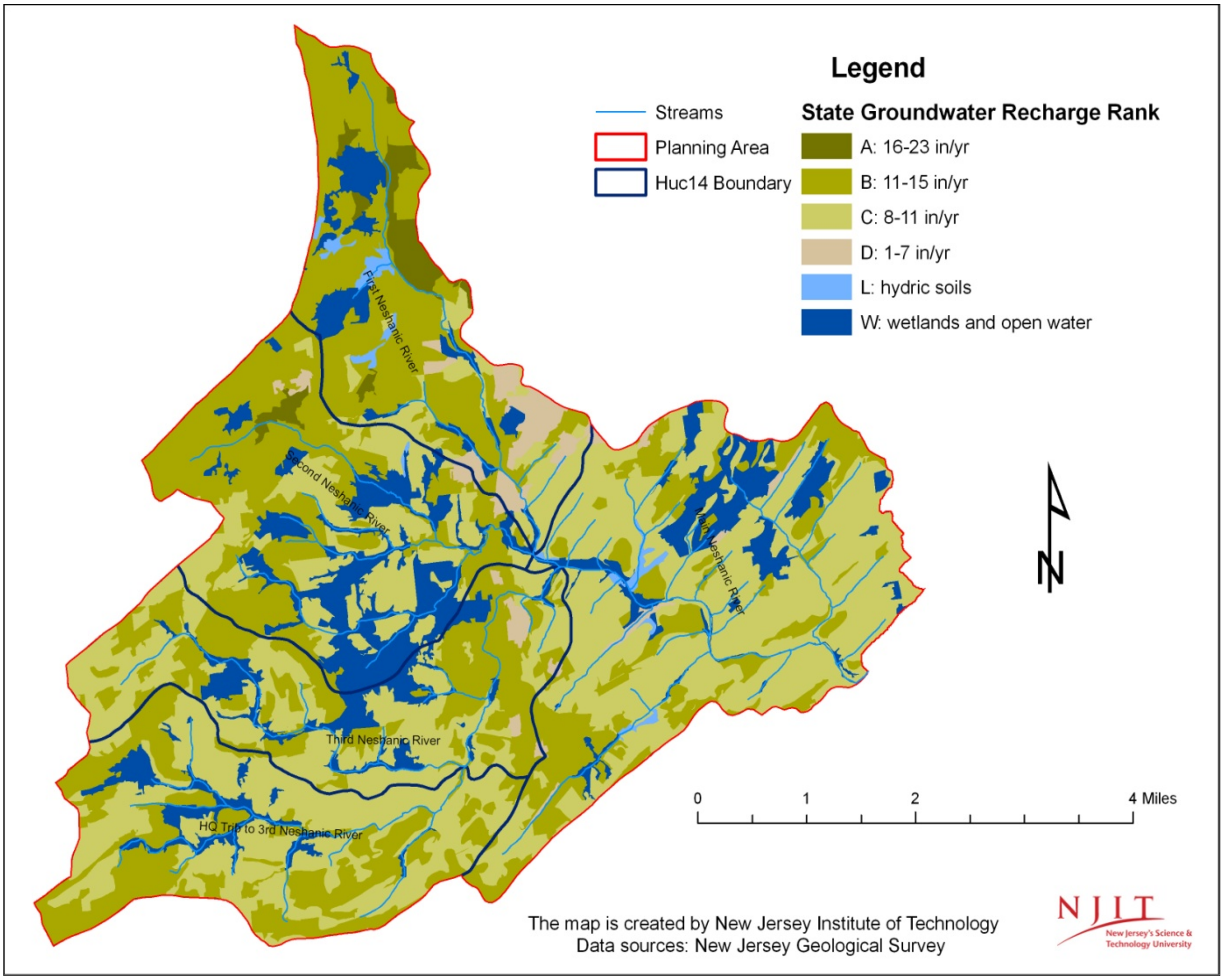


Figure 4.5: Spatial distribution of groundwater recharge in the Neshanic River Watershed

4.1.11. Hydrology and Morphology

Watershed hydrology characterizes water movement in a watershed in response to storm events. The average annual precipitation in the Neshanic River Watershed is about 48 inches. Estimated annual mean evapotranspiration, groundwater recharge, and runoff in the Neshanic River Watershed are 23.96 inches, 5.25 inches and 15.78 inches, respectively. Precipitation data are based on a long-term water budget analysis for the Raritan River Basin that assumes long-term stream baseflow equals long-term groundwater recharge (below the plant root zone) except for the impacts of depletive and consumptive uses within the watershed (NJWSA, 2000).

In this project, the watershed hydrological model SWAT was used to better understand the watershed hydrology. The model was carefully calibrated to evaluate the watershed hydrology during 1997 and 2008 based on the best available data. The SWAT assessment shows the streamflow is 21.32 inches, which is slightly higher than 21.03 inches (i.e., 5.25 + 15.78 inches) in the earlier study by NJWSA (2000); the difference is insignificant. More than 50 percent of the annual precipitation is lost by evapotranspiration during dry years and less than 50 percent during wet years in the watershed. Lateral flow contributions to streamflow and tributary loss in the watershed are not significant. Streamflow mainly comes from surface runoff and groundwater discharge. According to the annual precipitation, 1997 and 1998 were two dry years, and 2003 and 2006 were two wet years during the assessment period. In the wet years, the annual surface runoff contributions to streamflow are 66.3 percent and 65.1 percent and groundwater contributions are 33.0 percent and 34.2 percent in 2003 and 2006, respectively. During dry years, the annual surface runoff contributions are 70.4 percent and 62.6 percent and groundwater contributions are 28.9 percent and 37.4 percent in 1997 and 1998, respectively. Therefore, surface runoff dominates water yield in both wet and dry years. Compared to wet years, the annual groundwater (base flow) contribution to streamflow during a dry year may be increased or reduced depending on the initial soil water content and temporal distribution of precipitation over the year.

Geomorphological conditions in the watershed are deteriorating. Downcutting and widening of stream channels occur extensively in the watershed. Stream bank erosion results in substantial water quality degradation in some parts of the watershed. There are accumulated sediments in the bottom of the streams especially in the main branch of the Neshanic River, which is a significant water pollution source, especially during high flow events. Although there is no comprehensive morphological assessment for the watershed, the general morphological conditions were assessed using the Rosgen stream classification system, Schumm's Channel Evolution Model (CEM) and the USDA Stream Visual Assessment Protocol (SVAP), which are summarized in next chapter and can also be found in separate project task reports.

4.1.12. Sewer Service Area (SSA) and Onsite Disposal Systems (OSDSs)

The NJDEP maintains a statewide SSA map that shows the planned method of wastewater disposal for specific areas (i.e., whether the wastewater will be collected at a regional treatment facility or treated onsite and disposed of through a surface water discharge or a groundwater discharge). However, SSA maps do not indicate where actual infrastructure is present. The areas that are not specifically mapped represent either water features where no construction can occur or land areas that default to individual subsurface disposal systems discharging less than 2,000 gallons per day where site conditions and existing regulations allow. Based on the 2010 updated SSA map maintained by NJDEP, 7,026 acres of the watershed are in SSAs. There are three types of SSAs in the watershed: GW < 20,000; SW; and GWIND. In terms of the size of the SSAs: 4,073 acres of SSAs are in GW < 20,000, which indicates a groundwater discharge less than 20,000 gallons per day; and 2,699 acres of SSA are in SW, which implies that the discharge goes to surface water. The most developed areas in the watershed are in SSAs with surface water discharge. The remaining 254 acres of SSAs are in GWIND, which indicates that the discharge goes to groundwater through an individual New Jersey Pollution Discharge Elimination System (NJPDES) permitted facility. The GWIND SSAs include Cooper Hill County Club, Copper Hill School and Verduccis Specialty Market. Figure 4.6 illustrates the spatial distribution of SSAs in the Neshanic River Watershed. All SSAs are within Raritan Township.

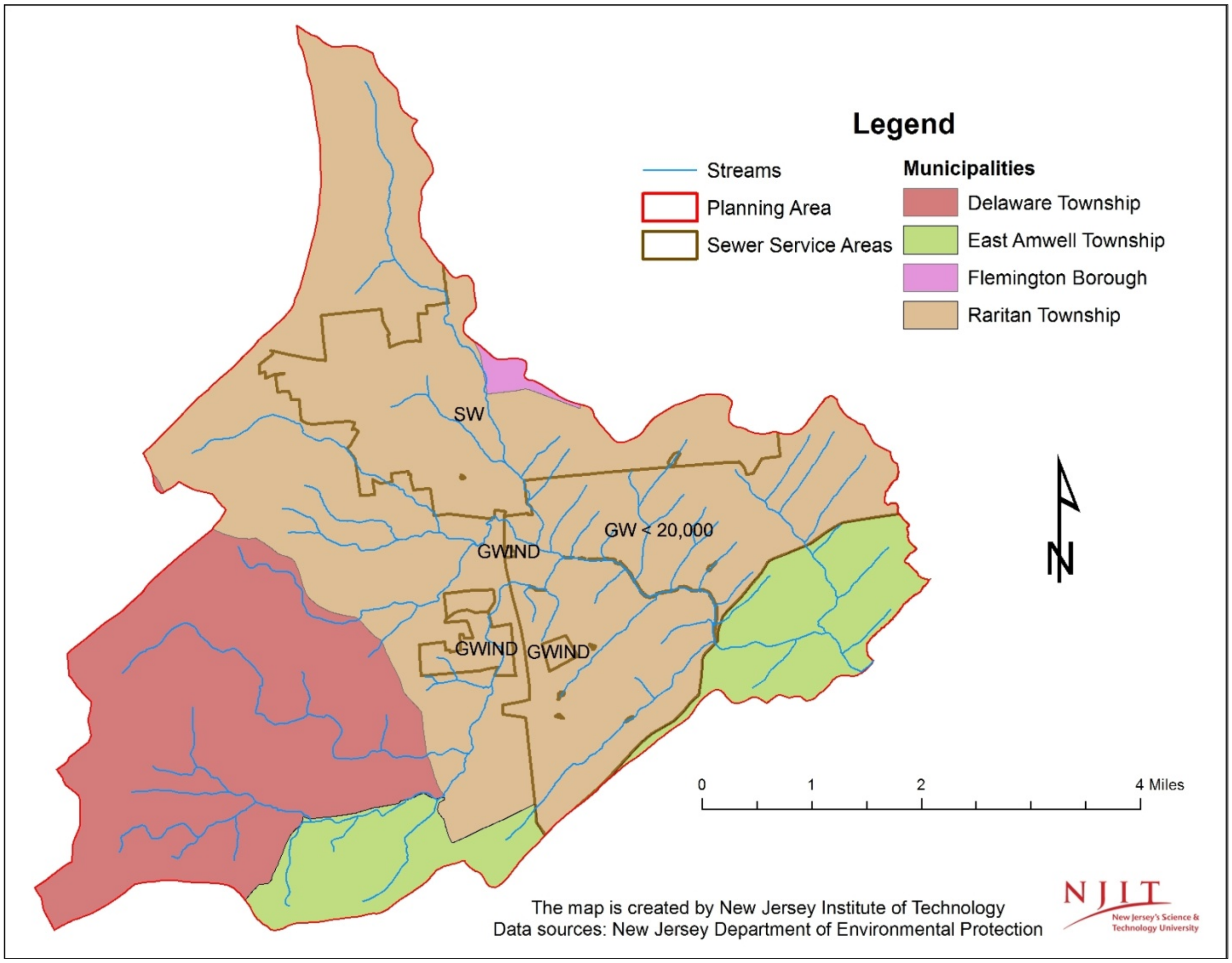


Figure 4.6: Spatial distribution of SSAs in the Neshanic River Watershed

The Raritan Township Municipal Utilities Authority (RTMUA) operates and maintains a 3.8 MGD conventional activated sludge wastewater treatment plant located at 365 Old York Road in Raritan Township which discharges treated effluent into the South Branch of the Raritan River at Three Bridges (RTMUA Main Treatment Plant). The portion of the RTMUA SSA that falls within the Neshanic River Watershed comprises the sewered areas south of Reaville Avenue/Road in Raritan Township and sewered areas south of Route 12 and the Hunterdon County Complex. These areas are tributary to the RTMUA Main Treatment Plant via sewers that lead to the RTMUA Pump Station No. 1, which was rehabilitated in 1999 and 2000. Sewered areas may improve water quality within the watershed because the sewage is conveyed to a central treatment facility that is regulated under the Clean Water Act and NJPDES. This arrangement may eliminate the alternative of sewage discharge to septic systems, which can malfunction.

Some homes in the SSAs and almost all homes outside the SSAs rely on OSDS to treat sewage and other waste water. There is no inventory on OSDSs in the watershed and municipalities. For planning purposes, the number of OSDSs is estimated based on the distribution of SSAs and parcel and land use maps. There are 2,696 homes in the low density and rural residential areas of the watershed according to the 2007 NJDEP land use data. Among those homes, 1,508 are in SSAs delineated by NJDEP and 1,188 are in the non-SSA. Assuming one fifth of these households are in SSAs and all households in the non-SSA rely on OSDSs, about 1,490 households are likely to rely on septic systems.

4.1.13. Water Supply and Availability

Neshanic streams drain to the South Branch of the Raritan River, which is a source of drinking water supply for 1.75 million people in Central New Jersey. Water availability in the Neshanic River Watershed can be measured by the streamflow at the watershed outlet. The streamflow includes surface runoff plus lateral flow plus groundwater recharge (i.e., water from the shallow aquifer that returns to the reach) minus transmission losses ((i.e., water lost from tributary channels via transmission through the bed that becomes recharge for the shallow aquifer). Since there is no streamflow monitoring station at the watershed outlet, water availability was estimated using the SWAT watershed hydrological model.

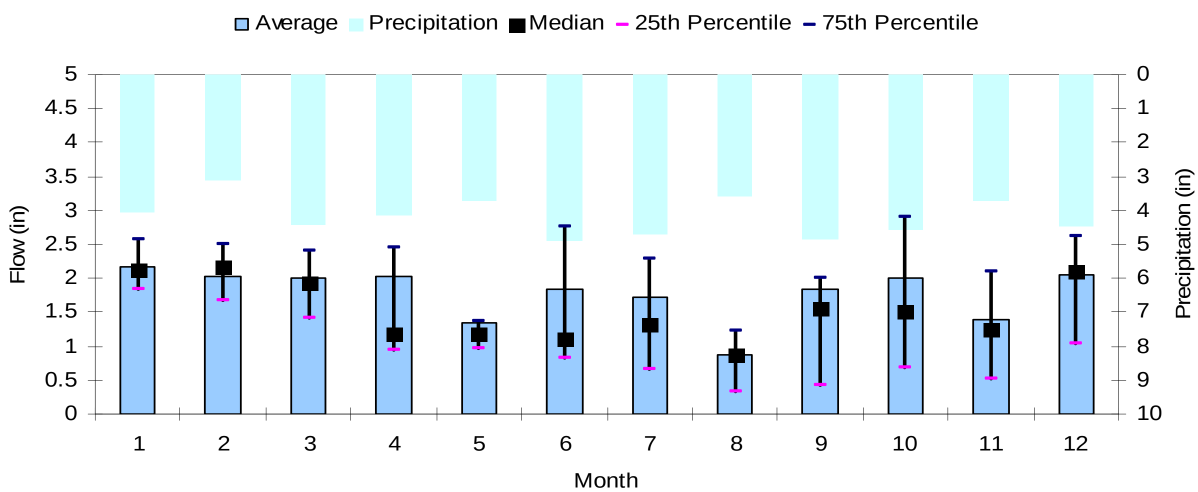


Figure 4.7: Average monthly precipitation in watershed and streamflow at watershed outlet, 1997-2008

The SWAT simulation results indicate that the average annual water yield at the outlet of the Neshanic River Watershed is 1.51E+09 cubic feet per year, or equivalently 21.32 inches of precipitation. Figure 4.7 illustrates average monthly precipitation in the watershed and median, 25^{th} percentile and 75^{th} percentile monthly streamflow at the outlet of the watershed. The average monthly precipitation varies from 3.11 to 4.88 inches with the highest precipitation in June and the lowest in February. The average monthly streamflows vary from 0.88 inches in August to 2.17 inches in January, which are equivalent to 24 to 66 percent of the monthly precipitation, respectively. The seasonal variations in average monthly precipitation and average monthly streamflows are similar. Average monthly streamflows are greater than two inches in January to April and October to December, two inches in May to July and September to November, and less than one inch in August. There are annual variations in the monthly streamflow due to changes in weather and climate patterns. Annual variations in the monthly streamflows are measured by the spans between the 25^{th} and 75^{th} percentiles. This variation is the largest in October and smallest in May. Variations in April, June, July, September, November and December are generally larger than in other months. The SWAT results also reflect the impacts of annual variation in land cover on the streamflow. Higher vegetative cover generally results in greater interception of water and therefore, lower streamflow. For example, even though the highest precipitation occurs in June, streamflow in June is lower than some months in fall, winter and spring because of the impacts of vegetation.

4.2. **Critical Environmental Areas**

4.2.1. Hydric Soils

The NRCS defines a hydric soil as a soil that 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 the same thing. An area must have hydric soils, wetland-adapted plants, and the presence of water for some time during the year to be considered a wetland. There are five different hydric soil types in the watershed with a total area of 847.69 acres as listed in Table 4.6. The Reaville wet variant silt loam is the predominant hydric soil in the watershed. The spatial distribution of the hydric soils in the watershed is also presented in Figure 4.8. Like the linear wetlands, most of the hydric soils are also found along the streams the streams.

Table 4.6: Hydric soil type and their acreages in the Neshanic River Watershed

Hydric Soil Name	MUSYM	Acres
Bowmansville silt loam, 0 to 2 percent slopes, frequently flooded	BoyAt	153.06
Croton silt loam, 0 to 2 percent slopes	CoxA	24.84
Croton silt loam, 0 to 6 percent slopes, very stony	CoxBb	35.11
Reaville wet variant silt loam, 0 to 2 percent slopes	RepwA	304.02
Reaville wet variant silt loam, 2 to 6 percent slopes	RepwB	330.66
Total		847.69

4.2.2. Wetlands

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, 1979). For regulatory purposes under the Clean Water Act, the term wetlands 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 soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas (the EPA Regulations listed at 40 CFR 230.3(t))." Wetlands provide important functions such as filtering pollutants from stormwater runoff, acting as storage areas for flood waters, protecting streambanks from erosion, providing wildlife habitat, and providing recreational opportunities for communities. The major concern related to wetlands in the watershed is losses due to agriculture and urban development. The loss of wetlands significantly alters the watershed hydrology and contributes to many of the water quality and quantity problems observed today.

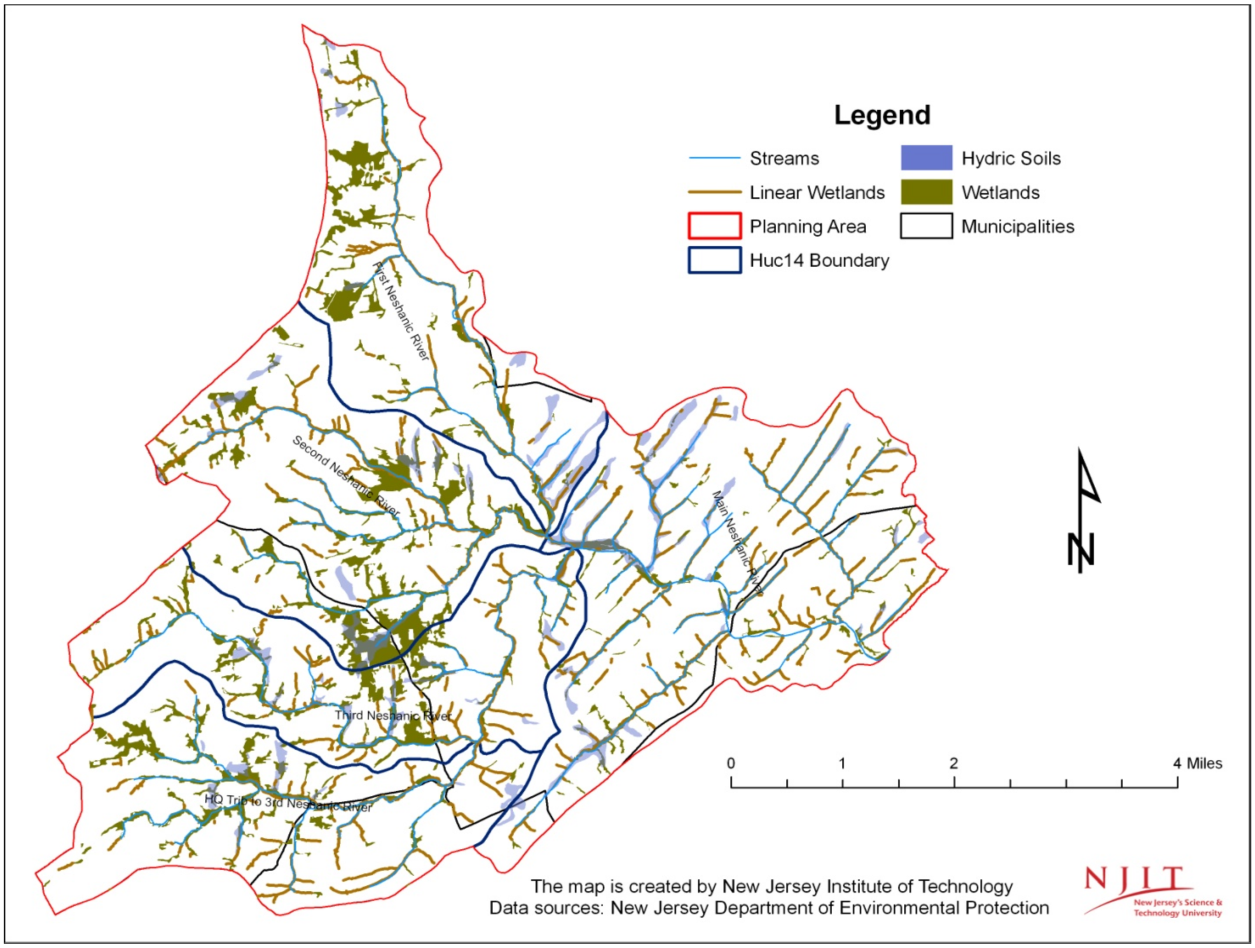


Figure 4.8: Spatial distribution of hydric soils, linear wetlands and wetlands in the Neshanic River Watershed

The NJDEP developed and maintains two types of wetlands information for general planning and regulatory purposes. The first type is delineated wetlands listed in the NJDEP land use/cover change database. These wetlands are primarily located along interior stream systems as well as wetlands that have been modified for recreational, agricultural or industrial uses. There are a total of 1,877 acres of delineated wetlands based on the NJDEP 2007 land use/cover database. Table 4.7 lists the types of wetlands and their NJDEP class codes and acreages. The dominant types of wetlands in the watershed are deciduous wooded wetlands (class code 6210) and modified agricultural wetlands (2140), which comprise 53 and 30 percent of the total wetlands in the watershed, respectively.

The second type of wetlands is the linear wetlands derived from the freshwater wetlands data developed by the New Jersey Freshwater Wetlands Mapping Program of NJDEP, which fulfills a requirement of the 1987 Freshwater Wetlands Act. This program mapped all freshwater wetland polygons greater than one acre in area and all linear freshwater wetland features greater than 10 feet in width. There are about 70.68 miles of linear wetlands in the watersheds.

Figure 4.8 shows the spatial distribution of both delineated wetlands and linear wetlands in the watershed. Delineated wetlands are primarily located in the upper part of the watershed (i.e., the First, Second, and Third Neshanic Rivers, and HQ tributary to the Third Neshanic River

HUC14s (02030105030010, 02030105030020, 02030105030030, and 02030105030040)). There are very few wetlands in the lower main Neshanic River HUC14 (02030105030060). Linear wetlands are generally located along streams.

Table 4.7: The types and areas of wetlands in the Neshanic River Watershed, 2007

Types of Wetlands	NJDEP Land Use Class Code	Acres	Percent
Agricultural wetlands (modified)	2140	558.68	29.77
Cemetery on wetland	1711	0.30	0.02
Coniferous scrub/shrub wetlands	6232	4.82	0.26
Deciduous scrub/shrub wetlands	6231	44.33	2.36
Deciduous wooded wetlands	6210	1,001.23	53.35
Disturbed wetlands (modified)	7430	10.28	0.55
Former agricultural wetland (becoming shrubby, not built-up)	2150	23.08	1.23
Herbaceous wetlands	6240	104.11	5.55
Managed wetland in built-up maintained recreational area	1850	18.24	0.97
Managed wetland in maintained lawn green space	1750	26.72	1.42
Mixed scrub/shrub wetlands (coniferous dom.)	6234	20.88	1.11
Mixed scrub/shrub wetlands (deciduous dom.)	6233	56.28	3.00
Mixed wooded wetlands (deciduous dom.)	6251	0.67	0.04
Wetland rights-of-way	1461	7.17	0.38
Total		1,876.79	100.00

Sources: NJDEP 2007 land use/cove database

4.2.3. Hydrologically Sensitive Areas

Hydrologically sensitive areas (HSAs) refer to watershed areas that are especially prone to generating runoff and, as such, are potentially susceptible to transporting contaminants to perennial surface water bodies (Walter et al., 2000). If HSAs are disturbed, significant changes in the movement of water, nutrients and biota within landscapes may occur (Clark et al., 2009).

Figure 4.9 shows the spatial distribution of HSAs in the watershed. The pattern of HSAs can be explained by the concept of variable source area (VSA) hydrology developed in the 1960s and has modified over the last forty years (Walter et al., 2002; Qiu et al., 2007). The detailed procedure for identifying the pattern of HSAs in the Neshanic River Watershed can be found in Qiu (2009). Specifically, HSAs are derived using a modified topographic index approach based on VSA hydrology that involves two steps. First, a digital elevation model (DEM) and the NRCS SSURGO soil database are used to generate the topographic index for each grid of the watershed; grid size is determined by the DEM resolution. The measured values of the topographic index in the Neshanic River Watershed range from 1 to 28. A higher topographic index value indicates a greater likelihood of saturation and runoff during a storm event. Second, HSAs can be defined as areas where the topographic index exceeds a specific threshold level. In this project, a threshold value of 11 was arbitrarily selected. Areas with a topographic index of 11 or higher were considered to be HSAs. Such areas cover about 2,642 acres (i.e., 13.7 percent of the watershed). A value of 13.7 percent is considered more practical than the 20 percent value suggested by Herron and Hairsine (1998). HSAs are mostly distributed in the upper part of the watershed. HUC14 02030105030010 (the First Neshanic River) has the most HSAs as shown in Figure 4.9. Although there are some HSAs distributed along the streams, most HSAs are located in the upland areas outside the immediate riparian areas of the streams.

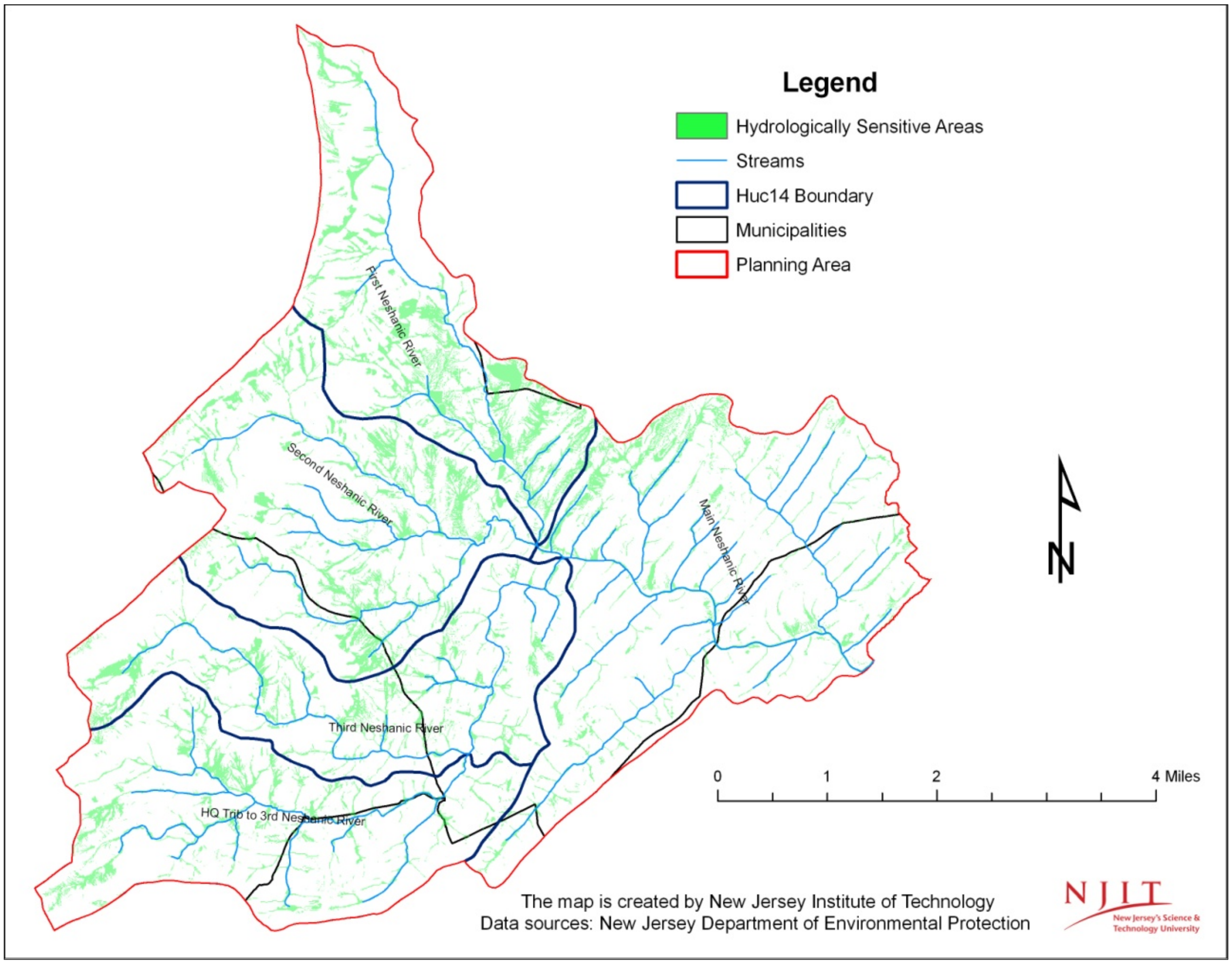
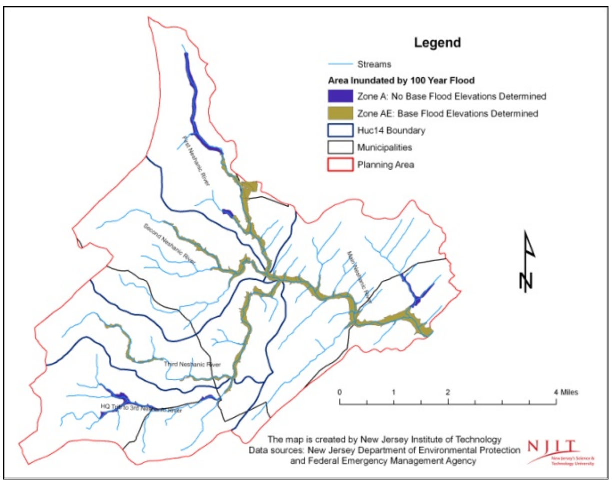


Figure 4.9: Spatial distribution of HSAs in the Neshanic River Watershed

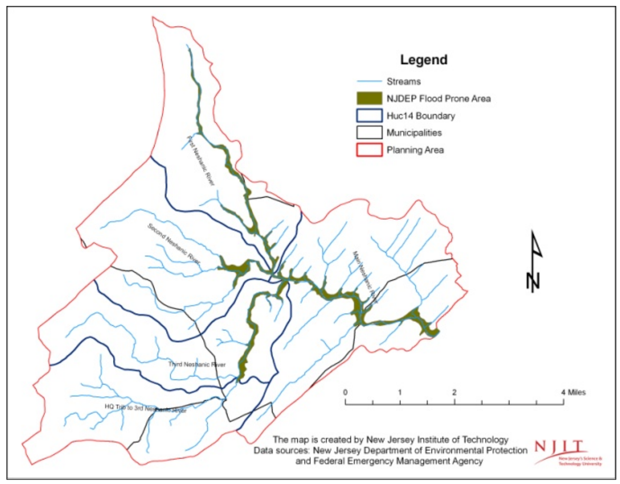
Information on the HSAs is valuable for water resource management. Qiu (2003, 2009) demonstrated how such information can be used to prioritize conservation buffer placement in watersheds. Because of the profound impacts of runoff on environmental quality, the spatial pattern of HSAs can be used as a basis for prioritizing other conservation efforts in a watershed, such as conservation easements, open space and farmland preservation that target HSAs for achieving higher environmental benefits. Various land use planning tools and ordinances can be used to protect and preserve HSAs from urban development. Since the HSAs can be spatially displayed at high resolution, they can be valuable for designing onsite BMPs that mitigate the negative environmental impacts of runoff.

4.2.4. Floodplains

A floodplain is flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding. The extent of floodplain inundation depends in part on the flood magnitude, defined by the return period. For example, the commonly used flood insurance rate maps typically depict both the 100-year and the 500-year floodplains. In addition to the flood magnitude, the extent of the floodplain is influenced primarily by topography as well as land use conditions in upland areas of the watershed. For example, increases in urban lands and roads have dramatic impacts on where the floods are likely to occur during a storm. Two sets of floodplain related spatial data are available for the Neshanic River Watershed: the flood hazard zones from the Federal Emergency Management Agency (FEMA) based on flood model projections; and the flood prone areas from NJDEP based on historical flooding. Figure 4.10 compares the FEMA's flood hazard map and NJDEP's flood prone area map.



(a) FEMA flood hazard map



(b) NJDEP flood prone area

Figure 4.10: Comparison between (a) FEMA flood hazard map and (b) NJDEP flood prone area map in the Neshanic River Watershed

FEMA identifies five flood hazard zones two of which are relevant to the watershed as described below:

- Zone A – an area inundated by 1 percent annual chance of flooding for which no Base Flood Elevations (BFEs) have been determined.
- Zone AE – an area inundated by 1 percent annual chance of flooding for which BFEs have been determined.

BFE is defined as the elevation associated with the flood that has a 1 percent annual chance of being equal to or exceeded in any given year. FEMA identified 989 acres of flood hazard area of which 218 acres are in Zone A and 771 acres are in Zone AE. NJDEP identified 695 acres of flood prone areas in the watershed.

4.2.5. Riparian Areas

Riparian areas are the land areas adjacent to the stream bank. Riparian areas connect the terrestrial landscape with the aquatic environment and play a critical role in mediating the effects of landscape disturbance on streams; therefore, human disturbances in the riparian areas tend to exert a stronger influence on stream condition than areas further away from the streams (Gregory et al., 1991; NRC, 2002). They are CSAs like the floodplain, but are generally more extensive. Protection of riparian areas has become an important water resource management goal in many watersheds. The Raritan Basin Watershed Management Plan (NJWSA, 2002a) identified the damage to streams and their riparian areas as one of six critical issues in the basin. The restoration, protection and preservation of riparian areas of the Raritan Basin are among the key strategies for improving water quality and enhance aquatic and wildlife habitats. NJWSA (2002a) defined riparian areas as areas adjacent to streams that are either within the 100-year floodplain, contain hydric soils, contain streamside wetlands and associated transition areas or are within a 150-foot or 300-foot wildlife corridor on both sides of a stream.

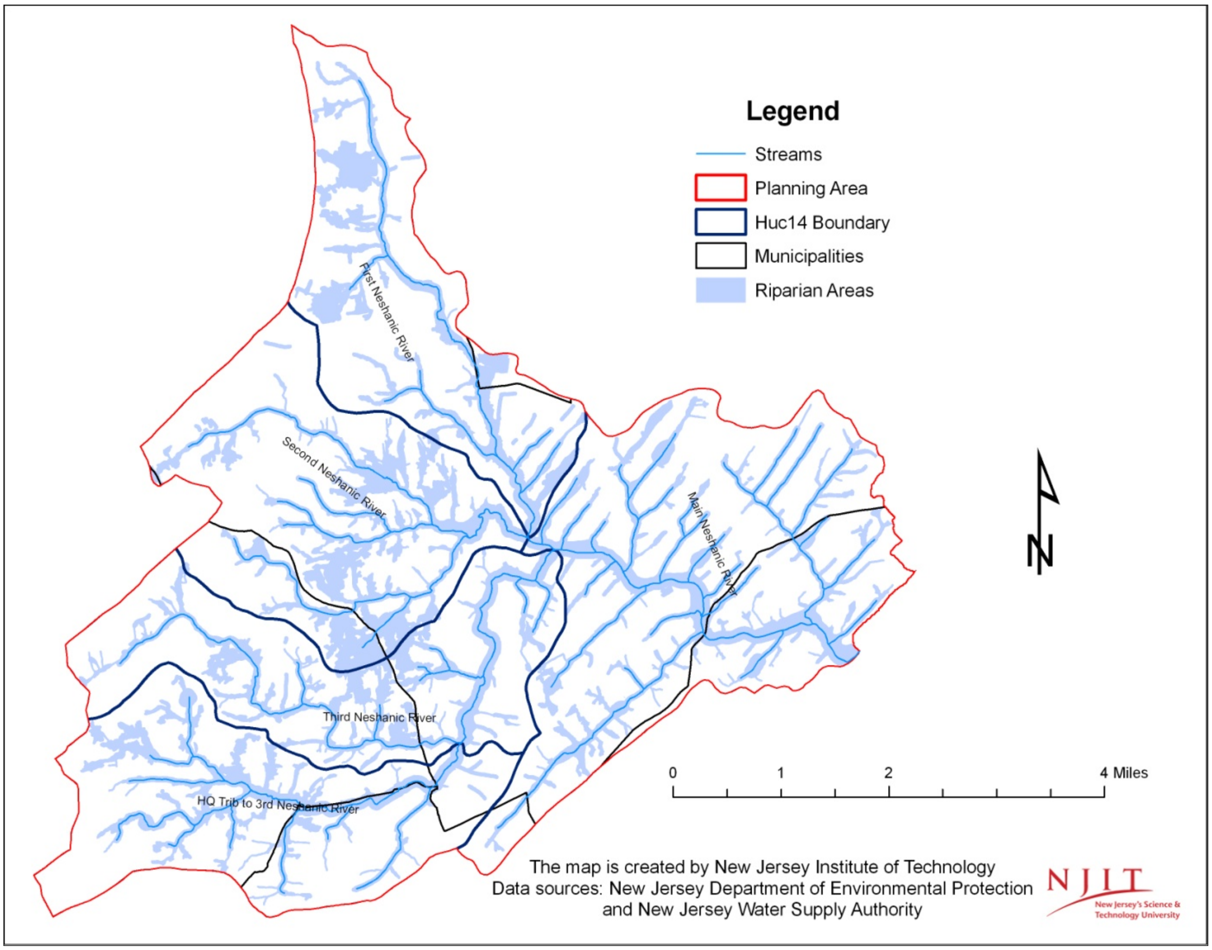


Figure 4.11: Spatial distribution of the riparian areas in the Neshanic River Watershed

The width of the riparian areas varies along the stream corridors depending on site-specific conditions. The NJWSA derived the riparian areas using the 1995 NJDEP stream network data for the Raritan Basin. Since then, updated 2002 stream network data has been released by NJDEP. Compared to the 1995 stream network data, the 2002 stream network data contain more stream miles, especially the headwater streams in Raritan Basin. In this project, riparian areas are redefined to include the NJWSA's original riparian areas plus the 100-foot buffer areas of the additional streams in the 2002 stream network data. The total area of the delineated riparian areas in the watershed is 5,714 acres. Figure 4.11 shows the spatial distribution of the riparian areas in the Neshanic River Watershed.

4.3. **Land Use**

4.3.1. Settlement and Historical Changes

The land in the watershed was originally the territory of the Lenni Lenape Native Americans, as was all of Hunterdon County. The area was first settled in the early 18th century by Colonel John Reading (1657-1717), who was instrumental in the creation of Amwell Township in 1708 and also worked for the creation of Hunterdon County in 1714. Amwell Township was established by a royal patent from Queen Anne in 1708. The territory of the original Amwell Township comprised 200 mi^2 and included present day Delaware Township, Raritan Township, Readington Township, East and West Amwell Townships and portions of Clinton, Lebanon and Tewksbury Townships. Raritan, East Amwell and Delaware Townships were incorporated as independent townships by an Act of the New Jersey Legislature on April 2, 1838, from portions of the now-defunct Amwell Township. Flemington town was formed within Raritan Township on March 14, 1870, and became an independent borough on April 7, 1910 following an Act of the New Jersey Legislature (Snyder, 1969).

Row crop agriculture was essentially the primary land use in the watershed because of its fertile farmland during the early settlement. However, as early German and English settlers engaged in industries in the surrounding urban centers, their dependence and demand for farm products increased. Poultry and dairy farms gradually superseded crops and became an important part of agriculture. The watershed and surrounding communities remained agricultural until the 1970s when urbanization and suburbanization started to significantly affect land uses. Like the rest of Hunterdon County, land use patterns were first driven by the high-density residential development around the existing urban centers in the 1970s to accommodate low-income housing needs, followed by corporate and industrial expansion into rural communities in the 1980s. The presence and employment of the corporations and industries spurred a new round of urban development starting in the 1990s, characterized by the medium and low density residential development. In the 2000s, residents from the city and/or suburbs moved into exurban areas that have very low density residential development. Suburbanization and exurbanization in the last two decades blurs the traditional rural and urban interfaces and creates the communities that exist today.

4.3.2. Historical Land Use Change

The NJDEP maintains a detailed land use/cover change database. The land uses in this watershed are classified into six broad land use categories, including agriculture, barren, forest, urban, water and wetlands, and around 50 subcategories following a 4-digital land use classification code based on a modified Anderson Land Classification system (NJDEP, 2010). Figure 4.12 depicts the spatial distribution of land uses in the Neshanic River Watershed in 1986, 1995, 2002 and 2007. Figure 4.12 shows the expansion of urban lands and the loss of agricultural lands through the watershed over the past two decades.

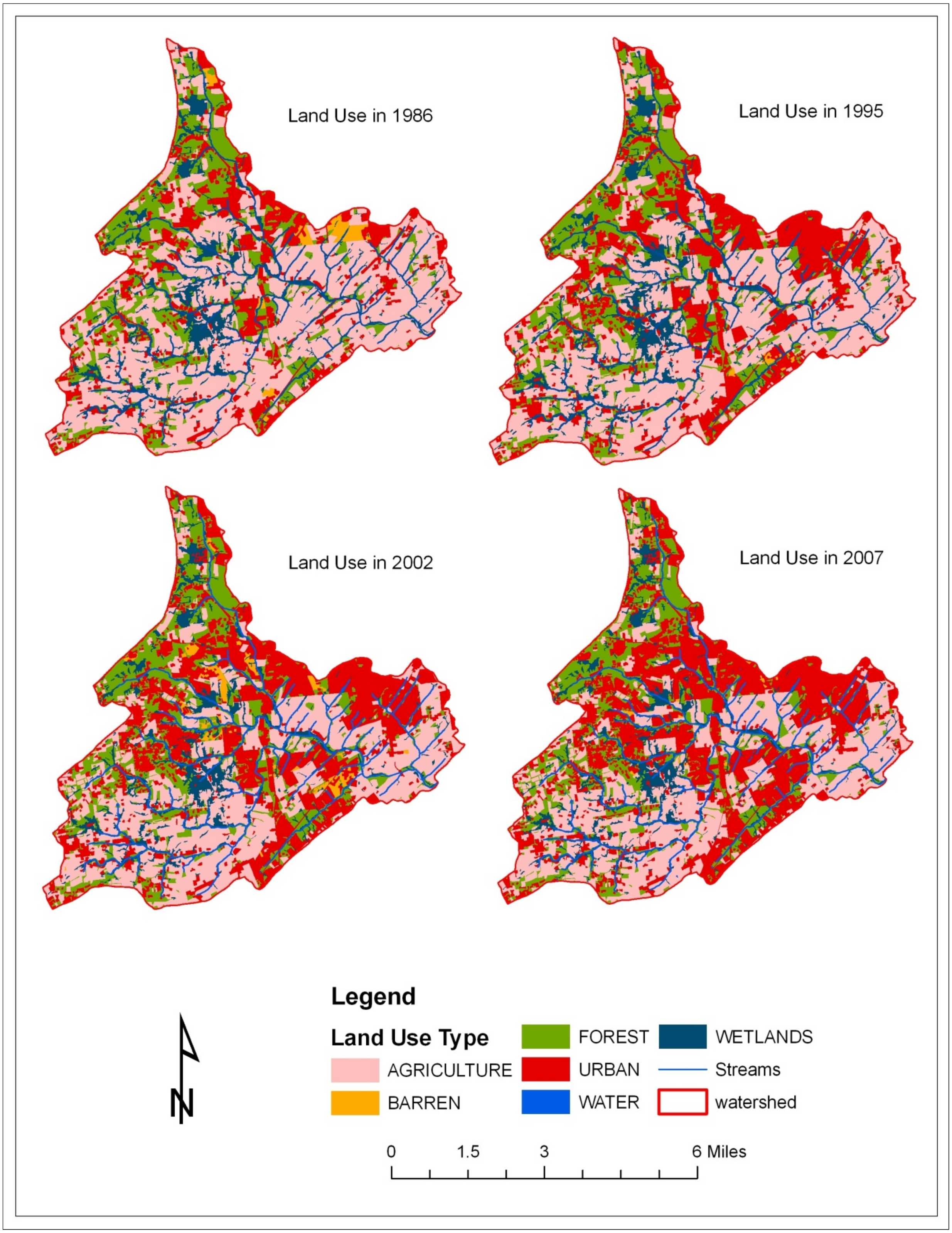


Figure 4.12: Spatial distribution of land uses in the Neshanic River Watershed, 1986, 1995, 2002 and 2007

Table 4.8 gives the area distribution in various land uses in 1986, 1995, 2002 and 2007. The percentage of urban land in the watershed increased from 17 percent in 1986 to 25 percent in 1995, 31 percent in 2002 and 35 percent in 2007. The increases in urban land are accompanied by notable decreases in agricultural land in the watershed. Agricultural lands in the watershed decreased from 51 percent in 1986 to 43 percent in 1995, 36 percent in 2002 and 35 percent in 2007. Forest area increased from 1986 to 1995, but decreased from 1995 to 2007. Wetland areas declined continuously during the past two decades.

Table 4.8: Land uses in the Neshanic River Watershed, 1986, 1995, 2002 and 2007

Land Use Type	1986		1995		2002		2007	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Agriculture	10189.2	51.4	8531.5	43.0	7220.9	36.4	6937.3	35.0
Barren	287.7	1.5	63.8	0.3	333.9	1.7	53.1	0.3
Forest	3897.5	19.6	4138.5	20.9	4069.7	20.5	3905.7	19.7
Urban	3284.2	16.6	4970.1	25.0	6199.7	31.2	6972.5	35.1
Water	40.8	0.2	52.7	0.3	93.6	0.5	95.9	0.5
Wetlands	2141.9	10.8	2084.7	10.5	1923.5	9.7	1876.8	9.5
Total	19841.3	100.0	19841.3	100.0	19841.3	100.0	19841.3	100.0

4.3.3. Preserved Farmlands

There are 2,975 acres of preserved farmland in the watershed. Figure 4.13 shows the spatial distribution of these preserved farmlands. Farmland is primarily located in HUC14s 02030105030 (the HQ tributary to the Third Neshanic River), 02030105040 (the Third Neshanic River) and 02030105060 (the Main Neshanic River). In addition to being essential for agricultural production, farmland provides scenic benefits to residents. Rapid development in New Jersey has stimulated the rise of farmland preservation as an important policy tool to combat urban sprawl and enhance the quality of life in local communities. In New Jersey, the Farmland Preservation Program is administered by the State Agriculture Development Committee (SADC). Farmland preservation was traditionally achieved by purchasing farmland. Recently, the purchase of the development rights or easements has become a popular tool to preserve farmlands. An example of the latter is the Municipal Planning Incentive Grant (PIG) Program that enables SADC to provide grants to eligible counties and municipalities to purchase development easements for permanent preservation of farmland in designated areas. Forty-three 43 percent of all agricultural lands in the watershed are preserved through various programs. Of the preserved farmlands, 1,765 acres are preserved through the traditional farmland preservation programs and the remaining 1,210 acres through the PIG program.

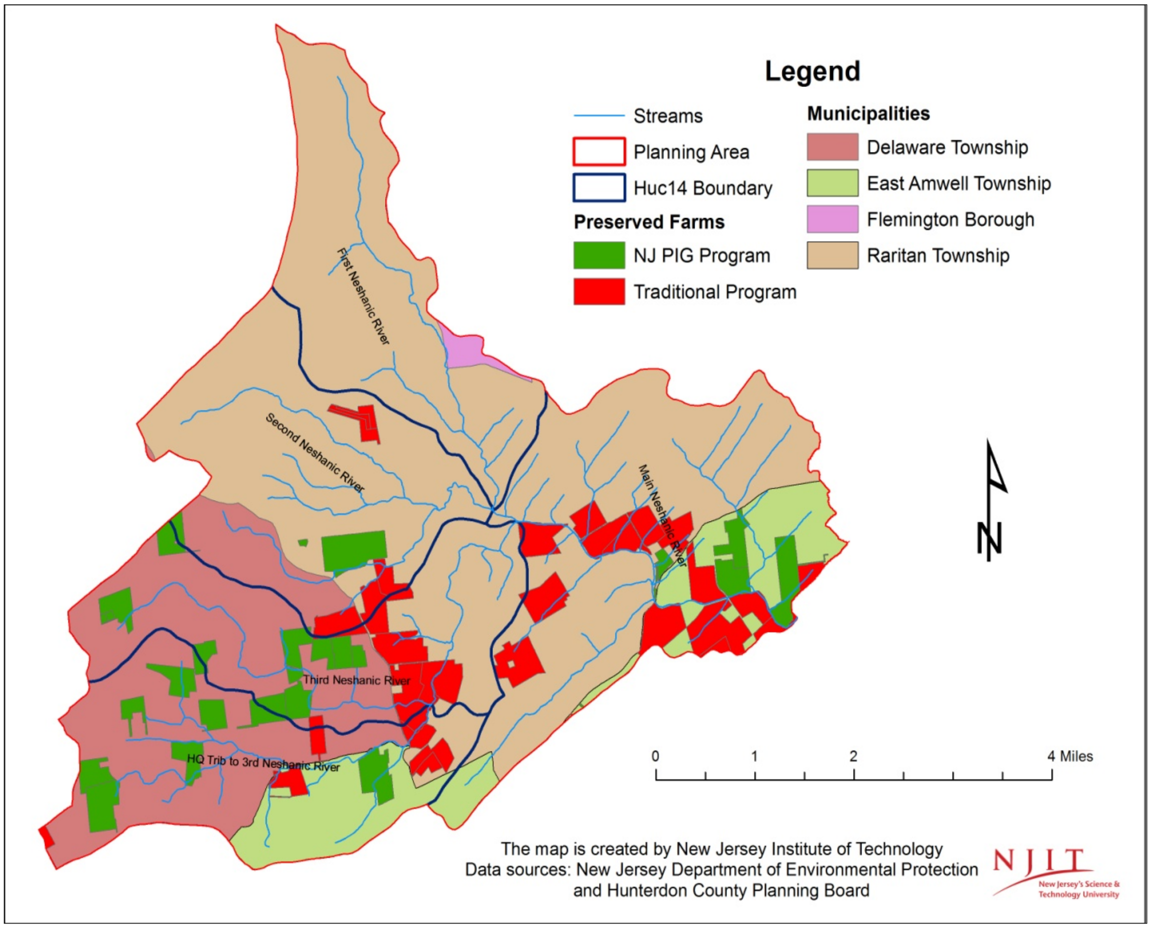


Figure 4.13: Spatial distribution of preserved farmlands in the Neshanic River Watershed

4.3.4. Preserved Open Space

Open space generally refers to a tract of land that is protected from further development. While preserved farmlands are used to protect agriculture, preserved open space has various uses, including recreational parks, natural preserves and schools. Open space offers aesthetic view, recreational opportunities, and ecological benefits and are important assets to the local communities. Many different preservation programs have been developed by state, county and municipal governments, private organizations and individuals. The open space preservation programs in this watershed include the Green Acres programs operated by the state of New Jersey, the Hunterdon County Parks Service and individual municipalities and organizations.

The preserved open space by Board of Education includes Delaware Township Elementary School and Barley Sheaf School and Robert Hunter School in Raritan Township. The preserved open space by county is county parkland including 92 acres of Uplands Reserve and 241 acres of Hunterdon County Golf Course. Both are in Raritan Township. The preserved municipal open space are primarily municipal parks and open space. Except the Marion F. Clawson Memorial Park located along the south edge of the watershed in East Amwell Township, all other municipal open space is located in Raritan Township. There is also a piece of 38 acres of conservation lands located in Raritan Township in adjacent to Flemington Borugh preserved by a non-profit organization. There is also a tiny piece of common-owned open space along the east edge of the watershed in Raritan Township preserved by a private entity. The opens space preserved by the state is 59 acres of Abratiles' Pine Stand Preserve owned by New Jersey Natural Lands Trust.

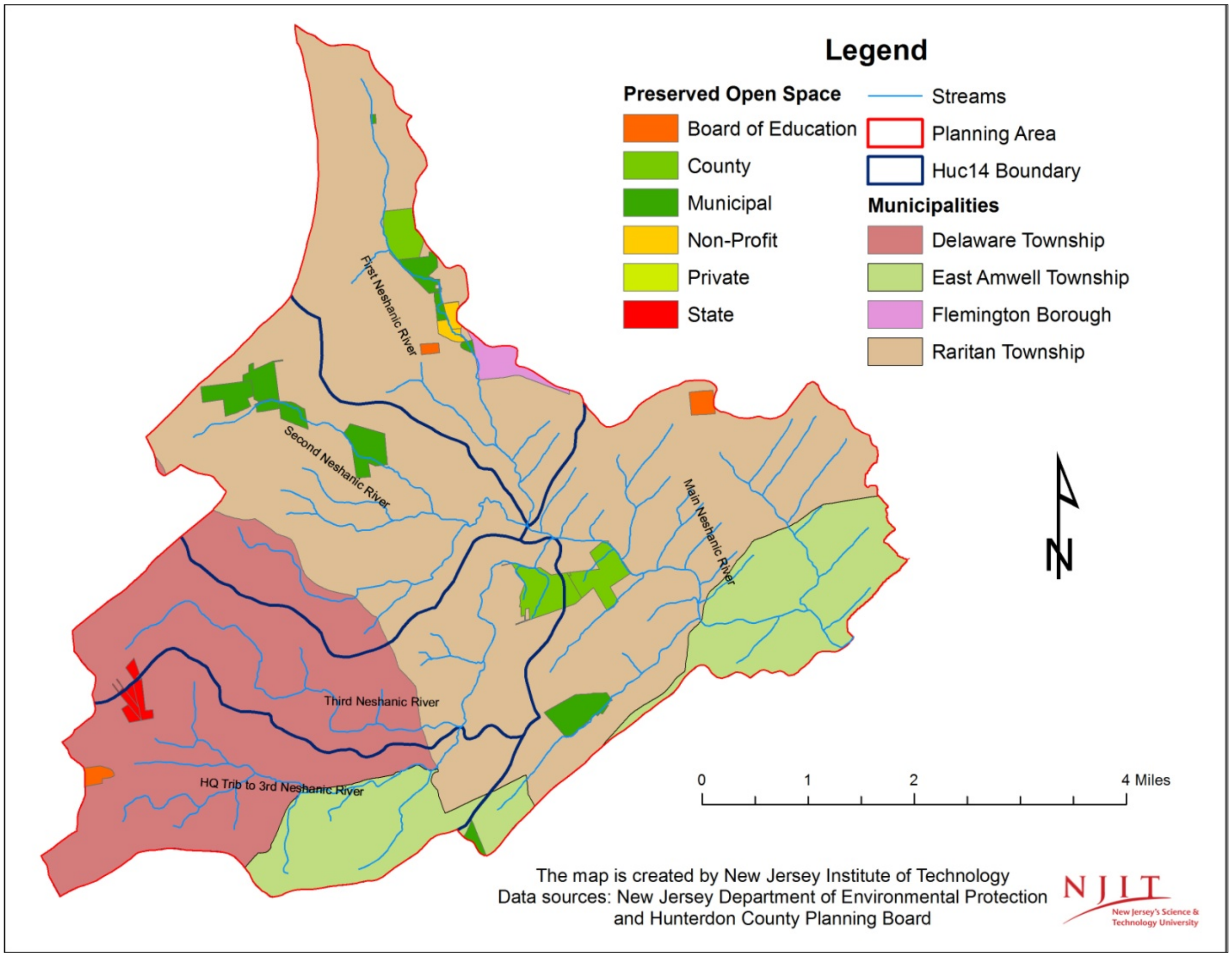


Figure 4.14: Spatial distribution of preserved open space in the Neshanic River Watershed

4.3.5. Land Use Controls and Ordinances

In addition to farmland and open space preservation as discussed above, municipal master plans and various land use controls and ordinances are also used to dictate land use changes and protect water quality. Examples include stream corridor protection, steep slope restrictions, septic management and impervious restrictions.

Stream corridor protection is mandated by the NJDEP Stormwater Management Rule (NJAC 7:8), the NJDEP Flood Hazard Control Act (NJAC 7:13); and the state wetland protection and mitigation rules and implemented through municipal stream buffer ordinances to prevents urban development and other disturbance in the areas adjacent to the streams for water quality improvement. The purpose of stream corridor protection is to maintain or enhance the current functional value of the streams and overall condition of the stream corridor protection area. The NJDEP Stormwater Management Rule requires the stream corridor to include the stream buffer area that is at least 150 feet as measured perpendicular to the streams. The NJDEP Flood Hazard Control Act (NJAC 7:13) defines the riparian zone or corridor as the 75, 100, 150 or 300 foot along the streams depending on the type of the streams. The stream corridor protection area defined by municipalities often includes not only stream channels and their riparian areas, but also floodplains, and the sloping areas that are adjacent to the riparian areas of the streams and floodplains.

Steep slope restriction is required by the NJDEP Water Quality Management Planning Rules (NJAC 7:15) to control the land use changes and any disturbance in the areas with steep slope. Municipalities implement steep slope restriction through zoning regulations for development on and disturbance of steep slopes. The purpose of steep slope restriction is to prevent soil erosion and reduce the risk of landslides that endanger lives, damage property and infrastructure, harm water quality, and degrade wildlife habitat. Additional benefits include preservation of the aesthetic character of visually prominent hillsides by discouraging vegetative clearing and excessive earthwork to accommodate development. Steep slope restrictions vary by each slope tier (10 to 20 percent and 20 percent and greater) with a series of permitted, prohibited, and conditional uses. In general, development is prohibited in areas with slopes that are equal to or greater than 20 percent as measured over any minimum run of 10 feet.

Impervious surface restriction limits the rate of impervious surface in a municipality or watershed and helps to achieve the goals of stream protection. The rate of impervious surface in a municipality or watershed is measured by the percentage of the total area of impervious surface to the total area of the municipality or watershed. As urban land expands, so do the impervious surfaces such as roads, streets, parking lots, driveways and rooftops. With increased pavement, rainfall is less able to percolate into the ground. This raises the volume and velocity of runoff that carries pollutants and sediments into waterways. Groundwater recharge zones are diminished and water tables can be threatened (USEPA, 2000). Increases in impervious surface due to urban development are considered to be one of the largest threats to water quality. Much of the current literature indicates that once the rate of impervious cover exceeds the threshold level of about 10 percent in a watershed, streams typically show signs of declining stream health; at 25 percent impervious cover, streams will no longer support their designated uses in terms of hydrology, channel stability, habitat, water quality, or biological diversity (Schueler 1994).

The NJWSA (2008) assessed the status of stream corridor protection, steep slope restriction and impervious surface restriction in Delaware and Raritan Townships, the two largest municipalities in the watershed and made the following conclusions: both townships have a good stream corridor ordinance, but fair steep slope and impervious surface restriction. The NJWSA recommended that both townships revise the existing Steep Slope Provisions of the Land Use Code in conformance with the Water Quality Management Rules Planning (N.J.A.C.7:15) and reduce permitted impervious surface areas to 5% in areas zoned agricultural, rural or low density residential.

4.4. **Stormwater Infrastructure**

4.4.1. Stormwater Infrastructure Systems

As one of the first portions of Hunterdon County to urbanize, the Neshanic River Watershed possesses some of the County's oldest stormwater infrastructure. The watershed has mixed land uses and has three different types of stormwater infrastructure systems: urban; suburban subdivision; and ditch and pipe.

The urban systems are found along the highways and in commercial centers where there is a high percentage of impervious surfaces. These well-connected impervious surface areas generate much more stormwater then do the less developed parts of the watershed and therefore require a higher density of catch basins and/or other stormwater collectors. These areas have extensive subsurface pipe networks. Roof drains are commonly directly connected to the subsurface pipe system, which is interconnected so as to pass stormwater across maintenance jurisdictions. Detention basins are used in connection with commercial structures. These urban systems generally can effectively and quickly remove stormwater from private properties. However, these systems will generate large amounts of concentrated runoff, which contributes to flash flooding, causes significant distresses to the streams which leads to streambank erosion and water quality degradation. They are very expensive to build and maintain.

The largely autonomous suburban subdivision systems are located throughout the watershed. These systems typically include lot line swales that drain to catch basins located along residential roads, which in turn feed a subsurface pipe network. These pipes discharge stormwater to one or more detention basins usually located in the lowest portion of the development. Suburban subdivision systems tend to be well planned and extensively reviewed, and reflect design standards at or near the time of construction. Compared to the urban systems, the suburban subdivision systems might be cheaper to build and maintain. They are also effective in removing stormwater from properties, and therefore have the similar destructive effects on watershed hydrology and stream integrity.

The ditch and pipe system is a low cost stormwater infrastructure system found primarily in more rural areas located in the southern and western parts of the watershed. It is characterized by open roadside ditches, driveway culverts and an absence of detention basins. Maintenance is primarily the responsibility of the municipality and most of the stormwater infrastructure is confined to road right-of-ways. This portion of the stormwater system typically lacks modern designs or upgrades. Lack of modern design and poor maintenance makes these systems a source of water pollution.

4.4.2. Stormwater Infrastructure Inventory

Table 4.9 gives a brief description of the various types of stormwater infrastructure that were inventoried in the watershed. A stormwater infrastructure inventory was performed to map and assess the stormwater infrastructure in the watershed. The inventory effort is based on *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments* by Brown et al. (2004). This document provides excellent background information on mapping and understanding municipal stormwater systems. The general types of stormwater infrastructures inventoried include dams, culverts, swale and ditch, catch basin, and catch basin pipe inlet, discharge pipe and outfall, detention basin, detention basin inflows, detention basin discharge, and detention basin low flow channel. Their locations and general attributes were recorded using a Global Positioning System (GPS) following GPS Data Collection Standards by NJDEP (2002).

Table 4.9: Types and numbers of inventoried stormwater infrastructure

Name	Brief Description	Num
Catch Basins	The primary collection points where stormwater enters into the municipal stormwater system	4,482
Catch Basin Pipe Inlets	Serve the same purpose as catch basins or storm drains, but omit the grate, head and sump found in catch basins	115
Culverts Up Stream	A culvert is a conduit used to enclose a concentrated flow. The upstream portion of a culvert signifies the point at which water enters the conduit	714
Culverts Down Stream	The downstream portion of a culvert signifies the point at which water exits from the conduit	714
Dams	Stream structures that hold back, impound or restrict streamflow	8
Detention Basin Discharges	The point of discharge of a detention basin commonly located in low area adjacent to streams or wetlands	118
Detention Basins	Constructed impoundments that may include bermed stream corridors for reducing flooding, lowering the volume and velocity of stormwater flows and/or improving water quality	153
Detention Basin Outlet Structures	A structure that regulates stormwater flows exiting from a detention basin; ranges from simple concrete weirs regulating flows to complex multi-outlet cast concrete towers	151
Detention Basin Inflows	Pipes that carry stormwater into a detention basin	220
Detention Basin Low Flow Channels	Defined flow paths located on the floor of a detention basins. Some basins have multiple channels while others do not have a low flow channel.	196
Discharge Pipes and Outfalls	The discharge pipes or pipe outfalls located near streams, wetlands or other low lying areas where stormwater exits the stormwater system	409
Swales and Ditches	The defined flow paths that direct stormwater flows; most common in rural areas where piped drainage is less prevalent	853

4.4.3. Stormwater Infrastructure Assessment

A general assessment of infrastructure conditions is given for three major types of stormwater infrastructure. There are 853 (40.06 miles) mapped swale and ditch segments. Of the mapped segments, 185 (8.68 miles) are actively eroding, contributing sediment to stormwater which flows through them and in urgent need of repair. Of the 853 segments, 515 (25.81 miles) have exposed earth in at least portions of the conveyance and need some repair. Only 153 (5.57 miles of) swale and ditch segments are in good condition and consistent with the soil erosion standards for a grassed waterway or rip-rap channel. Swales in good condition help to improve water quality or at least do not further degrade water quality (Schueler, 1995). Properly vegetated swales with good maintenance regimes have been shown to promote recharge while reducing volume, velocity and peak flows (The Center for Neighborhood Technology, 2009).

Discharge structures are made up of detention basin inlets, detention basin discharges and discharge pipes and outfalls that denote locations where piped stormwater flows exit the covered (piped) system and re-enter the environment. As shown in Table 4.10, there are 747 mapped discharge structures including 220 detention basin inflows, 118 detention basin discharges and 409 discharge pipes and outfalls. Out of the 747 mapped discharge structures, 39 were found to be eroding and 158 were depositional. Eroding conditions indicate the frequent presence of stormwater flow with high velocity. Depositional conditions indicate the presence of accumulated sediments and debris. Also of interest is the fact that the number of direct discharge pipes and outfalls (409) is almost four times the number of detention basin discharge outfalls (118). The nearly 4:1 ratio of direct discharge pipes and outfalls to detention basin discharge outfalls implies that, when designing those detention basins, a large amount of the stormwater in the watershed is discharged without considering volume and velocity reductions. Retrofitting those discharge structures involves correcting eroding conditions by adding energy dissipaters (i.e., conduit outlet protection) and regularly removing the sediments and debris accumulated in depositional areas. Such retrofitting will decrease bank erosion, reduce siltation and decrease non-point source pollution (The Center for Neighborhood Technology, 2009).

Table 4.10: Status of stormwater discharge structures in the Neshanic River Watershed

Type	Detention Basin Outfalls	Detention Basin Inflows	Outfall pipes	Total
Total	118	220	409	747
Erosive	5	13	21	39
Depositional	34	*	124	158

Note: * Deposition associated with detention basin inflows is noted in the detention basin data

There are 153 mapped detention basins in the Neshanic River Watershed that have a variety of designs, including wet ponds, infiltration basins, bio-retention basins, extended dry detention basins, and bermed-off stream corridors with flow control weirs. There are several maintenance levels ranging from heavily landscaped and manicured to benign neglect and outright abandonment. Virtually all detention basins in the watershed present an opportunity for upgrades or retrofits. Many detention basins have various bottom conditions that are suitable for retrofits: 106 of 153 basins were found to have mowed turf bottoms; eight basins had weeds or successional vegetation due to a lack of mowing; three basins were fully overgrown with trees and shrubs; and one basin lacked any vegetation and was covered with deposited material. Low flow channels were very common in the watershed's detention basins. Of the 196 mapped low flow channel segments, 156 were found to be concrete. Only one third of the detention basins have outlet structures with a three-inch water quality orifice required by NJDEP. The three-inch orifice outlet structure extends the water detention time in the basin to allow TSS and the attached nutrients to settle and therefore achieve certain water quality benefits. The remaining detention basins in the watershed were not constructed to achieve water quality benefits through extended water detention.

The assessment of the conditions of these stormwater infrastructure systems reveals infrastructure retrofitting opportunities. Detailed mapping of these stormwater infrastructures and assessment of their conditions shows the need for implementation of BMPs to manage stormwater runoff and mitigate its negative impacts on watershed hydrology and stream water quality.

5. Causes and Sources of Pollution

5.1. Land Use Change

As discussed previously, like many other parts of New Jersey, the Neshanic River Watershed has experienced dramatic land use changes during the last two decades, notably decreases in wetlands, forest and agricultural lands. The percentage of the urban land in the watershed increased from 17 percent in 1986 to 25 percent in 1995, 31 percent in 2002 and 35 percent in 2007. These increases were accompanied by notable decreases in agricultural land. Agricultural lands in the watershed decreased from 51 percent in 1986 to 43 percent in 1995, 36 percent in 2002 and 35 percent in 2007. Forest areas increased from 1986 to 1995, but have been decreasing since 1995. The wetlands have been in constant decline.

The trends in land use changes in the watershed are expected to continue as land development occurs in the rural landscape. Ballesteros (2008) developed a sophisticated land use change model for Hunterdon County where the watershed is located. The model integrates advanced machine-learning algorithms, such as cellular automata and decision trees. Although agricultural lands will continue to decrease and urban lands increase, the pace of change will be slower due to the extensive farmland and open space preservation programs and implementation of various land use planning and ordinances in local municipalities (Ballesteros, 2008).

5.2. Hydrological Alteration

Land use changes significantly alter watershed hydrology and have direct impacts on both water quality and quantity. As urban land increases at the expense of agricultural and forest lands, impervious surfaces, such as rooftops, driveways, additional roads, and parking lots, increase, which decreases infiltration and groundwater recharge and increases surface runoff. Urban and suburban developments also bring additional roads and stormwater infrastructure, such as drainage pipes and ditches that are designed to quickly disperse stormwater from individual properties. For the same reason, tile drainage and swale infrastructure are also constructed in agricultural lands. In general, urban development and intensive agricultural operations create flashier streams in the watershed. The impacts of intensive land uses and development can be characterized in terms of drainage density, which measures the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin and is an indicator of how well or how poorly a watershed is drained by stream channels. The calculated drainage density in the Neshanic River Watershed is 2.02 miles if the water is drained through streams and 7.05 miles if the water is drained by both streams and roads. The latter are shown in Figure 5.1. Streams and roads act as drainage pathways for water. The drainage density could be even higher when incorporating the impacts of stormwater and runoff infrastructure, such as tile drainage, swales, drainage pipes and ditches that direct runoff to streams. Drainage density affects the shape of the hydrograph of a river during a rain storm. Rivers that have a high drainage density will often have a flashier hydrograph with a steep falling limb, and therefore, greater flood risk. Figure 5.2 shows the hydrograph observed at the USGS Neshanic River at Reaville Gage Station for a 0.03-inch storm on December 7, 2008, a 0.53-inch storm on December 10, 2008, a 1.91-inch storm on December 11, 2008 and a 0.67-inch storm on December 12, 2008. The streamflow went from less than 100 cubic feet per second (cfs) several hours after the December 11 storm to a peak of 3,000 cfs. The spike hydrograph implies the flash flooding in the watershed as evidenced by the photos in Figure 5.3 below.

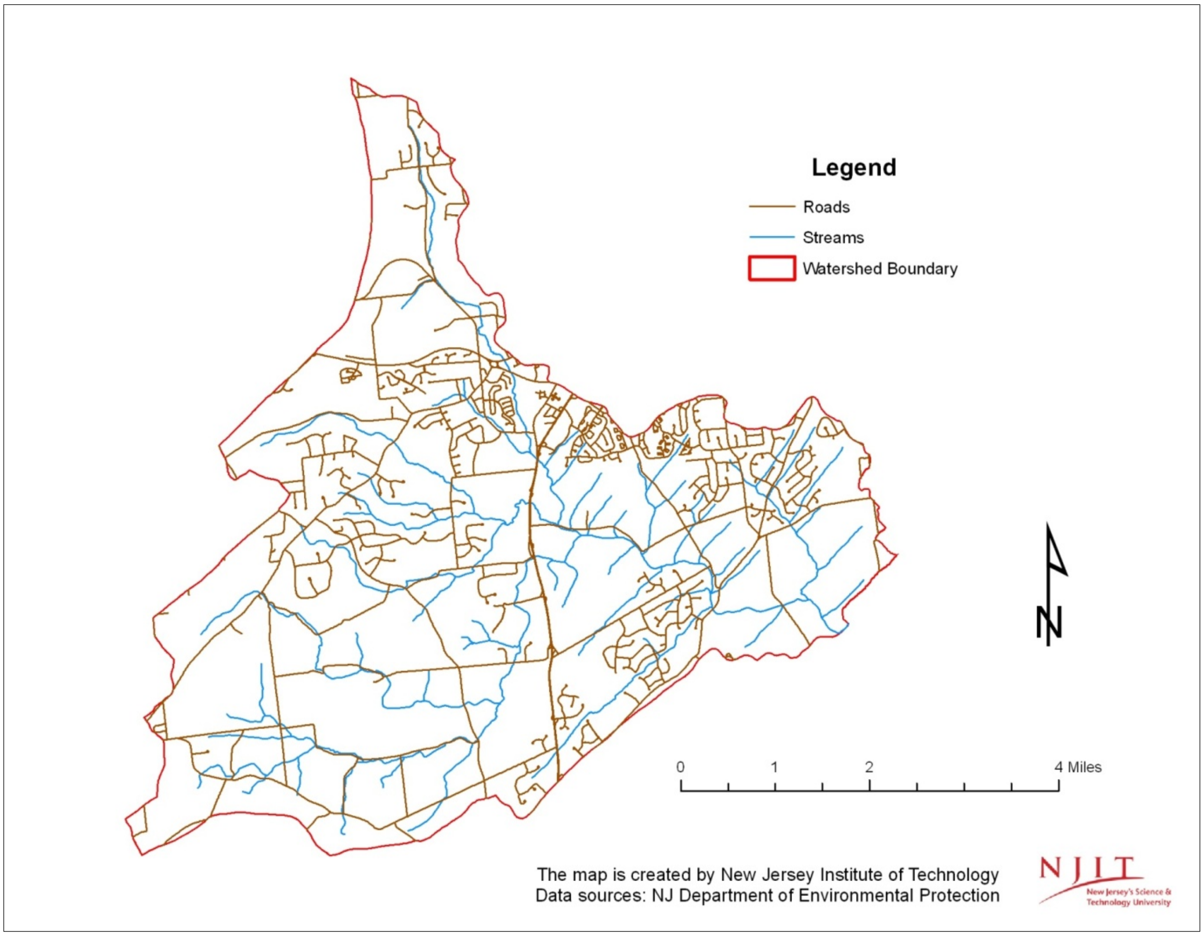


Figure 5.1: Distribution of streams and roads in the Neshanic River Watershed

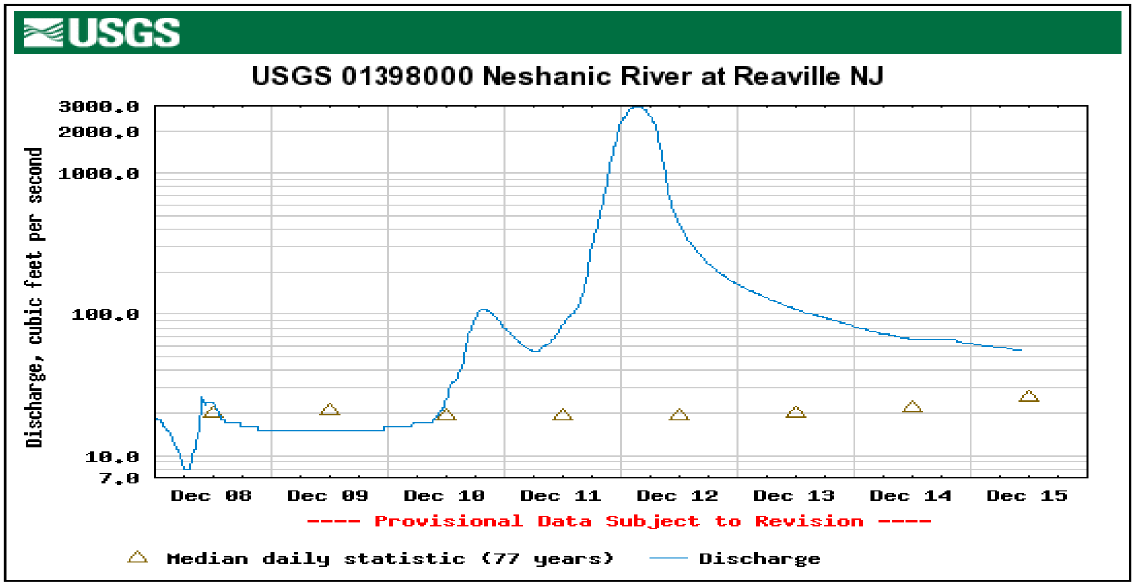


Figure 5.2: Hydrograph at the USGS Reaville station in the Neshanic River Watershed

Figure 5.3: Flooded Hampton Corners Road after a spring storm

Hydrological alteration is attributed to not only the quantitative changes in land uses as discussed above, but also where various land use changes take place in the watershed. In the Neshanic River Watershed, many intensive land use activities have taken place in critical environmental areas in the watershed, such as hydric soils, HSAs and riparian areas. A major concern in the watershed is that agriculture and urban development occur in hydric soils. According to the 2007 NJDEP land use/cover data, agriculture occurs on 202 acres and urban development occurs on 237 acres of hydric soils. The agricultural and urban use acreage accounts for more than half of the total hydric soil acreage in the watershed. A very similar observation can be made for HSAs in the watershed as discussed above. Figure 5.4 shows the acreages of different land uses in HSAs in 2007. In 2002, HSAs contained 714 acres of agricultural land and 743 acres of urban land, which accounts for 54 percent of the HSAs. Agricultural lands were decreased slightly to 677.3 acres, but urban land rose to 848.7 acres in 2007. More than half (57 percent) of the HSAs in the watershed were in agricultural and urban land uses in 2007.

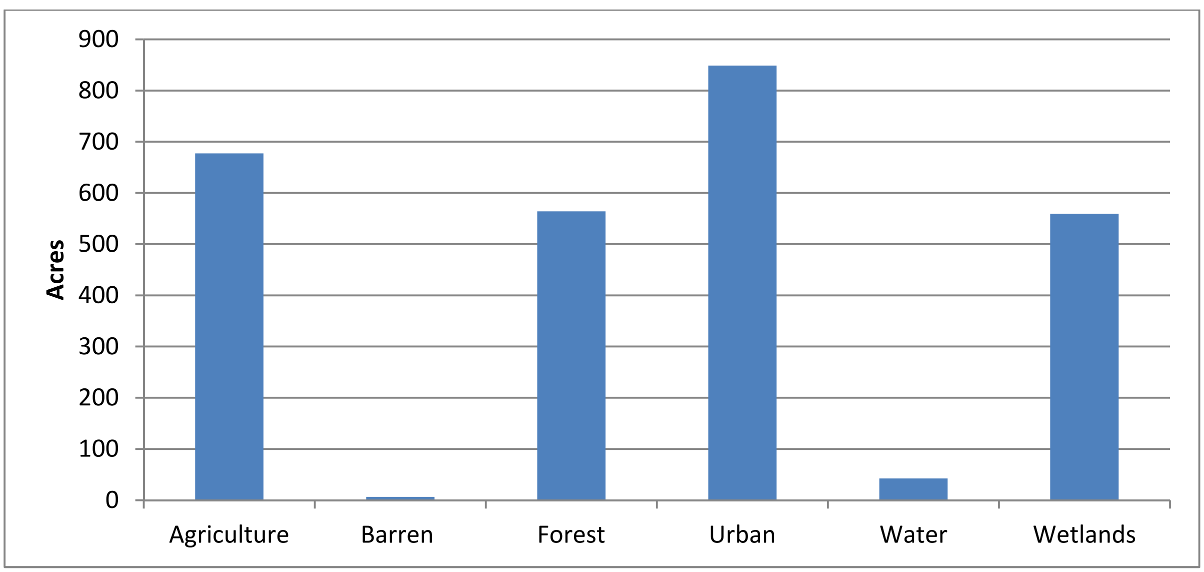


Figure 5.4: Land uses in HSAs in the Neshanic River Watershed, 2007

Land use changes during the past decades have disrupted riparian areas of the watershed. In particular, riparian areas of the watershed have been increasingly used for urban development. Figure 5.5 presents the land uses in riparian areas of the Neshanic River Watershed in 1986, 1995, 2002 and 2007. In 1986, riparian areas were primarily used for agriculture, wetlands and forest; only about 500 acres of riparian areas were in urban uses. Urban uses of riparian areas have increased substantially in the last two decades; the increases were 282 acres during 1986-1995, 294 acres during 1995-2002 and 151 acres during 2002-2007. Increases in urban lands that occurred during the last two decades were accompanied by losses in agriculture and wetlands in riparian areas. Losses in agricultural lands in riparian areas amounted to 309 acres, 256 acres and 55 acres during the periods 1986-1995, 1995-2002 and 2002-2007, respectively. Although poorly managed agricultural areas could contribute to water quality degradation in the watershed, converting pervious agricultural lands to urban land with more impervious surfaces changes watershed hydrology and contributes to both frequent flooding and water quality degradation.

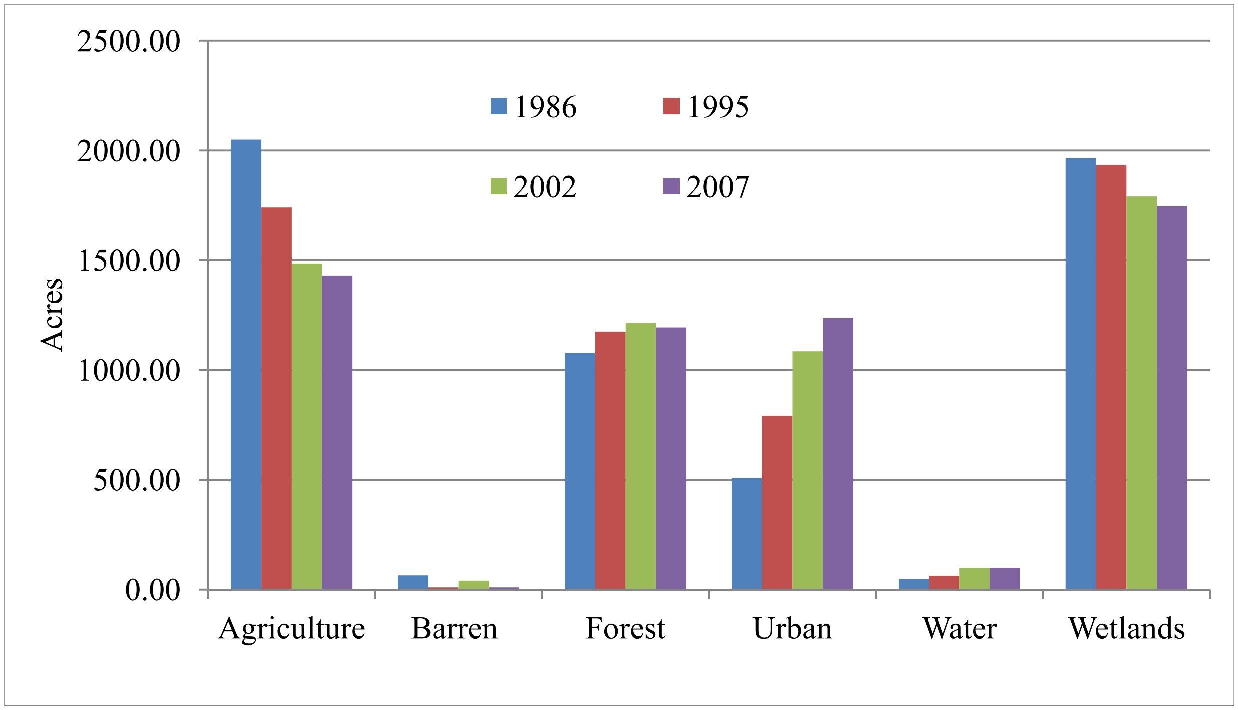


Figure 5.5: Land uses in riparian areas of the Neshanic River Watershed, 1986, 1995, 2002 and 2007

Wetland losses and agriculture and urban development in hydric soils and riparian areas usually destroy natural pathways for water drainage and reduce the storage capacity for runoff; the latter leads to higher runoff quantity and velocity reaching streams. The latter increases the occurrence of flash flooding and stream sedimentation that is discussed in detail later. Additionally, the loss of wetlands reduces water treatment of runoff before it reaches the streams.

5.3. **Surface Water Quality**

5.3.1. Designated Uses and Impairments

The NJDEP (2010a) designated the Neshanic River and its tributaries as FW2-NT. "FW2" refers to freshwater bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters may support other fish species, but are not suitable for trout production or trout maintenance due to their physical, chemical, or biological characteristics.

According to the designated use FW2-NT, the following surface water quality standards are applicable to the Neshanic River and its tributaries following NJAC 7:9B, as amended on January 4, 2010 (42 N.J.R. 68a):

- *E. coli* shall not exceed a geometric mean of 126 counts per 100 milliliter (mL) or a single sample maximum of 235 counts per 100 mL;
- Fecal coliform shall not exceed a geometric average of 200 counts per 100 mL, nor shall more than 10 percent of the total samples taken during any 30-day period exceed 400 counts per 100 mL;
- Dissolved oxygen (DO) shall not be less than 5.0 mg/L for its 24 hour average, but not less than 4.0 mg/L at any time;
- pH shall be between 6.5 and 8.5;
- TP as shall not exceed 0.1 mg/L;
- TSS shall be less than 40 mg/L;
- Temperatures shall not exceed a daily maximum of 31 degrees Celsius or rolling seven-day average of the daily maximum of 28 degrees Celsius, unless due to natural conditions; and
- Nitrate shall be below 10 mg/L.

In accordance with Section 305(b) of the Clean Water Act, New Jersey has authority to address overall water quality of the State's waters and identify impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies*. The list details the presence and level of impairment for each monitored waterbody. It is recommended that this list be a guideline for water quality management actions that address the cause of impairment.

Based upon numerous monitoring sources, including the NJDEP Ambient Biomonitoring Network (AMNET), the NJDEP/ USGS water quality monitoring network and the Metal Recon Program, the Neshanic River and its branches are impaired for aquatic life, phosphorus, TSS and copper and are listed on Sublist 5 of the New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report (NJDEP, 2004b). Sublist 5 of the 2004 Integrated List contains the waterbodies that are impaired or threatened for one or more designated uses by a pollutant(s) and require a TMDL (NJDEP, 2004b). According to the 2006 Integrated List, which uses a HUC-14 based water quality impairment listing methodology, the Neshanic River and its tributaries (HUC14 02030105030010, 02030105030020, 02030105030030, 02030105030040, and 02030105030060) are impaired for DO, arsenic and phosphorus, and listed on Sublist 5 for aquatic life and drinking water supply and Sublist 4 for primary contact recreation impairments (NJDEP, 2006). Sublist 5 of the 2006 Integrated List contains the waterbodies that are impaired or threatened for one or more designated uses by a pollutant(s) and require a TMDL. Sublist 4 contains the waterbodies that are impaired or threatened for their designated uses, however development of a TMDL is not required (NJDEP, 2006).According to the most recent listing (i.e., the 2008 Integrated List), the Neshanic River and its tributaries are impaired for DO, pH, arsenic and phosphorus and listed on Sublist 5 for aquatic life, drinking water and industrial water and Sublist 4 for recreation impairments (NJDEP, 2009a). According to NJDEP (2009a), both Sublist 4 and Sublist 5 list waterbodies where the designated use attainment is threatened and/or a waterbody is impaired, however, a TMDL is not required for the waterbodies listed under Sublist 4, but for the waterbodies listed under Sublist 5. A nutrient TMDL is being developed by NJDEP for the entire Raritan Basin. Like many waterbodies in New Jersey, the Neshanic River and its tributaries are also contaminated by pathogens. A TMDL for fecal coliform was adopted for the Neshanic River in 2003 that requires 87 percent 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).

5.3.2. Monitoring Stations

The NJDEP assessed the impairment status of the Neshanic River and its tributaries based on the surface water quality monitoring at the USGS Reaville Gage Station near the stream-road crossing between the Reaville Road and the main Neshanic River noted as N1 as well as AMNET monitoring at four biological monitoring stations AN0330, AN0331, AN0332 and AN0333 represented by FN1, SN1, TN3 and N1 in Figure 5.6, respectively.

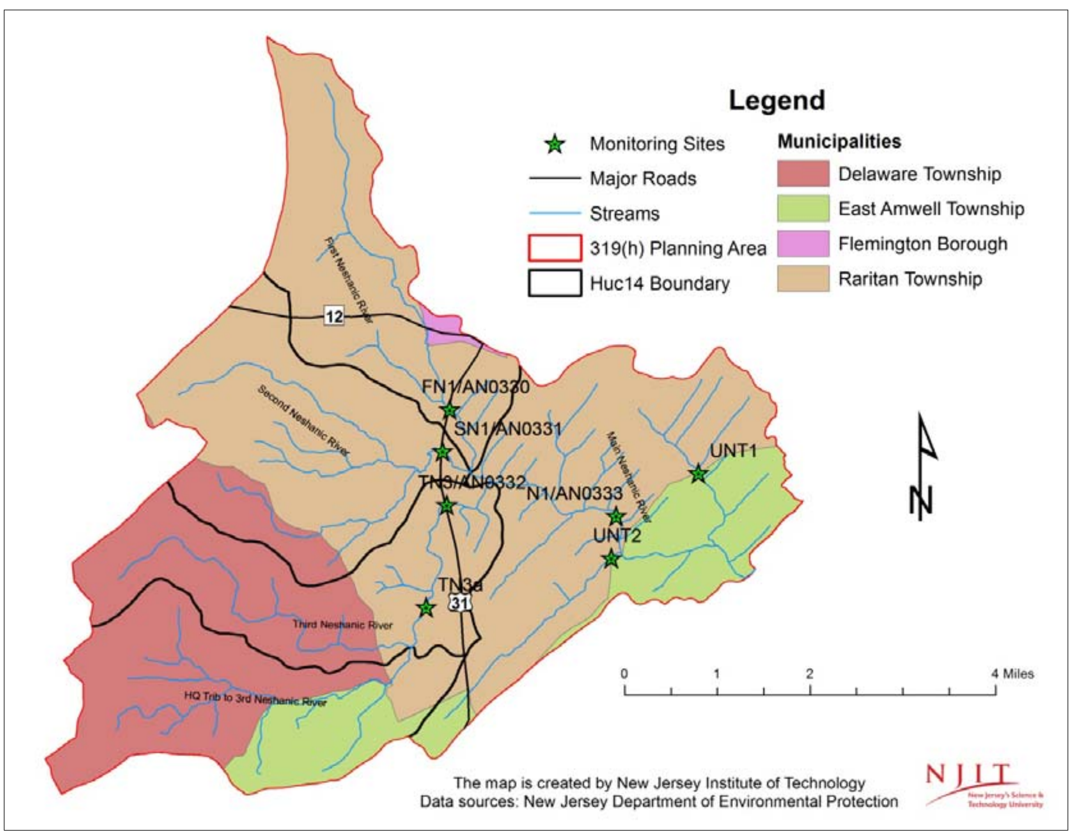


Figure 5.6: Location of seven monitoring stations in the Neshanic River Watershed

In order to understand the causes and sources of water pollution in the watershed, surface water quality monitoring was expanded to include seven monitoring stations in the watershed. Additional water quality monitoring stations include FN1, SN1, TN3, TN3a, UNT1 and UNT2. Biological monitoring was continued at all four biological monitoring stations.

Station FN1, First Neshanic River at the Route 202 crossing, was selected to characterize the First Neshanic River (HUC 02030105030010), a major tributary to the Neshanic River, upstream from the confluence with the Neshanic River. Station SN1, Second Neshanic River at the Route 202 crossing, was selected to characterize the Second Neshanic River (HUC 02030105030020), a major tributary to the Neshanic River, upstream from the confluence with the Neshanic River. Station TN3a, Third Neshanic River at the Everitts Road bridge crossing, was selected to characterize both the southern and northern branches of the Third Neshanic River, a major tributary that drains areas having substantial agricultural land. Station TN3, third Neshanic River at the Route 202 crossing, was selected to characterize the Third Neshanic River, a major tributary to the Neshanic River, upstream from the confluence with the Neshanic River. Station TN3 is located further downstream from the confluence of the northern and southern branch of the Third Neshanic River. Both TN3 and TN3a were selected to characterize HUCs 02030105030030-40. Station N1, Neshanic River main stem at the Everitts Road and Reaville Road, was selected to characterize the main stem of the Neshanic River downstream from the confluence and drainage from the First, Second, and Third Neshanic Rivers. This site was selected to also characterize portion of HUC 02030105030060. Station UNT1, the unnamed tributary at the Route 514 crossing, was selected to help identify if loadings are coming from areas within this subwatershed that are suspected of having failing septic systems. Station UNT2, the unnamed tributary at Old Mill Court and Hunterdon Pointe Boulevard crossing, was selected to help characterize the loadings from suburban/urban areas within this subwatershed.

Figure 5.7: USGS Reaville gage station (N1)

5.3.3. Summary of Water Quality Data

The USGS began monitoring the water quality at station N1 in the late 1970s. The earlier monitoring efforts focused on nutrients in water, including ammonia-N (NH_3-N), nitrate-N (NO_3-N), nitrite-N (NO_2-N), organic N, TN, phosphorus, and orthophosphate. Monitoring is usually conducted 3 to 5 times a year with some interruption. Water quality monitoring at station N1 was later expanded to include TSS and fecal coliform. The historical USGS/NJDEP water quality monitoring data at station N1 was used by NJDEP to evaluate the impairment status compared to the designated uses for the Neshanic streams and develop integrated water quality reports that recommended the development of TMDLs and this watershed restoration plan as discussed in Section 5.3.1.

In order to assess the water quality conditions in different parts of the watershed, this project conducted additional surface water quality and physical conditions monitoring under both dry and wet weather conditions at all seven monitoring stations. Both historical monitoring data and the additional monitoring results are used to assess the pollutant load reductions required to meet the water quality standards for the designated uses. Dry weather monitoring included biweekly surface water sampling and additional bacteriology sampling during June-November 2007. Biweekly (twice a month) surface water samples were collected from June to November 2007, which resulted in 12 sampling events. Water samples were tested for ammonia-N, nitrate-N, nitrite-N, total Kjeldahl nitrogen, TP, dissolved orthophosphate phosphorus, TSS, fecal coliform, *E. coli*. pH, temperature, DO, stream width, stream depth and stream velocity were measured onsite during sampling. During June, July and August 2007, three additional water samples per month (i.e., 9 events) were collected for testing fecal coliform and *E. coli*, resulting in five bacteria samples per month for June, July and August 2007. Three wet weather monitoring events were conducted between June and November 2008. A series of water samples were collected during the course of a storm event; only three samples at the beginning, middle and end of the storm event were tested for TP, dissolved orthophosphate phosphorus, TSS and *E. coli*, the primary pollutant. Due to safety concerns, no physical parameters of water were measured during the wet weather sampling.

Biological monitoring was conducted at four of the seven monitoring stations in the watershed: FN1, SN1, TN3 and N1. Biological samples were taken once in early summer 2007 for analysis of benthic macroinvertebrate survey. A habitat assessment was performed during each biological sampling event. The physical parameters, such as pH, temperature, DO, stream width, stream depth and stream velocity, were also measured during the sampling.

5.3.4. Surface Water Quality

Table 5.1 gives the basic statistics of the water quality results of the biweekly and additional bacteria sampling during the dry weather condition and the percentage of samples that were in violation of the surface water quality standards or exceeded the surface water quality criteria (SWQC) in the monitoring stations. The average pH at all seven sites exceeded 6.5, the minimum requirement, and occasional violations of the pH criterion were observed throughout the watershed. There was only a single violation of the DO criterion at sites UNT2, UNT1 and SN1. A high percentage of the samples collected throughout the Neshanic River Watershed exceeded both the current bacteria criterion for *E. coli* and the former criterion for fecal coliform. The TP criterion was also exceeded often. Only a single violation of the TSS criterion was observed at UNT2. In regard to the wet weather sampling, 98 percent of the samples collected throughout the watershed exceeded SWQC for *E. coli*, and 84 percent of the samples collected exceeded the criterion for TP. Persistent and continual violations of the TSS criterion were not observed during the wet weather sampling events. The NJDEP's Integrated Water Quality Monitoring and Assessment Methods indicate that if the frequency of water quality results exceed the water quality criteria twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2009).

Table 5.1: Basic statistics of water quality monitoring results in the Neshanic River Watershed

Monitoring Station	SWQC	Count	Minimum	Maximum	Mean	% of Violating SWQC
UNT2	**pH** minimum 6.5 (SU)	12	6.21	7.25	6.75	8 (1/12)
UNT1		12	6.12	6.88	6.62	25 (3/12)
N1		13	6.11	7.50	6.79	25 (3/12)
TN3a		12	5.74	7.31	6.82	17 (2/12)
TN3		12	5.69	8.35	6.91	25 (3/12)
SN1		13	6.16	7.67	6.85	23 (3/12)
FN1		13	5.56	7.75	6.82	8 (1/12)
UNT2	**Dissolved Oxygen** Not less than 4 (mg/L) at any time	12	3.63	11.93	7.26	8 (1/12)
UNT1		12	3.82	10.70	6.05	8 (1/12)
N1		13	4.23	12.22	6.99	0
TN3a		12	5.26	12.62	8.14	0
TN3		11	5.11	12.01	7.90	0
SN1		13	3.24	11.42	7.15	8 (1/12)
FN1		13	4.62	10.95	7.02	0
UNT2	***E. coli*** Single sample maximum of 235 (counts/100 ml)	21	5	76,000	855	86 (18/21)
UNT1		21	5	32,000	390	57 (12/21)
N1		21	50	26,000	429	62 (13/21)
TN3a		21	60	6,200	544	71 (15/21)
TN3		21	80	4,000	397	71 (15/21)
SN1		21	20	38,000	468	71 (15/21)
FN1		21	10	46,000	678	81 (17/21)
UNT2	**Fecal Coliform** No more than 10% of the total samples taken during any 30-day period can exceed 400 (counts / 100 ml)	21	40	44,000	1,065	67 (14/21)
UNT1		21	10	24,000	401	57 (12/21)
N1		21	40	18,000	402	38 (8/21)
TN3a		21	40	8,200	543	52 (11/21)
TN3		21	68	12,000	613	52 (11/21)
SN1		21	2	12,000	539	48 (10/21)
FN1		21	2	23,000	733	71 (15/21)
UNT2	**Total Phosphorus** 0.1mg/L in any stream	12	0.03	0.29	0.11	25 (3/12)
UNT1		12	0.03	0.27	0.12	58 (7/12)
N1		12	0.03	0.19	0.10	33 (4/12)
TN3a		12	0.05	0.13	0.09	33 (4/12)
TN3		12	0.04	0.15	0.10	42 (5/12)
SN1		12	0.05	0.28	0.11	58 (7/12)
FN1		12	0.04	0.37	0.14	58 (7/12)
UNT2	**Total Suspended Solids** 40.0 (mg/L)	12	0.25	110	13.40	8 (1/12)
UNT1		12	0.25	35.00	6.23	0
N1		12	0.25	8.00	2.52	0
TN3a		12	0.25	13.00	4.81	0
TN3		12	0.25	21.00	5.15	0
SN1		12	0.25	14.00	3.38	0
FN1		12	0.50	36.00	7.00	0

The water quality in the Neshanic River Watershed is clearly compromised given the continual and persistent violations of the SWQC for bacteria and TP, and the occasional violation of the minimum pH. These results are consistent with the assessment presented in the *Integrated List of Waterbodies* by NJDEP (2009a). However, the water quality monitoring shows that TSS, even during wet weather events, and DO do not appear to be a problem for the Neshanic River Watershed, which is not consistent with the assessment presented in the *Integrated List of Waterbodies* by NJDEP (2009a). Additional assessments are needed to further evaluate the impairment status of the Neshanic River and its tributaries.

5.3.5. Microbial Source Tracking

Microbial source tracking is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical) and chemical methods to identify the origin of fecal pollution (Scott et al., 2002; USEPA, 2005). The microbial source tracking techniques were applied as a supplemental tool to identify the causes and sources of pathogen contamination in the Neshanic River Watershed. Samples were collected in sterile bottles at the seven monitoring locations as part of the wet weather surface water sampling and held at 4˚C until processing. For each ½ inch wet weather event, three samples were collected (A, B, and C) between the onset of the storm and the time when the flow reached the pre-storm level. The protocol used for the Neshanic River Watershed samples is a modification of the procedure found in the DNeasy Tissue Handbook (Qiagen, Inc., 2004); it measures the number of bacteroides present. After extraction, all DNA samples were quantified by spectroscopy (Beckman DU 640) at 260 and 280 ηm and then diluted in sterile water to a concentration of 1 μg/mL. The diluted DNA was used as the template for quantitative, real-time polymerase chain reactions (PCRs) to measure the number of bacteroides present. Three sets of PCR primers (targets) were used to quantify bacteroides from human sources (HuBac), bovine sources of bacteroides (BoBac) and other sources of bacteroides (OtherBac) (e.g., wildlife, birds, horses, domestic animals, etc.).

The microbial source tracking results show that Monitoring Stations UNT2, UNT1, N1, FN1 and TN3a have a higher incidence of human bacteroides than at SN1 and TN3. For the first wet weather event, human bacteroides were detected at N1 in the second set of samples. By the time the third sample was collected, no bacteroides were detected; they were most likely flushed from the system. For the second wet weather event, human bacteroides were detected in the first set of samples from UNT2 and N1, but none were detected in the second or third set of samples collected at these locations. Human bacteroides were detected at FN1 and TN3a in the second set of samples, but by the third set of samples, human bacteroides were not detected and were most likely flushed from the system. For the third wet weather event, human bacteroides were detected at UNT2, TN3a and FN1 in the first set of samples, at UNT2 and N1 in the second set of samples and at UNT2 and UNT1 in the third set of samples.

Bovine bacteroides were not detected in any of the samples collected and analyzed. This is most likely due to the sampling locations not being in close proximity to bovine sources. In studies conducted in Salem and Cumberland Counties, New Jersey, bovine bacteroides were not detected much beyond 1,000 feet downstream from bovine sources, possibly due to the effect of settling, die-off and/or predation of the bovine *Bacteroides* within 1,000 feet of the source. Not surprisingly, other sources of bacteroides were detected at all the sampling locations during each wet weather event. Possible other sources of bacteroides include wildlife, birds, horses, domestic animals, etc. Although these data illustrate the highly variable nature of water quality measures, these data are useful for determining the potential sources and extent of fecal contamination within the watershed.

5.3.6. Biological Monitoring and Results

Biological monitoring in the Neshanic River Watershed was conducted in the same manner as AMNET administered by the NJDEP. It used a modified version of the USEPA Rapid Bioassessment Protocol II (NJDEP, 2004). Biological monitoring assesses both the impairment status of streams by measuring the presence of benthic macroinvertebrate communities in streams and the habitat conditions for supporting the benthic macroinvertebrate communities in streams by evaluating the physical and biological habitat attributes.

The NJDEP (2004) developed a scale of biological integrity referred to as the New Jersey Impairment Score (NJIS) to classify the impairment status of a monitoring site. NJIS is based on several measurements on the benthic macroinvertebrate communities including taxa richness, EPT (Ephemeroptera, Plecoptera, Trichoptera) index, percent EPT, percent contribution of the dominant family and the family biotic index. NJIS ranges from 0 to 36. Monitoring sites with total NJIS scores ranging from 24 to 30 are considered as non-impaired sites, from 9 to 21 as moderately impaired sites, and from 0 to 6 as severely impaired sites. A non-impaired site generally has a benthic community comparable to other high quality "reference" streams within the region characterized by maximum taxa richness, balanced taxa groups and a good representation of intolerant individuals. A moderately impaired site is characterized by reduced macroinvertebrate taxa richness; in particular, the EPT taxa. Changes in taxa composition result in reduced community balance and intolerant taxa become absent. A severely impaired site is one in which the benthic community is significantly different from that of the reference streams, where the macroinvertebrates are dominated by a few taxa which are often very abundant, and tolerant taxa are typically the only taxa present.

The habitat assessment is designed to provide an estimate of habitat quality based upon qualitative estimates of selected habitat attributes. The assessment involves evaluating instream substrate, channel morphology, bank structural features, and riparian vegetation based on numerical scoring of ten habitat attributes (i.e., epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, channel sinuosity, bank stability, vegetative protection, and riparian vegetative zone width). Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200, sites with suboptimal/good habitat conditions have total scores ranging from 110 to 159, sites with marginal/fair habitat conditions have total scores ranging from 60 to 109 and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential (NJDEP, 2004).

The NJDEP Bureau of Biological & Freshwater Monitoring maintains four AMNET monitoring locations in the Neshanic River Watershed (i.e., stations AN0330, AN0331, AN0332 and AN0333). Station AN0330 is the same as Monitoring Station FN1, Station AN0331 as SN1, Station AN0332 as TN3 and Station AN0333 as N1 in the above the Neshanic River Watershed monitoring station map. All four stations were sampled in 1994, 1999 and 2004 by NJDEP

(1995; 2000; and 2008a) and in 2007 by the project team. Table 5.2 summarizes the AMNET monitoring results at these sites in the four rounds of assessments. In 1994, 1999, and 2004, Station AN0330 (FN1) was classified as being moderately impaired and its habitat conditions were found to be sub-optimal in 1999 and 2004. In the 2007 assessment, biological condition remained moderately impaired, but habitat conditions were degraded from sub-optimal to marginal conditions. Station AN0331 (SN1) was assessed as being non-impaired in 1994, but was degraded to moderately impaired in 1999 and non-impaired in 2004. Habitat conditions in 1999 and 2004 were found to be sub-optimal. Like Station AN0331, Station AN0332 (TN3) was found to be non-impaired in 1994, moderately impaired in 1999 and non-impaired in 2004. Habitat conditions for the site were found to be sub-optimal in both 1999 and 2004. The 2007 assessment indicated that the stream impairment status remained at non-impaired and the habitat condition remained as sub-optimal at both AN0331 (SN1) and AN0332 (TN3). Station AN0333 (N1) was assessed as being moderately impaired in 1994, 1999 and 2004. Its habitat conditions were found to be sub-optimal in 1999 and 2004. The 2007 assessment indicated that the impairment status at site AN0333 (N1) was downgraded to a non-impaired status and the habitat condition remained as sub-optimal. In summary, the Neshanic River continued to support a non-impaired to moderately impaired benthic macroinvertebrate community.

Table 5.2: AMNET monitoring results in the Neshanic River Watershed, 1994, 1999, 2004 and 2007

AMNET Station		AN0330 (FN1)	AN0331 (SN1)	AN0332 (TN3)	AN0333 (N1)
1994	Impairment Status (Score)	moderately impaired (15)	non-impaired (27)	non-impaired (24)	moderately impaired (18)
1999	Impairment Status (Score)	moderately impaired (12)	moderately impaired (21)	moderately impaired (21)	moderately impaired (12)
	Habitat Status (Score)	sub-optimal (138)	sub-optimal (148)	sub-optimal (149)	sub-optimal (133)
2004	Impairment Status (Score)	moderately impaired (12)	non-impaired (27)	non- impaired (30)	moderately impaired (21)
	Habitat Status (Score)	sub-optimal (142)	sub-optimal (137)	sub-optimal (129)	sub-optimal (130)
2007	Impairment Status (Score)	moderately impaired (15)	non-impaired (24)	non-impaired (24)	non-impaired (24)
	Habitat Status (Score)	Marginal (105)	sub-optimal (144)	sub-optimal (149)	sub-optimal (127)

5.4. **Point Sources**

According to regulations in the United States, point sources generally include municipal wastewater (sewage), industrial wastewater discharges, municipal separate storm sewer systems and industrial stormwater discharges (Public Law 100-4. 1987). These facilities are required to obtain National Pollution Discharge Elimination System permits or state/local permits. According to NJDEP’s permitted point source surface discharges database, there are only two permitted industrial point sources that discharge treated petroleum products cleanup wastewater to the Neshanic River streams during certain periods of time. First is Exxon Company, USA (NJPDESID: NJ0000892) that is located just outside of the Neshanic River Watershed in Raritan Township at latitude 40° 30' 10.2" and longitude 74° 51' 14.5" and discharged treated groundwater to the First Neshanic River via storm sewer before 2000. Second is Suburban Sunoco Inc. (NJPDESID: NJG0136034), located just inside of the watershed boundary in East Amwell Township, at latitude 40° 26' 29.7" and longitude 74° 51' 26.5"; that source discharged treated groundwater to the Neshanic River via an unnamed tributary and storm sewer during 2001-2006. Exxon Company no longer holds the active permit. Suburban Sunoco Inc. has an active permit, but no longer discharges treated groundwater into Neshanic River streams according to the latest record inquiry from NJDEP. Therefore, there are no point sources considered in the Plan.

5.5. **Nonpoint Sources**

Nonpoint sources (NPS) is comprised of diffuse sources of water pollutants originating from the landscape. Although the exact location of the pollution may not be easily identified due to its diffuse nature, it is well recognized that agriculture and urban development are major sources of nonpoint source pollutants. Agriculture has been identified as a leading source of water pollution in the U.S. by USEPA (1994). Agricultural sources are responsible for many pollutants, such as sediment, nutrients, pesticides, pathogens, and organic enrichment. Agriculture here refers to irrigated and non-irrigated crop production, confined animal feeding operations, grassland and rangeland. Table 5.3 lists the potential pollutants generated by different agricultural activities.

Table 5.3: Agricultural activities and potential related pollutants (Krivak, 1978)

	Crop Production		Animal Production	
Pollutant	Irrigated	Non-irrigated	Confined	Pastured/Grazing
Sediment	o	x	o	x
Nutrients	o	o	x	o
Salts	x	-	o	-
Organics	o	o	x	o
Pesticides	o	o	-	-
Pathogens	-	-	o	o

Note: x indicates a principal problem, o indicates a secondary problem and - indicates a minor problem, if any.

Urban development has taken a new form in the last several decades called urban sprawl, characterized by low density residential development. Nonpoint source pollutants associated with urban development are sediments, nutrients and pathogens originating from site development, sewer and wastewater, and fertilizer and pesticides that are used for greening the lawns. Prime examples of urban development are exurbanization (i.e., residential developments in large lots in rural settings) (Nelson, 1992; Davis et al., 1994) and the development of hobby farms associated with exurbanization. The examples of hobby farms include horse and other animal farms, orchard and small cash crop farms, which blurs the traditional distinction between agricultural and urban NPS.

Wildlife such as deer, raccoons and geese are another source of pollutants. The wastes deposited by wildlife contain nutrients and pathogens, which are all potential water pollutants. The protective regulations on deer, such as the limitations placed on deer hunting, greatly contribute to deer population growth. The well-maintained lawns in low density residential areas, commercial and industrial complexes and recreational facilities, such as golf courses creates the perfect habitat for the Canada goose.

Although the contribution of individual sources may be small, the cumulative effect of nonpoint sources is large. Because all the pollutants generated by agriculture, urban development and wildlife are accumulated in land surface, the natural hydrological processes, such as runoff and percolation during a storm event, will eventually transport these pollutants into nearby streams and groundwater causing water pollution.

The transport of pollutants from the source to streams (receptors) is not a simple and straightforward process. It is affected by weather and natural resource conditions, such as topography, soils and land uses during the pathway. Under certain ideal weather and natural resource conditions, the risk of transporting pollutants from sources to receptors could be limited. However, the human interactions with nature tend to increase such risk. As discussed previously, land use activities in the watershed have caused significant hydrological alteration and in some ways accelerated the extent and the speed of pollutant transport from sources to streams.

The following sources of pollutants, including sediment, nutrients and pathogens in the Neshanic River Watershed, were identified and assessed: (1) crop and hay production; (2) livestock production; (3) wildlife; and (4) urban land use. In crop production, the impacts of tillage and fertilizer (both synthetic fertilizer and animal manure) on water quality are considered. Impacts of grazing and direct access to streams are considered for livestock production. Impacts of urban land uses include fertilizer applications on lawns and failing OSDS in low density and rural residential areas. These sources are described below in detail and their impacts and relative contribution to the water quality problems in the watershed were assessed using the SWAT biophysical simulation model. SWAT simulates the transport process for pollutants from the sources to receptors given the weather and natural resource conditions in the watershed. The SWAT model utilizes 2002 NJDEP land use/cover data, NJDEP 10-meter DEM and streams data and the SSURGO soil survey database maintained by NRCS.

5.5.1. Crop and Hay Production

The Neshanic River Watershed had the highest percentage of agricultural lands among all watersheds in the Raritan River Basin. According to the NJDEP land use/cover, about 36.4 percent of the watershed (7,221 acres) was in agricultural lands during 2002. This included the following subcategories with their 4-digit classification codes in parenthesis: cropland and pastureland (2100); confined feeding operations (2300); orchard/vineyard/nursery/horticultural areas (2200); and other agriculture (2400). The 2002 agricultural land class did not include agricultural wetlands (modified) (2140) and former agricultural wetlands (2150), which were counted as wetlands, but were frequently in agricultural uses. Including both agricultural wetlands (modified) and former agricultural wetlands in agricultural lands increases total agricultural lands to 7,726 acres or 39 percent of the watershed in 2002.

The NJDEP land use/cover classification system does not distinguish the agricultural types (i.e., specific crops and types of animals) within cropland and pastureland (2100), the dominant class of agricultural lands. In order to understand the water quality impacts of agriculture in the watershed, the detailed pattern of agricultural land use has to be identified. Agricultural land use surveys were conducted in 2007 and 2008. Using maps and aerial photographs, an agricultural specialist and volunteers were able to identify the specific crops and types of animals in fields. In cases where the data were difficult to collect due to limited access, best educated guesses were made. The agricultural land use survey data were combined with the 2002 NJDEP land use data to estimate detailed agricultural land use patterns in the watershed. The final estimate of agricultural lands in the watershed is about 8,074 acres, of which 58 percent (i.e., 4,662 acres) is for row-crop production, such as corn, soybean, wheat and rye. There are about 2,420 acres of hay fields (i.e., 30 percent of agricultural lands) that produce timothy and other types of hay to support livestock operations in the watershed and the neighboring communities. Also, there are 892 acres of pasture that are used for livestock grazing. The remaining 100 acres are in orchards and nurseries.

In addition to the spatial pattern of agricultural land uses, crop or plant-specific information on tillage, fertilizer, pesticide applications, and harvest, and animal grazing schedules are required to run the SWAT model. Such information was collected through interviews with several individual farmers in or near the watershed and then generalized to represent the conditions in the watershed. The latter were then discussed and finalized through several meetings with agricultural specialists in RC&D, NJDA and HCSCD and the resource conservationists from NRCS who have worked in the region. The choices of farming practices depend on farmers' experiences and specific resource conditions, which makes data collection on farming practices difficult. The information used in the SWAT model does not capture details of farming practices, but does reflect the general farming conditions in the watershed. Specific farming operations and their schedules are in the SWAT modeling report.

Given the large area of the watershed in agricultural land uses, the management of row crops, hay and other agriculture has significant implications for water quality and quantity in the watershed. On the negative side, agricultural operations could be sources of sediments that can be carried into stream. In addition, agricultural fertilizers and pesticides not used by the crops and plants could be carried by runoff into streams. On the positive side, all agricultural lands have pervious surfaces, which allow water to infiltrate into the ground during a storm event, which reduces surface runoff.

5.5.2. Livestock Production

Livestock in the watershed include horses, cattle, sheep, goats and many other small animals. There are no large-scale confined animal feeding operations in the watershed. Small-scale livestock operations can have significant impacts on water quality in the watershed. Nutrients, fecal coliform and *E. coli* in manure could end up in the streams because of improper manure management and manure applications in row-crop and hay production. In addition, livestock grazing in pastures could cause water quality degradation via soil erosion and sediment transport to streams. Animal access to streams could further expose the streams to water quality degradation.

Accurately counting the type and number of livestock in the watershed is very difficult. To estimate the impacts of livestock production on water quality in the watershed, this project primarily focused on the impacts of large livestock (i.e., horses, beef cattle and dairy cows) on water quality because they generate much more manure than other animals. The total number of cattle and horses was estimated using the animal density in Hunterdon County obtained from the 2007 Agricultural Census published by the National Agricultural Statistics Service (NASS) and the total agricultural area of the watershed. The project further assumes that cattle and horses are annually active and evenly distributed among the pasture land in the watershed. Manure production, in terms of nutrient and pathogen loads in the Neshanic River Watershed, was estimated based on the total number of cattle and horses and manure production, fecal coliform content and loading rates of cattle and horses determined from the daily manure production and fecal coliform amounts for typical livestock estimated by ASAE (2003). There is no established measurement for *E. coli* in animal manure. *E. coli* content of animal manure was assumed to be 62.5 percent of fecal coliform for those livestock animals (IDNR, 2006). Additional information on the nutrient loads from manure is based on the percentages of nutrient content in dry manure given in various fertilizer databases.

5.5.3. Wildlife

Wildlife in the Neshanic River Watershed include, but are not limited to deer, raccoons, rodents, geese and ducks. There is no wildlife inventory for the watershed. Deer and geese are considered the dominant wildlife in the watershed because of their pervasive presence. White-tailed deer are found throughout New Jersey except in the most urbanized areas of the state. The estimated annual deer population during 1984 and 2006 ranged from 120,000 to 200,000 (i.e., a density of 13.7 to 22.9 deer per mi^2) (NJDEP, 2008b). The total number of deer in the watershed is estimated assuming a deer density of 20 deer per mi^2. The total number of deer is estimated to be 620 in the watershed.

Canada geese have a clear preference for tender, mowed and fertilized turf grass, although they also feed heavily on small grains, such as corn and soybeans, during the fall and winter. They prefer to feed in large open areas with few obstructions that give the birds a 360-degree view of potential predators. Giant Canada geese differ from seasonally migrating interior Canada geese. The NJDEP Division of Fish and Wildlife conducts a breeding population survey each spring when only resident species are present because the migrating geese have already traveled to northern breeding grounds. The population of "resident" Canada geese in New Jersey was estimated at approximately 98,000 or 11.2 per mi^2 (NJDEP, 2010b). Suburban development leads to an increase in lawns, recreational fields and other grassy areas that are suitable habitat for Canada geese. As suburban development continues in the watershed, the population of resident geese is expected to increase. Considering the seasonally migrated interior Canada geese during winter and the hatching and growing of young residential Canada geese during spring and summer, the annual average goose density in the watershed is assumed to be twice the number of resident geese–about 22 geese per mi^2.

The numbers of and amount of manure produced by animals are used to estimate the nitrogen, phosphorus, fecal coliform and *E. coli* loads to streams from wildlife. Manure production for deer and goose come from the TMDL study in the Salt Creek watershed in Cook County, Illinois (WHPA, 2004). Daily fecal coliform loading rates of deer and goose come from the TMDL for Pathogens in Beeds Lake Franklin County, Iowa (IDNR, 2006). Nutrient loads are based on the percentages of nutrient content in dry manure. Since various fertilizer databases do not reflect wildlife animals, such as deer and geese, it is assumed that the dry manure from deer and geese have the same percentages of nutrient content as from goats and ducks, respectively.

5.5.4. Urban Land Uses

Urban land uses in the Neshanic River Watershed include high, medium, low density and rural residential areas, commercial, industrial, recreational, transportation and other urban land uses. The acreages in various urban land use types are given in Table 5.4. The rural residential area is the dominant urban land use and comprised almost 64 percent of all urban uses.

Table 5.4: Areas and percentages of urban land uses in the Neshanic River Watershed, 2002

NJDEP Classification	Land Use Type	Area (Acres)	Percentage (%)
1110	Residential, High Density Or Multiple Dwelling	96.18	1.58
1120	Residential, Single Unit, Medium Density	216.70	3.56
1130	Residential, Single Unit, Low Density	382.04	6.27
1140	Residential, Rural, Single Unit	3,897.06	63.96
1200	Commercial/Services	290.34	4.76
1300	Industrial	78.24	1.28
1400	Transportation/Communication/Utilities	16.77	0.28
1410	Major Roadway	43.34	0.71
1462	Upland Rights-Of-Way Developed	12.99	0.21
1463	Upland Rights-Of-Way Undeveloped	90.45	1.48
1499	Stormwater Basin	93.05	1.53
1700	Other Urban Or Built-Up Land	452.20	7.42
1710	Cemetery	14.52	0.24
1800	Recreational Land	375.57	6.16
1804	Athletic Fields (Schools)	33.99	0.56
Total	All urban land uses	6,093.42	100.00

Runoff from urban areas is a potential source of nutrients and pathogens for streams and rivers. Fertilizers applied to lawns can be carried into streams by stormwater during a storm event. Since many residents in the watershed use OSDSs to treat wastewater, failing wastewater treatment systems in the watershed could contribute nutrients and pathogens to the streams, which is discussed in detail in the next section. Since the watershed has experienced rapid urbanization during the last two decades, another water pollution source is improper management of sediment and runoff during the land development and construction periods. Many regulatory measures and ordinances are utilized to deal with the control of sedimentation and runoff during construction. Additional nutrients and bacteria sources from urban lands include pet feces, urban wildlife, sanitary sewer cross-connections and deficient solid waste collection.

To assess the water quality impacts of urban land uses in the watershed using SWAT, those land uses in Table 5.4 were regrouped into eight different land use types embedded in SWAT model based on the similarity of hydrological responses: high (1110), medium (1120), medium/low residential (1130), low density residential (1140), commercial/industrial (1200 and 1300), institutional (1800 and 1804) transportation uses (1400, 1410, 1462, and 1463), and other urban areas (1499, 1700 and 1710). Each of the 8 urban land use types was further distinguished into pervious (e.g., lawns) and impervious (e.g., built-up areas) areas to capture different hydrological processes and water quality impacts in those areas. A set of linear regression equations developed by the USGS (Driver and Tasker, 1988) were used to estimate storm runoff volumes and sediment and nutrients loads from impervious sections. Lawns are assumed to be in pervious sections. Fertilizer application rates on lawns were estimated based on information provided by local landscaping companies.

5.5.5. Onsite Disposal Systems (OSDSs) for Wastewater Treatment

Household OSDSs for wastewater treatment have the potential to release nutrient and bacteria to streams due to system failures caused by improper maintenance, malfunctions and/or close proximity to streams. Although most households in the watershed rely on OSDSs for sewer and waste water treatment, there is no inventory of those systems and their operational status in the watershed. Many residents do not know that their wastes are treated by OSDS; they assume all sewer and waste waters are transported by regular municipal sewer systems and processed by municipal waste water treatment facilities. According to the 2007 NJDEP land use data, the watershed contains 2,696 households located in the low density and rural residential areas. Of those households, 1,508 are in SSAs delineated by NJDEP and 1,188 are in the non-SSAs. Assuming one-fifth of the households in SSAs and all households in non-SSAs rely on OSDSs, about 1,490 households are likely have septic systems.

No study clearly estimates how many OSDSs fail or do not properly function in the watershed. Generally, septic system failures occur in older homes. Improper maintenance also increases the failure rate of septic systems. Virginia Department of Environmental Quality (2002) estimated the failing rate of septic systems based on their construction dates. Failing rates were estimated to be 40, 20, and 5 percent for systems built before 1970, during 1970-1989, and after 1989, respectively. Several studies found that 30 percent of all septic systems were either failing or not functioning at all. Based on the construction ages of housing units in the 2000 Census and the failure rates discussed above, the general failure rate for septic systems in Hunterdon County is assumed to be 26.5 percent. Because 10 years have passed since the 2000 Census, a 30 percent failure rate was assumed for failing OSDSs in the watershed, which results in 447 failing OSDSs in the Neshanic River Watershed. Only failing OSDSs close to the streams are likely to directly impact water quality. Of the 447 potentially failing OSDSs, 164 OSDSs are located within the 656 foot (200 meter) buffer zone of the streams and are assumed to have direct impacts on water quality. Nutrient and pathogen loads from failing OSDSs were estimated based on the following assumptions: (1) average number of persons served by each system is 2.8; (2) septic system effluent discharge rate of 70 gallons per person per day; and (3) concentrations in septic tank effluents were 40 mg/l TN, 12 mg/l TP, 1×10^6 cfu per 100mL fecal coliform, and 6.3×10^5 cfu per 100mL *E. coli*. These assumptions come from Indiana's Salt Creek *E. coli* TMDL study (WHPA, 2004).

5.5.6. Source Area Assessment Based on Water Quality Monitoring Data

As discussed previously, the source areas of pollutants of concern were assessed based on water quality data for seven monitoring stations in the watershed. Monitoring sites are shown in Figure 5.8. Each of the monitoring stations represents the outlet of a subwatershed in the Neshanic River Watershed. To identify which subwatersheds contribute the most pollution to the Neshanic River, data from the monitoring stations were used to determine the annual pollutant load and the annual pollutant loading rate for the seven subwatersheds. [1] The subwatersheds were then ranked by their annual pollutant load.

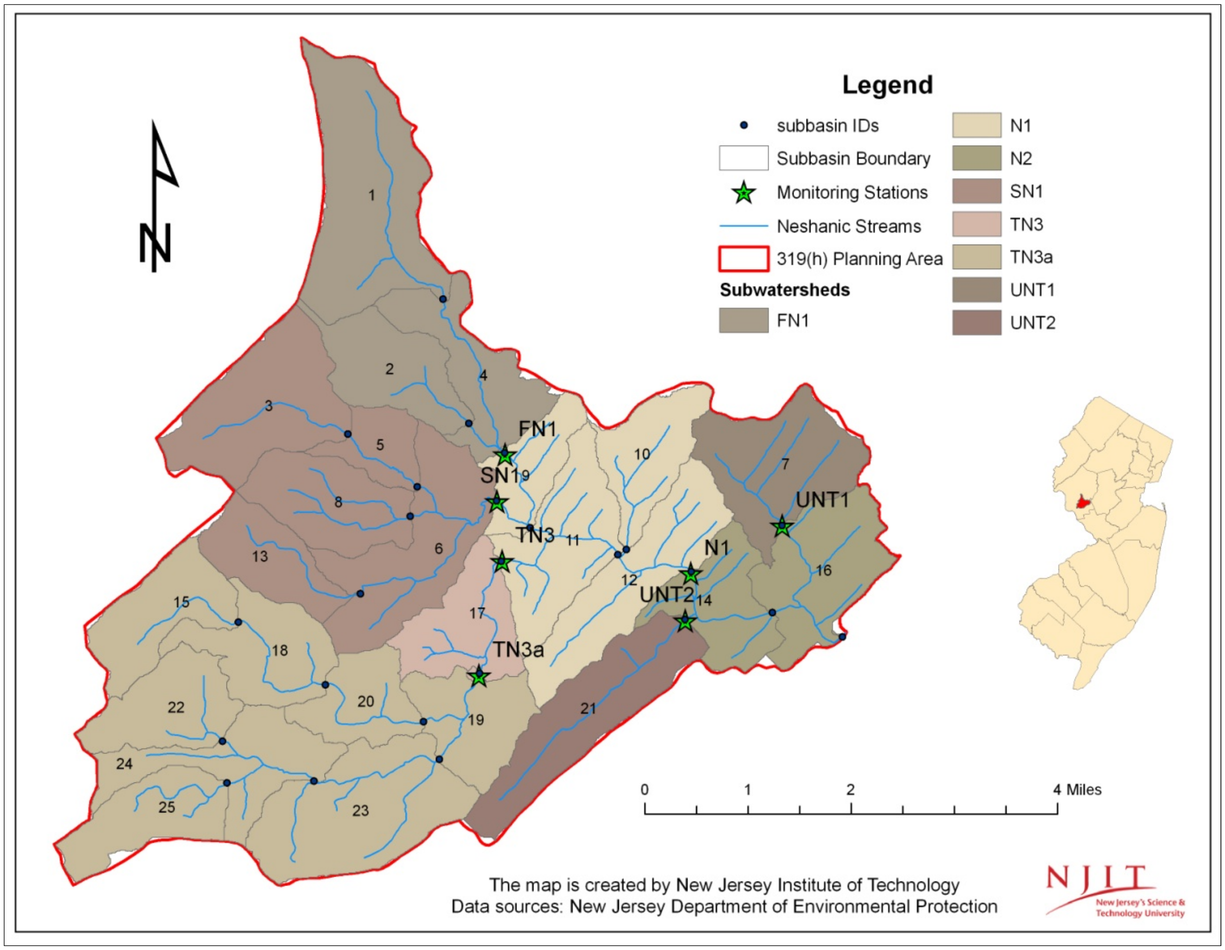


Figure 5.8: Water quality monitoring stations, subbasins and subwatersheds in the Neshanic River Watershed

The two primary pollutants of concern in the watershed are TP and fecal coliform; the latter is an indicator of pathogen contamination. Flow and pollutant concentrations were used to calculate the load for each sampling event at each monitoring station. Annual total load for each subwatershed was determined by averaging the daily loads and multiplying the average daily load by 365 days. Annual load of TP is measured in pounds per year. Annual load of fecal

[1] For streams that have multiple sampling locations, the load measured at the upstream station was subtracted from the load measured at the downstream station to determine the pollutant load contributed by the watershed located between the two sampling stations.

coliform is measured in colonies per year. Since each subwatershed has a different size, the annual loads were then normalized by dividing them by the number of acres in the subwatershed. This resulted in a TP loading rate in pounds per acre per year and a fecal coliform loading rate in colonies per acre per year.

Subwatersheds were ranked from highest to lowest according to the normalized pollutant loading rate. The resulting ranking is given in Table 5.5. For TP, subwatershed N1 ranked the highest, followed by subwatershed TN3. Subwatershed FN1 ranked the lowest in terms of TP loading. Subwatershed N1 also ranked the highest for fecal coliform, followed by subwatershed UNT2. Subwatershed TN3 ranked the lowest in terms of the fecal coliform loading. These rankings can be used to prioritize the implementation of stormwater and agricultural BMPs in the watershed.

Table 5.5: Ranking of the subwatersheds by normalized annual pollutant loads

Subwatershed	FN1	SN1	TN3	TN3a	UNT1	UNT2	N1
Drainage area (ac)	2,897.15	3,817.72	659.43	5,828.73	956.43	997.3	2,581.23
Total Phosphorus							
Annual Load (lbs/yr)	154.79	364.47	186.11	385.17	74.80	104.68	1159.59
Annual Load Rate (lbs/ac/yr)	0.05	0.10	0.28	0.07	0.08	0.10	0.45
Ranking	7	4	2	6	5	3	1
Fecal Coliform							
Annual Load (colonies/yr)	2.23E+13	2.56E+13	2.42E+12	4.51E+13	4.56E+12	2.89E+13	1.94E+14
Annual Load Rate (colonies/ac/yr)	7.70E+09	6.71E+09	3.67E+09	7.74E+09	4.77E+09	2.90E+10	7.52E+10
Ranking	4	5	7	3	6	2	1

5.5.7. Source Area Assessment Based on SWAT Modeling

The SWAT model gives a more comprehensive assessment of the source areas of water pollutant loads at a much more detailed level than the subwatershed ranking described in the section above. It was used to quantify the pollutant loads originating in each source area and to assess the extent to which various BMPs reduce pollutant loads in the watershed. Application of the SWAT model involved delineating 25 subbasins in the Neshanic River Watershed as shown in Figure 5.8. Subbasins were further divided into 625 HRUs based on land use, soil type and topography so that each HRU has a unique combination of land use, soil type and slope.

Table 5.6 presents the source contribution of average annual loads for TN and TP in the watershed. It appears that TN and TP loads to the streams originate primarily from the agricultural land sources in the watershed, which includes row crops and other agriculture. Row crops, such as corn, soybeans, wheat and rye, account for about 64 percent of the TN load and about 44 percent of the TP load. Other agricultural production, including hay and pasture, accounts for about 12 percent of the TN load and about 17 percent of the TP load. Lawn care fertilizers in urban lands contribute about 11 percent of the TN load and about 17 percent of the TP loads and are the second largest land source of the TN and TP loads to the streams. The other minor land sources include forest and wetlands, which discharge nitrogen and phosphorus into the environment that eventually ends up in the streams.

In addition to the land sources discussed above, there are several other sources of nutrient loads to streams, including livestock access to streams, failing OSDSs and streams themselves. Livestock access to streams results in the deposition of animal manure in streams. The nutrients in the wastewater from failing OSDSs may also end up in the streams. Stream contribution is much more complicated than livestock and failing OSDSs. Nutrients may be detached from the eroded sediments from streambanks and resurfaced sediments from the bottom of the streams. In addition, biological processes related to algae growth can significantly affect the TN and TP in streams. The algae activities in the stream may absorb or contribute TN and TP to streams. Results of the SWAT model indicate that algae activities in Neshanic streams generally absorb TN and TP. As shown in Table 5.6, streams are a minor source of nutrient loads, contributing only 1.77 percent of the annual load of TN and only 5.01 percent of the annual loads of TP. Nutrient loads from livestock access to streams and falling OSDS systems are generally minor.

Table 5.6: Average annual loads of TN and TP in the Neshanic River Watershed

Sources	Total Nitrogen (TN)			Total Phosphorus (TP)		
	Average Load (lbs/ac/yr)	Total Load (lbs/yr)	Source Contribution (%)	Average Load (lbs/ac/yr)	Total Load (lbs/yr)	Source Contribution (%)
Urban	3.84	24,461	10.68	0.55	3,504	28.53
Row crop	33.92	146,976	64.15	1.24	5,351	43.62
Other agriculture	8.19	27,962	12.20	0.61	2,068	16.86
Forest	2.73	11,292	4.93	0.07	301	2.45
Wetland	10.85	13,468	5.88	0.13	165	1.34
Total Land Contribution		224,159	97.84		11,389	92.83
Livestock access to streams		111	0.05		31	0.25
Failing OSDS systems		784	0.34		235	1.92
Streams		4052	1.77		614	5.01
Total		229,106	100.00		12,269	100.00

Human and animal wastes are sources of pathogens in the Neshanic streams. Table 5.7 presents the approximate source contribution of average annual loads of fecal coliform and *E. coli*. Livestock access to streams and falling OSDS systems contribute significant amounts of pathogens to the streams. Failing OSDS systems are the largest source for pathogens and contribute almost half of the pathogenic loads to the Neshanic River streams. The second largest source of pathogens is manure applied to row crops, which accounts for about 31 percent of the annual pathogenic load to the Neshanic River streams. Livestock access to streams contributes about 19 percent of the annual pathogenic loads in the watershed, which makes it the third largest source of pathogens. Livestock grazing on pastures contributes about 2 percent of the pathogenic load. Another minor source of pathogens is wildlife, including geese and deer.

Table 5.7: Average annual loads of fecal coliform and *E. coli* in the Neshanic River Watershed

Sources	Fecal Coliform		*E. Coli*	
	Load (cfu/yr)	Contribution (%)	Load (cfu/yr)	Contribution (%)
Failing OSDS	7.20E+13	45.94	4.54E+13	46.09
Livestock access to streams	2.96E+13	18.90	1.85E+13	18.81
Manure application	4.91E+13	31.34	3.08E+13	31.25
Livestock grazing	3.85E+12	2.45	2.41E+12	2.45
Wildlife	2.15E+12	1.37	1.37E+12	1.40
Total	1.57E+14	100.00	9.84E+13	100.00

Table 5.8: Average annual loads for nutrients and pathogens by subbasin and ranks of subbasins based on average annual loads

Sub-basin	Area (acres)	Drainage area (acres)	Total Nitrogen		Total Phosphorus		Fecal Coliform		*E. Coli*	
			Load (lbs/ac)	R*	Load (lbs/ac)	R*	Load (cfu)	R*	Load (cfu)	R*
1	1480.2	1480.2	4.93	23	0.27	25	1.8E+14	18	1.1E+14	18
2	689.4	689.4	7.27	17	0.60	15	1.6E+14	19	1E+14	19
3	1082.3	1082.3	5.23	22	0.36	24	3E+14	13	1.9E+14	13
4	726.5	2891.1	7.14	18	0.64	13	1.4E+14	20	9E+13	20
5	333.6	1413.4	8.00	16	0.54	18	8.3E+13	21	5.2E+13	21
6	1109.5	3830.1	10.15	12	0.56	17	1.8E+14	17	1.1E+14	17
7	956.3	956.3	6.00	21	0.61	14	3.4E+14	12	2.1E+14	12
8	738.8	738.8	8.46	15	0.46	20	2E+14	16	1.2E+14	16
9	434.9	7141.3	27.32	2	0.94	2	4.2E+16	3	2.6E+16	3
10	580.7	580.7	6.28	19	0.68	12	2.4E+15	7	1.5E+15	7
11	879.7	14529.8	12.06	10	0.72	11	7.4E+14	10	4.6E+14	10
12	958.8	16061.8	13.36	9	0.85	6	2.4E+16	5	1.5E+16	5
13	556.0	556.0	4.89	24	0.45	21	5.9E+14	11	3.7E+14	11
14	622.7	17668.0	9.68	13	0.58	16	7.4E+13	22	4.6E+13	22
15	664.7	664.7	6.28	20	0.43	22	5.2E+13	23	3.2E+13	23
16	879.7	19521.3	17.19	5	1.00	1	2.8E+15	6	1.7E+15	6
17	652.4	6498.9	14.39	8	0.90	5	2.9E+16	4	1.8E+16	4
18	709.2	1373.9	39.59	1	0.75	7	1.3E+17	1	8.2E+16	1
19	625.2	5831.7	15.29	7	0.74	9	4.4E+13	25	2.7E+13	25
20	511.5	1885.4	15.99	6	0.91	4	2.1E+15	8	1.3E+15	8
21	995.8	995.8	4.50	25	0.42	23	2.7E+14	15	1.7E+14	15
22	654.8	654.8	9.06	14	0.52	19	4.7E+13	24	3E+13	24
23	1272.6	3335.9	11.66	11	0.73	10	1.1E+15	9	7E+14	9
24	775.9	2053.4	20.72	4	0.74	8	2.9E+14	14	1.8E+14	14
25	622.7	622.7	26.63	3	0.93	3	8.3E+16	2	5.2E+16	2
Total	19513.9	19521.3	11.74		0.63		3.2E+17		2E+17	

Note: R* indicates the rank for subbasins.

Table 5.8 presents the average annual loads and ranks for both nutrients and pathogens by the 25 subbasins in the watershed. Average annual load for a subbasin includes loads from all sources in that subbasin for the specific pollutants. Since the nutrients are primarily from land sources, subbasins are ranked by the average annual load per acre. For TN, subbasin 18 generates the most TN load per acre to streams, followed by subbasins 9, 25 and 24. Subbasin 21 generates the smallest TN load per acre. Subbasin 16 generates the largest TP load per acre and is assigned the highest rank based on the average TP load, followed by subbasins 9, 25 and 20. Subbasin 1 generates the least TP load per acre to the stream. Since pathogenic sources are site specific, such as where failing OSDSs are located, the livestock is present and the manure is applied, it is more reasonable to rank subbasins based on total annual pathogenic loads from the subbasins. Since fecal coliform and *E. coli* are closely related, subbasin rankings for both pathogens are the same. Subbasin 18 generates the largest pathogenic load and is the highest ranked subbasin for pathogenic loads, followed by subbasins 25, 9 and 17. Subbasin 19 generates the smallest pathogenic load to the streams in the watershed.

5.6. **Soil Erosion and Sedimentation**

Soil erosion and sedimentation are two different but interrelated processes and concepts. Soil erosion is the process of weathering and transport of soil particles in the environment. Sedimentation occurs when eroded soil particles are deposited and transported to nearby land and streams. The primary causes of soil erosion and sedimentation are ice, water and wind. Both soil erosion and sedimentation are natural processes, but are often accelerated by intensive land use activities, such as agriculture, road construction and urban development. For example, urban development increases runoff and drainage density, which results in flashy streamflow as discussed previously. The energy embedded in flashy streamflow not only causes flash flooding, but also erodes streambanks, which delivers substantial amounts of sediment to streams. A notable example of soil erosion is in the Walnut Brook, where a streambank stabilization project was conducted in 2009 under this 319 grant contract.

From a water quality perspective, sediment entering the streams is a concern because the sediment in water, measured as TSS, is an important water quality indicator. Many other water pollutants, such as nutrients, pesticides and pathogens, are also attached to sediments. Potential sources of the TSS are land, streambank, and deposited sediment in the bottom of streams. This project used several methods to quantify soil erosion and sedimentation in the Neshanic River Watershed, which are briefly summarized below.

5.6.1. Soil Erodibility

Soil erodibility measures the soil erosion potential of a specific site. Soil erosion not only results in less productive soil, but also is linked to many water quality problems, such as sediment loads and nutrients and pesticides attached to the soil particles transported to streams. In this project, the NRCS soil erodibility index (EI) was used to approximate soil erodibility. EI provides the numerical expression of the potential for a soil to erode that considers the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the more susceptible the soil is to erosion. EI equals the potential erodibility for the soil (RKLS) divided by the soil loss tolerance value (T) following Wischmeier and Smith (1978):

$$EI = \frac{RKLS}{T}, \quad (1)$$

where R measures rainfall and runoff intensity, K is soil erodibility that indicates the susceptibility of the soil to water erosion, L is slope length and S is slope steepness. T is the soil loss tolerance factor defined as the maximum amount of soil erosion that can occur without degrading the quality of a soil as a medium for plant growth. EI is usually estimated for each soil type and used to define the highly erodible lands mapping units in NRCS soil surveys. Soils with an EI greater than 8 are considered to be highly erodible (NRCS, 2008). EI was estimated for each 10-m grid in the watershed.

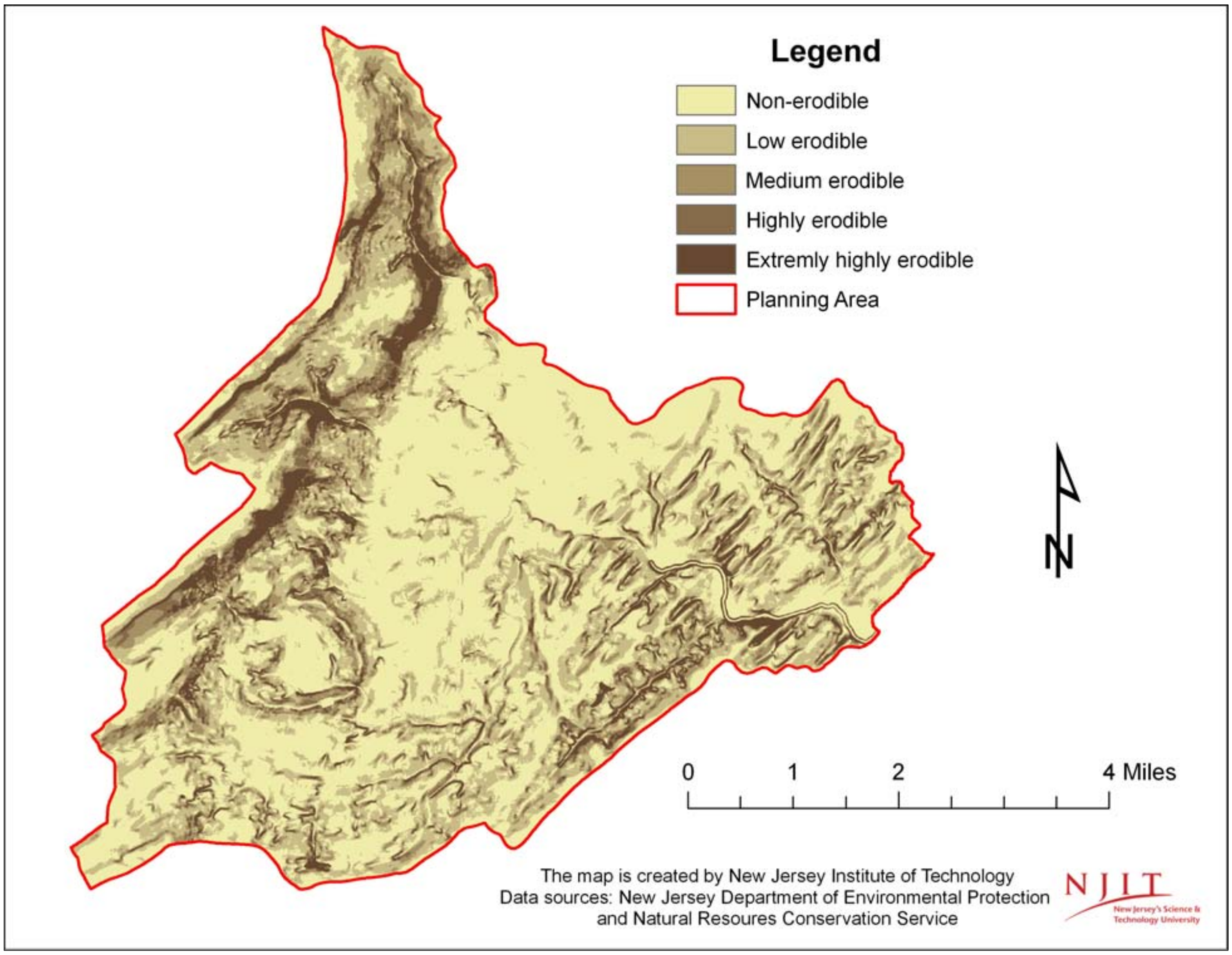


Figure 5.9: Location of soil erodibility classes in the Neshanic River Watershed

Soil erodibility was grouped into five classes based on the estimated EI values. Grids with EI values less than or equal to 2 were considered to be non-erodible. The low erodibility class includes grids with EI values between 2 and 5 and the medium erodibility class grids with EI values ranging from 5 to 8. Two high soil erodibility classes are defined: grids with EI values between 8 and 12 are considered to be highly erodible and grids with EI values greater than 12 are considered to have extremely high erodibility. The non-erodible, low erodibility and medium erodibility classes comprise about 48, 28 and 11 percent of the watershed, respectively. About 6 and 7 percent of the watershed are in the highly and extremely high erodibility classes, respectively. Figure 5.9 shows the location of the five different soil erodibility classes in the watershed. The highly erodible lands tend to be located in the upper part of the watershed along the northwestern ridge of the watershed as well as the lower portion of the watershed where the terrain is steep. Agricultural lands in the watershed are primarily in the non-erodible, low or medium erodibility class (54, 29 or 10 percent, respectively). Only about 5 and 3 percent of the agricultural lands are in the high and extremely high erodibility classes, respectively. In general, the soil erodibility assessment indicates that 87 percent of the watershed has soils in the non-erodible, low erodible or medium erodible classes.

5.6.2. Geomorphic Evaluation of Streams

While soil erodibility assesses soil erosion potential of land, the geomorphic evaluation examines the processes of bank erosion and channel sedimentation, meander evolution, sediment budgets and connectivity as a means of understanding how water and sediment are related to channel form and function. The Rosgen Stream Classification System and Schumm's 1984 Channel Evolution Model (CEM) were used to assess the streams in the Neshanic River Watershed. Based on the simplified Rosgen analysis, several typical stream types were identified within the watershed as shown in Table 5.9.

Table 5.9: Rosgen analysis for Neshanic River subwatersheds

	Sampling Stations						
	FN1	SN1	TN3	TN3a	N1	UNT1	UNT2
Single Threaded Channels	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Entrenchment Ratio	Moderate	Slight	Slight	Entrenched	Slight	Slight	Slight
Width/Depth Ratio	<12	<12	>12	<12	<12	<12	<12
Sinuosity	1.2	2	1.3	1.64	1.16	1.15	1.15
Stream Type	B	E	C	G	C	E	E
Slope	0.014	0.008	0.00125	0.004	0.0022	0.001	0.00675
Channel Material	Clay/Silt	Clay/Silt	Clay/Silt	Clay/Silt	Silt/Clay	Clay/Silt	Clay/Silt
Stream Classification	B6c	E6	C6	G6c	C6	E6	E6

Type B is a moderately entrenched, moderate gradient, riffle dominated channel with frequently spaced pools. This stream type has a very stable plan and profile with stable banks. Type C is a low-gradient, meandering stream containing point-bars, riffle/pools and alluvial channels within a broad, well-defined floodplain. This type of stream has a fairly stable plan and profile. Type E is a low-gradient, meandering riffle/pool stream with a low width/depth ratio and little deposition; it is very efficient and stable. Type E streams have a high meander width ratio. Type G is an entrenched "gully" step/pool stream with low width/depth ratio on moderate gradients. This type of stream is unstable with grade control problems and high bank erosion rates (Rosgen, 1994).

Although stream types B, C and E are stable, streams could undergo morphological changes due to various alterations in the watershed, such as increases in urbanization or changing farming practices. A stream can start as Type C, a very stable system, but can change to Type G with downcutting and then change to Type F through widening, ultimately changing back to Type C, a stable condition with a connected floodplain and terracing. These evolutions are predominately caused by changes in land use in the upper watershed.

Schumm et al. (1984) developed a five-stage CEM to describe the systematic response of a channel to base level lowering, encompassing conditions that range from disequilibrium to a new state of dynamic equilibrium. The CEM illustrates how a stable channel (Stage I) can become unstable through incision (Stage II) and widening (Stage III) and then gradually aggrading (Stage IV) and becoming stable again (Stage V). CEM was applied to 15 locations in the watershed to evaluate the stages that the channels are experiencing during the channel evolution process. Figure 5.10 shows the 15 locations where CEM was applied and the stages of the reaches at those locations.

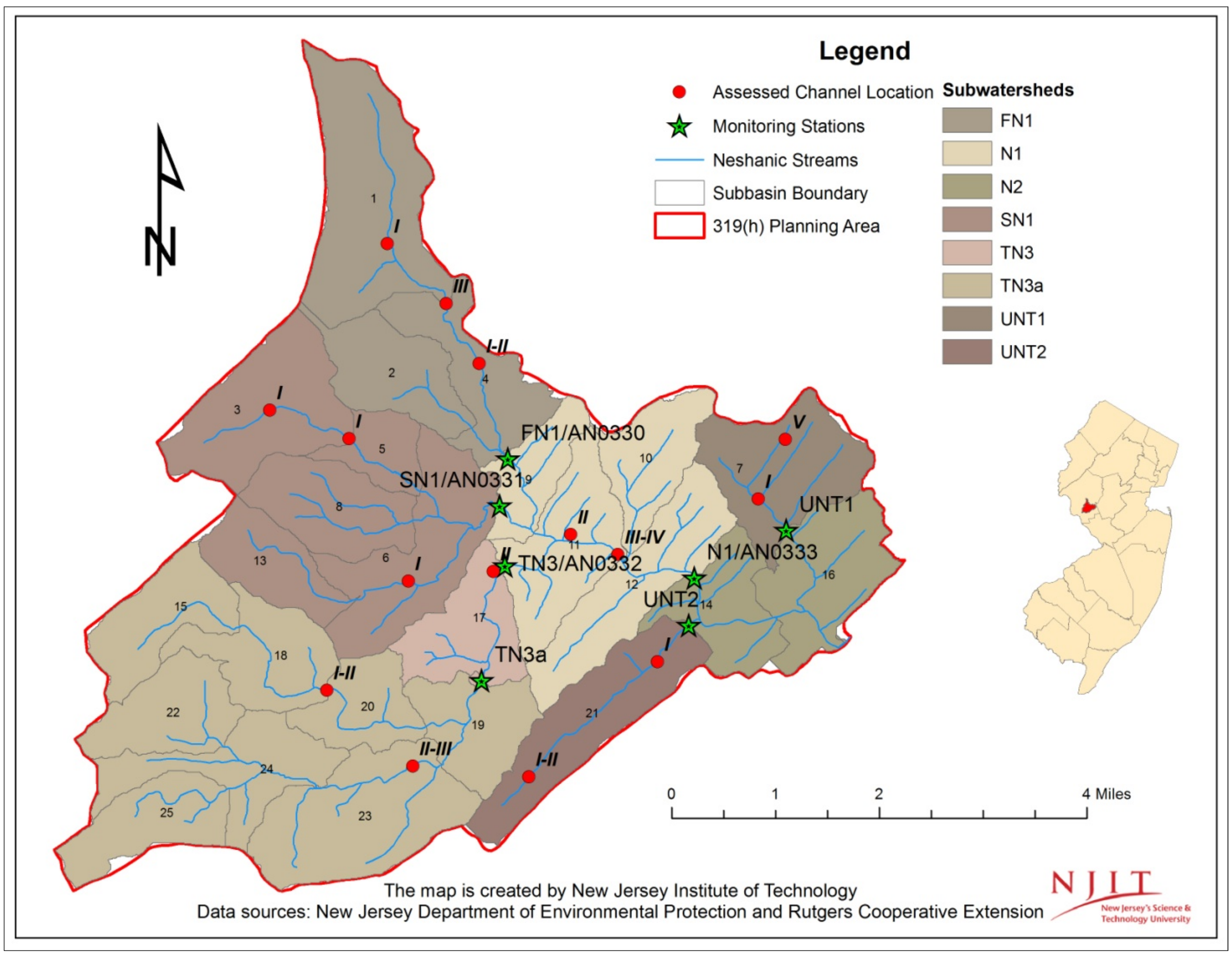
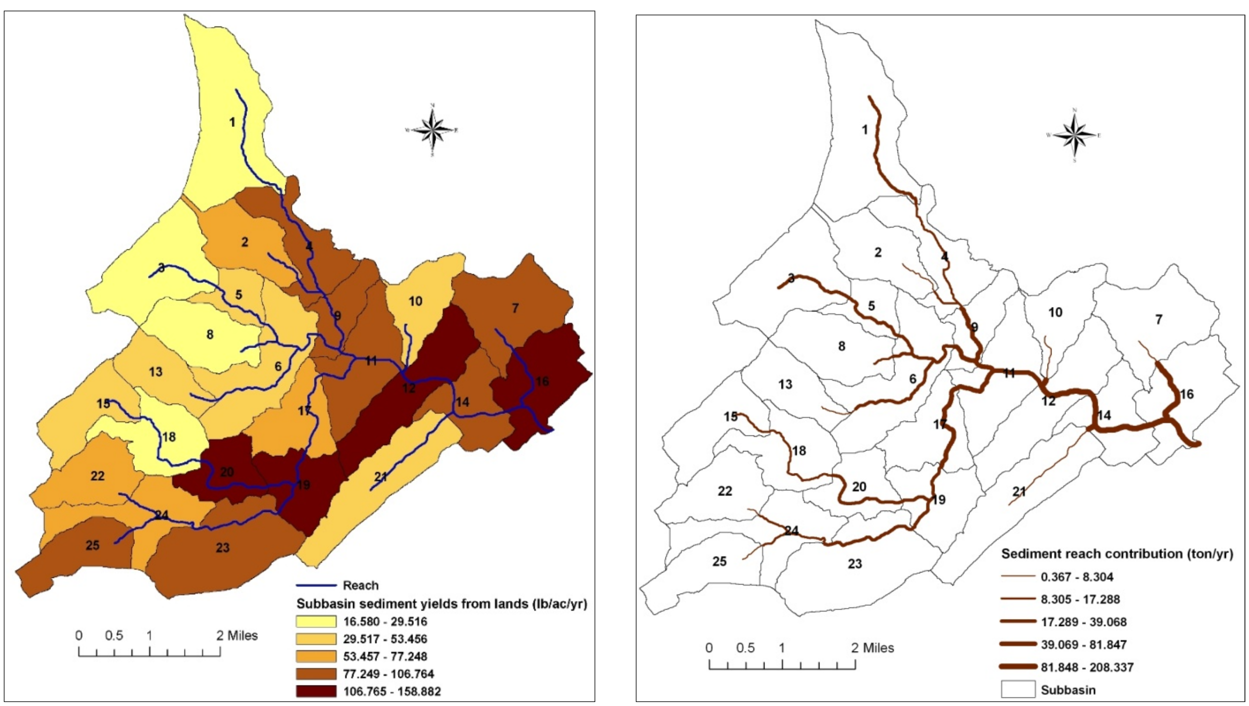


Figure 5.10: Channel stages at fifteen selected locations in the Neshanic River Watershed

The assessment indicates that streams in the watershed are experiencing dramatic changes. Among the 15 reaches that were assessed, five reaches were assigned Stage I, three were in the transition from Stage I to II, two were in Stage II, one was in the transition from Stage II to III, one was in Stage III, one was in the transition from Stage III to IV and one was in Stage V. The changes in the channel stages are closely associated with suburbanization in the watershed. The stage number of reaches generally tends to be higher as the percentage of agricultural land in the drainage area increases and lower as the percentage of forest land increases with a few of exceptions. Reaches classified in Stage II or III are unstable and can contribute significant amounts of sediment to the streams. Streams in Stage II or III are most likely suffering from higher peak stormwater flows resulting from land use changes in the upper watershed. In most cases, the downcutting and widening seen in Stages II and III can be linked to increases in impervious cover that are directly connected to the stream, resulting in very flashy hydrology.

5.6.3. Source Contributions to Sediment Based on Watershed Modeling

The soil erodibility and Rosgen analyses and the CEM provide qualitatively assessments of soil erosion and sedimentation potential from land and reaches. In contrast, the SWAT model integrates the topography, land use, soil, streams and weather data in the watershed to provide quantitative measures of where and how much sediment is generated in the watershed. Based on current land use and weather conditions in the watershed from 1997 to 2008, the average annual sediment yield is 1,715 tons. Reaches are the primary sediment source and contribute 1,021 tons of sediment per year, which accounts for 60 percent of the total annual sediment load. The remaining 40 percent of annual sediment load, roughly 694 tons, comes from various land uses in the watershed. Of the various land uses in the watershed, row-crop agriculture is the largest land source of sediment, accounting for about 57 percent of the sediment load, followed by urban land (28 percent) and other agricultural lands, such as pasture and hay (15 percent).



A. from land sources B. from reach sources

Figure 5.11: Sediment sources and yields in the Neshanic River Watershed

Figure 5.11 illustrates subbasin sediment yields from land in panel A and from reaches in panel B. It is not surprising that lands with more row-crop production generate higher sediment yields, and are primarily located in the lower part of the watershed along both sides of the First Neshanic River, the Third Neshanic River and the main branch of the Neshanic River. Sediment contribution from reaches increases as the stream order increases. Reaches encompassing first-order streams contribute less sediment than higher order streams, such as the main branch of the Neshanic River. Streambank soil erosion is the primary source of sediments in lower-order reaches. In addition to streambank soil erosion, the sediment deposited in the bottom of streams is a potentially important source of sediment for the higher order reaches. High streamflow with greater velocity could resurface those sediments, especially during the larger storm events.

5.7. **Stream Visual Assessment Protocol (SVAP)**

The SVAP was developed by USDA NRCS to assess the health of streams, identify pollutant sources and determine potential management measures to control pollutant sources based on visual inspection of the physical and biological characteristics of instream and riparian environments of assessed stream reaches. The SVAP assessment is based on a three-page worksheet modified for New Jersey by the RCE Water Resource Program. The SVAP assesses a set of 15 stream condition indicators and assigns each indicator a numerical score relative to reference conditions. Specific indicators include channel condition, hydrologic alteration, riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, insect/invertebrate habitat, canopy cover, manure presence, riffle embeddedness and macroinvertebrates observed, if applicable. This project did not assess macroinvertebrates. Indicators are scored on a scale of 1 to 10, with 1 being the worst and 10 being the best score for an indicator. The indicator scores at each stream reach are averaged to obtain an overall rating for that reach. A score of less than 6.0 is considered "poor", a score of 6.0 to 7.49 is considered "fair", and a score above 7.5 is considered "good." This numerical assessment is complemented by photographs and drawings of the stream reach, as well as notes on visual observations for items such as dumping, manure, runoff or outfall pipes, etc.

All stream-road crossings in the project area were evaluated and about 60 stream reaches at the crossings were identified as potential candidates for SVAP. It was decided that the SVAP would be performed on 42 stream reaches which was done by project team members and volunteers during the period July-October, 2007. Of the 42 sites assessed, 18 scored "poor," 13 scored "fair" and 11 scored "good," as shown in Figure 5.12. Of the five HUC-14 subwatersheds in the project area: HQ Tributary recorded three fair and four poor sites; the Third Neshanic River had three good, two fair and five poor sites; the Second Neshanic River had five good and one fair sites; the First Neshanic River had one good, three fair and three poor sites; and the Main Neshanic River had one good, four fair and six poor sites. Compared to the poor and fair sites, good sites had higher ratings for riparian zones, bank stability, channel condition, pools, in-stream fish cover, canopy cover and invertebrate habitat. Many of the "poor" sites have a stream bed of sand/silt/mud or gravel, while the "fair" and "good" sites have a stream bed of gravel/cobble/boulder. The "poor" sites often scored much lower on pools, channel condition, in-stream fish cover, canopy cover, and invertebrate habitat than the "good" sites.

Observations common to many of the sites include erosion, dry stream and low flow in summer, occasional dumping, exposed drainage pipes and overgrowing invasive plants.

Improving riparian zones and bank stability at the poor and fair sites will, over time, lead to better ratings for many of the other indicators observed in the SVAP assessment. Possible recommended remedies include riparian plantings, added or expanded riparian buffers, streambank stabilization, reconnection to flood plain and removal of invasive plants.

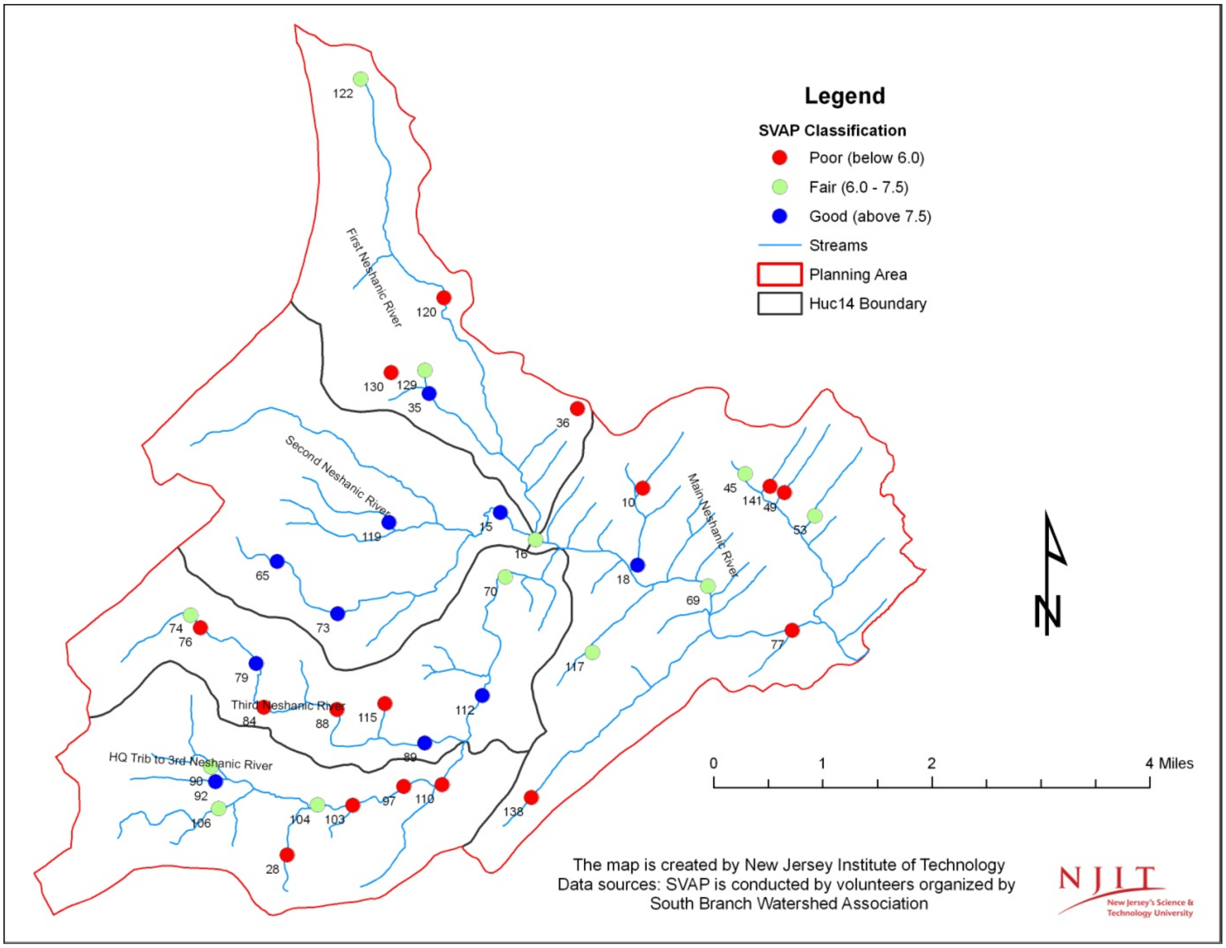


Figure 5.12: SVAP location and assessment results in the Neshanic River Watershed

5.8. Water Quantity

A water quantity concern in the watershed is the increasing occurrence of low/no streamflow during the late summer. Streamflow is the result of a range of climatic and hydrological processes, including precipitation, surface runoff, lateral flow and groundwater recharge and discharge. Since streamflow in late summer is primarily from base flow, low/no streamflow in the late summer may indicate a decline of the base flow contribution to the streamflow.

To better understand the base flow contribution to streamflow, the streamflow is separated into runoff and base flow through three passes by applying a digital filter program (Arnold and Allen, 1999). Each pass produces a pair of time series of daily base flow and runoff. The actual average base flow contribution is generally between the first and second pass averages. The mean fractions of base flows were filtered from the observed streamflow at the USGS Reaville

Gage Station during each decade from 1930 to 2008. The actual base flow contribution was 31-47 percent in the 1930s, 34 -51 percent in the 1960s and 30-46 percent since the 1970s; the lowest percentage of 28-44 percent was reached in the 1990s after which it increased to 30-45 percent in the 2000s. Temporal variability in base flow contribution may reflect increasing conversion of agricultural lands to urban lands. Historical data analysis indicates the low/no streamflow may result from both the seasonal variation and the general decline in base flow caused by the land use changes in the watershed.

Table 5.10: Average annual water yields of subbasins, 1997-2008

Subbasin	Area (acres)	Water yield[a] (inches per year)	Ranking	Surface runoff (%)	Lateral flow (%)	Groundwater discharge (%)
1	1,480.16	21.15	17	67.01	1.89	31.09
2	689.42	21.92	11	70.44	2.65	26.92
3	1,082.32	20.81	21	73.31	0.64	26.05
4	726.49	24.01	1	76.02	0.61	23.37
5	333.59	22.53	7	69.46	0.34	30.2
6	1,109.50	21.74	12	66.49	0.31	33.2
7	956.30	19.91	25	62.01	1.15	36.83
8	738.85	20.70	23	61.16	1.28	37.56
9	434.91	23.98	2	75.48	0.16	24.36
10	580.70	21.03	19	65.31	0.65	34.04
11	879.70	23.58	3	75.3	0.6	24.11
12	958.77	22.28	8	71.58	0.86	27.56
13	555.99	20.71	22	59.09	2.86	38.05
14	622.71	21.19	16	66.9	1.43	31.68
15	664.71	20.92	20	66.6	1.37	32.03
16	879.70	21.69	13	69.23	0.8	29.97
17	652.36	22.93	4	73.84	0.42	25.73
18	709.19	21.11	18	65.84	0.62	33.54
19	625.18	22.55	6	73.56	0.65	25.78
20	511.51	22.67	5	72.88	0.35	26.77
21	995.84	19.96	24	57.62	1.53	40.85
22	654.83	22.23	9	65.37	1.58	33.05
23	1,272.59	22.09	10	71.19	0.71	28.11
24	775.91	21.67	14	70.24	0.29	29.47
25	622.71	21.60	15	66.16	1.68	32.15
Watershed	19,513.91	21.69		68.54	1.02	30.44

a. Water yield is defined as the net amount of water that leaves the subbasin and contributes to streamflow in the main channel (reach).

The SWAT model was used to simulate average annual water yields exported from subbasin outlets during the simulation period 1997-2008. As reported in Table 5.10, average annual water yield exported from the watershed outlet is 21.69 inches per year, of which about 69, 30 and 1 percent are attributed to surface runoff, groundwater and lateral flow, respectively. There are notable spatial variations in water yields. Annual water yields of subbasins range from 20 inches per year to 24 inches per year. Surface runoff is the most important component, contributing 58 to 76 percent of water yield and groundwater is the second most important component, contributing to 23 to 41 percent of water yield. The contributions from lateral flow are small amounting to less than 3 percent of water yield. Such spatial variation in water yield is attributed to the heterogeneous land uses in the watershed.

To better understand the impacts of land uses on water yields, Table 5.11 summarizes the SWAT-simulated annual total and average water yields for different land uses in the watershed for the period 1997-2008. Residential-low density, corn, soybean, timothy, forest-deciduous, and wetlands-forested lands, which each cover areas greater than 1,100 acres, generate water yields of more than 10^8 ft^3 per year. Water yields are lower for land uses covering smaller areas, ranging from 7.119E+06 to 7.535E+07 ft^3 per year. The impacts of land use on water yields were also evaluated by the annual average water yields (i.e., total water yield for a land use divided by the total area of that land use) and rankings of land uses by annual average water yields as shown in Table 5.11.

Table 5.11: Total and annual average water yields by land use, 1997-2008

Land use	Area (acres)	Total water yield (ft^3 per year)	Average water yield (inches)	Ranking
Residential-High Density	92.27	1.03E+07	30.676	3
Residential-Medium Density	190.97	1.79E+07	25.866	6
Residential-Med/Low Density	336.45	2.92E+07	23.903	10
Residential-Low Density	4,899.21	3.15E+08	17.724	19
Commercial/Industrial	256.73	3.05E+07	32.730	2
Institutional	451.27	4.92E+07	30.027	4
Transportation	149.05	1.98E+07	36.516	1
Corn-soybean Rotation	328.95	2.83E+07	23.734	11
Corn	1,834.41	1.60E+08	24.055	9
Soybean	1,847.59	1.65E+08	24.665	8
Rye	321.96	2.10E+07	17.928	18
Hay	748.80	5.18E+07	19.052	17
Timothy	1,671.27	1.19E+08	19.591	16
Pasture	892.46	7.54E+07	23.259	12
Orchard	99.93	7.12E+06	19.626	15
Forest-Deciduous	3,047.60	2.48E+08	22.439	13
Forest-Evergreen	179.55	1.33E+07	20.391	14
Forest-Mixed	902.41	5.76E+07	17.59	20
Wetlands-Forested	1,101.95	1.02E+08	25.37	7
Wetlands-Mixed	139.72	1.39E+07	27.419	5

High-density urban land uses (including transportation, commercial, institutional and high and medium density residential uses), wetlands and row crops (corn and soybeans) generate much higher water yields than other types of land uses. Although all land uses generate high water yields, the mechanism by which water yield is generated can vary with land use. Water yields for urban and row crop land uses come primarily from surface runoff, whereas groundwater discharge is the primary source of water yield from wetlands. The SWAT simulation results clearly indicate that human activities, including both urban development and row-crop production, are major contributors to water yields in the watershed.

5.9. **Discussion**

The water quality monitoring and watershed modeling results presented above clearly establish cause and effect relationships between upland land use activities and downstream water quality. It appears that intensive land use activities, such as urban development and agriculture, have altered watershed hydrology and degraded water quality in the Neshanic River Watershed. Although the assessments are extensive, they are still insufficient relative to the increasing demand for detailed site-specific information. Due to the diffuse nature of nonpoint source water pollution, it is cost prohibitive to monitor water quality in each stream segment and land use in each parcel in the watershed. Certain simplifying assumptions need to be made in modeling the impacts of land use changes on water quality. A watershed model is not an exact representation of real world conditions, but rather a simplified representation of those conditions that is designed to capture the aggregate impacts of land use changes and management practices on watershed hydrology and water quality. The limitations and assumptions of a watershed model do not invalidate model results and model-based conclusions regarding the sources and causes of water pollution in the watershed. Despite its limitations and assumptions, the models utilize rigorous protocols for collecting, processing and analyzing data and results. Furthermore, the similar models have been used in other watersheds in the U.S. and other parts of the world. However, results and conclusions need to be applied and interpreted with caution; they are not intended to be valid for each and every individual parcel in the watershed. Different methods and models and more detailed monitoring and data are required to make site-specific assessments.

6. Pollutant Load Reduction and Allocation

This chapter discusses the pollutant load reductions required to meet the TMDL requirements for the streams in the Neshanic River Watershed. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. The development of TMDLs is required by EPA for all impaired streams. A TMDL for fecal coliform was adopted for the Neshanic River by NJDEP in 2003. It requires 87 percent reduction in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest and agricultural lands (NJDEP, 2003). A total nutrient TMDL for the Raritan Basin that contains the Neshanic River Watershed was developed and is still under review by NJDEP. The adopted fecal coliform TMDL and the nutrient TMDL under development are all based on the water quality monitoring data at the USGS Reaville Gage Station, and therefore cover only the upper portion of the Neshanic River Watershed restoration planning area. Therefore, the project team developed its own pollutant load reductions to meet the TMDL requirement in the Neshanic River Watershed.

6.1. Load Reduction Targets

6.1.1. Load Duration Curve Method

A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. Calculation of a TMDL must include a margin of safety (MOS) to ensure that a waterbody can be used for its designated use and account for seasonable variation in water quality. A TMDL has been defined by the following simple equation:

$$TMDL = LC = WLA + LA + MOS + RC \quad (6.1)$$

where: LC = loading capacity; WLA = wasteload allocation for point sources; LA = load allocation for nonpoint sources; MOS = margin of safety; and RC = reserve capacity.

Rearranging Equation 6.1, a Modified Loading Capacity (LC') is defined as:

$$LC' = LC - MOS - RC = WLA + LA \quad (6.2)$$

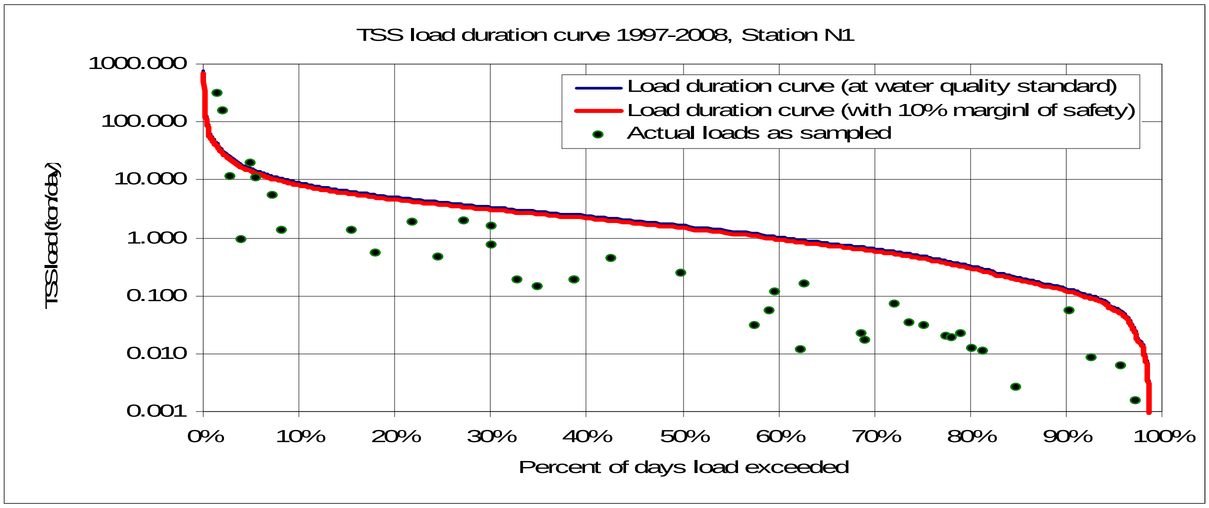
LC' equals the TMDL allocated among all point and nonpoint sources taking into consideration both RC and MOS. LC' is often expressed as an average daily load based upon average long-term flow conditions and represents the long-term average TMDL. The latter have been dubbed as “bare bones” TMDLs due to the simplicity of the calculation. While these TMDLs satisfy the requirements of the Clean Water Act, they have contributed little to any watershed/waterbody assessment and restoration plans. These types of TMDLs do little to characterize the problems the TMDLs are intended to address and to identify and implement appropriate solutions (Rahl, 2002).

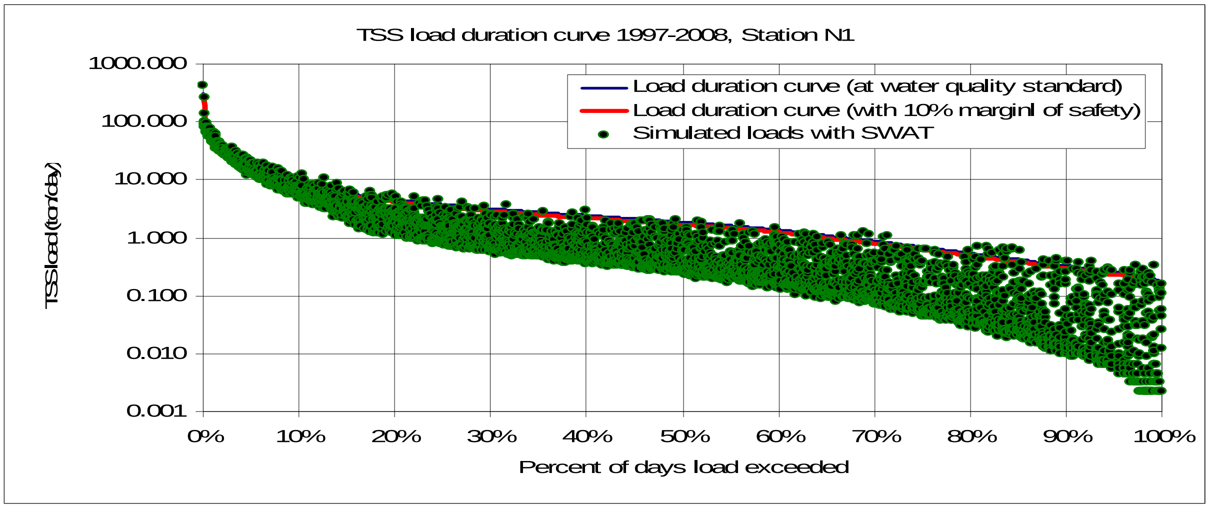
For TMDLs to be beneficial in the assessment and implementation process, they should reflect water quality for a range of flow conditions rather than for a single flow condition, such as average daily flow. This project uses a more robust load duration curve method for setting TMDL targets required by USEPA (2007). A load duration curve is a graph representing the percentage of time during which the value of a given parameter (e.g., flow or load) is equaled or exceeded. The load duration curve method is a useful tool for characterizing the pollutant problems over the entire flow regime (USEPA, 2007). The steps in developing a load duration curve are briefly described. The first step is to develop a flow duration curve using available daily streamflow data at the watershed outlet. A flow duration curve relates flow values to the percent of time those values have been met or exceeded. The second step is to develop a load duration curve by multiplying the ranked streamflow data by the water quality standard for the pollutant of concern and a unit conversion factor. The results are then multiplied by 0.9 to take into consideration the 10 percent MOS. The third step is to compare the measured or simulated water quality data to the desired pollutant loads by plotting the water quality data on the load duration curve developed in the second step. In order to do so, the water quality data measured in terms of concentration has to be converted into daily loads using the pollutant concentration and streamflow. Points above the pollutant load curve represent exceedance of the water quality standards and the associated allowable loadings. The "less than 10 percent" exceedance threshold is commonly used when defining the TMDL reduction targets. The fourth step is to assess the load reduction target if the frequency of exceedance is greater than 10 percent. Several load reduction rates can be applied to the calculated daily pollutant load from the measured or simulated water quality data to evaluate the resulting frequency of exceedance as in the third step. The largest reduction rate that achieves less than 10 percent frequency of exceedance is the TMDL load reduction target.

6.1.2. Load Reduction Targets

The load reduction target for the Neshanic River Watershed is defined as the total pollutant load reductions that are required to satisfy the water quality standards for the non-trout FW2 streams in the watershed as defined by NJDEP. A 10 percent MOS and less than 10 percent frequency of exceedance were adopted to determine the pollutant load reduction targets. Three sets of load duration curves were developed in the watershed for the time period 1997- 2008. Each set contains five load duration curves for five pollutants (i.e., TSS, TN, TP, fecal coliform and *E. coli*). The first set of load duration curves was based on observed streamflow and water quality data at the USGS Reaville Gage Station (i.e., N1 monitoring station in the watershed), whose drainage areas only contain the upper portion of the watershed. The second set of load duration curves was based on streamflow and water quality simulations obtained with the SWAT model at N1 station. Since there are no observed streamflow and water quality data at the watershed outlet, the third set of load duration curves was only based on the SWAT-simulated streamflow and water quality during the same period.

Figure 6.1 shows the load duration curves for TSS based on observed streamflow and TSS data at the N1 station (upper graph) and SWAT-simulated results at the N1 station (middle graph) and at the watershed outlet (lower graph). The observed TSS sampling results are distributed within the broad range simulated by SWAT. Given 10 percent of MOS, the frequencies of exceedance for TSS are about 7 and 8 percent based on the observed data and the SWAT-simulated results, respectively. Since the frequencies of exceedance are below 10 percent of the threshold, TSS contamination at the N1 station is not considered to be a water quality issue. However, the frequency of exceedance at the watershed outlet based on the SWAT-simulated results is about 12 percent. In order to reduce the frequency of exceedance to 10 percent or below, a 9 percent reduction in TSS concentration at the watershed outlet is required. Load duration curves for TN, TP, fecal coliform and *E. coli*. are shown in Figure 6.2, Figure 6.3, Figure 6.4 and Figure 6.5, respectively.





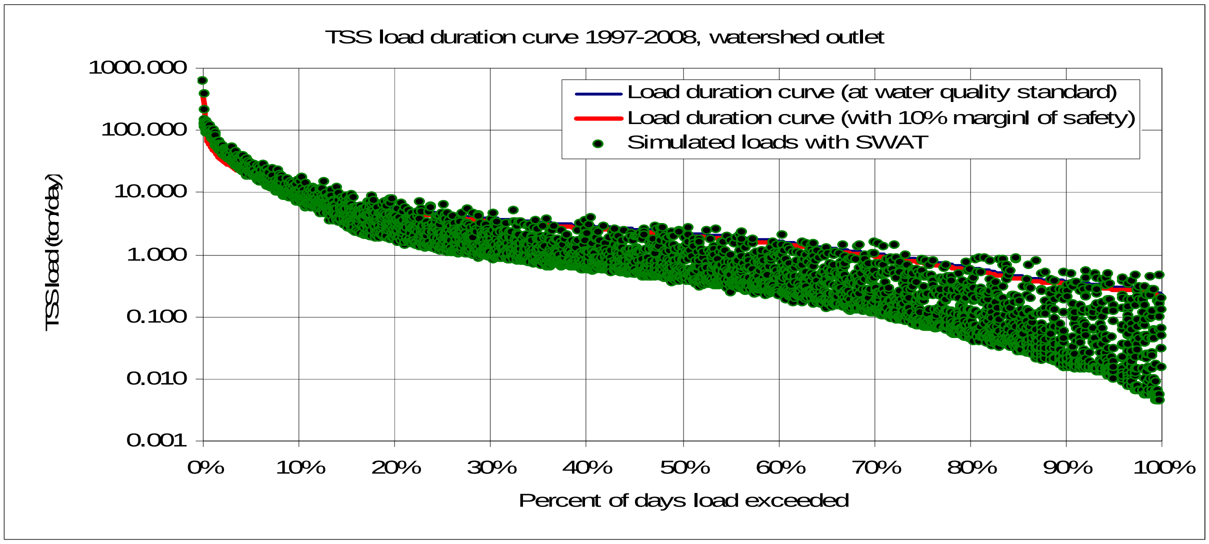


Figure 6.1: Load duration curves for TSS

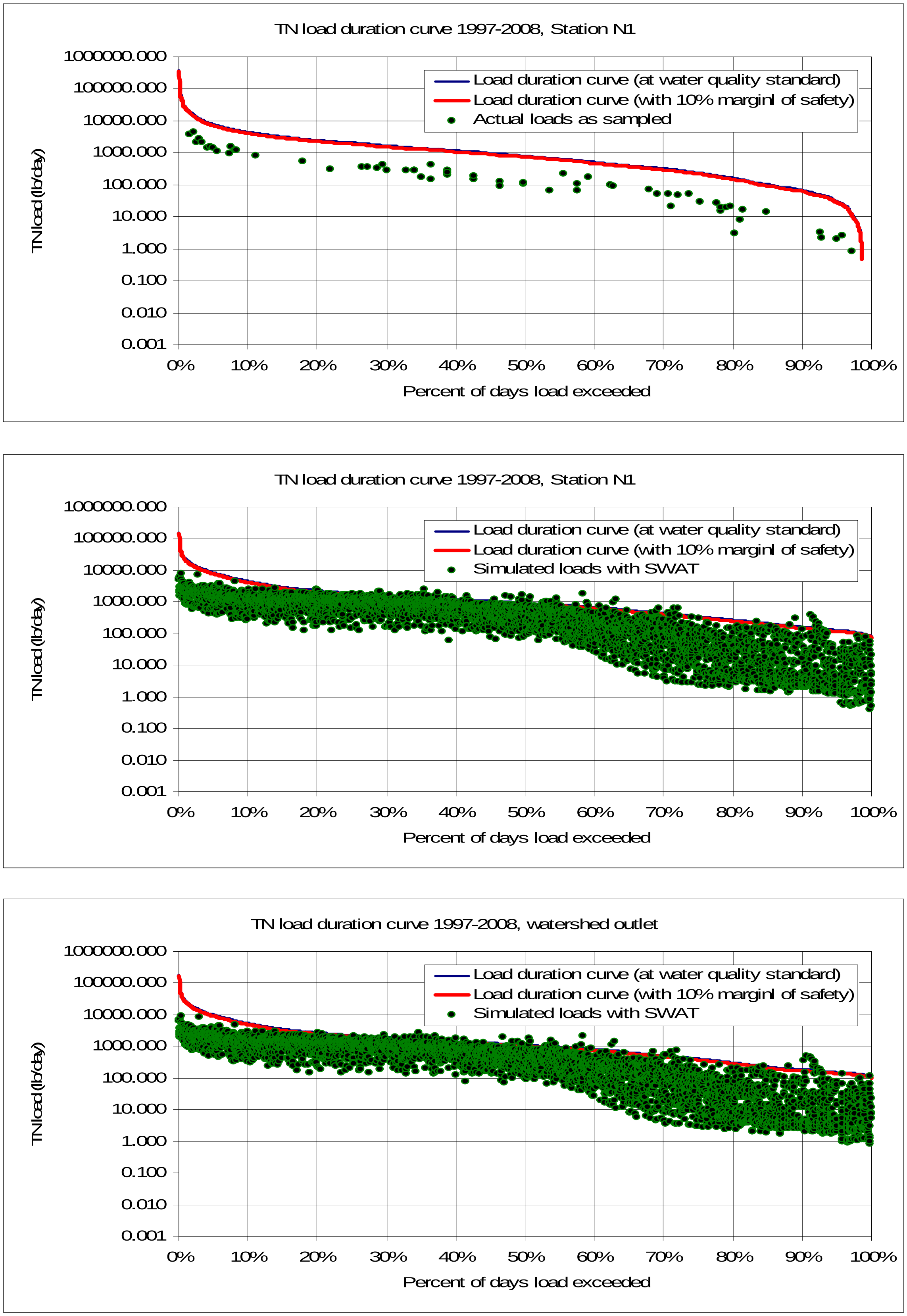
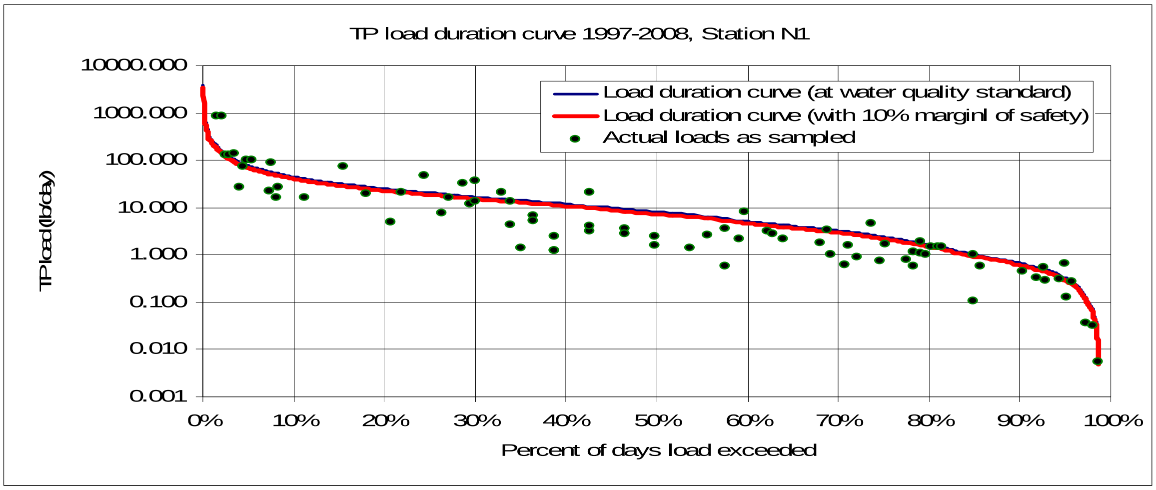
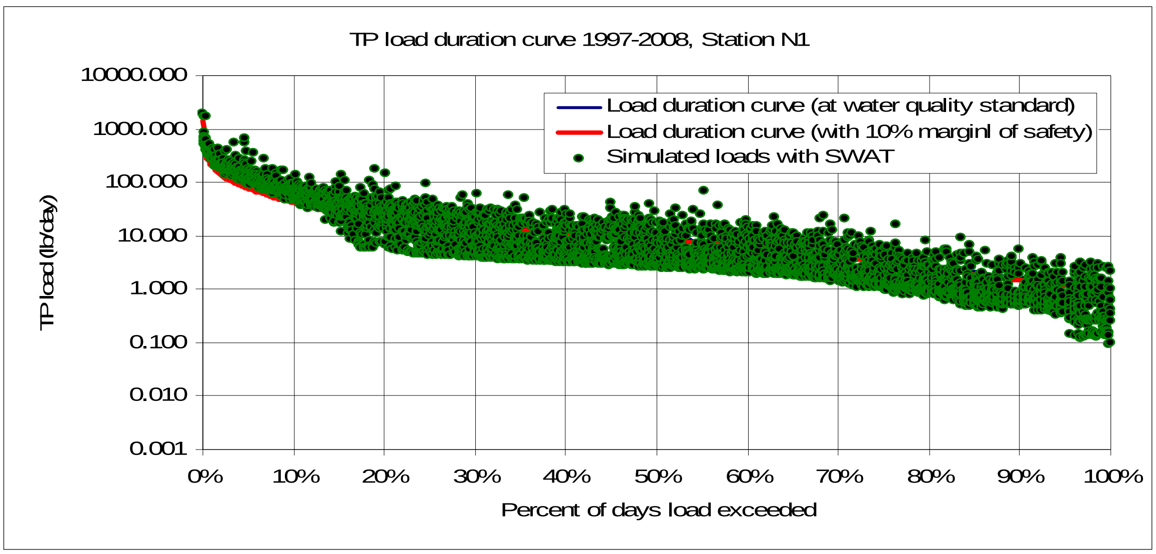


Figure 6.2: Load duration curves for TN





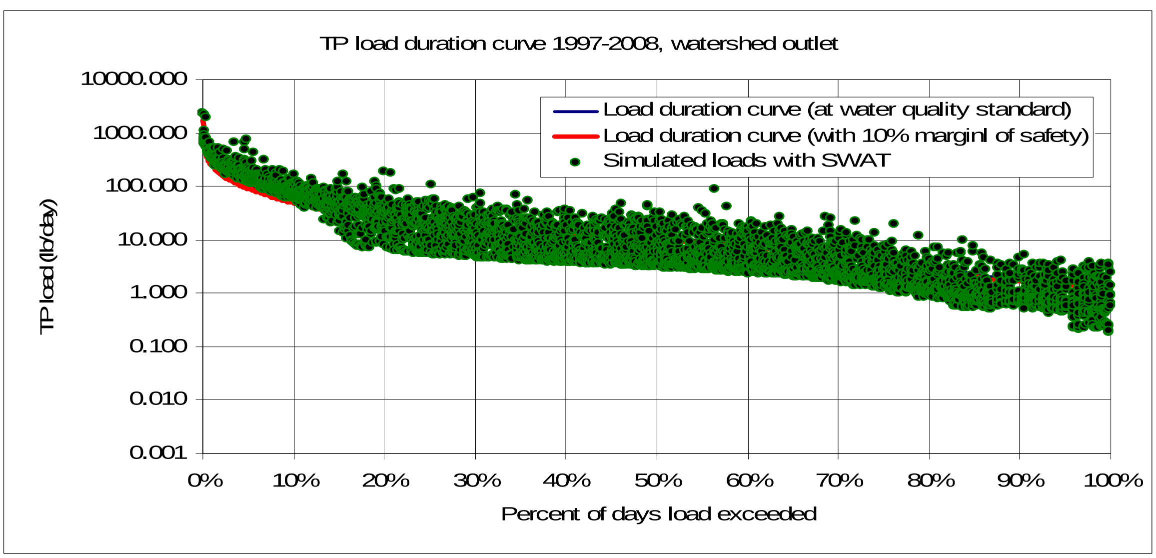
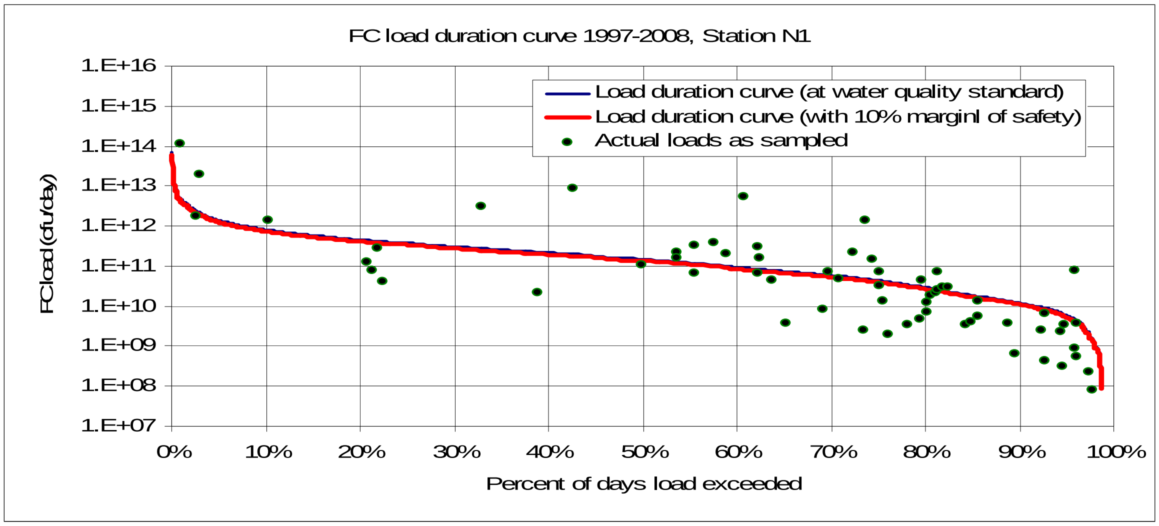
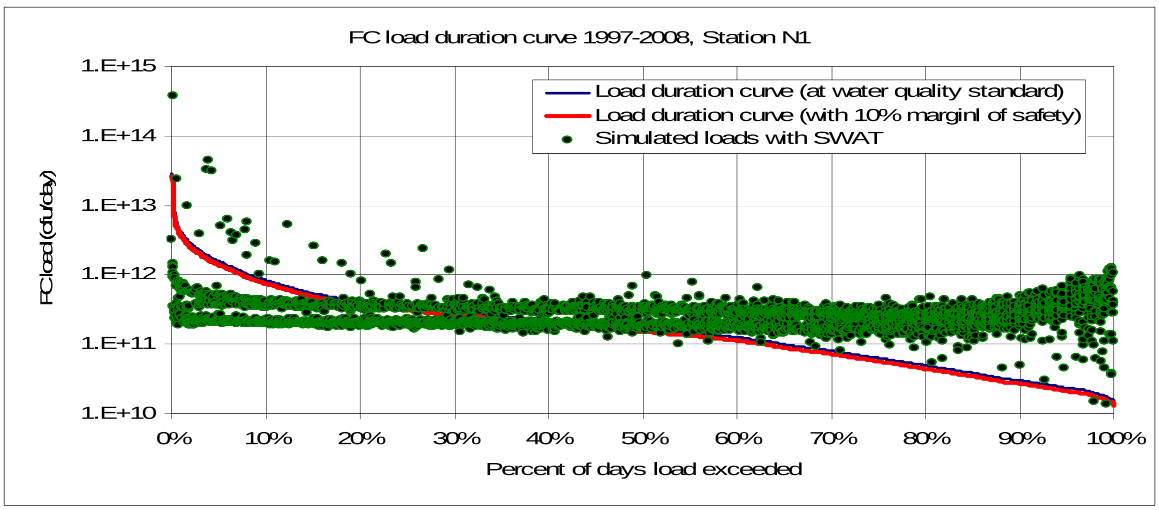


Figure 6.3: Load duration curves for TP





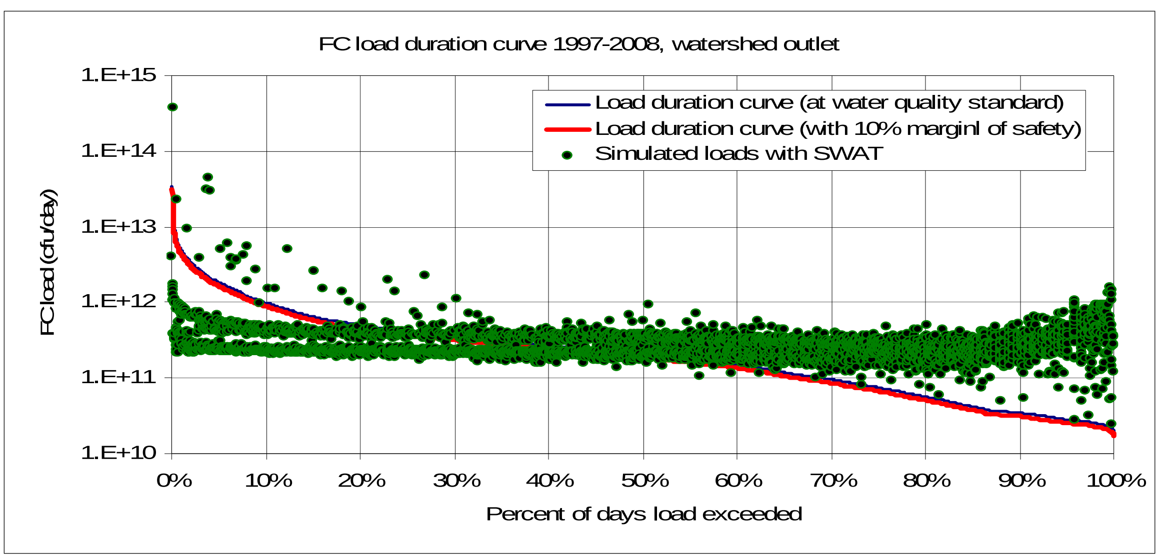


Figure 6.4: Load duration curves for fecal coliform

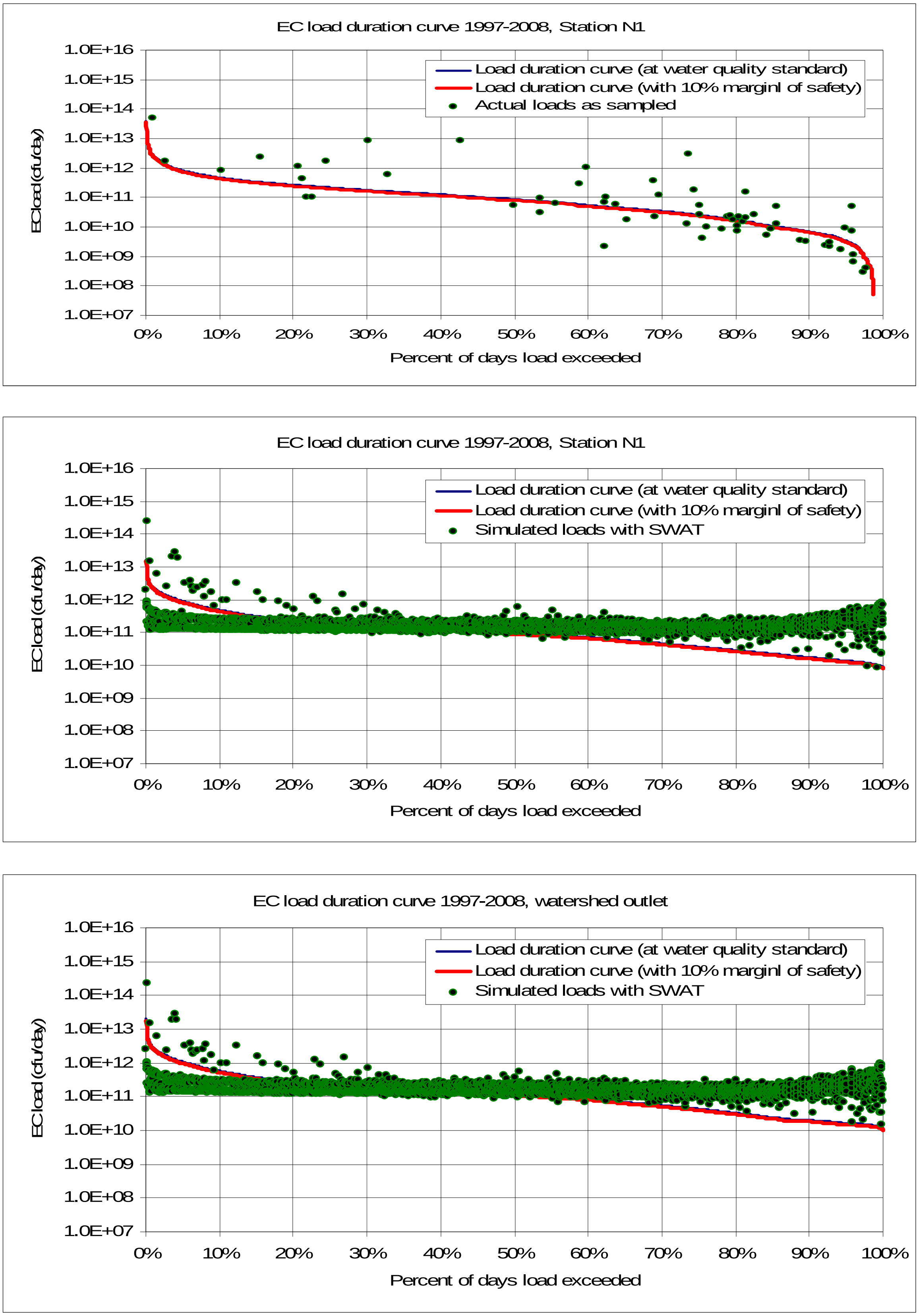


Figure 6.5: Load duration curves for *E. coli*

These load duration curves demonstrate interesting differences in the relationship between the pollutant and streamflow. For the load duration curves for TSS, TN and TP based on observed data at the N1 Station, there is a positive relationship between pollutant load and streamflow (i.e., a high pollutant load is associated with a high streamflow). Such a relationship implies that water pollution from TSS, TN and TP is dominated by nonpoint sources in the watershed. The positive relationships between fecal coliform and streamflow and *E. coli* concentrations and streamflow in the respective load duration curves based on observations at the N1 Station are not as obvious as for TSS, TN and TP. Many observed loads during medium and low streamflow are just as high as those during high streamflow. This phenomenon indicates that pathogenic contamination may be attributed to weather-independent and persistent sources, such as manure deposited by livestock into the streams and effluent from failing OSDS located near streams. Similar trends were observed for the load duration curves based on the SWAT simulations for both the N1 Station and watershed outlet. There is a flat band of simulated pollutant loads in the load duration curves for fecal coliform and *E. coli*, which results from the simplifying assumption that the effluent from failing OSDS into streams remains constant throughout the year and livestock manure deposited into streams remains constant during the grazing period.

The frequencies of exceedance of water quality standards and load reduction targets for the five pollutants of concern at the N1 station and watershed outlet are summarized in Table 6.1. Based on the observed streamflow and water quality data at the N1 Station, the frequencies of exceedance for TSS, TN, TP, fecal coliform and *E. coli* are about 7, 0, 30, 38 and 59 percent, respectively. While TSS and TN satisfy the threshold of “less than 10 percent” frequency of exceedance, the load reduction targets of 48, 90 and 91 percent for TP, fecal coliform and *E. coli*, respectively, are required to achieve the specified TMDL goals including MOS and the threshold for the frequency of exceedance at the N1 Station. The SWAT simulated results at the N1 Station show the frequencies of exceedance to be about 8, 2, 38, 61 and 63 percent for TSS, TN, TP, fecal coliform and *E. coli*, respectively. There is no load reduction requirement for TSS and TN, but there are load reductions of 48, 90 and 91 percent for TP, fecal coliform and *E. coli* relative to the respective TMDL goals. At the watershed outlet, the SWAT-simulated results indicate that the frequencies of exceedance for TSS, TN, TP, fecal coliform and *E. coli* are about 12, 1, 38, 61 and 63 percent, respectively. Load reduction targets need to be 9 percent for TSS, 49 percent for TP, 89 percent for fecal coliform and 89 percent for *E. coli* in order to meet the TMDL goals at the watershed outlet.

Table 6.1: Frequency of exceedance and load reduction target for the pollutants of concern in the Neshanic River Watershed

	Frequency of Exceedance (percent)			Load Reduction Target (percent)		
Pollutant of Concern	Observed Data at N1 Station	SWAT-Simulated Results		Observed Data at N1 Station	SWAT-Simulated Results	
		N1	Outlet		N1	Outlet
TSS	7.32	8.30	12.25	0	0	9
TN	0	2.03	1.76	0	0	0
TP	30.49	38.49	37.96	48	48	49
Fecal Coliform	37.50	61.15	60.96	90	90	89
E. coli	59.02	63.91	63.38	91	91	89

6.2. **BMP Assessment of Pollutant Load Reduction**

The previous section discusses the pollutant load reduction target required to achieve water quality standards in the watershed. This section uses the SWAT modeling results to evaluate the potential for achieving the pollutant load reduction targets with BMPs.

Table 6.2: Definition of BMPs

Number	BMP	Description
S0	Baseline	Modest N and P commercial fertilizer applications and reduced tillage for agricultural lands. Cattle and horse manures are applied to 11 percent of corn lands at standard rates. Minimum (chisel/disk plows) for crops in a corn-soybean-rye rotation; 6-year rotation moldboard/disk/hallow plows for hay and pasture. Orchards, forests, and wetlands are modeled using their default SWAT schedules.
S1	Reduce manure application	Reduce application rates of cattle and horse manures to corn from 45 Mg/ha to 11.6 Mg/ha.
S2	Grazing management	Increase the minimal grass biomass of pasture lands from 200 kg/ha to 700 kg/ha to reduce soil erosion caused by over grazing.
S3	Nitrogen commercial fertilizer management	Reduce N commercial fertilizer application rates by 25 percent for all agricultural lands and urban lawns.
S4	Phosphorus commercial fertilizer management I	Reduce P commercial fertilizer application rates by 25 percent for all agricultural lands and urban lawns.
S5	Phosphorus commercial fertilizer management II	Reduce P commercial fertilizer application rates by 25 percent for all agricultural lands and 100 percent for urban lawns.
S6	No tillage	Change minimum and conventional tillage to no-till practices for all row crops (corn-soybean-rye rotation).
S7	Cover crop	Plant winter rye following crop harvest and kill winter rye by crop planting for corn-soybean rotation.
S8	Filter strips	Apply 5-m (15-ft) edge-of-field filter strips to all agricultural lands.
S9	Fencing	Construct fences for all pasture lands within 100 meters of a stream to control livestock access to streams.
S10	Eliminate failing OSDSs	Improve the maintenance of OSDSs and increase the reliability. Assume 0 percent failure rate after improvement.
S11	Channel protection	Increase vegetative cover of channel banks or use riprap to stabilize banks.
S12	Combo 1	Combination of BMPs S1, S2, S3, S4, S7, S9, S10
S13	Combo 2	Combination of BMPs S1, S2, S3, S4, S8, S9, S10
S14	Combo 3	Combination of BMPs S1, S2, S3, S4, S7, S8, S9, S10
S15	Combo 4	Combination of BMPs S1, S2, S3, S4, S7, S8, S9, S10, S11
S16	Combo 5	Combination of BMPs S7, S8
S17	Combo 6	Combination of BMPs S4, S7, S8
S18	Combo 7	Combination of BMPs S1, S9
S19	Combo 8	Combination of BMPs S1, S8, S9
S20	Combo 9	Combination of BMPs S1, S8, S9, S10

Table 6.2 presents the pollutant load reductions and frequency of daily load exceedance for five pollutants with the alternative BMPs simulated with the SWAT model. BMP 0 (S0) is the baseline, representing the current condition. Each of BMPs 1-11 represents a single BMP. BMPs 12-20 are various combinations of single BMPs represented by BMPs 1-11. The combination BMPs consider the aggregated effects of the single BMPs for certain water pollutants. For example, the combination BMPs S16 and S17 were designed to evaluate the aggregated effects of selected BMPs on TP load reduction. The combination BMPs S18, S19 and S20 were designed to evaluate the aggregated effects of selected BMPs on pathogen load reduction. The combination BMPs S12, S13, S14 and S15 were designed to evaluate the aggregated effects of all BMPs on load reductions for all pollutants. Table 6.3 presents the effects of the alternative BMPs on the pollutant load reduction and the frequency of daily load exceedance for five pollutants of concern in the Neshanic River Watershed. The BMPs that achieve the pollutant load reduction targets are also highlighted in the table. The bold numbers indicate that the specific BMP scenario attains the water quality standard for the specific pollutant.

No tillage (S6), cover crop (S7), filter strips (S8) and channel protection (S11) are effective BMPs for sediment removal; they lead to average annual sediment load reductions of about 10, 15, 17 and 60 percent, respectively, compared to the baseline. Reducing channel erosion has a large impact on TSS loads. For appropriate application of BMPs in the watershed, a target daily load exceedance frequency of less than 10 percent can be achieved. In other words, each of these four BMPs and any combination BMP that contains at least one of the four BMPs has the potential to achieve the required 9 percent of TSS load reduction.

TN is not a water quality concern in the watershed even under the baseline. The SWAT modeling assessment indicates that reducing manure application (S1), nitrogen fertilizer management (S3), cover crop (S7) and filter strips (S8) are effective measures for TN reduction that achieve TN load reduction rates of more than 10 percent.

Reducing manure application (S1), phosphorus fertilizer management I and II (S4 and S5), cover crop (S7) and filter strips (S8) are more effective than other BMPs, achieving average annual TP load reductions of about 4, 15, 26, 16 and 38 percent, respectively. The frequency of daily TP load exceedance of the filter strip BMP (S8) cannot be accurately assessed because of a limitation of the SWAT model. The frequency of exceedance for several single BMPs is more than the 10 percent. However, by themselves, none of the single BMPs can achieve the required 49 percent of annual TP load reduction. Several BMPs must be implemented together to achieve the required TP load reduction target. As shown in Table 6.3, the combination BMPs S14 and S15 can achieve the desired TP load reduction rates with frequencies of exceedance less than 23 percent. The reason why their frequencies of exceedance cannot be precisely assessed is because both combination BMPs contain the filter strip BMP. Considering the effectiveness of conservation buffers in TP removal demonstrated by numerous empirical studies, we can reasonably assume the frequency of exceedance required by TMDLs can be achieved as well under both scenarios.

As shown in Table 6.3, although most load reductions are positive, there are negative load reductions for some BMPs. Negative reductions imply that the corresponding pollutant loads increase because of the aggregated impacts of complicated overland and instream biological processes. One example of this is BMP S5 (no phosphorus in lawn fertilizer application) for which a 100 percent reduction in P application reduces lawn growth causing N intake to fall and TN loads in streams to increase.

Table 6.3: Pollutant load reduction and the frequency of daily load exceedance for five pollutants with alternative BMPs in the Neshanic River Watershed

	Pollutant Load Reduction (percent)					Frequency of Exceedance (percent)				
	TSS	TN	TP	Fecal	*E. coli*	TSS	TN	TP	Fecal	*E. coli*
S0	na*	na	na	na	na	12.25	1.76	37.96	60.96	63.38
S1	0.05	25.65	4.40	23.23	23.17	12.21	0.34	36.46	60.57	63.08
S2	2.75	0.83	1.53	0.12	0.12	11.36	1.78	37.58	60.94	63.40
S3	-0.72	11.10	-3.89	0.39	0.39	12.25	1.00	38.60	60.99	63.56
S4	0	-0.17	15.36	0	0	12.25	1.76	33.45	60.96	63.38
S5	-1.57	-44.66	25.97	0.31	0.31	12.55	13.00	28.04	60.89	63.40
S6	**9.80**	2.46	-5.89	-7.90	-7.88	**9.51**	1.21	43.44	59.84	62.15
S7	**15.21**	23.03	15.77	1.04	1.04	**7.76**	0.62	30.80	62.79	65.16
S8**	**17.28**	46.21	37.72	11.91	11.88	**<12.25**	<1.62	<37.96	<60.96	<63.38
S9	0	0.04	0.21	19.30	19.22	12.25	1.76	37.37	51.22	54.96
S10	0	0.29	1.64	46.92	47.09	12.25	1.76	35.75	32.56	34.20
S11	**59.60**	-1.65	0.85	4.05	4.05	**2.30**	1.78	37.76	59.73	61.76
S12	**23.99**	55.40	32.72	**90.20**	**90.23**	**5.86**	0	22.56	**0.18**	**0.23**
S13**	**25.03**	61.93	46.29	**93.82**	**93.84**	**<10.75**	<0.07	<29.93	**<0.25**	**<0.27**
S14**	**31.90**	68.76	**51.46**	**94.05**	**94.07**	**<5.86**	0	**<22.56**	**<0.18**	**<0.23**
S15**	**83.04**	68.39	**51.86**	**94.45**	**94.47**	**<1.12**	0	**<22.36**	**<0.16**	**<0.21**
S16**	**24.48**	55.37	41.86	12.95	12.92	**<7.76**	<0.55	<30.80	<62.79	<65.16
S17**	**24.49**	55.35	**51.07**	12.95	12.92	**<7.76**	<0.55	**<26.17**	<62.79	<65.16
S18	0.05	25.70	4.62	42.53	42.39	12.21	0.34	36.09	50.67	54.48
S19**	**17.32**	55.69	37.53	45.56	45.41	**<12.21**	<0.34	<36.09	<50.67	<54.48
S20**	**24.27**	56.04	39.16	**92.49**	**92.51**	**<11.43**	<0.34	<34.43	**<0.25**	**<0.27**

Note: * Not applicable;
** Indicates that exact frequency of daily load exceedance cannot be determined.

Single BMPs, including reducing manure application (S1), filter strips (S8), fencing (S9), eliminating failing OSDSs (S10) and channel protection (S11), reduce fecal coliform by about 23, 12, 19, 47 and 4 percent, and E. coli by about 23, 12, 19, 46 and 4 percent, respectively. These reductions are less than the required load reduction targets of 89 percent for fecal coliform and 89 percent for *E. coli*. The frequencies of daily load exceedance of these single BMPs are more than 30 percent, which is higher than the 10 percent frequency of exceedance required by the TMDLs. The bacteria load reduction targets and frequency of daily load exceedance can be achieved by using a combination of several effective BMPs. Combination BMP S20, which involves reducing manure application, filter strips, fencing and eliminating septic failure, reduces the average annual load for fecal coliform by 92 percent and *E. coli by* 93 percent. With additional BMPs, including grazing management, nitrogen and phosphorus fertilizer applications, cover crop and channel protection, the combination BMP S15 reduces pathogenic load by almost 94 percent. Both S15 and S20 achieve frequencies of daily load exceedance for fecal coliform and *E. coli* of less than 10 percent.

The BMP analyses indicate it is possible to achieve the pollutant load reduction targets required to satisfy water quality standards for the Neshanic River Watershed. The BMPs evaluated here include only BMPs that can be easily assessed using the SWAT model. There are many other BMPs that can be implemented to achieve the required pollutant load reductions in the watershed as discussed in Chapter 7. Examples of such BMPs include rain gardens, detention basin retrofitting and ditch and swale retrofitting. Because these BMPs involve site-specific engineering structures, their water quality impacts cannot be simulated using the SWAT model and therefore they are excluded from the BMP analysis. As indicated in the literature, BMPs involving site-specific engineering structures are generally very effective in achieving load reductions in sediment, nutrients and pathogens. For that reason, those BMPs provide alternative ways to achieve pollutant load reductions in the watershed.

7. Restoration Strategies and Best Management Practices

7.1. Watershed Restoration Strategies

7.1.1. Strategies for Controlling Pathogenic Contamination

Pathogenic contamination is the most significant water quality issue in the Neshanic River Watershed. Pathogens of concern include, among others, fecal coliform and *E. coli* from human and animal wastes. Pathogenic loading in the planning area was assessed using the SWAT watershed model. Based on the SWAT modeling results, the largest source of pathogens in the watershed is failing OSDSs. They contribute 46 percent of the pathogen load in the Neshanic River Watershed. The second largest source of pathogenic contamination is manure application to row crops, which contributes 31 percent of the annual pathogenic load to the Neshanic streams. Livestock in streams contributes 19 percent of the annual pathogenic load in the watershed. Livestock grazing on pasture contributes 2 percent of the pathogenic loads. Wildlife, including geese and deer, is a minor contributor to pathogenic loads. The TMDL for fecal coliform adopted for the Neshanic River in 2003 requires 87 percent reductions in fecal coliform in the upper part of the Neshanic River Watershed (NJDEP, 2003). As discussed in Chapter 6, this project updated the pathogenic reduction goals that satisfy the required water quality standards by incorporating additional water quality monitoring data and using SWAT modeling results. The updated assessment calls for 90 percent reduction of fecal coliform load and 91 percent reduction of *E. coli* load for the same upper portion of the Neshanic River Watershed. In terms of the whole study area, the load reduction required to meet the TMDL requirements is 89 percent for both fecal coliform and *E. coli*. The following strategies are recommended to control pathogenic contamination in the watershed.

7.1.1.1. OSDS Education and Management

Many residential homes and businesses in the Neshanic River Watershed rely on OSDSs for wastewater treatment. OSDSs require regular inspections and maintenance to function properly. Failing OSDSs are often very expensive to repair and may need to be rebuilt or replaced. Hunterdon County currently requires the inspection of an OSDS before a certificate of occupancy will be issued for new construction and prior to the sale or lease of an existing residence. Although such regulation helps reduce the number of failing OSDSs in the watershed, it affects only a very small portion of the OSDSs in the watershed. A comprehensive watershed-wide OSDS education and management program is needed to control pathogenic contamination and to improve water quality in the Neshanic River Watershed. The comprehensive education and management program should include the following elements:

- An education campaign (including regional educational workshops, flyers, newspaper articles and outreach at events like the Hunterdon County 4-H Fair) to make residents and businesses aware of their OSDSs and how to care for them;
- A regular (three-year) inspection and certification program;
- A technical assistance program on OSDS inspection, operation and maintenance; and
- A financial incentive program to motivate residents and businesses to properly maintain and care for their OSDSs. The program could include subsidies to install OSDSs that comply with current state and local regulations, replace or repair failing

systems, and inspect and maintain existing systems. These subsidies could be combined with fines for failing to maintain properly functioning OSDSs.

7.1.1.2. Animal Manure Management

Animal manure is both a health hazard and an environmental hazard. Proper management of animal manure in the Neshanic River Watershed is essential to control pathogenic contamination. The NJDA has developed and adopted the Criteria and Standards for Animal Waste Management (N.J.A.C. 2:91) to proactively address NPS that may originate from livestock operations in New Jersey. All farms with livestock must follow the general requirements of N.J.A.C. 2:91. Requirements for agricultural animal operations do not allow animals in confined areas to have uncontrolled access to waters. Manure storage areas must be located at least 100 linear feet from waters. Land application of animal waste must be performed in accordance with the principles of the NJDA BMPs Manual (NJACD, 2009). Farms with more than eight but less than 300 Animal Units (AU) [1 AU= 1,000 pounds of live animal weight] or those receiving or applying 142 tons or more of animal manure per year are required to develop and implement a self-certified Animal Waste Management Plan. Farms with 300 or more AU must adopt a comprehensive nutrient management plan certified by NJDA.

The NJDA Animal Waste Management Rules must be enforced in the Neshanic River Watershed. The NRCS has cost-share programs to help farms with livestock improve their manure management practices. A technical assistance program should be developed to assist farmers in designing and implementing manure management plans. Those programs should be expanded and implemented in the watershed to improve water quality. A comprehensive livestock manure management program that implements the NJDA Animal Waste Management Rules and NRCS cost-share programs should include the following elements:

- Each farm with livestock should develop an on-site manure management plan directing how manure will be collected, stored and dispersed.
- Regional manure composting facilities should be established that compost manure generated on farms for fertilizer to be used in home gardens and crop fields. Composting preserves the nutrient components of the manure, but significantly reduces the pathogenic components.
- Implement proper management on manure application in row crop, hay and pasture lands. Manure application timing, amounts and methods in agricultural fields are critical to improving downstream water quality. Extensive manure application in the beginning of the growing season (April) should be strongly discouraged. The amount of manure applied should be reduced to minimize negative water quality impacts. Better integration of manure with soil and use of appropriate cover crops should help to improve water quality.

.

7.1.1.3. Livestock Access Control

Livestock with direct access to streams and their riparian areas not only damage streambank and cause soil erosion, but also deposit manure directly into streams and cause pathogenic contamination. One way to prevent such damages is to install exclusion fencing along streams that cross pasture. Such fencing prevents livestock from directly accessing the streams and their riparian areas and therefore helps improve water quality. The NRCS recommends that fencing be installed at least 35 feet from the streams to protect both streams and their riparian areas. The NRCS has been implementing exclusion fencing education, outreach and implementation projects in the watershed. Such programs should be expanded to completely eliminate livestock on pasture from having direct access to streams.

7.1.1.4. Sewer Infrastructure Maintenance in SSAs

The Raritan Township Municipal Utilities Authority (RTMUA) operates and maintains a 3.8 MGD conventional activated sludge wastewater treatment plant that treats wastewater discharges from sewered areas of Raritan Township, including a major portion of SSAs in Neshanic River Watershed. Maintaining the functional sewer system and preventing potential sewer leaking are critical to achieving the pathogenic reduction goals in the Neshanic River Watershed. As a part of its preventative maintenance program, RTMUA maintains internal cleaning and inspection equipment used to perform routine inspections of its collection system. The plant is staffed 24 hours a day. Plant staff performs daily inspections of its pump stations. The pump stations in this area include Hunterdon Estates, Walnut Brook, Flemington Fields, Pump Station No. 1, Pump Station No. 2 and Sun Ridge Station 2. These stations, collection system and developments were constructed in 2001-2003 with few exceptions. Pump Station No. 1 was rehabilitated in 1999 and 2000, and Sun Ridge Station 2 in 2010. Pump Station 2 is scheduled for rehabilitation in 2015. These collection systems (pipes and manholes) were low pressure air-tested prior to being placed in service to ensure watertight construction.

The RTMUA conducted sewer and manhole repair projects in Flemington South in 2006. The RTMUA has no history of sewer overflows. The RTMUA experiences an increase in sewage flow to its treatment plant in wet weather primarily due to connection of residential sump pumps and roof leaders to the collection system. In 2007, the RTMUA worked with Raritan Township to pass an ordinance banning illicit connections to the RTMUA sewer system. In addition, during periods of elevated groundwater levels, RTMUA can experience some infiltration of groundwater into its collection system. There is no evidence that sewage exfiltrates out of the sewers.

There are still homes and businesses in SSAs that depend on OSDSs for wastewater treatment. The previously mentioned comprehensive OSDS education and management program in Section 7.1.1.1 should also be applied to these OSDSs to ensure their properly functioning. A plan should also made to connect some homes and businesses that rely currently on OSDSs to the RTMUA sewer system. It should be noted that the RTMUA currently does not have any sewer capacity that can be allocated for this purpose. Hooking potential failing septics to the RTMUA is not an option unless the plant were expanded, and there are no plans for expansion. The RTMUA should periodically assess the conditions and capacity of all sewer infrastructures in its service area and make planned updates and/or improvements in the sewer infrastructure. Such updates and improvements should help reduce pathogenic loads to Neshanic streams and therefore improve water quality.

7.1.1.5. Wildlife Management

Like many other suburban watersheds in New Jersey, the Neshanic River Watershed faces wildlife overpopulation problems, particularly for deer and geese. Wildlife waste is a source of pathogenic contamination in the watershed. Wildlife waste dropped in and along streams could generally have much greater impacts on water quality than in areas away from the streams. Although the SWAT modeling results indicate that the contribution of wildlife to pathogenic contamination in the watershed is generally minor compared to other sources, active wildlife management measures should be taken to reduce wildlife impacts on water quality for several reasons. First, wildlife's pathogenic contribution to water contamination is usually heavier during the winter season, due to low vegetative cover, than in other seasons. Second, as management measures are gradually implemented to control other sources of pathogenic contamination as discussed above, the wildlife contribution to the pathogenic contamination becomes much more significant. Third, reduction of pathogens from any source would help to achieve the required 89 percent reduction in pathogenic load in the watershed.

The state and county have been implementing various programs to control wildlife populations. The NJDEP Division of Fish and Wildlife published the Community Based Deer Management Manual for Municipalities (http://www.nj.gov/dep/fgw/cbdmp.htm) to guide the communities' effort to control deer population. The recommended measures to control deer population include controlled hunting, trap and euthanize, and chemical fertility control. The NJDEP Division of Watershed Management (2001) published a guide regarding the management of Canadian geese in suburban areas. The guide recommended the following measures to reduce the geese population and its negative impacts on streams and water quality: indirect measures such as stopping all feeding, hazing, altering habitat, and direct measures such as geese removal and harvest. The most practical measures the municipalities in the watershed can take are to alter the geese habitat. The habitat most desirable to geese is a large, flat to gently rolling managed turf area close to a lake, pond, or slow moving watercourse. Habitat alteration consists of eliminating, modifying, or reducing access to areas that provide attractive spots for geese. Such measures include reducing turf adjacent to streams, building barrier fence and rock barriers, establishing vegetative buffers along the streams and placing overhead lines on the waterbodies. The simplest one among habitat alteration measures is to maintain non-mowed areas along the streams. The vegetation in those undisturbed areas will naturally grow into vegetative buffers in a couple of years.

7.1.1.6. Detention Basin Retrofitting

There are 153 mapped detention basins in the study area of which one-third have outlet structures with a three-inch water quality orifice. A three-inch orifice outlet structure extends the water detention time in the basin, allowing TSS and attached nutrients to settle out, and thereby improving water quality. The remaining two-thirds of detention basins in the watershed were not constructed to achieve water quality benefits through extended water detention.

Virtually all detention basins in the watershed present an opportunity for upgrading or retrofitting to reduce pathogenic loads and improve water quality in the watershed. There is no existing empirical study indicating how much retrofitting detention basins would reduce pathogenic loads. Depending on the final design of the detention basin, a retrofitted detention basin can function like a bio-retention basin or a constructed wetland. Removal rates of bioretention basins and wetlands are 90 percent or greater for fecal coliform (Rusciano and Obropta, 2007; Karathanasis et al., 2003). Since the drainage areas for each basin were not readily available, it was difficult to estimate the reductions in total pathogenic loads from retrofitting detention basins in the watershed.

7.1.2. Strategies for Controlling Nutrient Contamination

Nutrients refer to TN and TP in streamflow. Multiple water quality monitoring efforts by USGS, NJDEP and the project team indicate that TP is and TN is not a serious water quality issue in the watershed. The attainment of the water quality standard for the FW2- NT streams requires a 49 percent reduction in the concentration of TP in the Neshanic River Watershed. Watershed assessment using the SWAT model indicates that the primary source of nutrients in the watershed is agriculture, including row crop and other agriculture. Row crops, such as corn, soybeans, and wheat and rye account for 67 percent of the TN load and 47 percent of the TP load. Other types of agricultural production, including hay and pasture, account for 12 percent of the TN load and 17 percent of the TP load. Lawn care fertilizers applied to urban lands contribute 11 percent of the TN load and 29 percent of the TP load; they are the second largest source of TN and TP loads in the watershed. Other minor land-based sources include forests and wetlands, where wildlife and natural processes contribute nitrogen and phosphorus into the environment. Since TP is the primary nutrient contaminant in the watershed, strategies were developed to reduce TP as discussed in the remainder of section 7.1.2. All of these strategies should also reduce TN loads since TN and TP are closely related.

7.1.2.1. Integrated Crop Nutrient Management (ICM)

Fertilizer application to crops and plants is essential because it achieves economic yields and acceptable levels of profit. However, excess fertilizer use, poor application methods and the timing of application can cause fertilizer to move into and contaminate ground and surface waters. One way to eliminate the negative impacts of agricultural fertilizer application is to implement an ICM program for fertilizer application that optimizes fertilizer application rates, timing and methods and maximizes profit subject to minimizing adverse effects on water quality.

The SWAT model was used to evaluate the water quality impacts of three nutrient management scenarios for both agricultural lands and urban lawns. The first scenario is to reduce N commercial fertilizer application rates on all agricultural lands and urban lawns by 25 percent (N Reduction). The second scenario is to reduce P commercial fertilizer application rates on all agricultural lands and residential lawns by 25 percent (P Reduction I). The third scenario is to reduce P commercial fertilizer application rates on all agricultural lands rates by 25 percent and eliminate application of P commercial fertilizer on urban lawns (P Reduction II). These nutrient management scenarios have little effect on TSS, fecal coliform and *E. coli* loads in the watershed. As expected, the N Reduction scenario reduces TN load by 11 percent, but increases TP load by 4 percent. The scenario P Reduction I reduces TP load by 15 percent and has limited impacts on TN loads. The scenario P Reduction II reduces TP load by 26 percent, but increases TN load by almost 45 percent. The SWAT analysis indicates that nutrient management for both crops and lawns is a complicated balancing act. Simply limiting one nutrient or another will affect plant growth and result in additional water quality problems. Crop nutrient management should be plant specific and site specific. Fertilizer application rates should be based on reasonable crop yield goals and available nutrients in soils as determined by soil testing. The soil test-based ICM can be offered as part of a technical assistance program for farmers in the watershed designed to improve water quality. A similar program is currently under way in the Mulhockaway Creek watershed in the Raritan River Basin (NJWSA, 2007).

7.1.2.2. Conservation Buffers

Conservation buffers are structuralized vegetative mixtures of trees, shrubs and grasses placed in the landscape to influence ecological processes and enhance ecosystem goods and services. There are many types of conservation buffers, such as contour buffer strips, field borders, grassed waterways, filter strips and riparian forest buffers (Bentrup, 2008). In this project, the term conservation buffer is used to refer to all types of buffer practices being used in the watershed. Different conservation buffer practices can be applied in different settings in the watershed to improve water quality, control soil erosion and enhance wildlife habitat. Water quality benefits of conservation buffers are well documented. As runoff flows through conservation buffers, the buffers filter out sediments and pollutants attached to sediments. Buffers also dissolve some pollutants through chemical and biological processes, promote ground water recharge and evapotranspiration and reduce runoff. Well designed and positioned conservation buffers can achieve at least 50 percent reduction of N, P, and sediment loads (Lowrance et al., 1986). In New Jersey, vegetative buffers are expected to reduce TSS by 80 percent and N and P by 30 percent in stormwater runoff (Semple et al., 2004). Research is more limited on the effectiveness of buffers in reducing pathogenic loads than in reducing TSS, TN, TP and pesticides. Some research suggests that conservation buffers can remove up to 60 percent of pathogens in runoff (SWCS, 2001). A suit of conservation buffer practices should be applied in critical source areas to maximize the effectiveness of conservation buffers in reducing nutrient loads and improving water quality (Qiu, 2009).

7.1.2.3. Cover Crop

Cover crops are grasses, legumes, forbs or other herbaceous plants 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 has other benefits, including reducing farm operational costs, less herbicide use and better overall soil health. Technical assistance and financial incentives should be provided to incorporate cover crops into cropping system for fields that are not in use for all or part of a year.

The SWAT model was used to evaluate the impacts of planting winter rye as a cover crop after harvesting corn or soybeans in continuously operated row crop fields in the watershed. A well implemented cover crop program can potentially achieve a 15 percent reduction in TSS, a 23 percent reduction in TN and a 16 percent reduction in TP loads to Neshanic streams. Cover crops have limited capacity to reduce pathogenic loads. The expected reduction in pathogenic loads to Neshanic streams is only about 1 percent. Besides the measured water quality benefits, cover crops have soil health benefits including breaking up fragipan or manmade compaction, improving nutrient cycling and increasing corn and soybean yields.

The NRCS provides cost share to farmers who establish cover crop in their fields. An education and assistance program should be implemented to help farmers implement cover crops in their fields to achieve the water quality and other environmental benefits.

7.1.2.4. Manure management

The animal manure management program for pathogenic load reduction as discussed in Section 7.1.1.2 should also reduce TP and TN loads to the streams in the watershed. While nitrogen in field-applied manure is easily dissolved, phosphorus in field-applied manure usually builds up in soils. Phosphorus that accumulates in soil can be transported to streams via runoff. Cropland should not be simply used as a dumping ground for animal manure. Rotating manure application among different fields can reduce manure concentration in a limited area. Manure should not be applied to HSAs in the watershed where soils can be easily saturated. Just like any other nutrients, manure should be applied based on an ICM or nutrient management plan. Manure should be tested for nutrient content and then applied according to crop needs to protect water resources and promote crop growth and soil health.

7.1.2.5. Prescribed Grazing

Prescribed grazing is a system that helps agricultural producers to manage grazing and browsing of animals to ensure there is always adequate ground cover and proper nutrition for livestock. A prescribed grazing plan may include reducing the number of livestock grazing an area and rotating livestock among paddocks more frequently. The latter requires using temporary fencing to exclude livestock from pasture recovering from grazing pressure. Prescribed grazing helps maintain healthy and productive pastures by reducing soil erosion and the resulting transport of phosphorus and pathogens in runoff. In addition, an actively growing pasture takes up nutrients and improves water infiltration.

7.1.2.6. Nutrient Management for Lawn Care

As urban development continues in the watershed, fertilizer use in lawns, and its contribution to water contamination, will increase. Nutrient management for lawns is essential to achieve the nutrient reduction goals in the Neshanic River Watershed. The newly-enacted New Jersey Fertilizer Control Law establishes standards for certain fertilizer applications, requires certification of professional fertilizer applicators and regulates labeling and sale of certain fertilizers. Key provisions of the law are:

- Eliminate phosphorus in lawn fertilizer used and sold in New Jersey, helping to curb excess phosphorus from running off soils already laden with the nutrient. Require at least 20 percent slow release nitrogen in all lawn fertilizers to help keep nitrogen out of waterways.
- Require lawn care professionals to attend training about appropriate fertilizer application and content.
- Prohibit application of lawn fertilizer when it is raining or when rain is predicted, between November 15 and March 15 for individuals caring for their own laws and

December 1 and March 15 for professional lawn care providers when the ground is typically frozen and lawns cannot absorb nutrients.

- Prohibit licensed professionals from applying fertilizers within 10 feet and homeowners within 25 feet of a waterway.

Nutrient management for lawns should be implemented by strictly carrying out the new Fertilizer Control Law in the watershed. Since phosphorus contamination is a common water quality issue in New Jersey, the NJDEP encourages municipalities to adopt non-phosphorus fertilizer ordinances to minimize the water quality impacts of fertilizer applications in residential and commercial lawns. Some municipalities, such as Jefferson and Morris Townships, have adopted such ordinances. Although the implementation of the new Fertilizer Control Act and the establishment and enforcement of the municipal phosphorus ordinance help reduce nutrient loads to streams in the watershed, attention should be paid to the long-term effects of non-phosphorus fertilizer application. Long-term application of non-phosphorus fertilizer could potentially result in a phosphorus deficiency, which could limit lawn growth and reduce the intake of nitrogen. If the same amount of nitrogen is still being applied, the extra nitrogen could end up in streams, which can result in nitrogen pollution of water. As with agricultural fertilizer application, lawn fertilizer application rates should based on soil tests in order to promote healthy lawns and reduce nutrient loads to streams.

7.1.3. Strategies for Controlling Sediment Contamination

The SWAT modeling results indicate that the Neshanic River Watershed carries 1,823 tons of sediment away from the watershed each year and that streams are the primary sediment source and contribute 1,094 tons of sediment each year, which is equivalent to 60 percent of the total annual sediment load. The remaining 40 percent of sediments, roughly 729 tons, comes from land. Among the various land uses, row-crop agriculture, such as corn, soybean, wheat and rye, is the largest land contributor of sediment. Row-crop agriculture accounts for about 60 percent of land contribution of sediment, followed by urban land (16 percent) and other agricultural lands, such as pasture and hay (14 percent). A 9 percent reduction in the TSS concentration is required to achieve the designated water quality standard for the Neshanic River Watershed. The following strategies are proposed to control sediment. It should be noted many strategies for reducing nutrient loads also reduce sediment.

7.1.3.1. Contour Farming

Contour farming uses ridges and furrows formed by tillage, planting and other farming operations to change the direction of runoff from directly downslope to around the hill slope. Contour farming reduces sediment from gully erosion and slows down surface water runoff, which reduces the transport of sediment, phosphorus and other contaminants to surface waters.

7.1.3.2. Conservation Buffers

As discussed previously, conservation buffers have multiple water quality benefits. The best documented water quality benefit is to reduce sediment loads to streams. As runoff flows through a conservation buffer, dense vegetation in the buffer acts as a filter, preventing sediments and sediment-absorbed nutrients, pesticides and pathogens from entering streams. Conservation buffers should be installed in proper locations to achieve their optimal effectiveness in improving water quality.

7.1.3.3. Livestock Exclusion Fence

As discussed previously, livestock exclusion fencing should be installed in pasture areas located along streams to eliminate livestock's direct access to streams and thereby reduce the pathogenic loads into the streams in the watershed. The same exclusion fencing also eliminates livestock disturbances to streambanks and maintains streambank stability. A stable streambank generates less soil erosion, which reduces TSS loads to streams in the watershed.

7.1.3.4. Cover Crops

As discussed previously, cover crops have multiple environmental benefits. Cover crops can be incorporated into any cropping system that has fields that are not in use for all or part of a year to reduce the exposure of bare soil to wind and rain and therefore reduce soil erosion. The growing vegetation and healthy soil reduce runoff, which brings less sediment to the nearby streams.

7.1.3.5. Prescribed Grazing

Prescribed grazing helps to maintain healthy and productive pastures. Healthy pastures protect soil from erosion, which reduces phosphorus and pathogens in runoff. In addition, an actively growing pasture uptakes nutrients and improves water infiltration.

7.1.3.6. Roadside Ditch Retrofitting

There are 853 mapped roadside swale and ditch segments in the watershed having a total length of 40 miles. Of the mapped segments, 185 (about 9 miles) are actively eroding, thus contributing sediment to stormwater that flows through them that need to be repaired. 515 out of 853 segments (about 26 miles) have exposed earth in at least some portions of the conveyance and need repair. Roadside ditch retrofitting convert ditches into bio-retention systems that are very similar to constructed wetlands to remove sediments and nutrients.

7.1.3.7. Streambank Stabilization

Streambank erosion is a natural process that occurs in streams as water flows through the channel and wears away soil and rock. The SVAP assessment indicates that streambank erosion is a common problem in the Neshanic River Watershed. The SWAT modeling results indicate that streambank erosion contributes significantly to TSS in streams in the watershed. Streambank stabilization is an important way to reduce streambank erosion, improve water quality and enhance stream ecology. The SVAP assessment and the stormwater infrastructure inventory were used to identify potential sites for streambank stabilization. A wide range of streambank stabilization methods and techniques can be used. The selection of appropriate streambank stabilization methods should be based on the channel evolution stage of the stream, which can be identified using channel evolution models. Although the streambank can be temporarily stabilized through various streambank stabilization measures, permanent stabilization requires controlling the amount and velocity of stormwater runoff in the watershed. In order to stabilize streambanks, any land use activities that disturb the streambank should be prohibited.

7.1.4. Strategies for Restoring Watershed Hydrology and Streamflow

Land use changes and the associated stormwater infrastructure have significantly altered watershed hydrology. Watershed restoration is one way to mitigate the negative impacts of land use changes on watershed hydrology. The following BMPs are proposed to restore watershed hydrology and streamflow in the Neshanic River Watershed. These BMPs also improve water quality.

7.1.4.1. Bio-retention Systems

Traditional stormwater infrastructure is designed to quickly deliver stormwater from sources to streams. Bio-retention systems are BMPs that are designed to retain stormwater and then discharge it to stormwater systems and/or streams if necessary. These systems are designed to treat the retained stormwater to achieve substantial water quality benefits through various biological processes embedded in the system. The stormwater retained in those systems could infiltrate through the soils to recharge groundwater, thus reducing the amount of stormwater entering streams. Bio-retention systems in the watershed should include a series of bio-retention facilities. They include:

- Rain gardens to capture, treat, and infiltrate stormwater at homes;
- Bio-retention facilities at business and corporate campuses; and
- Constructed wetlands along roads.

7.1.4.2. Conservation Buffers

Conservation buffers provide both water quality and quantity benefits. Conservation buffers could achieve runoff reduction through evapotranspiration processes by plants and could promote groundwater recharge through multiple biological and hydrological processes.

7.1.4.3. Conservation Planning and Ordinances

Land use changes, especially suburban development, substantially alter watershed hydrology and cause many water quality problems in the watershed. In response to those water quality and quantity problems, municipalities in the watershed have developed various conservation plans and ordinances to control land use activities and protect water resources. For example, steep slope ordinances were developed to regulate the intensity of use in areas having steeply sloped terrain in order to limit soil loss, erosion, excessive stormwater runoff and degradation of surface water, and maintain the natural topography and drainage patterns of the land. Stream corridor protection ordinances were enforced to restrict land use activities in riparian areas of streams in order to improve water quality, mitigate the impacts of floods and protect streams and their surrounding ecosystems. As suburban development continues in the watershed, conservation plans and ordinances should be reviewed, developed, implemented and enforced to help prevent harmful land use activities and protect water resources in the watershed.

An ordinance review was conducted for municipalities in the Lockatong and Wickecheoke Creek Watershed Restoration and Protection Plan developed by NJWSA (May 2009) and recommendations were made to improve the conservation planning and ordinances in those communities for water resource protection and water quality improvement (NJWSA, 2009). That review covered Raritan and Delaware townships, portions of which are also located in the Neshanic River Watershed. The NJWSA (2008) concluded that Delaware Township has an excellent Master Plan, Environmental Resource Inventory, Riparian Protection and Well Testing Ordinance; and Raritan Township had the most up-to-date and comprehensive collection of Plans, Policies and Ordinances. As a Stormwater Tier A community, Raritan Township had passed Ordinances on Pet Waste, Litter Control, Improper Disposal of Waste, Wildlife Feeding, Yard Waste Collection, and Illicit Connections. The NJWSA made the following recommendations for Delaware Township:

- Prepare a build-out analysis in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15.
- Prepare a Wastewater Management Plan in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15.
- Revise the existing Steep Slope Provisions of the Land Use Code in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15.
- Prepare a Woodlands Protection Ordinance.
- Prepare a Wellhead Protection Ordinance.
- Prepare a Septic Management Plan and implementing ordinance in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15.
- Prepare a Soil Erosion and Sediment Control Ordinance to regulate activities not under the jurisdiction of the County Soil Conservation District.
- Revise the existing Floodplain Provisions of the Land Use Code in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15 and Flood Hazard Control Act Rules at N.J.A.C. 7:13.
- Prepare a Wetlands Protection Ordinance.
- Prepare a Nutrient Management Plan and adopt a Fertilizer Management Ordinance.
- Prepare a Pet Waste Ordinance.
- Prepare a Litter Control Ordinance.
- Prepare an Improper Disposal of Waste Ordinance.
- Prepare a Wildlife Feeding Ordinance.
- Prepare a Containerized Yard Waste Ordinance.
- Prepare a Yard Waste Collection Ordinance.
- Prepare and Illicit Connection Ordinance.
- Prepare a Water Conservation Ordinance.
- Reduce permitted impervious surface areas to 5% in areas zoned agricultural, rural or low density residential.

- Conduct on-going Outreach and Education programs through the Environmental Commission to inform local residents of the value of water resource protection. Engage local schools to participate in activities that are protective of water resources.

The following recommendations were made to Raritan Township:

- Prepare a build-out analysis in conformance with the Water Quality Management Planning Rules at N.J.A.C. 7:15.
- Prepare a Nutrient Management Plan and adopt a Fertilizer Management Ordinance.
- Prepare a Containerized Yard Waste Ordinance.
- Prepare a Water Conservation Ordinance.
- Reduce permitted impervious surface areas to 5% in areas zoned agricultural, rural or low density residential.
- Conduct on-going Outreach and Education programs through the Environmental Commission to inform local residents of the value of water resource protection. Engage local schools to participate in activities that are protective of water resources.

Similar reviews should be conducted and recommendations made in other municipalities in the watershed.

7.1.4.4. Farmland and Open Space Preservation

All the municipalities in the Neshanic River 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 urban and suburban development, 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 be continued and expanded to protect Hydrologically Sensitive Areas (HSAs) from intensive land use disturbances and prevent water resources from being degraded at their sources.

The NJWSA (2002) identified 20 criteria to rank parcels for open space acquisition and easements for water resource protection in the Raritan River Basin. Those criteria are listed in Table 7.1.

Table 7.1: NJWSA open space criteria for acquisition and easements (NJWSA, 2002)

Recharge Areas	Floodplains and Riparian Corridors	Trout Production Streams
Wellhead Protection Areas	Wetlands	Vegetative Cover
Drinking Water Source Areas	Mature Forest	Soil Type
Headwaters	Threatened or Endangered Species	Proximity to Water Body
Water Pollution Hazard Areas	Contamination and Previous Use	Land Use/Land Cover
Areas with Steep Slopes	Size of Parcel	% Impervious Surface
Lakes and Ponds	Length of Stream	

Several project partners, including NJIT, RC&D, and NJWSA, are including new information in the criteria to define the areas for future protection and preservation. The new information is called HSAs and is derived from a modified topographic index that simulates the likelihood that runoff is generated during a storm event. HSAs are the parts of the watershed that are likely to be saturated during a storm event. These areas should be protected from development and disturbance through farmland and open space preservation programs. As discussed in Section 4.2.3, the total area in HSAs is about 2,642 acres (i.e., about 14 percent of the watershed). Figure 4.9 illustrates the location of HSAs that should be prioritized for protection and preservation in the Neshanic River Watershed.

7.2. **Stormwater BMPs and Prioritization**

Two intensive land uses in the Neshanic River Watershed are agriculture and urban with urban consisting of residential, commercial and industrial uses. For urban land uses, four primary stormwater BMPs were recommended to address the sediment, nutrient and pathogen contamination and to restore watershed hydrology in the watershed: building rain gardens, retrofitting detention basins, retrofitting roadside ditches and establishing vegetative buffers.

7.2.1. Rain Gardens

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

A typical rain garden is designed to capture, treat and infiltrate the rain water from a storm of 1.25 inches from a 1,000 square foot impervious area from an individual lot (i.e., a 25' by 40' roof for a house or a 20' wide by 50' long driveway). By collecting runoff generated by the first 1.25 inches of rainfall, the rain garden prevents the “first flush” of runoff from entering the stream, which characteristically has the highest concentration of contaminants. To handle a rain storm of 1.25 inches, the rain garden needs to be 10' by 20' and six inches deep. Since 90 percent of all rainfall events are less than one inch, rain gardens are able to treat and recharge a majority of runoff from these storms. If designed and installed correctly, rain gardens will reduce the pollutant loading from a drainage area by 90 percent. Furthermore, they will reduce stormwater runoff volumes and the flashy hydrology of local streams. The latter will lessen streambank erosion and stream bed scour, thereby reducing TSS and phosphorus loads in the waterway. According to Rusciano and Obropta (2007), rain gardens remove 90 percent of fecal coliform from stormwater runoff.

There are 3,545 low density residential homes in the Neshanic River Watershed that are suitable for rain garden installation. Figure 7.1 shows the potential neighborhoods in the watershed where rain gardens can be installed. Appendix 1 lists the potential numbers of rain gardens in each of those neighborhoods by subwatersheds in the watershed. If each suitable home installs a rain garden to capture, treat and infiltrate runoff from 1,000 square feet of impervious surface, then about 89 million gallons of stormwater runoff would be captured, treated and infiltrated. Assuming aerial loading coefficients of 0.6 pounds per acre per year of TP, 5.0 pounds per acre per year of TN and 100 pounds per acre per year of TSS, the total pollutant loads removed by the 3,545 rain gardens are conservatively estimated to be 44 pounds per year of TP, 366 pounds per year of TN and 7,324 pounds per year of TSS.

Rain gardens can be installed almost anywhere. Ideally, the best installation sites are those where the soils are well-drained so that an underdrain system is not required. Reduction in runoff and increase in groundwater recharge from rain gardens would help reduce the stream peak flow and increase the baseflow, thereby improving watershed hydrological conditions. The willingness of home and business owners to adopt rain gardens is essential to their installation. Home and business owners in the identified target neighborhoods who are willing to install and maintain rain gardens on their properties should be encouraged to do so. Education and outreach programs should be conducted and demonstration projects should be initiated to educate the general public and municipal officials about the benefits of installing rain gardens and to train landscape professionals in such installation.

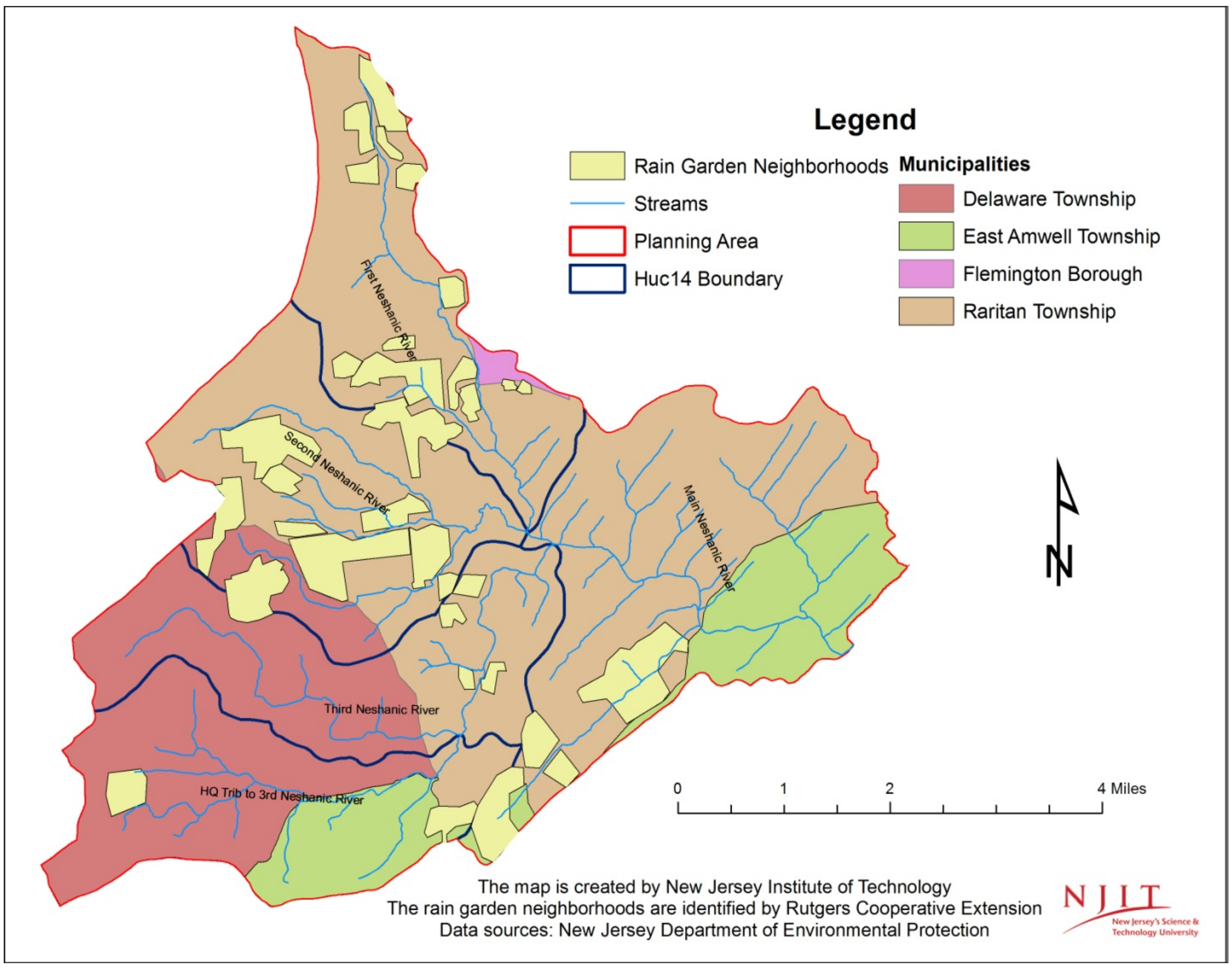


Figure 7.1: Location of potential neighborhoods for rain garden installation in the Neshanic River Watershed

Table 7.2 lists annual pollutant load reduction and volume of water intercepted for different homeowner adoption rates for residential rain gardens in the Neshanic River Watershed. There may be additional locations throughout the watershed where commercial and industrial properties can install rain gardens and achieve similar load reductions.

Table 7.2: Annual pollutant load reduction and volume of water intercepted for different homeowner adoption rates for residential rain gardens in the Neshanic River Watershed

Adoption Rate for Rain Gardens	Pollutants Removed (lbs/yr)			Stormwater Intercepted (million gallons/yr)
	TP	TN	TSS	
25%	11	92	1,831	22
50%	22	183	3,662	44
75%	33	275	5,493	66
100%	44	366	7,324	89

7.2.2. Roadside Ditch Retrofitting

In the rural areas of the watershed, piped drainage is less prevalent. Stormwater in those areas is usually routed by the use of drainage ditches along the roadways. Most roadside ditches lack the design standards of conventional stormwater infrastructure systems. Roadside ditches are ad hoc creations and appear to be designed not for stormwater management, but for the convenience of landowners. This approach to ditch design exacerbates water quality problems.

Typically, ditches are not well maintained and consist of bare soil. This project mapped 853 swale and ditch segments (40 miles) in the watershed. Of the mapped segments, 185 (about 9 miles) are actively eroding. These segments contribute sediment to stormwater and are in urgent need of repair. 515 out of 853 segments (about 26 miles) have exposed earth in at least portions of the ditch and need some repair. Only 153 swale and ditch segments (about 6 miles) were found to be in good condition and conform to soil erosion standards for a grassed waterway or rip-rap channel.

The eroded roadside ditches should be retrofitted to protect them from erosion and improve the water quality of runoff traveling through them. To prevent erosion, the New Jersey Department of Transportation Roadway Design Manual requires outlet protection of conduits for runoff velocity generated during the 25-year storm (at a minimum). Therefore, it is recommended that any alteration of designs for a drainage ditch should provide for the capacity of a 25-year storm to prevent erosion in the ditch.

Roadside ditch retrofitting should also improve water quality of the runoff entering the ditch. A common method of improving water quality is to reduce the velocity of runoff to allow contaminants to settle out. Designs should work to mimic the flow reductions seen in grassed filter strips for water quality improvement. Reducing velocities also increases infiltration of stormwater by increasing the length of time that runoff is retained in ditches.

The first retrofitting strategy to improve roadside ditches is to widen the ditches and plant them with a diverse mix of native vegetation. Vegetation creates friction, which reduces flow and encourages infiltration. The Neshanic River Watershed, especially Delaware Township where the majority of roadside ditches are located, has a very narrow right of way (ROW) along the side of the road. Ditches should be widened when vegetation is planted to make maintenance of ditches easier and more affordable.

Due to the limiting size of ROWs, there is very little space available for widening ditches in the Neshanic River Watershed. For that reason, use of rip-rap (large stones), stone-filled gabion baskets and weirs is recommended to control the flow in ditches. A gabion basket is a cube made of wire mesh that is filled with large stones. The stones provide structural support and the mesh holds the stones in place. Because gabion baskets are porous, they reduce the velocity of water flow in drainage ditches, which improves water quality. The reduction in flow velocity requires the ditches to have a larger storage capacity. Because there is little room to widen ditches, the need for larger storage capacity can only be achieved by deepening the ditches. The cost of this strategy depends on how many gabion baskets are installed in each ditch. Material and installation cost for the one gabion basket is approximately $200.

A second retrofitting strategy is to use French drains that are exposed to the surface. A French drain is an underground drainage trench or channel filled with stone that creates a path for water to flow. Because the French drain reduces the velocity of the runoff flowing through the drain, the ditch upstream of the drain and the channels of the drain need to have additional storage capacity. In addition, the inlet and outlet of the French drain need to have structural support to prevent stone from being washed out of the drain over time. A gabion basket check dam placed at the front and back of each exposed French drain would provide sufficient storage capacity for the drain. A larger gabion basket should be used where vehicles cross the ditch on a routine basis; farmers often make such crossings. The strategy involves installing gabion baskets as well as laying stone in narrow ditches. Material and installation cost is about $400 per gabion basket and $100 per linear foot of stone in between the two gabion baskets.

A third retrofitting strategy is to install weirs. Gabion baskets provide a basic form of water flow velocity control, but they lack the flexibility of other flow control devices, such as weirs. A weir is simply a small dam with a notch cut out of it. The size and placement of the notch affects water flow past the weir. The flow is controlled by the shape, elevation, location and size of the notch and the height of the water behind the notch. The higher the water behind the weir and the larger the shape and size of the weir, the higher the flow rate. Although weirs are interchangeable with gabion baskets, the former allow greater control over flow and cost more to design and implement than the latter. Installation of a weir with a scour hole in place of a gabion basket costs $400.

Further details regarding how roadside ditches can be retrofitted using the strategies described above are provided by the examples in Section 7.4. If all existing ditches in the Neshanic River Watershed were retrofitted with the recommended strategies, then 48.5 acres of roadway and many more acres of surrounding drainage areas would be affected.

Using the retrofitting strategies described above would turn roadside ditches into something very similar to constructed stormwater wetlands. Care needs to be taken with constructed wetlands due to the need for maintenance of roadways and potential permitting issues. The removal rate for constructed stormwater wetlands is 90 percent for TSS, 50 percent for TP and 30 percent for nitrogen. The fecal coliform removal rate of wetlands is 93 percent (Karathanasis et al., 2003). Assuming ditches treat 90 percent of the stormwater runoff, aerial loading coefficients for the 48.5 acres of roadways being treated by these ditches of 2.1 pounds of TP per acre per year, 22 pounds of TN per acre per year and 200 pounds of TSS per acre per year, 46 pounds of TP per year, 288 pounds of TN per year and 7,857 pounds of TSS per year would be removed. In reality, the ditches would treat a much larger area than the 48.5 acres of roadway. They should be able to treat the land adjacent to the roadways, yielding much larger reductions in pollutant loads.

Every roadside ditch and culvert in the Neshanic River Watershed is listed in the project Stormwater Infrastructure Inventory, along with their type and condition. Roadside ditches are categorized using three criteria: ditch type; ditch condition; and whether the ditch conforms to any design standards. Table 7.3 summarizes the roadside ditch prioritization criteria and criteria scores. Those roadside ditches with the highest total score have the highest priority for retrofitting.

Table 7.3: Roadside ditch prioritization criteria and criteria scores

Prioritization Criteria for Ditch	Criteria Score					
	1	2	3	4	5	6
Type	Wetland	Vegetation	Stone	Mixed	Soil	Other
Condition	Good				Need Repair	Urgent
Design	Yes					No or unsure

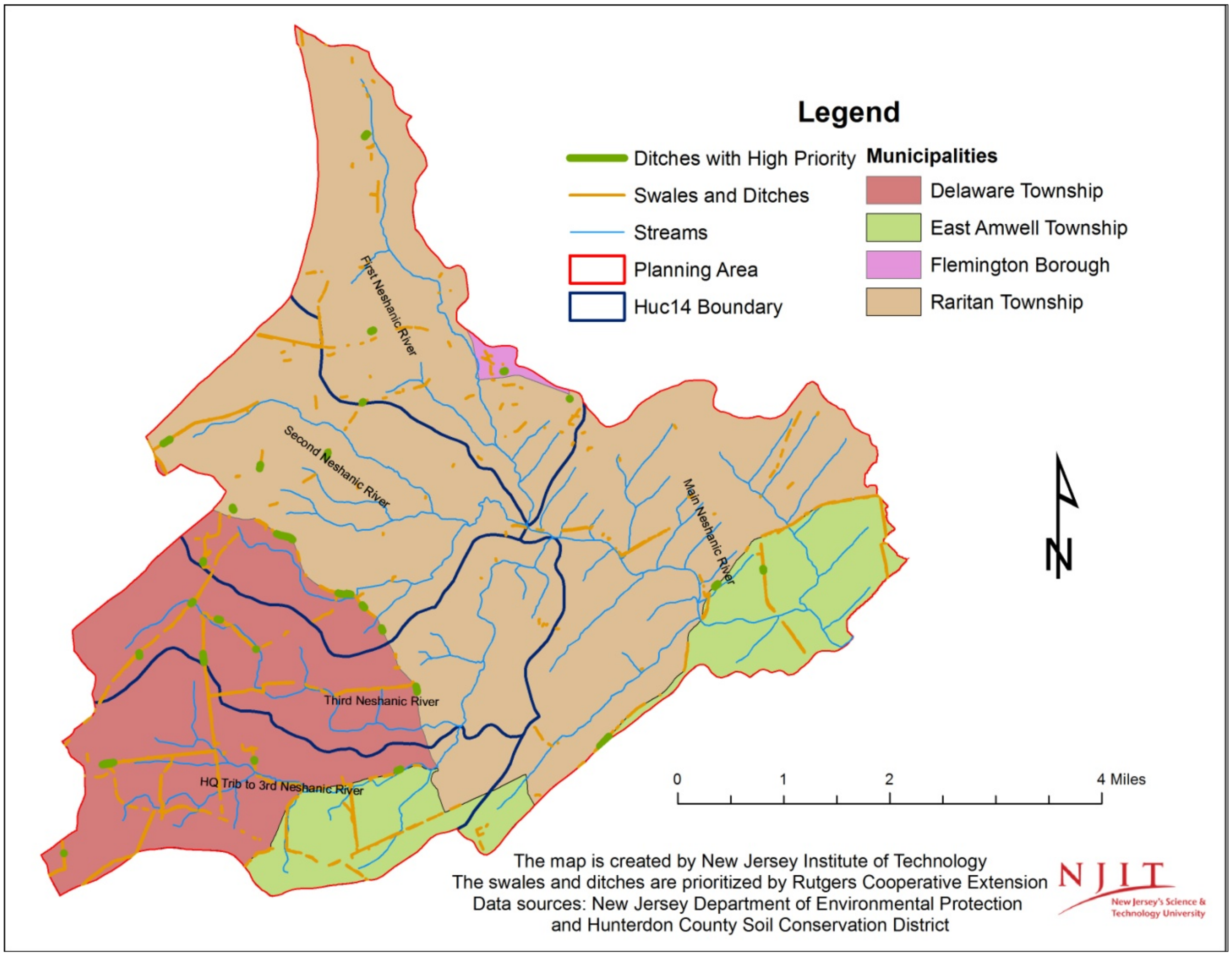


Figure 7.2: Location of swales and ditches in the Neshanic River Watershed

Prioritization criteria and criteria scores are based upon the inputs provided by the project partners. The highest score a ditch can have is 18 and the lowest score is 3. Any ditch with a score equal to or less than 5 is a good quality ditch and does not need retrofitting. The score of 5 was arrived at by assuming that a good quality ditch should be in good condition (1 point), have a stone-type ditch (3 points), and have a formal design (1 point). Only 33 swales and ditches have scores of 5 or lower. The 138 ditches and swales with prioritization scores of 16 or higher were considered high priority for retrofitting. Figure 7.2 shows the location of all 853 swales and ditches in the watershed; ones with high priority for retrofitting are highlighted in green. Appendix 2 list all ditches with their prioritization scores and the prioritization categories by subwatersheds in the Neshanic River Watershed.

7.2.3. Detention Basin Retrofitting

Stormwater from the more developed areas of the watershed is usually managed with detention basins. Detention basins are constructed impoundments for reducing flooding and lowering the volume and velocity of stormwater that flows into streams immediately after a storm. Figure 7.3 shows a detention basin in Subwatershed TN3a. There are 153 mapped detention basins in the Neshanic River Watershed with a variety of different detention basin designs including wet ponds, infiltration basins, bio-retention basins, extended dry detention basins and even bermed-off stream corridors with flow control weirs. The quality of maintenance of the existing basins ranges from heavily landscaped and manicured, to benign neglect, to outright abandonment. Virtually every detention basin in the watershed presents an opportunity for upgrades or retrofits to improve water quality.

Figure 7.3: Detention basin in TN3a

The condition of the bottoms of many detention basins are suitable for retrofits: 106 of 153 basins were found to have mowed turf bottoms; eight basins had weeds or successional vegetation due to a lack of mowing; three basins were fully overgrown with trees and shrubs; and one basin lacked any vegetation and was covered with deposited material.

Low flow channels were very common in the detention basins in the watershed. Out of 196 mapped low flow channel segments, 156 were found to be concrete. Only one-third of the detention basins have outlet structures with a three-inch water quality orifice. The three-inch orifice outlet structure extends the water detention time in the basin to allow TSS and the attached nutrients to settle, which achieves certain water quality benefits. The remaining detention basins in the watershed were not constructed to achieve water quality benefits through extended water detention and should be retrofitted to do so.

A common design feature for detention basins is a low flow concrete channel that carries runoff from the inlets to the outlet structure of the detention basin. This feature is intended to force water through the basin during small storm events to avoid ponding and maintenance issues. Due to sediment and debris accumulation in these channels and the lack of regular maintenance, these channels tend to clog, causing ponding of water in the channel. The small stagnant ponds become ideal mosquito breeding habitat, thereby creating a problem they were originally intended to avoid. Low flow concrete channels act as an impediment to improving water quality in a detention basin. It is recommended to remove the concrete channel replacing it with a vegetated swale or a rip-rap stone channel depending on site-specific conditions.

A low-flow vegetated swale should have a 0.1 percent side slope to ensure easy maintenance and a slope not to exceed 3 percent. The swale should be seeded with native grasses to minimize maintenance. Where possible, replacement soils should be installed. The top 1.5 feet of soil should be composed of a bioretention soil mix to encourage infiltration. Below this infiltration media, a 6″ layer of 3/4″ diameter clean stone should be installed. The native vegetation in the swale should be cut once or twice a year. Dense native vegetation creates friction along the flow path of runoff through the detention basin. This friction slows the water allowing sediment to settle out. Water is held in the detention basin longer, increasing infiltration and allowing the vegetation to take up nutrients carried in stormwater runoff. Finally, native vegetation that is allowed to grow taller will develop a deep root structure allowing a much greater infiltration rate than soil with short turf grass. The channel should be designed to infiltrate and pass water through within 48 hours after a storm to prevent mosquito breeding.

A low flow rip-rap stone channel should not be any wider than 10 feet. The bottom should be at least three feet above the seasonal high groundwater elevation and the channel should be designed to hold the runoff volume of the water quality storm from the detention basin’s drainage area. Infiltration rate of the soil where the channel is installed should be taken into consideration before sizing. The channel should infiltrate any storm equal to or smaller than the water quality storm within 48 hours.

Detention basins in the watershed are usually covered with turf grass that provides for minimal infiltration. Turf grass has a shallow root structure that does not open up the soil below the surface allowing water to infiltrate. One important measure in retrofitting detention basins is to replace turf grass with native grasses and vegetation that requires low maintenance. By introducing native grasses and reducing the frequency of mowing from once a week to once or twice a year (usually in the winter), native grasses develop a deep root structure. The height of the grass is directly proportional to the depth of the root structure. Limiting mowing and allowing the grass to grow taller ensures development of a deep root structure. Using native grasses reduces maintenance costs because they require less mowing and improves water quality by increasing infiltration and subsequently decreasing stormwater discharges to nearby waterways.

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

Retrofitting detention basins should take a short amount of time. Although heavy equipment may be needed to remove a concrete channel and install a vegetative channel, precautions should be taken to avoid over-compacting the basin. Deep-tilling may be needed to loosen the soil in areas where heavy equipment is driven. Native grass should be seeded in the basins after the turf grass has been eliminated with an herbicide. Seed will need to be covered and protected from erosion. Detention basins must be inspected for excessive debris and sediment accumulation at least four times per year, as well as after every storm exceeding one inch of rainfall. Sediment removal should take place when the basin is thoroughly dry. Disposal of debris, trash, sediment and other waste material should be done at suitable disposal/recycling sites and in compliance with all applicable local, state and federal waste regulations (Semple et al., 2004).

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

The cost of retrofitting a detention basin will vary depending on the amount of work that needs to be done to improve the detention basin. If the detention basin needs to be excavated and replanted, the cost is approximately \$2 to \$4 per ft^2 of the detention basin. When a detention basin needs to be re-vegetated the cost to improve the detention basin is \$0.25 to \$2 per ft^2. Cost estimates vary because there are many detention basin designs. The cost to remove a low flow concrete channel is approximately \$100 per linear foot.

Retrofit designs should target infiltration of runoff generated from the water quality storm of 1.25 inches of rain over two hours. In New Jersey, since approximately 90 percent of all storms in a year are smaller than the water quality storm, retrofit designs should have a dramatic effect on water quality in the watershed. While it is hard to measure the exact effect, the basins should have many of the same characteristics as a vegetated filter strip. It is difficult to estimate the reductions for each pollutant from retrofit designs because many of the functions of the basin will be enhanced by the proposed changes. Targeted reductions of 90 percent of TSS, 60 percent of TN and 30 percent of TP are expected. Depending on the final design of the detention basin, it will function like a bioretention basin or a wetland. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007; Karathanasis et al., 2003). Since drainage areas for each basin were not readily available, it is impossible to estimate the total pounds of pollutants removed by retrofitting the detention basins in the Neshanic River Watershed.

A stormwater infrastructure inventory completed as part of the project documents the existing conditions of detention basins, including the general condition of the basin, the vegetation on the basin bottom, the type and condition of any low flow concrete channel and/or under drain and the type of basin outlet structure. Such information was used to prioritize the detention basins for retrofitting. Table 7.4 lists criteria for prioritizing detention basins and criteria prioritization scores developed by the project team. The sum of the criteria scores for a detention basin gives the prioritization score. A higher retrofitting priority is given to detention basins with higher prioritization scores.

Table 7.4: Criteria for prioritizing detention basins and prioritization criteria scores

Prioritization Criteria	Prioritization Criteria Score					
	1	2	3	4	5	6
General Condition	Good				Need Repair	Urgent
Basin Bottom Vegetation	Wetlands, Tree Succession	Grasses Natural	Wetland, Turf grass	Turf Grass	Weeds	No Vegetation
Low Flow Channel	Wetland	Turf or Stone			Concrete	Other
Cutoff in Low Flow Channel	Yes					No
Water Quality Outlet	Yes					No

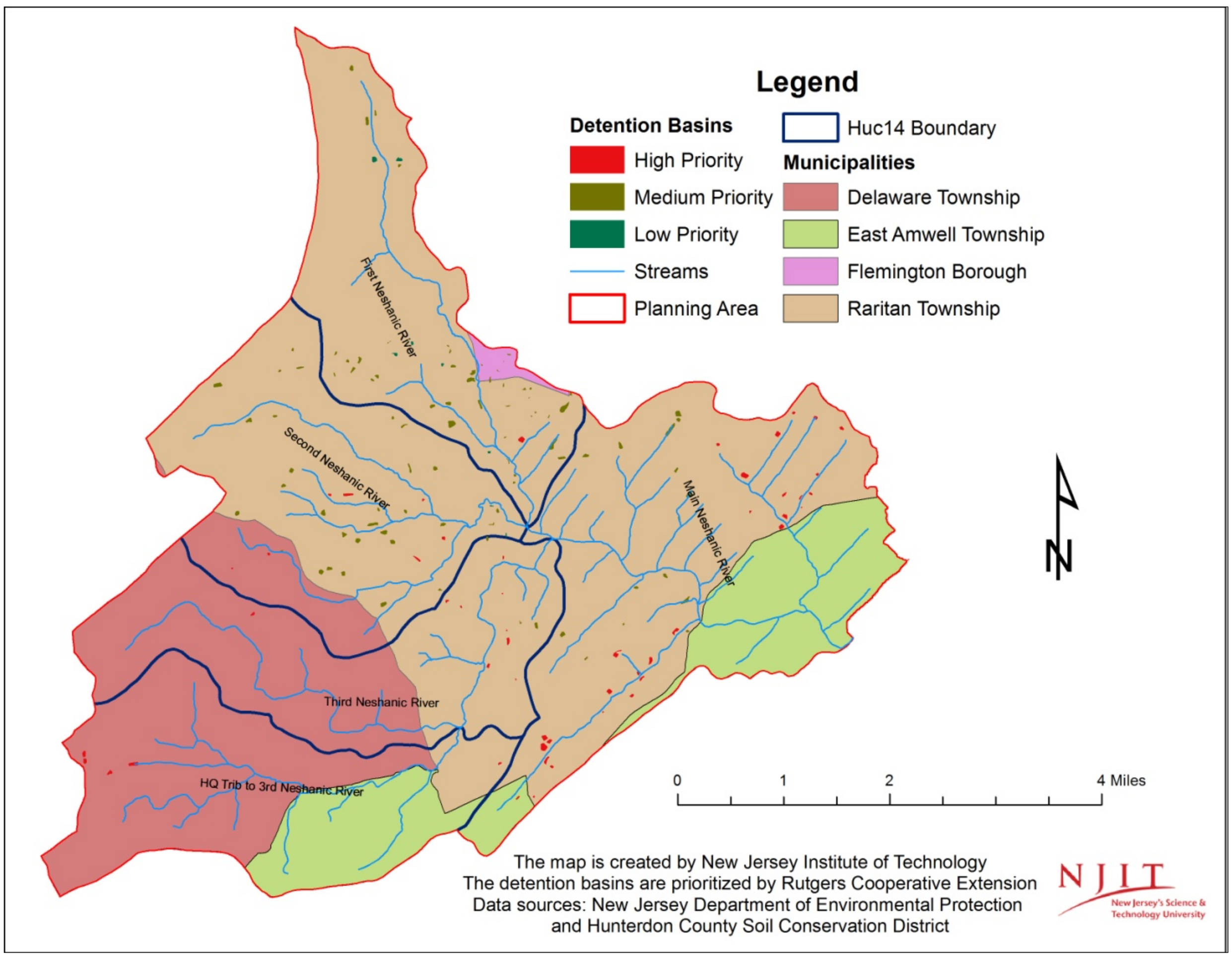


Figure 7.4: Location of detention basins with priority for retrofitting in the Neshanic River Watershed

There are 153 detention basins in the watershed mapped by HCSCD. The highest score a detention basin can have is 30 and the lowest score is 5. Any detention basin with a score equal to or less than 8 should be considered a good detention basin with low priority for retrofitting. There are 9 detention basins in this category. A score of 8 is arrived at by assuming that a good detention basin should at least be in good condition (1 point), have a turf grass basin bottom (4 points), a turf or stone low flow channel (2 points) with a cutoff (1 point) and a water quality outlet (1 point). Any detention basin with a score equal to or higher than 20 is prioritized as high priority for retrofitting. There are 51 detention basins in this category. Ninety-three detention basins have a priority score from 9 to 19, which are considered as medium priority for retrofitting. Figure 7.4 shows the location the detention basins with various priorities for retrofitting in the watershed. Appendix 3 lists all detention basins along with their prioritization scores and categories by subwatersheds in the Neshanic River Watershed.

7.2.4. Vegetative Buffers for Non-Agricultural Developed Lands

Non-agricultural land uses such as residential, commercial, industrial, barren lands and park lands contribute to the phosphorus and TSS loads entering streams. Sources of pollutants are typically roadway sediment and lawn fertilizer, as well as soil erosion from unstable areas. The Neshanic River Watershed was once dominated by agriculture and natural landscapes. Over time, more housing developments have been added to the watershed. As the natural landscapes decrease in the watershed, the protective vegetated buffers surrounding the Neshanic River and its tributaries have declined. Residential neighborhoods and commercial and industrial development have been replacing natural landscapes. These developments usually have turf grass as their dominant form of vegetation, some of which comes right up to the shoreline of streams. Streams need a diverse assemblage of vegetation along the shoreline to provide shade, establish habitat and filter stormwater runoff. Streams that run through developments not having vegetated buffers can be sources of nutrients and TSS. The nutrients and bacteria collect on the surface near the shoreline. When a storm event occurs, the stormwater runoff carries the nutrients and bacteria directly to the streams bypassing a vegetated buffer.

A vegetated buffer is an area designed to remove suspended solids and other pollutants, as well as associated pollutants, such as hydrocarbons, heavy metals, and nutrients, from stormwater runoff. Pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake and microbial activity. Vegetated buffers are designed to receive stormwater runoff as sheet flow for maximum pollutant removal. Pollutant removal rates for vegetated buffers depend upon the vegetative cover in the buffer. They range from 60 to 80 percent for TSS and 30 percent for phosphorus and nitrogen (Semple et al., 2004). Vegetated buffers that are

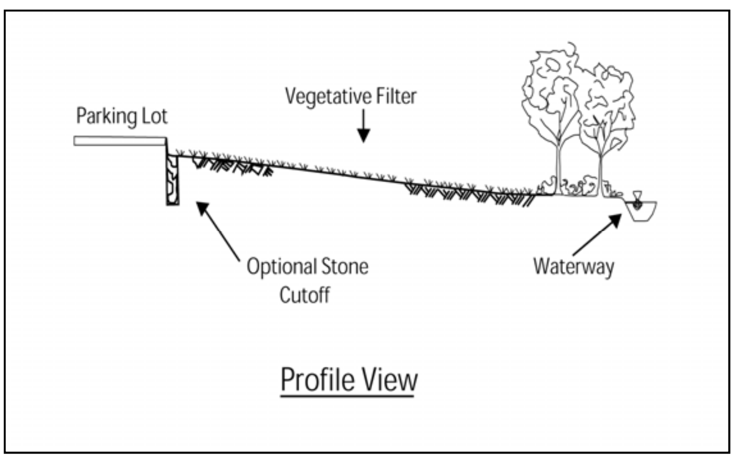


Figure 7.5: Typical profile of a vegetative buffer in a non-agricultural setting (Semple et al., 2004)

planted with woody material may also create shade along water bodies resulting in lower water temperatures, greater detritus and large woody debris for fish and other aquatic organisms, and habitat and protective corridors for wildlife. Figure 7.5 illustrates a typical profile of a vegetated buffer in a non-agricultural setting.

For vegetated buffers to be effective in trapping debris and sediment, they must be inspected for clogging and excessive debris and sediment accumulation at least four times per year and after every storm exceeding one inch of rainfall. Sediment removal should be done when the vegetated buffer is thoroughly dry. Debris and trash should be disposed of only at suitable disposal/recycling sites in a manner that complies with all applicable local, state and federal waste regulations (Semple et al., 2004). Mowing of vegetated buffers must be performed on a regular schedule, based on specific site conditions; typically, once every six months at a minimum. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour and at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation. When establishing or restoring vegetation, biweekly inspections of vegetative health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetative health, density and diversity should be performed during both the growing and non-growing seasons at least twice a year. Use of fertilizers, mechanical treatments, pesticides and other means, done to ensure optimum vegetative health, must not compromise the intended purpose of the vegetated buffer. Whenever possible, vegetative deficiencies should be alleviated without the use of fertilizers and pesticides. Vegetated buffer should be inspected for excess ponding after significant storm events and corrective measures should be taken when excessive ponding occurs (Semple et al., 2004).

Vegetated buffers should be designed and installed so as to remove 70 percent of the TSS and 30 percent of the nitrogen and phosphorus in the runoff that enters the buffers throughout the year. There is no established removal rate for bacteria in a vegetated buffer. However, it is fair to assume that the bacteria act as particles much like sediment, and the removal rate should be similar because the same mechanism that reduces TSS will reduce bacteria. Figure 7.6 is a map of the location of every potential buffer project along developed land uses in the Neshanic River Watershed. Any portion of a stream or waterbody that is surrounded by non-agricultural developed land and appears to have little or no existing vegetation along the stream is considered a potential site for a buffer project.

This project has identified approximately 27,603 feet (5.2 miles) of potential sites for vegetated buffer. Municipalities can partner with local environmental organizations, environmental commissions and other community organizations to reach out to home and business owners to identify neighborhoods and businesses willing to install and maintain vegetated buffers on their properties. A ranking of subwatersheds based on the greatest need for vegetated buffers on non-agricultural developed land uses can be based on the phosphorus ranking in Table 5.5.

The cost of vegetated buffers varies depending on the complexity of their design and size. Vegetated buffers consisting of warm season grasses are considerably less expensive than designs requiring more vegetation and a more complex design. In addition to being inexpensive and attractive, vegetative buffers need to be well-designed and consistent with the property owner's preferences.

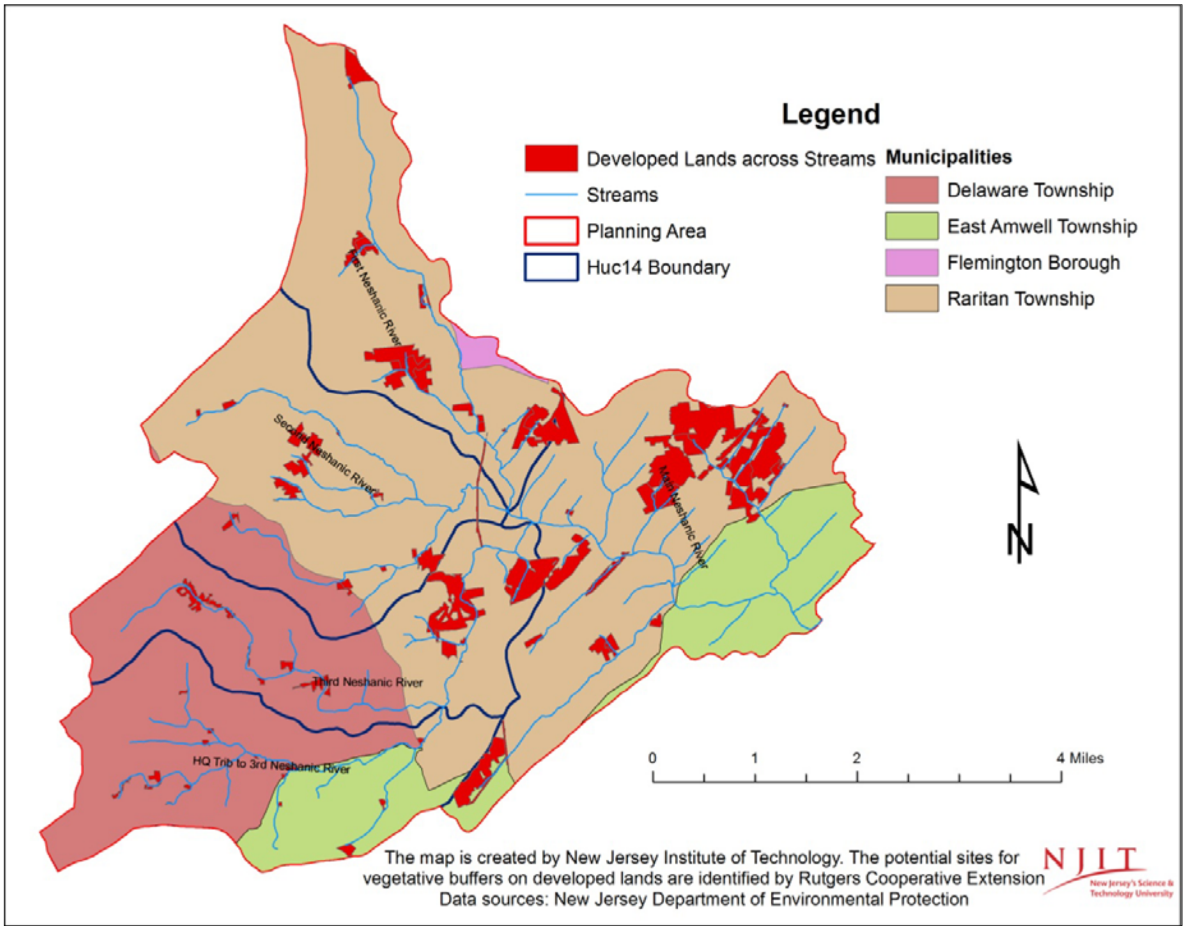


Figure 7.6: Potential sites for vegetative buffers on developed lands in the Neshanic River Watershed

7.3. **Agricultural BMPs and Prioritization**

7.3.1. Livestock Access Control – Exclusion Fencing

Livestock access to streams is a threat to water quality and a potential source of streambank degradation and soil erosion in the Neshanic River Watershed. Nutrients and pathogens from livestock manure can be transmitted to streams via direct deposit and runoff. Installation of exclusion fences along streams where livestock graze would protect streams from such contamination. Additionally, fencing promotes the restoration of riparian areas of streams. A fully functioning riparian area filters pollutants and prevents them from reaching streams. In addition, exclusion fencing should be installed along all waterways that run through pastures used by livestock that have access to those waterways. The NRCS BMP Manual requires installing livestock exclusion fencing at least 35 feet from streambanks, further depending on the stream width and other site-specific conditions. The 35-foot corridor allows for the establishment of a healthy riparian zone that protects streams from pastureland runoff. The type of fencing utilized depends on the type of livestock present and site-specific conditions. Once fencing is installed, livestock are no longer able to deposit manure in the streams during watering or crossing. Moreover, exclusion fencing reduces other damages to streambanks, allowing streams to return to a more natural state.

While fencing may be installed by any contractor or landowner, technical assistance should be obtained from NRCS or another support agency to ensure the effectiveness and longevity of the fence. Fencing costs vary according to livestock type and landowners' preferences. The NRCS approximates the cost of livestock exclusion fencing to be $4.78 per foot. Fencing cost to landowners can be reduced if a landowner applies and qualifies for cost share programs that pay a portion of the cost of fencing. Such programs often fund other practices associated with exclusion fencing such as the installation of an alternate water source for livestock. Currently, there are several state and federal cost-sharing programs. For example, the NRCS Agricultural Water Enhancement Program (AWEP) offers cost share in the Neshanic River Watershed. Currently, cost-sharing rates are as high as 100 percent of the installation cost.

The total length of the stream segments flowing through pasture in the Neshanic River Watershed was estimated based on the pasture locations given in the land use inventory for the watershed. Base on these stream segments, potential exclusion fencing sites cover about 24,663 linear feet of stream segments.

Table 7.5 gives the priority rankings (in terms of reducing pathogenic loads), length and installation cost of potential fencing sites in Neshanic River Watershed by subbasin and subwatershed. The estimated total cost of installing exclusion fencing on both sides of the stream segments associated with those sites is $236,000. Livestock access control fencing should completely eliminate the direct deposit of livestock manure into streams, which should result in 19 percent reduction in pathogenic loads to the Neshanic streams assessed using the SWAT model. Figure 7.7 shows the potential exclusion fencing sites in the Neshanic River Watershed.

Table 7.5: Priority rankings, length and installation cost of potential livestock exclusion fencing sites in Neshanic River Watershed

Subbasin	TP Priority	Subwatershed	TP Priority	Aggregate Ranking	Length (feet)	Installation Cost ($)
3	13	SN1	5	18	1,519.3	14,524.78
6	17	SN1	5	22	1,715.9	16,404.42
10	7	N1	1	8	2,339.1	22,362.06
12	5	N1	1	6	3,165.0	30,257.05
16	6	N2	n/a	6*	4,955.3	47,372.82
17	4	TN3	7	11	1,542.1	14,742.80
22	24	TN3a	2	26	100.3	958.66
23	9	TN3a	2	11	936.0	8,948.22
24	14	TN3a	2	16	7,157.4	68,425.20
25	2	TN3a	2	4	1,232.5	11,782.87
					24,663.1	235,778.88

Note: * aggregate rank is only based on the subbasin ranking.

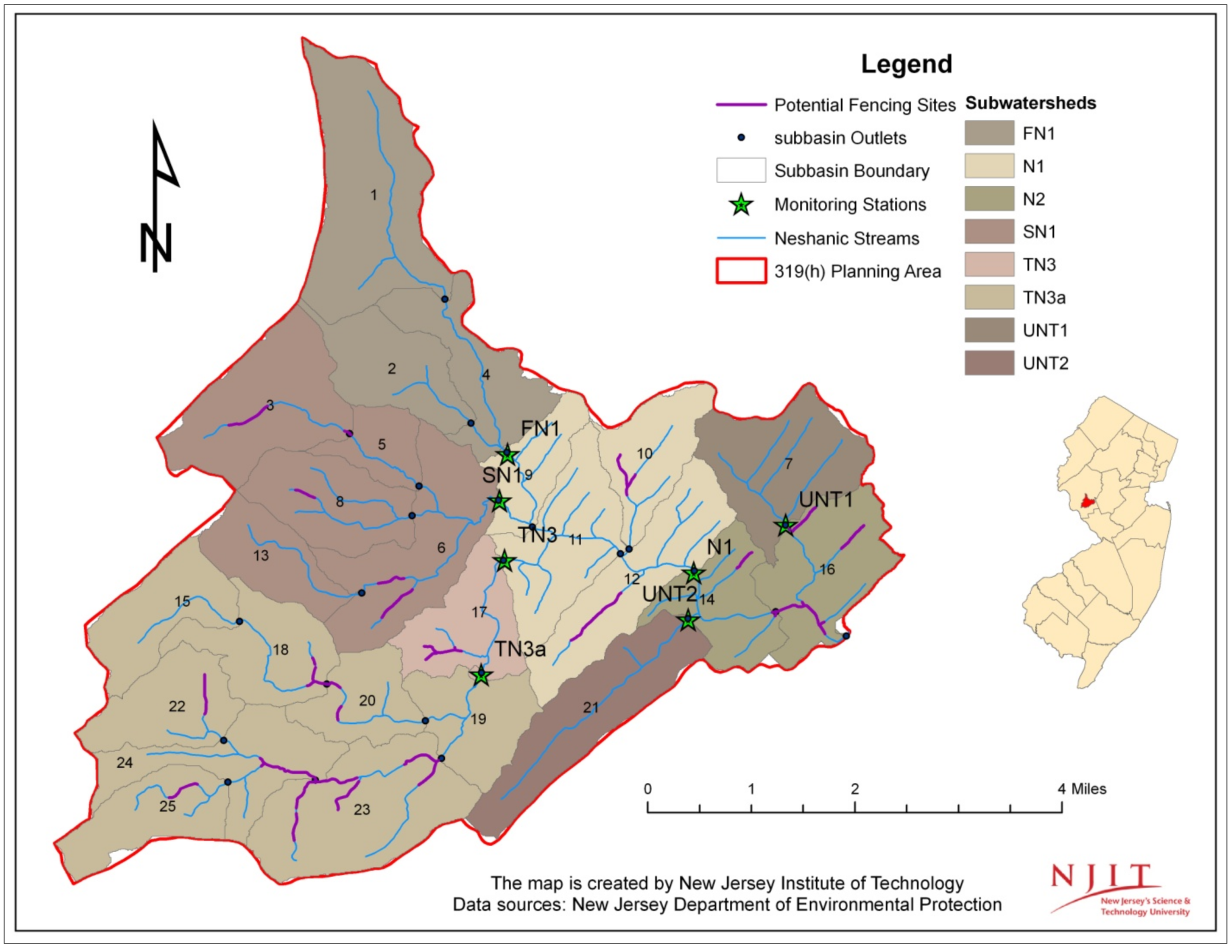


Figure 7.7: Potential sites for livestock exclusion fencing in the Neshanic River Watershed

7.3.2. Conservation Buffers

A conservation buffer is a structural vegetative mixture of trees, shrubs and grasses placed in a landscape to influence ecological processes and enhance ecosystem goods and services. There are many types of conservation buffers, such as contour buffer strips, field borders, grassed waterways, filter strips and riparian forest buffers (Bentrup, 2008). These terms tend to be used interchangeably without distinction. In this project, the term conservation buffer is used to refer to all types of buffer practices being used in the watershed.

Different types of conservation buffer practices can be applied in different parts of the watershed to maximize economic and environmental benefits, such as water quality improvement, soil erosion control and wildlife habitat enhancement. Water quality benefits of conservation buffers are well documented. As runoff goes through conservation buffers, the sediments and any pollutants attached to sediments are filtered out by the buffers. Buffers dissolve some of the pollutants through complicated chemical and biological processes, promote ground water recharge and evapotranspiration, and reduce runoff.

Well designed and positioned conservation buffers can achieve at least 50 percent reduction in N, P and sediment loads (Lowrance et al., 1986). In New Jersey, the vegetative filter is expected to achieve 60-80 percent reduction in TSS and 30 percent reduction in TN and TP (Semple et al., 2004).

Research on the effectiveness of buffers in reducing pathogenic loads is not as extensive as for reducing TSS, TN and TP. Some research suggests that conservation buffers can remove up to 60 percent of the pathogens in runoff (SWCS, 2001). Strategically locating conservation buffers is essential to maximize the effectiveness of the buffer in pollutant removal (Dillaha et al., 1989; Dosskey et al., 2002 and 2006; Qiu, 2003 and 2009).

Conservation buffers can be installed by any contractor or landowner. The NRCS has specific guidance for conservation buffer installation and maintenance. Technical assistance should be obtained from NRCS to ensure proper location, plant selection and buffer size. If livestock are present, fencing has to be installed to prevent damage to the buffer. The costs associated with the implementation of conservation buffers include the cost of materials and labor, maintenance and the opportunity cost of the land taken out of production. Various federal, state and local programs provide cost-sharing to implement conservation buffers. In New Jersey, the Conservation Reserve Enhancement Program (CREP) has been the primary funding mechanism for installing conservation buffers on agricultural lands. The $100 million New Jersey CREP offers a one-time sign-up incentive, covers 100 percent of the implementation costs of installing buffers and offers land rental payments for up to 15 years. The program supports four types of buffer practices in agricultural lands: grass waterways; contour grass strips; filter strips; and riparian buffers. The land rental payments offset the opportunity cost of the land taken out of agricultural production and are determined by soil type and the annual soil rental rate set by the USDA FSA. Other governmental agencies and non-profit conservation groups that are interested in implementing conservation buffers can also become involved by offering mini-grants and assisting in the implementation and maintenance of conservation buffers.

Installation costs of conservation buffers vary due to site-specific conditions and the choice of buffer practices. According to the NRCS AWEP 2010 practice catalog, installation costs of filter strips range from about $292 to $303 per acre, and installation costs of riparian buffers range from about $1,082 to $2,597 per acre. Grassed waterways are the most expensive and least used buffer practice; they often require installation of an engineering structure at the end of the waterway to ensure the proper dispersion of the concentrated runoff into the streams. The general annual maintenance cost of grassed waterways is about $4-$9 per acre.

Qiu (2009) applied the concept of Variable Source Area (VSA) hydrology to target the placement of conservation buffers in agricultural lands in the Neshanic River Watershed. The VSA concepts and modeling tools are used to identify the HSAs. Agricultural lands in the HSAs are targeted for conservation buffer placement. In this project, 875 acres of agricultural lands in HSAs were identified as being suitable for conservation buffers of which 331 acres are located within the riparian area of the Neshanic streams.

The project team members including NJIT, North Jersey RC&D and NJWSA developed another strategy to target agricultural lands for conservation buffers in Raritan Basin under a grant from the NRCS Cooperative Conservation Partnership Initiative (CCPI). The CCPI strategy prioritizes agricultural lands for conservation buffers based on multiple selection criteria, including soil erodibility, hydrological sensitivity, wildlife habitat and impervious surface rate to capture the conservation buffers' benefits in reducing soil erosion, controlling runoff generation, enhancing wildlife habitat and mitigating stormwater impacts, respectively.

989 acres of agricultural lands were identified as being suitable for conservation buffers based on the CCPI approach of which 326 acres are located within the riparian area of the Neshanic streams. Figure 7.8 illustrates the location of agricultural lands for conservation buffer placement under both strategies. As shown in the figure, there is substantial overlap in the areas identified. The overlapping area is about 573 acres.

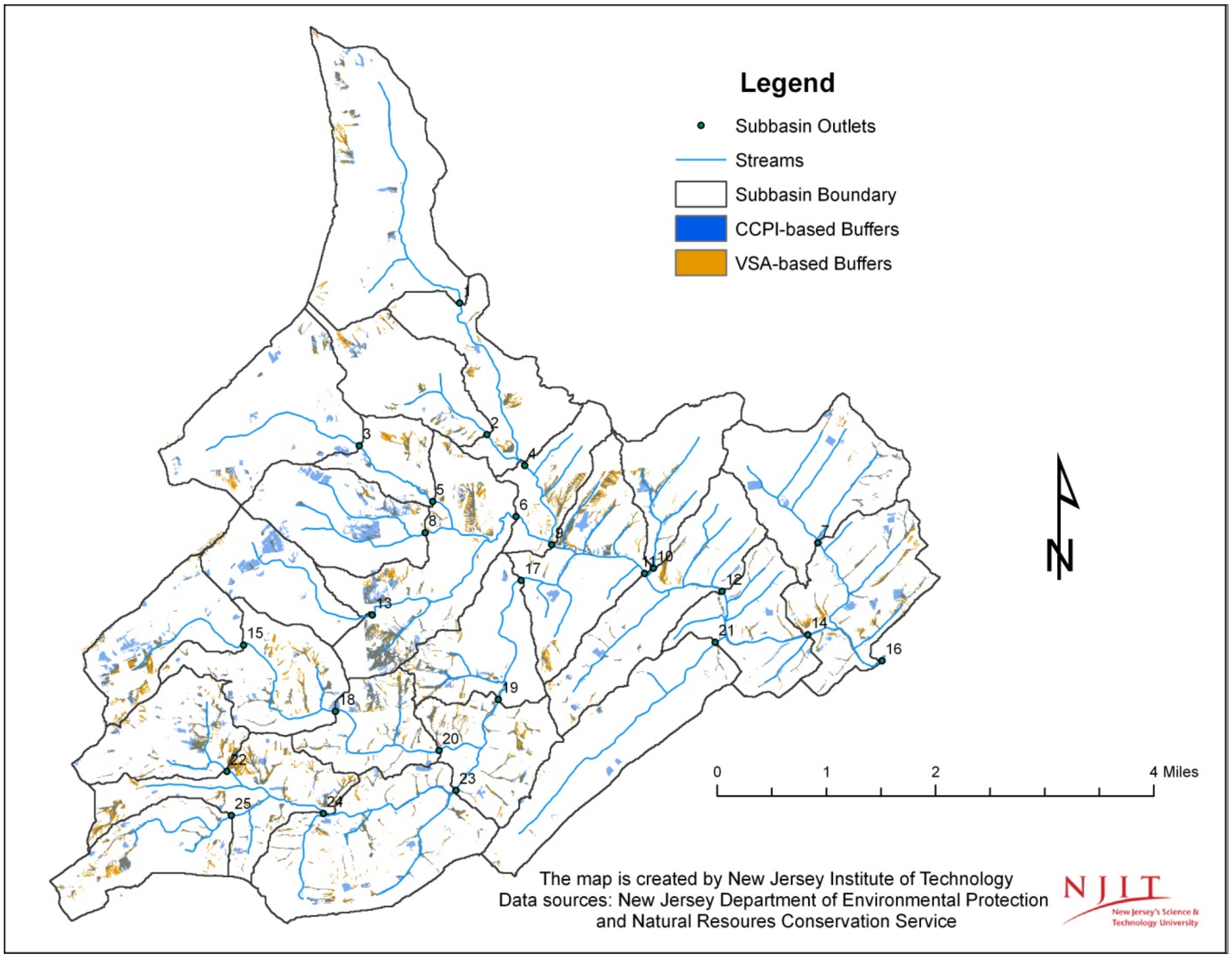


Figure 7.8: Location of the agricultural lands for conservation buffers under two targeting strategies

The cost estimates for the two buffer scenarios are presented in Table 7.6. Assuming the riparian buffers are installed in the identified agricultural lands in the riparian area of the Neshanic streams and the filter strips are installed in other identified agricultural lands, the total costs of installing and maintaining the conservation buffers in those 875 acres of agricultural lands in the watershed for 15 years are estimated at $1.43 million following the current New Jersey CREP rates. The estimate is based on an average installation cost of $300 per acre for filter strips and $1800 per acre for riparian buffers. The program costs can be easily doubled if some expensive buffer practices such as grassed waterways are used. The total estimated program costs to install conservation buffers in those 989 acres of agricultural lands identified by the CCPI strategy are $1.54 million.

Table 7.6: Cost estimates for two conservation buffer scenarios in Neshanic River Watershed

	Units	VSA Buffer Strategy	CCPI Strategy
Agricultural Lands	Acres	874.85	987.83
Ag Lands in Riparian Area	Acres	331.24	326.33
Annual Soil Rental Rate	$/acre	39.73	39.00
Signing Incentive Payments	$/acre	100.00	100.00
Installation Costs	$/acre	867.94	795.52
Annual Maintenance	$/acre	5.00	5.00
Average Program Costs	$/acre	1,638.89	1,555.52
Total Program Costs	$million	1.43	1.54

Table 7.7: Acreage of buffers and their priority ranking by subbasins in Neshanic River Watershed

Subbasin ID	Buffer Area (Acres)		Priority			Priority for buffers
	VSA Buffer	CCPI Buffer	TP	Pathogens	Aggregate	
1	23.2	30.0	25	18	43	17
2	23.0	22.0	14	19	33	12
3	15.1	33.4	24	13	37	14
4	18.0	11.2	13	20	33	12
5	15.9	14.2	18	21	39	16
6	107.6	108.1	17	17	34	13
7	13.2	27.3	15	12	27	10
8	14.5	60.2	21	16	37	14
9	26.8	12.5	2	3	5	1
10	18.6	23.0	12	7	19	7
11	67.5	59.1	11	10	21	8
12	27.3	29.4	6	5	11	5
13	5.4	41.2	20	11	31	11
14	21.9	28.8	16	22	38	15
15	41.1	53.2	22	23	45	18
16	59.3	66.6	1	6	7	2
17	29.9	31.1	5	4	9	4
18	40.5	35.8	7	1	8	3
19	44.5	38.3	8	25	33	12
20	39.0	44.3	4	8	12	6
21	4.7	10.7	23	15	38	15
22	42.0	44.6	19	24	43	17
23	59.3	70.2	10	9	19	7
24	76.0	58.4	9	14	23	9
25	34.5	29.9	3	2	5	1
Total	868.9	983.3				

Table 7.7 presents the acreage of agricultural lands targeted for conservation buffers by subbasin based on the VSA and CCPI strategies in columns 2 and 3, respectively. The last column in Table 7.7 gives the priority for implementing conservation buffers for each subbasin. The subbasin priority is developed from the subbasin priority scores for reducing TP and pathogenic loads, the two most important water quality issues in the watershed. The priority for reducing TP and pathogenic loads developed in Chapter 5 are shown in columns 4 and 5. Column 6 is the sum of the two priority scores in columns 4 and 5. Finally, the subbasin priority for conservation buffers developed from the aggregate score in column 6 is shown in column 7. A lower number indicates a higher priority for implementing conservation buffers in a subbasin.

As discussed previously, conservation buffers have multiple water quality benefits. Based on the assessment using SWAT modeling, a well implemented conservation buffer program will result in a 19 percent reduction in TSS, a 48 percent reduction in TN, a 38 percent reduction in TP, and a 12 percent reduction in pathogen loads to the Neshanic streams. In other words, the conservation buffer program alone would well achieve the required 9 percent reduction in TSS load and over three-quarter of the required 48 percent reduction in TP load, and dramatically reduce the pathogen loads to the Neshanic streams.

7.3.3. Animal Waste Management and Composting Facility

There are many agricultural properties in the Neshanic River Watershed which have livestock that produce more manure than what can safely be spread on the land due to overstocking or limited onsite use. In some cases the manure is being handled in a fashion which can potentially pose an environmental threat. Manure piled in HSAs or without proper distance from streams can leak phosphorus and pathogens into the streams. A remedy is to compost the raw manure to a safe and biologically stable organic material. The NJDA Animal Waste Management Rules must be enforced in the Neshanic River Watershed to properly manage the animal waste and reduce its impacts on water quality. Farms that apply animal manure as fertilizer should follow the nutrient management practices discussed in Section 7.3.7.

Composting facilities are recommended by the NJRC&D (2011) as a possible solution for any livestock operation that cannot safely use or remove manure from the property without negatively impacting water quality. The use of composting facilities can mitigate any potential phosphorus and pathogenic contamination generated by improper manure storage in the watershed. Secondary benefits accrue from turning manure into a safer alternative fertilizer than raw manure.

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

The task of installing a composting facility varies in difficulty and should be done with assistance from NRCS or another support agency so as to ensure the facility is sited properly and designed to handle runoff. There may be local and state ordinances which must be met in installing this practice and cost-share programs to offset expenses incurred by the landowner.

Use of this practice may require training for the operator, as the correct temperatures and the proper ratio of carbon-to-nitrogen must be maintained to encourage biological processes.

The cost of installing a composting facility varies based on the needs and preferences of the landowner. The cost range listed in the NRCS AWEP 2010 practice catalog is 10 cents to $16.73 per square foot. Cost share is not available for some of the equipment which is required to operate the facility, such as a tractor or a windrow turner. If an operator does not own such equipment, it would be an out of pocket expense.

7.3.4. Prescribed Grazing

A prescribed grazing plan manages grazing and browsing of animals to ensure there is adequate ground cover and proper livestock nutrition. Currently in the Neshanic River Watershed, there are agricultural properties which have overstocked livestock and/or poorly managed pasture. These conditions lead to pastures that have insufficient vegetated cover to prevent erosion and manure runoff. Generally, a prescribed grazing plan is written by a pasture professional and may incorporate temporary fencing for rotational grazing activity, pasture reseeding and a reduction in animal units.

Several government agencies can prepare a prescribed grazing plan for farmers, including NRCS. Such plans may require a farmer to install fencing or provide alternate watering as well as well as reseeding, fertilizing and liming pastures. Not all of these practices may be cost shared, but there can be economic benefits to healthy pastures that can further offset costs.

The cost of implementing prescribed grazing varies according to pasture needs and conditions and can include the cost to the operator of learning how to manage prescribed grazing. Prescribed grazing can often result in healthier pastures, which can make the practice worth the cost to the landowner. The AWEP 2010 practice catalog establishes a cost of between $242 and $321 per acre, not including fencing, watering or seeding. An implemented prescribed grazing plan allows pastures to regain healthy vegetation that aids in keeping manure and nutrient runoff out of streams. Healthy pastures reduce phosphorus loading and manure runoff.

The SWAT modeling was conducted to evaluate the impacts of prescribed grazing on water quality in the Neshanic River Watershed. Model results indicate that prescribed grazing would have only limited benefits in terms of improving water quality in the watershed. Specifically, it can reduce TSS by 2.75 percent, TN by 0.84 percent, TP by 1.51 percent and pathogens by 0.12 percent in the Neshanic streams. A prescribed grazing plan should be considered as a possible solution for any livestock operation that has poor pasture conditions, including land that is overstocked. The locations of pastures for prescribed grazing can be prioritized by ranking subwatersheds by their combined fecal coliform and TP loading. The 892 acres of pasture in the Neshanic River Watershed were prioritized by subbasin according to the TP loading. Table 7.8 gives the acreage and the TP priority by subbasin in the Neshanic River Watershed.

Table 7.8: Pasture acreage and priority for grazing management by subbasins in Neshanic River Watershed

Subbasin	Acres	Priority		Subbasin	Acres	Priority
3	33.1	24		15	8.9	22
5	12.6	18		16	169.3	1
6	72.4	17		17	67.7	5
7	14.3	15		18	49.2	7
10	44.6	12		20	72.2	4
11	13.2	11		22	80.6	19
12	27.1	6		23	116.6	10
13	8.8	20		24	54.9	9
14	13.3	16		25	33.9	3
Total					892.4	

7.3.5. Cover Crops

Cover crops are grasses, legumes, forbs or other herbaceous plants established for seasonal cover and other conservation purposes. Cover crops are widely recognized as having many benefits by agricultural professionals and farmers, including water quality improvement. Proper use of cover crops reduces field operation costs, tillage and herbicide uses, and enhances soil health. It is easy to incorporate cover crops into any cropping system applied to fields that are not used for all or part of a year. With proper promotion, education and assistance, cover crops can be implemented watershed-wide with excellent benefits.

Cover crops vary in cost. According to the NRCS AWEP 2010 practice catalog, the least costly is a winter cover crop at a cost of about $71 per acre and the most expensive is a summer legume at a cost of about $443 per acre. Cost share is available for these practices. Benefits of cover crops are lower fertilizer requirements on subsequent crops, lower wind and water erosion and increased soil health. Use of cover crops on barren crop fields reduces runoff. Nutrients left over from previous fertilizer and manure applications in the soil profile will be captured and recycled making them unavailable for runoff. There are 4,333 acres in row crops in the Neshanic River Watershed. Any barren acres in the watershed are potential locations for planting cover crops. Potential locations for cover crops were prioritized by subbasin, and ranked according to TP loading. Table 7.9 lists the acreages in different row crops for each subbasin in column 2 and the subbasin priority for TP load reduction in column 5.

Table 7.9: Acreage of agricultural lands and TP priority by subbasins in the Neshanic River Watershed

Subbasin	Agricultural Lands (Acres)			TP Priority
	Row Crop	Hay and Pasture	Total	
1	70.2	100.9	171.1	25
2	149.0	0.0	149.0	14
3	73.7	64.7	138.4	24
4	40.7	19.4	60.1	13
5	31.9	42.3	74.2	18
6	300.1	170.1	470.2	17
7	161.5	60.9	222.3	15
8	112.5	25.7	138.1	21
9	66.0	54.8	120.8	2
10	57.9	129.7	187.6	12
11	274.0	172.4	446.4	11
12	281.5	134.7	416.2	6
13	36.3	49.2	85.5	20
14	234.8	170.6	405.4	16
15	125.5	143.8	269.3	22
16	344.6	363.7	708.2	1
17	82.8	186.1	268.8	5
18	147.8	195.5	343.3	7
19	343.5	116.8	460.2	8
20	237.4	119.5	356.8	4
21	58.3	60.7	119.0	23
22	125.2	254.0	379.3	19
23	558.9	362.0	920.9	10
24	272.8	199.4	472.2	9
25	146.0	215.7	361.7	3
Total	4,332.9	3,412.6	7,744.5	

7.3.6. Contour Farming

Currently, row crops in the Neshanic River Watershed are planted in straight rows without regard to the contours of the land or slope direction, a practice that tends to increase erosion and fertilizer in runoff. Contour farming is described in the NRCS Field Operations Technical Guide as using ridges and furrows formed by tillage, planting and other farming operations designed to change the direction of runoff from directly downslope to around the hill slope. In essence, this means farming with the natural shape of the land instead of against it. In addition, the crop itself is used to slow water velocities with the ridges and furrows formed in row crops. The overall result is the reduction of the erosive capacity of the field which in turn reduces the potential for runoff. This practice is most effective on slopes from 2 to 10 percent without excessive rolling topography.

In its simplest form, contour farming changes the direction in which rows are planted from "up and down" the slope to across the slope. Because field conditions vary, the potential benefits of contour farming are highest when planning is done by an agricultural professional. Contour farming might have to be used in conjunction with other practices, such as terraces or filter strips, to realize its full potential. Cost share is not always available for contour farming. However, cost share is often available for practices that need to be instituted in conjunction with contour farming. The learning curve for farmers that use contour farming needs to be taken into consideration. There are no out-of-pocket costs for contour farming because it only involves changing the way rows are formed on the landscape. Cost for support practices are on a field-to-field basis and are often cost shared. A conservation planner from NRCS can provide free technical assistance in making decisions about what supportive practices are necessary and can guide landowners to appropriate cost share programs. Contour farming can reduce erosion, reduce the transport of phosphorus to surface water and increase water infiltration.

Table 7.10: Cropland acreage for contour farming and TP priority ranking by subbasin

Subbasin	Cropland (Acres)	TP Priority	Subbasin	Cropland (Acres)	TP Priority
1	33.4	25	14	128.9	16
2	59.6	14	15	79.4	22
3	42.6	24	16	167.4	1
4	1.4	13	17	21.9	5
5	12.3	18	18	36.5	7
6	37.0	17	19	182.3	8
7	90.6	15	20	117.1	4
8	33.4	21	21	29.4	23
9	4.8	2	22	59.2	19
10	24.5	12	23	297.7	10
11	84.0	11	24	71.2	9
12	154.2	6	25	54.9	3
13	22.6	20	Total	1,846.1	

The effectiveness of contour farming is amplified when incorporated with a strip cropping system, which involves growing small grains and forages in alternating strips. Contour farming should be used on all appropriately sloped agricultural land with row crops; not in a no-till system. Locations of strips can be prioritized by ranking subwatersheds according to their TP loading. Of the 4,333 acres of row-crop lands in the watershed, approximately 1,846 acres have a slope between 2 to 10 percent that can benefit from contour farming. Table 7.10 gives the cropland acreage in each of the 25 subbasins and the TP priority ranking for each subbasin in the watershed. Figure 7.9 illustrates the location of those croplands that are potential targets for contour farming in the watershed.

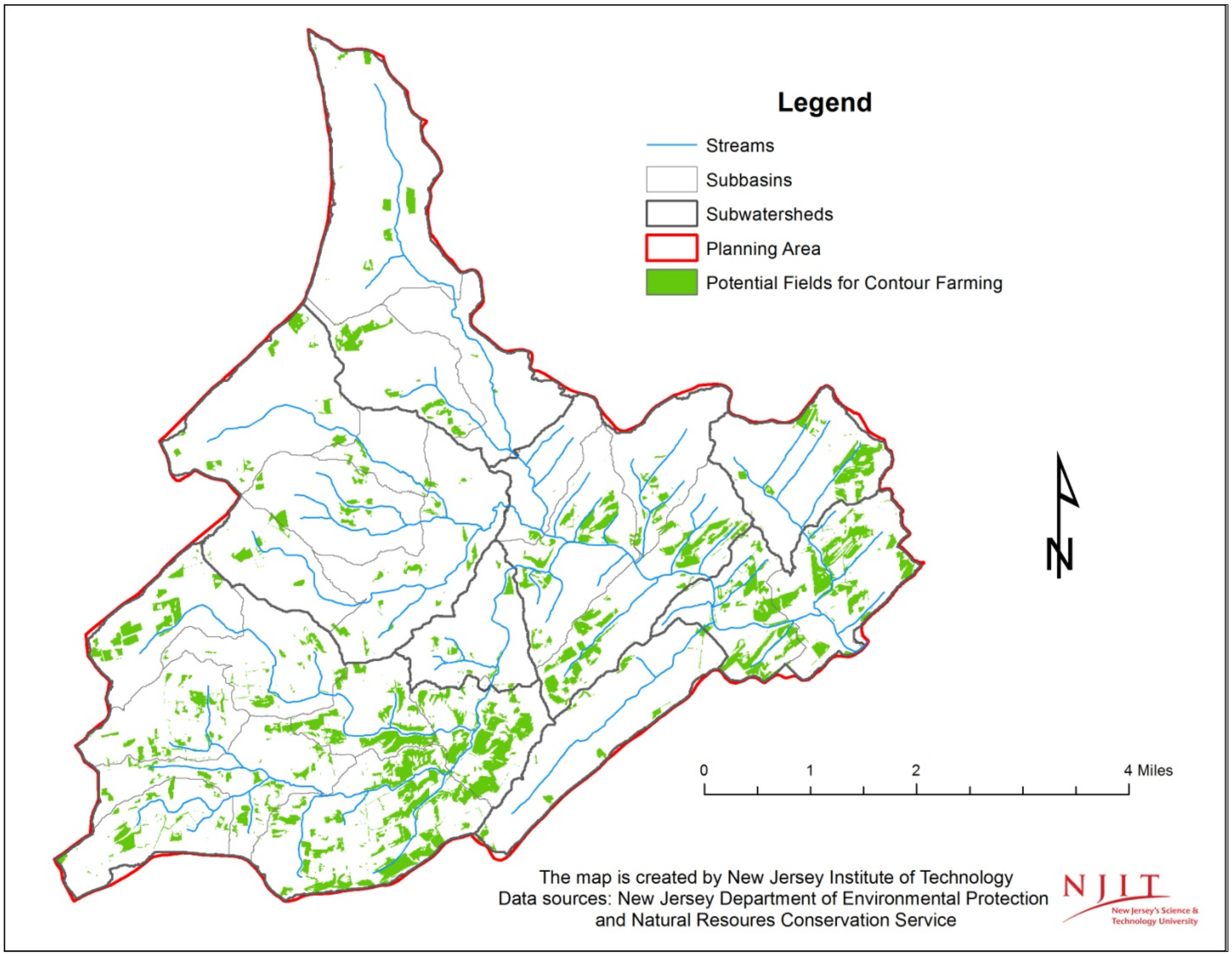


Figure 7.9: Location of the agricultural lands for contour farming in Neshanic River Watershed

7.3.7. Nutrient Management

Currently, in the Neshanic River Watershed, there are agricultural properties which apply fertilizers at a fixed date during the growing season without testing soil nutrients. This practice can lead to over-application, resulting in runoff of excess nutrients into streams. Nutrient management means managing the amount, source, form and timing of the application of nutrients and soil amendments. It includes having a current soil test to determine which nutrients are already in the soil for plant use. This avoids applying more fertilizer than what the crop needs. Nutrient management plans are often developed by a certified professional in nutrient management planning.

Several governmental agencies, including NRCS, prepare nutrient management plans for farmers. In addition, several local agencies and non-profit organizations offer this service for little or no cost. The use of a nutrient management plan can reduce input costs to the farmer. Soil fertility is linked to many agricultural issues. Through the planning process and soil testing, farmers detect not only nutrient deficiencies, but also pH imbalances in fields. Addressing these imbalances can increase yields and avoid potential negative impacts of over fertilization. If properly promoted, nutrient management is one of the most effective practices that can be implemented in the watershed.

The NRCS AWEP 2010 practice catalog estimates the cost of implementing a nutrient management plan to be about $25 per acre for grain crops and $53 per acre for specialty crops. Cost share is available for implementing nutrient management plans. The cost-share rate can be up to 100 percent. This practice is supported by agricultural professionals, agencies and farmers.

Implementation of nutrient management plans in the watershed would reduce the nutrients available for runoff. If fewer nutrients are applied, there will be less nutrients in the runoff. Since manure is a nutrient that can be applied to fields, a nutrient management plan inherently addresses the issues of manure storage and application, creating a dialog with the producers to solve these issues.

Any and all agricultural lands that receive fertilizer amendments are suitable for nutrient management plans. Following the plans is the only assurance that fertilizers are being applied in the proper amounts determined by the soil tests. There are 7,745 acres of agricultural lands in the Neshanic River Watershed. The locations can be prioritized by subbasin ranked according to TP loading. Table 7.9 presents the total acreages of agricultural lands for row crop, hay and pasture in column 4 for each subbasin and the subbasin priority for TP load reduction in Column 5.

7.4. **Site Specific Watershed Restoration Projects**

This section presents several examples of watershed restoration projects assessed by the project team. Assessments were based on site-specific information. In some cases, the location of the sites is intentionally omitted, especially for agricultural management practices.

7.4.1. Rain Garden Projects

7.4.1.1. Individual Residential Rain Garden

Project Name: Individual Residential Rain Garden	
Location: The residence at 1 Robin Hill Way in Raritan Township	Subwatershed Priority: High
BMP Type and Description: Rain Garden	
Issues and Concerns: Roofs and lawns in residential neighborhoods are considered potential sources of nutrients and sediment in a watershed. Pollutants accumulate on streets (sediment, phosphorus, nitrogen and bacteria). The fertilizer used in residential neighborhoods can be a source of phosphorus and nitrogen. Waste from house pets and wildlife found on homeowners properties can be a source of fecal coliform in a watershed. These accumulated pollutants can be carried to local waterways via stormwater runoff.	
Existing Conditions: The house at 1 Robin Hill Way in Raritan Township, New Jersey is similar to the rest of the houses in its development. It is a new home built within the last few years. Each house is on a lot of at least 1.25 acres in size and each lot has some landscaping features with trees and shrubs; development is relatively new and the vegetative features are small. The majority of each lot is covered with turf grass. The	

property is sloped towards the driveway and street. During a storm event, the stormwater runoff carries pollutants from the lawn, roof and driveway to the local waterway. While this individual lot is most likely a small source of pollutant loading, if all the loads from all new houses in the watershed are summed, the source of pollutant loading from residential housing throughout the watershed could be substantial. Additionally, the impervious surfaces associated with residential development increase the volume of stormwater runoff that flows directly into streams. These increases in runoff volume create a flashy hydrology in the stream, causing streambank erosion and channel scouring.

Proposed Solutions:

A rain garden could be used to capture, treat and infiltrate the stormwater runoff from residential development that would ordinarily flow directly to the storm sewer system and the local streams. To capture runoff from the driveway, a small notch will be cut out of the bottom of the driveway and, a drain would be installed in the notch with a grate on top of it. The drain would collect the runoff from the driveway and discharge it to a rain garden just west of the driveway. The rain garden will be large enough to capture all the runoff from the New Jersey Stormwater Quality Storm (1.25 inches). The rain garden will have an outlet for larger storms. That outlet will discharge excess runoff onto the street and route that runoff to a detention basin. The rain garden will be between six inches to 12 inches deep and contain native plants and shrubs.

Anticipated Benefits:

Since 90 percent of the rainfall events deliver less than 1.25 inches of rain, the rain garden is expected to capture approximately 90 percent of the stormwater runoff from the drainage area that it was designed to treat. By capturing and infiltrating runoff from approximately 90 percent of all the storms during the course of a year, the rain garden will reduce pollutant loads entering the stream by 90 percent. By installing a rain garden at this site that captures runoff from 1,000 square feet of driveway, this project would reduce TSS by 2.1 pounds per year, TP by 0.012 pounds per year and TN by 0.10 pounds per year. Additionally, the rain garden will capture, treat and infiltrate approximately 25,000 gallons of stormwater runoff per year.

Major Implementation Issues:

The most critical step in implementing individual rain gardens is to have the consent of the property owner. The property owner has to agree to have the rain garden installed on their property, keep the rain

garden for a long period of time, and properly maintain the rain garden. If the rain garden is not maintained, it will not work properly. This problem can be overcome by involving the property owner in the design process and incorporating their ideas into the design of the rain garden as much as possible.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Possible Partners/Stakeholders: Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA				
Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$500
2	Prepare final design			$500
	Activities for BMP installation	Unit Cost	Quantity	
	Install rain garden (assumes most work completed by volunteers)	$1,000	1	$1,000
	Supervision of volunteers	$500	1	$500
	Contingency (20%)	$150	1	$150
	Total BMP installation cost			$1,650
Estimated total project cost				**$2,650**
Annual operation and maintenance cost				$100

7.4.1.2. Road Side Rain Garden

Project Name: Road Residential Rain Garden	
Location: The Cul-De-Sac by 75 Johanna Farm Road in Raritan Township	Subwatershed Priority: High
BMP Type and Description: Road Rain Garden	
Issues and Concerns: Roofs and lawns in residential neighborhoods are considered potential sources of nutrients and sediment in a watershed. Pollutants (sediment, phosphorus, nitrogen and bacteria) accumulate on streets and can be carried to local waterways via stormwater runoff. Fertilizer use in residential neighborhoods can be a source of phosphorus and nitrogen. Waste from house pets and wildlife found on homeowners' properties can be a source of fecal coliform in the watershed.	
Existing Conditions: This new development, constructed within the past few years, consists of 11 houses on approximately 13.3 acres of land and contains approximately 3.5 acres of impervious surfaces. Approximately one acre of this impervious surface is the road. Just like driveways and other landscapes, roadways accumulate sediment and other pollutants that get washed away into the stream. The entire development drains into a large detention basin. Unfortunately, it has been well documented that detention basins do not treat stormwater runoff very well, especially for small storms. Before the stormwater runoff is routed to the detention basin, it passes over a measurable amount of the roadway to reach a catch basin. The runoff from lawns, roofs, driveways and roadways are combined on the roadway before it reaches the catch basin and ultimately the Neshanic River.	
Proposed Solutions: The roadway for this development routes the stormwater runoff from all the landscapes into the catch basin. Rain gardens can be installed along the roadway to capture the runoff just upstream of the catch basin. Such rain gardens will be strategically placed throughout the development to capture all the runoff	

generated from the development for the New Jersey Stormwater Quality Storm (1.25 inches of rain over two-hours). A curb cut will be made near each catch basin. That cut will allow stormwater runoff to flow off the roadway and into the road rain garden. To accommodate storms that produce more runoff than the road rain gardens can capture, the water elevation in the rain garden will be equal the elevation of the road. This allows runoff to bypass the rain garden and discharge directly to the catch basin. The road rain garden will be vegetated with woody shrubs and herbaceous plugs.

Anticipated Benefits:

Since 90 percent of the rainfall events deliver less than 1.25 inches of rain, the rain garden is expected to capture approximately 90 percent of the stormwater runoff from the drainage area that it was designed to treat. By capturing and infiltrating runoff from approximately 90 percent of all the storms that occur during the course of a year, the rain garden will reduce pollutant loads entering the stream by 90 percent. Installing rain gardens at this site to capture runoff from the entire one acre of roadway will reduce TSS by 180 pounds per year, TP by 0.81 pounds per year and TN by 19.8 pounds per year. Additionally, these rain gardens will capture, treat and infiltrate approximately 1.1 million gallons of stormwater runoff per year.

Major Implementation Issues:

The most critical step in implementing individual rain gardens is to have the consent of the property owner. The property owner has to agree to have the rain garden installed on their property, keep the rain garden for a long period of time, and properly maintain the rain garden. If the rain garden is not maintained, it does not work properly. This problem can be overcome by involving the property owner in the design process and incorporating their ideas into the design of the rain garden as much as possible.

This project may prove difficult because it requires the installation of multiple rain gardens in close

proximity to each home and all of the landowners must be willing to cooperate for the project to be implemented.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Possible Partners/Stakeholders: Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA				
Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$2,000
2	Prepare final design			$5,000
	Activities for BMP installation (per rain garden)	Unit Cost	Quantity	
	Install rain garden (assumes most work completed by volunteers)	$2,000	1	$2,000
	Supervision of volunteers	$1,000	1	$1,000
	Contingency (20%)	$200	1	$300
	Total BMP installation cost			$3,300
Estimated total project cost				**$10,300**
Annual operation and maintenance cost				$500

7.4.1.3. Commercial Rain Garden – Shoppes Parking Lot

Project Name: Shoppes Parking Lot Rain Garden	
Location: The Shoppes of Flemington (100 Reaville Avenue Flemington, NJ 08822)	Subwatershed Priority: High
BMP Type and Description: Rain Garden	
Issues and Concerns: Parking lots are considered potential sources of nutrients and sediment in a watershed. Pollutants (sediment, phosphorus, nitrogen and bacteria) accumulate on streets and are deposited on the surface of the parking lot by wildlife (nutrients and bacteria), vehicle wear and tear (sediment), erosion and wind (sediment and nutrients) and atmospheric deposition (sediment and nutrients). These accumulated pollutants can be carried to local waterways via stormwater runoff.	
Existing Conditions: This site is a portion of the parking lot for the Bensi Restaurant and the Shoppes of Flemington strip mall in Flemington, New Jersey off of Reaville Avenue. Vegetation in this portion of the parking lot is primarily decorative street islands with turfgrass and trees. This portion of the parking lot is sloped towards one catch basin. Due to the slope of the parking lot and the placement of the street island, stormwater runoff cuts between the street islands then flows to the catch basin. The slope of the parking lot is approximately 3 to 5 percent. The site is approximately 0.5 acres. Runoff is collected in a detention basin. Detention basins provide minimal water quality treatment of stormwater; they are primarily designed to prevent flooding downstream.	
Proposed Solutions: Transforming two of the street islands into rain gardens would dramatically reduce the amount of runoff produced from the site. There are two places in the site where stormwater runoff has to pass between street islands through a narrow channel. The curbs on the street island will be cut, the street island excavated, and the current vegetation replaced with native warm season grasses, herbaceous plugs and	

woody shrubs. Rain gardens in each island will be designed to capture the stormwater runoff generated from the New Jersey Stormwater Quality Storm (1.25 inches of rain over two-hours). The outlet of each rain garden will be near the inlet of the rain garden. During storms that are larger than the New Jersey Stormwater Quality Storm, the runoff will be routed through the rain garden, treated by the rain garden's vegetation and then discharged out of the rain garden to the catch basin. This design will reduce pollutant loading from the site.

Anticipated Benefits:

Since 90 percent of the rainfall events deliver less than 1.25 inches of rain, the rain garden is expected to capture approximately 90 percent of the stormwater runoff from the drainage area that it was designed to treat. By capturing and infiltrating runoff from approximately 90 percent of all the storms during the course of a year, the rain garden will reduce pollutant loads entering the stream by 90 percent. Installing a rain garden at this site will capture runoff from 0.5 acre parking lot. The project would reduce TSS by 90 pounds per year, TP by 0.41 pounds per year and TN by 9.9 pounds per year. Additionally, the rain garden will capture, treat and infiltrate approximately 550,000 gallons of stormwater runoff per year.

Major Implementation Issues:

The most critical step in implementing individual rain gardens is to have the consent of the property owner. The property owner has to agree to have the rain garden installed on their property, keep the rain garden for a long period of time and properly maintain the rain garden. If the rain garden is not maintained, it will not work properly. This problem can be overcome by involving the property owner in the design process and incorporating their ideas into the design of the rain garden as much as possible.

Possible Funding Sources:

319(h) grants from the NJDEP

Possible Partners/Stakeholders:

Flemington Borough; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$500
2	Prepare final design			$5,000
	Activities for BMP installation	Unit Cost	Quantity	
	Install rain garden (assumes most work completed by volunteers)	$10,000	1	$10,000
	Supervision of volunteers	$1,000	1	$1,000
	Contingency (20%)	$2,200	1	$2,200
	Total BMP installation cost			$13,200
Estimated total project cost				**$18,700**
Annual operation and maintenance cost				$300

7.4.1.4. Commercial Rain Garden – Shoprite Parking Lot

Project Name: Shoprite Parking Lot Rain Garden

Location:	Subwatershed Priority:
272 U.S. 202 in Raritan Township	High

BMP Type and Description:
Rain Garden

Issues and Concerns:
Parking lots are considered potential sources of nutrients and sediment in a watershed. Pollutants (sediment, phosphorus, nitrogen and bacteria) accumulate on streets. These pollutants are deposited on the surface of the parking lot by wildlife (nutrients and bacteria), vehicle wear and tear (sediment), erosion and wind (sediment and nutrients) and atmospheric deposition (sediment and nutrients). These accumulated pollutants can be carried to local waterways via stormwater runoff.

Existing Conditions:
This site is part of a parking lot for a strip mall on U.S. Route 202 in Flemington, New Jersey. This portion of the commercial parking lot slopes towards a concrete channel and routes water to a catch basin on Route 202. The drainage area for the concrete channel is approximately 0.18 acres. The concrete channel is surrounded by decorative vegetation that offers no storage options for stormwater runoff, and is directly underneath the roadside Shoprite sign for the strip mall. The catch basin collects runoff from Route 202.

Proposed Solutions:
The entire drainage area for this project is a parking lot. Parking lots produce runoff during each storm because there is no opportunity for rainfall to infiltrate. Replacing the concrete channel and decorative vegetation around the channel with a rain garden will allow the runoff from the parking lot to infiltrate into the ground and reduce the amount of runoff generated from the site. The concrete channel will be completely removed, and the decorative vegetation will be removed to install a rain garden.

The rain garden will be designed to capture the 1.25 inch storm, otherwise known was the New Jersey Stormwater Quality Storm. Vegetation for the rain garden will be carefully chosen and designed. Because this landscape feature is one of the first things customers see before they enter the strip mall, it needs to have the same or greater appeal than the existing landscaping. The outlet of the rain garden will discharge to the catch basin. During storms, runoff passing through the rain garden will be treated by the vegetation in the rain garden before it is ultimately discharged to the Neshanic River. This will reduce pollutant loading from the site.

Anticipated Benefits:

Since 90 percent of the rainfall events deliver less than 1.25 inches of rain, the rain garden is expected to capture approximately 90 percent of the stormwater runoff from the drainage area that it was designed to treat. Capturing and infiltrating runoff from approximately 90 percent of all the storms during the course of a year will reduce pollutant loads entering the stream by 90 percent. Installing a rain garden at this site to capture runoff from the 0.18 drainage area will reduce TSS by 32.4 pounds per year, TP by 0.15 pounds per year and TN by 3.6 pounds per year. Additionally, the rain garden will capture, treat and infiltrate approximately 200,000 gallons of stormwater runoff per year.

Major Implementation Issues:

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

Possible Funding Sources:

319(h) grants from the NJDEP

Possible Partners/Stakeholders:

Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description	Estimated Cost
1	Complete topographic survey and soils test	$500

2	Prepare final design			$1,000
	Activities for BMP installation	Unit Costs	Quantity	
	Install rain garden (assumes most work completed by volunteers)	$5,000	1	$5,000
	Supervision of volunteers	$1,000	1	$1,000
	Contingency (20%)	$200	1	$1,400
	Total BMP installation cost			$8,400
Estimated total project cost				**$14,900**
Annual operation and maintenance cost				$100

7.4.2. Roadside Ditch Retrofitting

7.4.2.1. 50 Kuhl Road in Raritan Township

Project Name: Retrofit of Roadside Ditch SD-187	
Location: To the left of the house addressed 50 Kuhl Road, Flemington, NJ when facing the house.	Subwatershed Priority: High
BMP Type and Description: Vegetated Swale	
Issues and Concerns: Roadways, agricultural lands and residential development generate sediment, phosphorus and bacteria that are carried to local waterways. Between storm events, pollutants settle out of the atmosphere and accumulate on impervious surfaces, such as streets, rooftops and parking lots. These pollutants are carried by stormwater runoff into local streams. Another source of pollution is the phosphorus and nitrogen fertilizers used on agricultural lands and residential lawns. Additionally, manure fertilizer applied to agricultural lands as well as waste generated by farm animals, wildlife and domestic pets can be a source of bacteria and nutrients in the watershed. These pollutants can be washed off the land and carried to the local waterways via stormwater runoff. A roadside ditch is one conveyance system that carries the runoff from these potential sources directly to streams and/or their tributaries.	
Existing Conditions: Roadside Ditch SD-187 has an estimated drainage area of 1.3 acres. The drainage area includes Kuhl Road and agricultural lands. The roadside ditch is approximately 440 feet long and approximately 5 to 10 feet wide. There is scouring along the entire length of the ditch. Where it exists, vegetation in the ditch is turf grass. Bare soil is exposed along the entire bottom of the ditch, which allows the ditch to become a source of sediment during storm events. The outlet of the ditch is a pipe that routes the water underneath Kuhl Road and discharges it to agricultural land. Because there is no inlet to the ditch, runoff flows over the land and enters the ditch along its entire length.	
Proposed Solutions: The general purpose of a roadside ditch is to transport stormwater runoff to a nearby stream. Although they generally are not designed to treat stormwater, roadside ditches can be designed to improve water quality while moving stormwater from one location to another. Currently roadside ditch SD-187 is not only transporting stormwater runoff, but it is also contributing to pollutant loads due to the highly eroded nature of the ditch. In its existing condition, the ditch is degrading water quality by contributing additional sediment to the local waterways. Several factors negatively affect the water quality of the runoff discharged from the ditch: (1) it has a poorly designed shape; (2) it has high steep side slopes that force the elevation to rise quickly in the channel; (3) the runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom	

preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallower side slopes and re-vegetated. Plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive in both dry and very wet environments. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream. Finally, the size of this roadside ditch, like many in the watershed, is constrained by the very small size of ROW, which severely limits the width of the ditch. Narrow widths limit how much the ditch can be shaped during re-grading. If the shape of the ditch cannot be dramatically changed, then other methods should be used to reduce runoff velocity in the ditch.

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

<u>Anticipated Benefits:</u>
The ditches are expected to increase infiltration of water during storm events thereby removing nutrients and sediment from runoff. The native vegetation added to the ditches will be allowed to grow taller, which will increase root structure making the soil at the bottom of the ditch more porous and infiltration rates. The latter will allow less water to leave the ditch during storms thereby preventing sediment and nutrients from the entering local waterways. After the retrofits are complete, the ditch is very similar to a

vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80 percent of TSS, and 30 percent of TP and TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project is expected to reduce TSS by 78 to 104 pounds per year, TP by 0.23 pounds per year and TN by 1.95 pounds per year.

Major Implementation Issues:
Because the efficacy of this practice rests on having tall vegetation, mowing should only be done once a year instead of the more common once per week. Residents of the township who believe ditches must be mowed more frequently are likely to object to this practice. A concentrated effort needs to be made by the project partners to inform the public about these new projects and the new natural aesthetic.

Possible Funding Sources:
319(h) grants from the NJDEP

Possible Partners/Stakeholders:
Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete topographic survey and soils test			$1,000
3	Prepare final design			$2,000
4	Prepare maintenance plan			$500
5	Prepare construction documents and solicit quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Re-vegetate the ditch (assumes installed by volunteers)	$0.5/sq. ft.	4,400 sq. ft.	$2,200
	Supervision of volunteers	$2,000	1	$2,000
	Re-grade ditch	$5,000	1	$5,000
	Rip-rap check dam	$1,000/100 linear feet	2	$2,000
	Soil erosion and sediment control	$1,000	1	$1,000
	Contingency (20%)	2,440	1	$2,440
	Total BMP installation cost			$14,640
Estimated total project cost				**$19,640**
Annual operation and maintenance cost				$500

7.4.2.2. South Side of Kuhl Road in Raritan Township

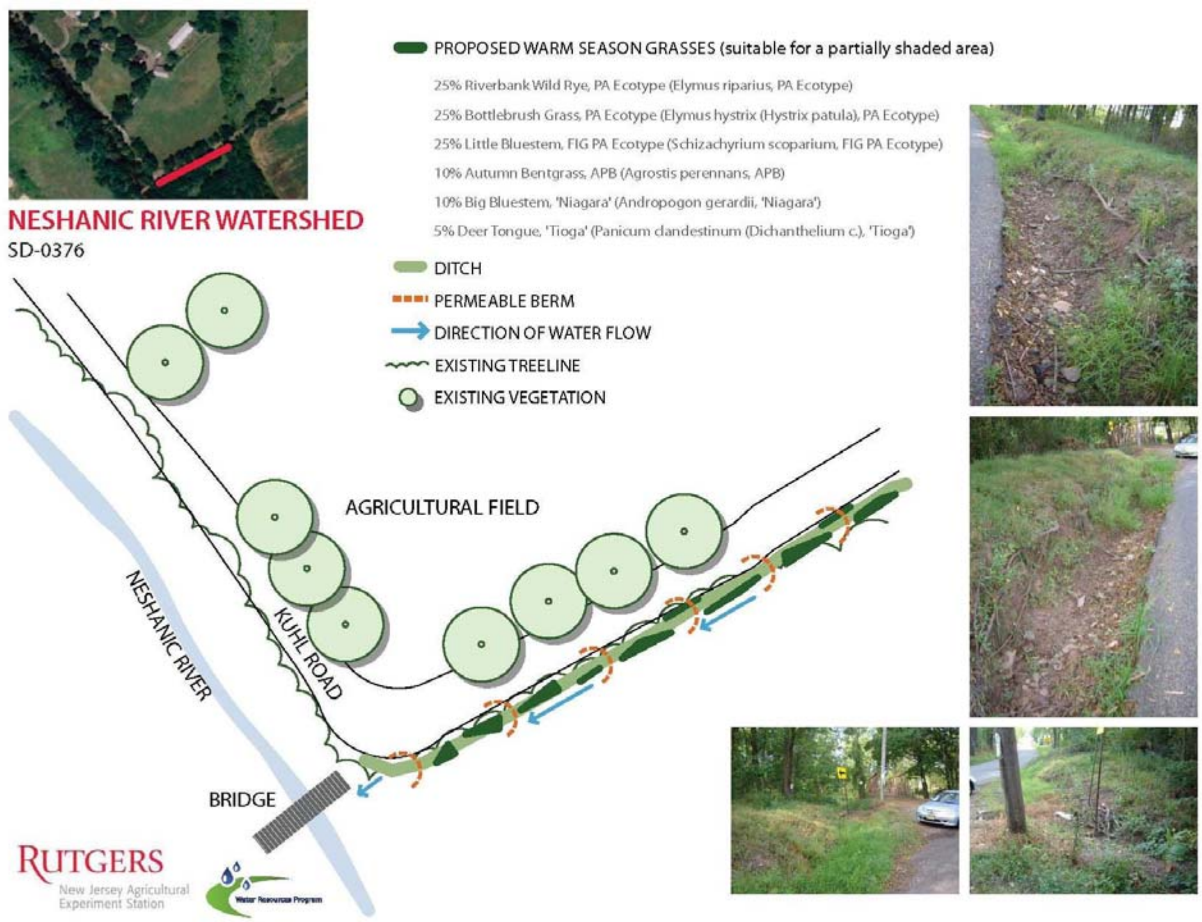
Project Name: Retrofit of Roadside Ditch SD-376	
Location: At the sharp bend in Kuhl Road in Raritan Township (south side of the road)	Subwatershed Priority: High
BMP Type and Description: Vegetated Swale	
Issues and Concerns: Roadways, agricultural lands and residential development can be sources of sediment, phosphorus and bacteria for local waterways. Between storm events, pollutants settle out of the atmosphere and accumulate on impervious surfaces, such as streets, rooftops and parking lots. These pollutants are washed into stormwater runoff and enter local streams during storm events. Another source of pollution, mainly phosphorus and nitrogen, is the fertilizer used on agricultural lands and residential lawns.	

Additionally, manure used as fertilizer on agricultural lands, wastes generated by farm animals, wildlife and domestic pets, are a source of bacteria and nutrient loads in the watershed. These pollutants can be washed off the land and carried to the local waterways via stormwater runoff. Roadside ditches are a conveyance system that carries the runoff from these sources into streams and/or their tributaries.

Existing Conditions:

Roadside Ditch SD-376 has an estimated drainage area of 0.63 acres, which includes Kuhl Road and agricultural lands. The roadside ditch is approximately 355 feet long and approximately 3 to 5 feet wide. There is scouring along the entire length of the ditch. When present, vegetation in the ditch is turf grass. Bare soil is exposed along the entire bottom of the ditch, which allows the ditch to become a source of sediment during storm events. At the outlet of the ditch is a pipe that routes the water directly to the Neshanic River. Because there is no inlet to the ditch, runoff flows over land and enters the ditch along its entire length.

Proposed Solutions:



The general purpose of a roadside ditch is to transport stormwater runoff to a nearby stream. Although generally not designed to treat stormwater, roadside ditches can be upgraded to improve water quality while moving stormwater from one location to another. Currently, roadside ditch SD-376 transports stormwater runoff and contributes to pollutant loads due to the highly eroded nature of the ditch. In its current condition, the ditch is degrading water quality by contributing additional sediment to the local waterways.

Several factors negatively affect the water quality of runoff discharged from the ditch: (1) it has a poorly designed shape; (2) it has high steep side slopes that force the elevation to rise quickly in the channel; and (3) the runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallower side slopes.

After the ditch is re-graded it needs to be re-vegetated. Plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive in both dry and very wet environments. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream. Finally, the size of this roadside ditch, like many in the watershed, is constrained by the very small size of ROW, which severely limits the width of the ditch. Narrow widths limit how much the ditch can be shaped during re-grading. If the shape of the ditch cannot be dramatically changed, then other methods should be used to reduce runoff velocity in the ditch.

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

Anticipated Benefits:

The ditches are expected to increase infiltration of water during storm events thereby removing nutrients and sediment from the runoff. The new native vegetation added to the ditches will be allowed to grow taller, which will increase root structure making the soil at the bottom of the ditch more porous and infiltration rates. The latter will allow less water to leave the ditch during storms thereby preventing sediment and nutrients from the entering local waterways. After the retrofits are complete, the ditch is very similar to a vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80 percent of TSS, and 30 percent of TP and TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project is expected to reduce TSS by 38 to 50 pounds per year, TP by 0.11 pounds per year and TN by 0.95 pounds per year.

Major Implementation Issues:

Because the efficacy of this practice rests on having tall vegetation, mowing should only be done once a year instead of the more common once per week. Residents of the township who believe ditches must be mowed more frequently are likely to object to this practice. A concentrated effort needs to be made by the project partners to inform the public about these new projects and the new natural aesthetic.

Possible Funding Sources:

319(h) grants from the NJDEP

Possible Partners/Stakeholders:

Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

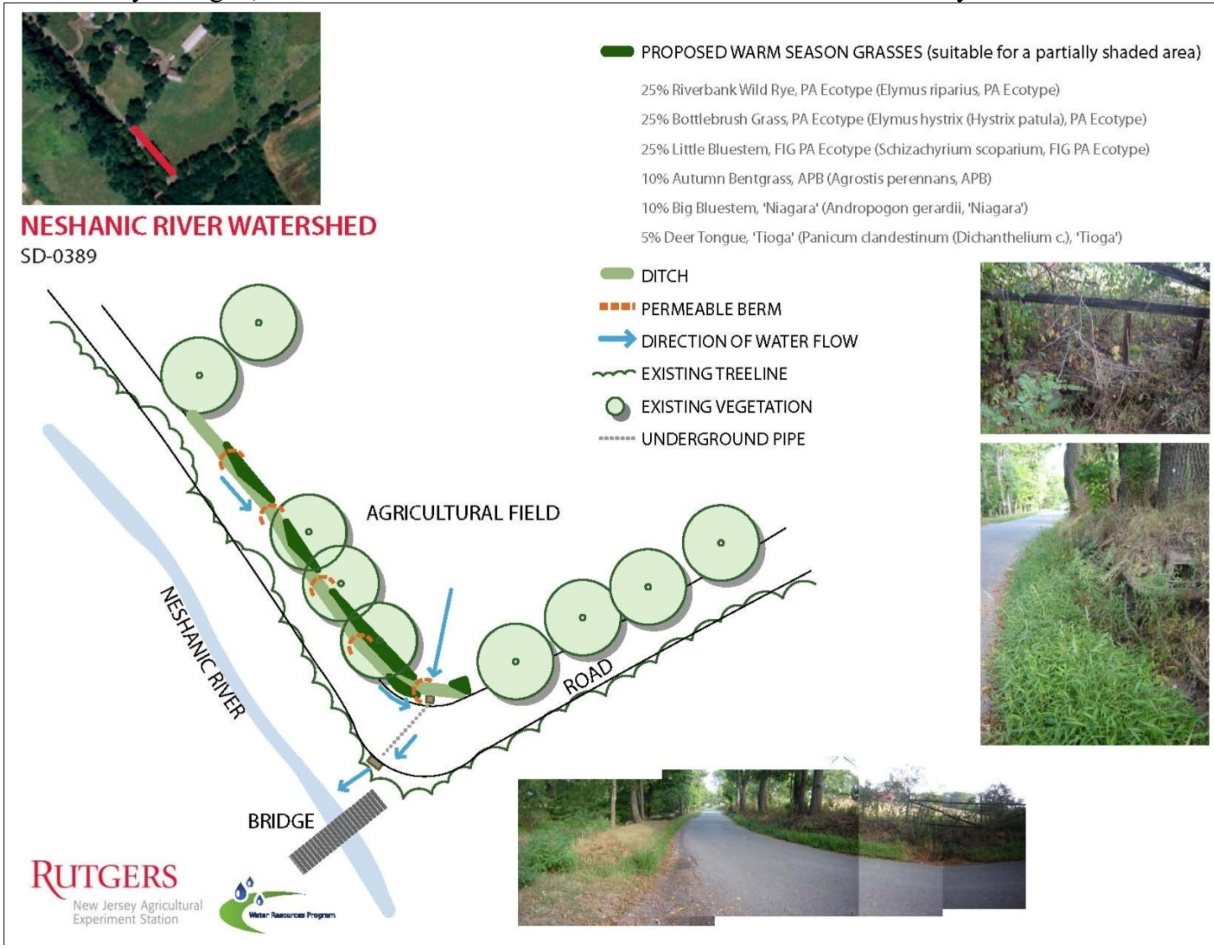
Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete topographic survey and soils test			$1,000
3	Prepare final design			$2,000
4	Prepare maintenance plan			$500
5	Prepare construction documents and solicit quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	

	Re-vegetate the ditch (assumes installed by volunteers)	$0.5/sq. ft.	1,775 sq. ft.	$888
	Supervision of volunteers	$2,000	1	$2,000
	Re-grade ditch	$5,000	1	$5,000
	Rip-rap check dam	$1,000/100 linear feet	3	$3,000
	Erosion and sediment control	$1,000	1	$1,000
	Contingency (20%)	$2,377	1	$2,377
	Total BMP installation cost			$14,266
Estimated total project cost				**$19,266**
Annual operation and maintenance cost				$500

7.4.2.3. North Side of Kuhl Road in Raritan Township

Project Name: Retrofit of Roadside Ditch SD-389	
Location: At the sharp bend in Kuhl Road in Raritan Township (north side of the road)	Subwatershed Priority: High
BMP Type and Description: Vegetated Swale	
Roadways, agricultural lands and residential development can be sources of sediment, phosphorus and bacteria for local waterways. Between storm events, pollutants settle out of the atmosphere and accumulate on impervious surfaces, such as streets, rooftops and parking lots. These pollutants are washed into stormwater runoff and enter local streams during storm events. Another source of pollution, mainly phosphorus and nitrogen, is the fertilizer used on agricultural lands and residential lawns. Additionally, manure used as fertilizer on agricultural lands, wastes generated by farm animals, wildlife and domestic pets, are a source of bacteria and nutrient loads in the watershed. These pollutants can be washed off the land and carried to the local waterways via stormwater runoff. Roadside ditches are a conveyance system that carries the runoff from these sources into streams and/or their tributaries.	
Existing Conditions: Roadside Ditch SD-389 has an estimated drainage area of 1.7 acres, which includes Kuhl Road and agricultural land uses. The roadside ditch is approximately 225 feet long and approximately 3 to 5 feet wide. There is scouring along the entire length of the ditch. The ditch has very steep side slopes that are mostly bare soil. Vegetation along the bottom of each ditch is sparse. Bare soil and sparse vegetation make the ditch a source of sediment during storm events. At the outlet of the ditch is a pipe that routes the water underneath the Kuhl Road and into the Neshanic River. Because there is no inlet to the ditch, runoff flows over land and enters the ditch along its entire length. The ditch is not connected to any other ditches and is responsible for the runoff from its drainage area.	
Proposed Solutions: The general purpose of a roadside ditch is to transport stormwater runoff to a nearby stream. Although generally are not designed to treat stormwater, roadside ditches can be made upgraded to improve water quality while moving stormwater from one location to another. Currently roadside ditch SD-389 transports stormwater runoff and contributes to pollutant loads due to the highly eroded nature of the ditch. In its current condition, the ditch is degrading water quality by contributing additional sediment to the local waterways. Several factors negatively affect the water quality of runoff discharged from the ditch: (1) it has a poorly	

designed shape; (2) it has high steep side slopes that force the elevation to rise quickly in the channel; and (3) the runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallower side slopes. Plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive in both dry and very wet environments. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream. Finally, the size of this roadside ditch, like many in the watershed, is constrained by the very small ROW, which severely limits the width of the ditch. Narrow widths limit how much the ditch can be shaped during the re-grading process. If the shape of the ditch cannot be dramatically changed, then other methods should be used to reduce runoff velocity in the ditch.



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

Anticipated Benefits:

The ditches are expected to increase infiltration of water during storm events thereby removing nutrients and sediment from the runoff. The native vegetation added to the ditches will be allowed to grow taller, which will increase root structure making the soil at the bottom of the ditch more porous and infiltration rates. The latter will allow less water to leave the ditch during storms, thereby preventing sediment and

nutrients from the entering local waterways. After the retrofits are complete, the ditch is very similar to a vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80 percent of TSS, and 30 percent of TP and TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year, and 5 pounds of TN per acre per year, the project is expected to reduce TSS by 144 to 152 pounds per year, TP by 0.34 pounds per year and TN by 2.85 pounds per year.				
Major Implementation Issues: Because the efficacy of this practice rests on having tall vegetation, mowing should only be done once a year instead of the more common once per week. Residents of the township who believe ditches must be mowed more frequently are likely to object to this practice. A concentrated effort needs to be made by the project partners to inform the public about these new projects and the new natural aesthetic.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Possible Partners/Stakeholders: Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA				
Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Re-vegetate the Ditch (assumes installed by volunteers)	$0.5/sq. ft.	1,125 sq. ft.	$563
	Supervision of Volunteers	$2,000	1	$2,000
	Re-grade Ditch	$5,000	1	$5,000
	Rip Rap Check Dam	$1,000/100 linear feet	2	$2,000
	Soil Erosion and Sediment Control	$1,000	1	$1,000
	Contingency (20%)	$2,127	1	$2,127
	Total BMP installation cost			$12,766
Estimated total project cost				**$17,676**
Annual operation and maintenance cost				$500

7.4.2.4. 55 Rittenhouse Road in Delaware Township

Project Name: Retrofit of Roadside Ditch SD-525	
Location: By 55 Rittenhouse Road in Delaware Township	Subwatershed Priority: High
BMP Type and Description: Vegetated Swale	
Issues and Concerns: Roadways, agricultural lands and residential development can be sources of sediment, phosphorus and bacteria for local waterways. Between storm events, pollutants settle out of the atmosphere and accumulate on impervious surfaces, such as streets, rooftops and parking lots. These pollutants are	

washed into stormwater runoff and enter local streams during storm events. Another source of pollution, mainly phosphorus and nitrogen, is the fertilizer used on agricultural lands and residential lawns. Additionally, manure used as fertilizer on agricultural lands, wastes generated by farm animals, wildlife and domestic pets, are a source of bacteria and nutrient loads in the watershed. These pollutants can be washed off the land and carried to the local waterways via stormwater runoff. Roadside ditches are a conveyance system that carries the runoff from these sources into streams and/or their tributaries.

Existing Conditions:

Roadside Ditch SD-525 has an estimated drainage area of 1.9 acres, which includes Rittenhouse Road and residential land uses. The roadside ditch is approximately 60 feet long and approximately 3 to 5 feet wide. There is scouring along the entire length of the ditch. There is no vegetation along the bottom of the ditch, only bare soil, which allows the ditch to become a source of sediment during storm events. The outlet of the ditch routed underneath Rittenhouse Road and discharged to another ditch, which eventually discharges to a tributary of the Neshanic River. Because there is no inlet to the ditch, runoff flows over land and enters the ditch along its entire length.

Proposed Solutions:

The general purpose of a roadside ditch is to transport stormwater runoff to a nearby stream. Although generally not designed to treat the stormwater, roadside ditches can be upgraded to improve water quality while moving stormwater from one location to another. Currently, roadside ditch SD-525 transports stormwater runoff and contributes to pollutant loads due to the highly eroded nature of the ditch. In its current condition, the ditch is degrading water quality by contributing additional sediment to the local waterways.

Several factors negatively affect the water quality of runoff discharged from the ditch: (1) it has a poorly designed shape; (2) it has high steep side slopes that force the elevation to rise quickly in the channel; and (3) the runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom

preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallower side slopes. After the ditch is re-graded it needs to be re-vegetated. Plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive in both dry and very wet environments. The vegetation should thrive in the ditch environment, acting as a buffer and treating the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream.
Anticipated Benefits: The ditches are expected to increase infiltration of water during storm events thereby removing nutrients and sediment from the runoff. The new native vegetation added to the ditches will be allowed to grow taller, which will increase root structure making the soil at the bottom of the ditch more porous and infiltration rates. The latter will allow less water to leave the ditch during storms thereby preventing sediment and nutrients from the entering local waterways. After the retrofits are complete, the ditch is very similar to a vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80 percent of TSS, and 30 percent of TP and TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project is expected to reduce TSS by 144 to 152 pounds per year, TP by 0.34 pounds per year and TN by 2.85 pounds per year.
Major Implementation Issues: Because the efficacy of this practice rests on having tall vegetation, mowing should only be done once a year instead of the more common once per week. Residents of the township who believe ditches must be mowed more frequently are likely to object to this practice. A concentrated effort needs to be made by the project partners to inform the public about these new projects and the new natural aesthetic.
Possible Funding Sources: 319(h) grants from the NJDEP
Possible Partners/Stakeholders: Delaware Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Re-vegetate the Ditch (assumes installed by volunteers)	$0.5/sq. ft.	300 sq. ft.	$150
	Supervision of Volunteers	$2,000	1	$2,000
	Re-grade Ditch	$5,000	1	$5,000
	Soil Erosion and Sediment Control	$1,000	1	$1,000
	Contingency (20%)	$1,630	1	$1,630
	Total BMP installation cost			$9,780
Estimated total project cost				**$14,780**
Annual operation and maintenance cost				$500

7.4.2.5. Yard Road in Delaware Township

Project Name: Retrofit of Roadside Ditch SD-618

Location: On Yard Road in Delaware Township approximately 4,000 feet east of the Sandbrook Headquarters Road intersection	Subwatershed Priority: High
BMP Type and Description: Vegetated Swale	
Issues and Concerns: Roadways, agricultural lands and residential development can be sources of sediment, phosphorus and bacteria for local waterways. Between storm events, pollutants settle out of the atmosphere and accumulate on impervious surfaces, such as streets, rooftops and parking lots. These pollutants are washed into by stormwater runoff and enter local streams during storm events. Another source of pollution, mainly phosphorus and nitrogen, is the fertilizer used on agricultural lands and residential lawns. Additionally, manure used as fertilizer on agricultural lands, wastes generated by farm animals, wildlife and domestic pets, are a source of bacteria and nutrient loads in the watershed. These pollutants can be washed off the land and carried to the local waterways via stormwater runoff. Roadside ditches are a conveyance system that carries the runoff from these sources into streams and/or their tributaries.	
Existing Conditions: Roadside Ditch SD-618 has an estimated drainage area of 1 acre, which includes Yard Road and residential properties. The roadside ditch is approximately 134 feet long and approximately 3 to 5 feet wide. There is scouring along the entire length of the ditch. When present, vegetation in the ditch is turf grass. Most of the vegetation in the ditch is dried out and dead. Bare soil and dead vegetation allow the ditch to become a source of sediment during storm events. Because there is no inlet for the ditch, runoff flows over land and enters the ditch along its entire length. This ditch is just one in a series of ditches along Yard Road. This particular ditch is in very bad condition.	
Proposed Solutions: The general purpose of a roadside ditch is to transport stormwater runoff to a nearby stream. Although generally not designed to treat the stormwater, roadside ditches can be upgraded to improve water quality while moving stormwater from one location to another. Currently, roadside ditch SD-618 transports stormwater runoff and contributes to pollutant loads due to the highly eroded nature of the ditch. In its current condition, the ditch is degrading water quality by contributing additional sediment to the local waterways. Several factors that negatively affect the water quality of the runoff discharged from the ditch: (1) it has a poorly designed shape; (2) it has high steep side slopes that force the elevation to rise quickly in the channel; and (3) the runoff travels very quickly through the ditch eroding the ditch's side slopes and bottom preventing vegetation from establishing itself there. The ditch needs to be re-graded with a wider bottom and shallower side slopes. After the ditch is re-graded it needs to be re-vegetated. Plants used to re-vegetate the ditch should only be native warm season grasses and herbaceous plants that can survive in both dry and very wet environments. This vegetation should thrive in the ditch environment. The vegetation will act as a buffer and treat the stormwater runoff that passes through the ditch removing sediment and other pollutants from the stream. Finally, the size of this roadside ditch, like many in the watershed, is constrained by the very small ROW, which severely limits the width of the ditch. Narrow widths limit how much the ditch can be shaped during the re-grading process. If the shape of the ditch cannot be dramatically changed, then other methods should be used to reduce the runoff velocity in the ditch. Gabion mattresses can be used as check dams in the ditch to reduce runoff velocity in the ditch. Gabion mattresses are metal cages in the shape of long, wide and flat boxes that are filled with large stone (rip-rap). The cages are several feet long and several feet wide and only six inches tall. After the stones are	

placed in the metal cage, the cage is closed tight. Approximately every 100 feet, the mattresses are placed across the side slopes and bottom of the ditch. They obstruct the flow of the runoff for small storms, thereby reducing runoff velocity. Flow from larger storms is reduced due to the presence of the mattresses. However, most of the runoff would flows over the mattresses and is less affected than the flow from larger storms.

Anticipated Benefits:

The ditches are expected to increase infiltration of water during storm events thereby removing nutrients and sediment from the runoff. The new native vegetation added to the ditches will be allowed to grow taller, which will increase root structure making the soil at the bottom of the ditch more porous and infiltration rates. The latter will allow less water to leave the ditch during storms thereby preventing sediment and nutrients from the entering local waterways. After the retrofits are complete, the ditch is very similar to a vegetative buffer and is expected to have the same pollutant removal rates. Vegetative buffers typically remove 60 to 80 percent of TSS, 30 percent of TP and TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project is expected to reduce TSS by 60 to 80 pounds per year, TP by 0.18 pounds per year and TN by 1.5 pounds per year.

Major Implementation Issues:

Because the efficacy of this practice rests on having tall vegetation, mowing should only be done once a year instead of the more common once per week. Residents of the township who believe ditches must be

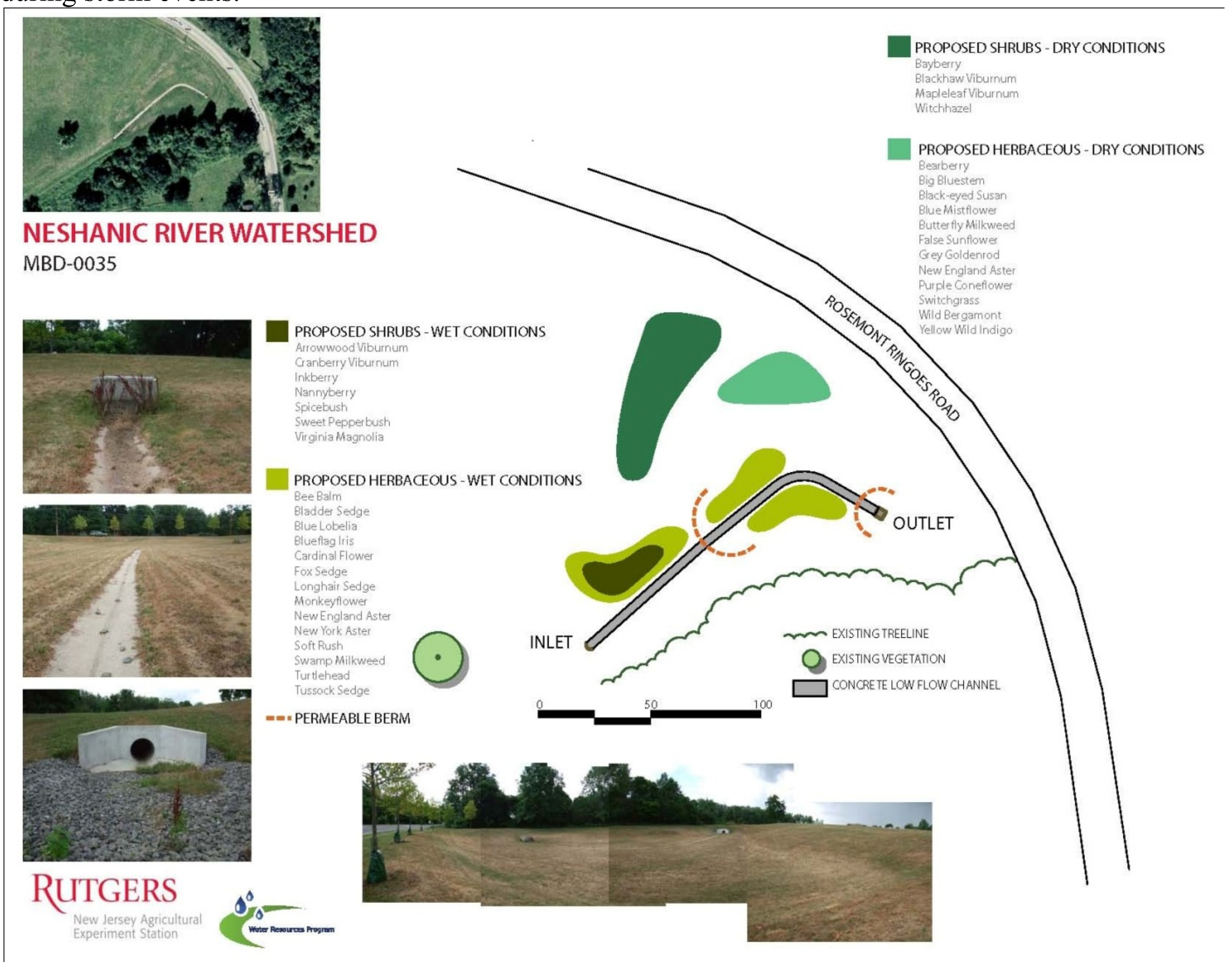
mowed more frequently are likely to object to this practice. A concentrated effort needs to be made by the project partners to inform the public about these new projects and the new natural aesthetic.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Possible Partners/Stakeholders: Delaware Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA				
Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Re-vegetate the Ditch (assumes installed by volunteers)	$0.5/sq. ft.	670 sq. ft.	$338
	Supervision of Volunteers	$2000	1	$2000
	Re-grade Ditch	$5000	1	$5000
	Rip Rap Check Dam	$1000/100 linear feet		$1,000
	Erosion and Sediment Control	$1,000	1	$1,000
	Contingency (20%)	$1,868	1	$1,868
	Total BMP installation cost			$11,206
Estimated total project cost				**$16,206**
Annual operation and maintenance cost				$500

7.4.3. Detention Basin Retrofitting

7.4.3.1. Intersection of Rosemont Ringoes Road and Lambert Road in Delaware Township

Project Name: Detention Basin Retrofit of Detention Basin MDB-0035	
Location: Intersection of Rosemont Ringoes Road and Lambert Road in Delaware Township	Subwatershed Priority: High
BMP Type and Description: Bioretention Basin	
Issues and Concerns: Residential neighborhoods can be a source of sediment, phosphorus and bacteria for local waterways. All the surfaces of a residential neighborhood (streets, sidewalks, roofs and lawns) are potential sources of one or more of these pollutants. Pollutants accumulate on roofs, sidewalks and streets. Local wildlife and domestic pet wastes are sources of bacteria and nutrients. Fertilizer used on residential lawns is a source of phosphorus and nitrogen. Accumulated pollutants are carried to local waterways via stormwater runoff.	
Existing Conditions: Detention Basin MDB – 0035 has an estimated drainage area of 20 acres. The drainage area is the Delaware Township Elementary School. The detention basin is approximately 0.84 acres in size. It has one inlet that connects to a low flow concrete channel. Accumulation of sediment in the concrete low flow channel suggests that it is not maintained on any regular basis. The basin is approximately 10 to	

15 feet deep with a side slope of 10 to 15 percent. The detention basin does not have a water quality outlet structure, but the outlet is protected by a trash rack. The detention basin is in clear view of an elementary school.
<u>Proposed Solutions:</u> The solution for this project is in two parts. The first part is re-vegetating the basin. Clusters of turf grass will be replaced with native warm season grasses, herbaceous plants, sedges, ferns and a minimum of woody vegetation. Over time, the new vegetation will expand past the boundaries of the clusters to cover the entire basin. The new vegetation will increase the infiltration rate of the basin. The basin will not be mowed on a weekly basis as it is now. Vegetation will be allowed to grow tall, increasing its ability to filter nutrients and sediment from stormwater runoff. Tall vegetation has a deeper and more complex root structure, allowing the basin to infiltrate greater amounts of water during storm events.



The second part of the solution is a small berm or series of berms surrounding the outlet of the basin. Each berm would be about one foot high and constructed using a permeable material, such as coconut fiber logs or ¾ inch clean stone secured with fabric. The berm will increase the amount of time runoff remains in the basin. In addition, the berm would constrict the flow of runoff for small, frequent storms, but not interfere with the capacity of the basin to prevent flooding from larger storms because runoff would flow over the berm. Runoff from smaller storms would inundate a larger surface area, increasing infiltration and treatment of runoff.
<u>Anticipated Benefits:</u> The detention basin is expected to increase infiltration of water and remove more nutrients and sediment from runoff during storm events. Native vegetation will be allowed to grow tall, which results

in a larger root structure. Taller plants are expected to increase infiltration of stormwater runoff and remove sediment and nutrients from runoff. The more extensive root structure will make the soil at the bottom of the basin more porous and increase infiltration rates. Increased infiltration rates of the basin will allow less water to leave the basin after storms, which would prevent sediment and nutrients from entering local water ways. After the retrofits are complete, the basin will be very similar to a bioretention basin with the same pollutant removal rates. Bioretention basins typically remove 90 percent of TSS, 60 percent of TP and 30 percent TN. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007 and Karathanasis et al., 2003). Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year, and 5 pounds of TN per acre per year, the project would reduce TSS by 1,800 pounds per year, TP by 7.2 pounds per year and TN by 30.0 pounds per year.

Major Implementation Issues:
There two impediments to the implementation of this project. The first is permitting. This project requires a permit from the local conservation district, which indicates the district approves the proposed alterations of the basin. The soil conservation district could be a partner on this project, but it would need evidence that the berms planned for the project would not adversely affect how the basin prevents flooding downstream or reduce the storage capacity of the basin.

The second impediment is aesthetics. This detention basin handles the drainage for the stormwater runoff of the Delaware Township Elementary School. School officials may resist the project because they may prefer the look of the basin with mowed turf grass and landscaped shrubs rather than the more natural look proposed in the project. Re-vegetation of the basin could be incorporated into the school's science curriculum and serve as a learning opportunity for students.

Possible Funding Sources:
319(h) grants from the NJDEP

Possible Partners/Stakeholders:
Delaware Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Remove old and install new vegetation (assumes volunteer work)	$0.25/sq. ft.	36,590 sq. ft.	$9,147
	Supervision of Volunteers	$2,000	1	$2,000
	Install berms	$5,000	1	$5,000
	Contingency (20%)	$3,229	1	$3,229
	Total BMP installation cost			$19,376
Estimated total project cost				**$24,376**
Annual operation and maintenance cost				$500

7.4.3.2. Intersection of Johanna Farms Road and Castleton Lane in Raritan Township

Project Name: Detention Basin Retrofit of Detention Basin MDB-0054	
Location:	Subwatershed Priority:

Intersection of Johanna Farms Road and Castleton Lane in Raritan Township	Medium
BMP Type and Description: Bioretention Basin	
Issues and Concerns: Residential neighborhoods can be a source of sediment, phosphorus and bacteria for local waterways. All the surfaces of a residential neighborhood (streets, sidewalks, roofs and lawns) are potential sources of one or more of these pollutants. Pollutants accumulate on roofs, sidewalks and streets. Local wildlife and domestic pet wastes are sources of bacteria and nutrients. Fertilizer used on residential lawns is a source of phosphorus and nitrogen. Accumulated pollutants are carried to local waterways via stormwater runoff.	
Existing Conditions: Detention Basin MDB – 0054 has an estimated drainage area of 14.3 acres. The drainage area is comprised of a low density residential area. The detention basin is approximately 0.81 acres in size. It has one inlet that connects to a low flow concrete channel. Accumulation of sediment in the concrete low flow channel suggests that it is not maintained on any regular basis. The basin is approximately three to five feet deep with a side slope of 2 to 5 percent. The detention basin does not have a water quality outlet structure, but the outlet is protected by a trash rack. The detention basin is in clear view of a commonly used roadway that is near a residential neighborhood.	
Proposed Solutions: The solution for this project is in three parts. The first part is re-vegetating the basin. Clusters of turf grass will be replaced with native warm season grasses, herbaceous plants, sedges, ferns and a minimum of woody vegetation. Overtime, the new vegetation will expand past the boundaries of the clusters to cover the entire basin. The new vegetation will increase the infiltration rate of the basin. The basin will not be mowed on a weekly basis as it is now. Vegetation will be allowed to grow tall, increasing its ability to filter nutrients and sediment from stormwater runoff. The tall vegetation has a deeper and more complex root structure allowing the basin to infiltrate greater amounts of water during each storm event. Rerouting the flow of the runoff is the second part of this solution. Currently, the low flow concrete channel directly connects to the outlet and inlet of the basin, which are very close to each other. The runoff only has to travel 71 feet from the inlet to the outlet. If a section of the low flow concrete channel could be removed, then the water would have to travel more than 71 feet to exit the basin, allowing more time for sediment and nutrients to be filtered out of the water column. The third part of the solution is a small berm or series of berms surrounding the outlet of the basin. Each berm would be about one foot high and constructed of a permeable material, such as coconut fiber logs or ¾ inch clean stone secured with fabric. The berm will increase the amount of time runoff remains in the basin. In addition, the berm would constrict the flow of runoff for small, frequent storms, but not interfere with the capacity of to prevent flooding from larger storms because the runoff would flow over the berm. Runoff from smaller storms would inundate a larger surface area, increasing infiltration and treatment of the runoff.	

Anticipated Benefits:
The detention basin is expected to increase infiltration of water and remove more nutrients and sediment from runoff during storm events. Native vegetation will be allowed to grow tall, which results in a larger root structure. Taller plants are expected to increase infiltration of stormwater runoff and remove sediment and nutrients from runoff. The more extensive root structure will make the soil at the bottom of the basin more porous and increase infiltration rate. Increased infiltration rates of the basin will allow less water to leave the basin after storms, which would prevent sediment and nutrients from the entering local water ways. After the retrofits are complete, the basin will be very similar to a bioretention basin with the same pollutant removal rates. Bioretention basins typically remove 90 percent of TSS, 60 percent of TP and 30 percent TN. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007 and Karathanasis et al., 2003). Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project would reduce TSS by 1,287 pounds per year, TP by 5.1 pounds per year and TN by 21.5 pounds per year.

Major Implementation Issues:
There two impediments to the implementation of this project. The first is permitting. This project requires a permit from the local conservation district, which indicates the district approves the proposed alterations of the basin. The soil conservation district could be a partner on this project, but they would need evidence that the berms planned for the project would not adversely affect how the basin prevents flooding downstream or reduce the storage capacity of the basin.

The second impediment is aesthetics. This site runs along a commonly used road and is easily visible from the road. Local residents may resist the project because they may prefer the look of the basin with mowed turf grass and landscaped shrubs rather than the more natural look proposed in the project.
Possible Funding Sources: 319(h) grants from the NJDEP
Possible Partners/Stakeholders: Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Remove old and install new vegetation (assumes volunteer work)	$0.25/sq. ft.	35,283 sq. ft.	$8,820
	Supervision of Volunteers	$2,000	1	$2,000
	Install berms	$5,000	1	$5,000
	Contingency (20%)	$3,164	1	$3,164
	Total BMP installation cost			$18,984
Estimated total project cost				**$23,984**
Annual operation and maintenance cost				$500

7.4.3.3. Intersection of Longbow Terrace and S. Autumn Leaf Blvd in Raritan Township

Project Name: Detention Basin Retrofit of Detention Basin MDB-0069	
Location: Intersection of Longbow Terrace and S. Autumn Leaf Blvd in Raritan Township	Subwatershed Priority: Medium
BMP Type and Description: Bioretention Basin	
Issues and Concerns: Residential neighborhoods can be a source of sediment, phosphorus and bacteria for local waterways. All the surfaces of a residential neighborhood (streets, sidewalks, roofs and lawns) are potential sources of one or more of these pollutants. Pollutants accumulate on roofs, sidewalks and streets. Local wildlife and domestic pet wastes are sources of bacteria and nutrients. Fertilizer used on residential lawns is a source of phosphorus and nitrogen. Accumulated pollutants are carried to the local waterways via stormwater runoff.	
Existing Conditions: Detention Basin MDB – 0069 has an estimated drainage area of 37.2 acres. The drainage area is comprised of a low density residential area. The detention basin is approximately 0.86 acres in size. It has two inlets that connect to a low flow concrete channel. The latter does not appear to be maintained on any regular basis. The basin is approximately five to six feet deep with a side slope of 5 to 10 percent. The detention basin does not have a water quality outlet structure, but the outlet for the basin consists of a trash rack that covers the opening of a concrete pipe. The detention basin is in clear view of a commonly used roadway in the middle of a residential neighborhood.	

Proposed Solutions:
The solution for this project is in two parts. The first part is re-vegetating the basin. Clusters of turf grass will be replaced with native warm season grasses, herbaceous plants, sedges, ferns and a minimum of woody vegetation. Over time, the new vegetation will expand past the boundaries of the clusters to cover the entire basin. The new vegetation will increase the infiltration rate of the basin. The basin will not be mowed on a weekly basis as it is now. The vegetation will be allowed to grow tall, which increases its ability to filter nutrients and sediment from stormwater runoff. Tall vegetation has a deeper and more complex root structure, allowing the basin to infiltrate greater amounts of water during storm events.

The second part of the solution is a small berm or series of berms surrounding the outlet of the basin. Each berm would be about one foot high and constructed using a permeable material, such as coconut fiber logs or ¾ inch clean stone secured with fabric. The berm will increase the amount of time runoff remains in the basin. In addition, the berm would constrict the flow of runoff for small, frequent storms, but not interfere with the capacity of the basin to prevent flooding from larger storms because runoff would flow over the berm. Runoff from smaller storms would inundate a larger surface area, increasing infiltration and treatment of runoff.

Anticipated Benefits:
The detention basin is expected to increase infiltration of water and remove more nutrients and sediment from the runoff during storm events. Native vegetation will be allowed to grow tall, which results in a larger root structure. Taller plants are expected to increase infiltration of stormwater runoff and remove sediment and nutrients. The more extensive root structure will make the soil at the bottom

of the basin more porous and increase infiltration rates. Increased infiltration rates of the basin will allow less water to leave the basin after storms, which would prevent sediment and nutrients from entering local water ways. After the retrofits are complete, the basin will be very similar to a bioretention basin with the same pollutant removal rates. Bioretention basins typically remove 90 percent of TSS, 60 percent of TP and 30 percent TN. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007 and Karathanasis et al., 2003). Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project would reduce TSS by 3,348 pounds per year, TP by 13.4 pounds per year and TN by 55.8 pounds per year.

Major Implementation Issues:

There two impediments to the implementation of this project. The first is permitting. This project requires a permit from the local conservation district, which indicates the district approves the proposed alterations of the basin. The soil conservation district could be a partner on this project, but it would need evidence that the berms planned for the project would not adversely affect how the basin prevents flooding downstream or reduce the storage capacity of the basin.

The second impediment is aesthetics. This site runs along a commonly used road, making the site visible from the road. Local residents may resist the project because they may prefer the look of the basin with mowed turf grass and landscaped shrubs rather than the more natural look proposed in the project.

Possible Funding Sources:

319(h) grants from the NJDEP

Possible Partners/Stakeholders:

Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Remove old and install new vegetation (assumes volunteer work)	$0.25/sq. ft.	37,461 sq. ft.	$9,365
	Supervision of Volunteers	$2,000	1	$2,000
	Install berms	$5,000	1	$5,000
	Contingency (20%)	$3,273	1	$3,273
	Total BMP installation cost			$19,638
Estimated total project cost				**$24,638**
Annual operation and maintenance cost				$500

7.4.3.4. Hardy Drive in Raritan Township

Project Name: Detention Basin Retrofit of Detention Basin MDB-0136

Location:	Subwatershed Priority:
Hardy Drive in Raritan Township	High

BMP Type and Description:

Bioretention Basin

Issues and Concerns:
Residential neighborhoods can be a source of sediment, phosphorus and bacteria for local waterways. All the surfaces of a residential neighborhood (streets, sidewalks, roofs and lawns) are potential sources of one or more of these pollutants. Pollutants accumulate on roofs, sidewalks and streets. Local wildlife and domestic pet wastes are sources of bacteria and nutrients. Fertilizer used on residential lawns is a source of phosphorus and nitrogen. Accumulated pollutants are carried to the local waterways via stormwater runoff.

Existing Conditions:
Detention Basin MDB – 0136 has an estimated drainage area of 35.4 acres. The drainage area is comprised of a low density residential area. The detention basin is approximately 1.26 acres in size. It has one inlet that connects to a low flow concrete channel. The low flow concrete channel does not appear to be maintained on a regular basis. The basin is approximately two to four feet deep with a side slope of 2 to 5 percent. The detention basin does not have a water quality outlet structure, but the outlet is protected by a trash rack. The detention basin is in clear view of a commonly used roadway near a residential neighborhood.

Proposed Solutions:
The solution for this project is in two parts. The first part is re-vegetating the basin. Clusters of turf grass will be replaced with native warm season grasses, herbaceous plants, sedges, ferns and a minimum of woody vegetation. Over time, the new vegetation will expand past the boundaries of the clusters to cover the entire basin. The new vegetation will increase the infiltration rate of the basin. The basin will not be mowed on a weekly basis as it is now. Vegetation will be allowed to grow tall, increasing its ability to filter nutrients and sediment from stormwater runoff. The tall vegetation has a deeper and more complex root structure, allowing the basin to infiltrate greater amounts of water during storm events.

The second part of the solution is a small berm or series of berms surrounding the outlet of the basin.

Each berm would only be about one foot high and constructed using a permeable material, such as coconut fiber logs or ¾ inch clean stone secured with fabric. The berm will increase the amount of time runoff remains in the basin. In addition, the berm would constrict the flow of runoff for small, frequent storms, but not interfere with the capacity of the basin to prevent flooding from larger storms because the runoff would flow over the berm. Runoff from smaller storms would inundate a larger surface area, increasing infiltration and treatment of runoff.

<u>Anticipated Benefits:</u>
The detention basin is expected to increase infiltration of water and remove more nutrients and sediment from the runoff during storm events. Native vegetation will be allowed to grow tall, which results in a larger root structure. Taller plants are expected to increase infiltration of stormwater runoff and remove sediment and nutrients from runoff. The more extensive root structure will make the soil at the bottom of the basin more porous and increase infiltration rates. Increased infiltration rates of the basin will allow less water to leave the basin after storms, which would prevent sediment and nutrients from entering local waterways. After the retrofits are complete, the basin will be very similar to a bioretention basin with the same pollutant removal rates. Bioretention basins typically remove 90 percent of TSS, 60 percent of TP and 30 percent TN. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007 and Karathanasis et al., 2003). Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year, and 5 pounds of TN per acre per year, the project would reduce TSS by 3,186 pounds per year, TP by 12.7 pounds per year and TN by 53.1 pounds per year.

<u>Major Implementation Issues:</u>
There two impediments to the implementation of this project. The first is permitting. This project requires a permit from the local conservation district, which indicates the district approves the proposed alterations of the basin. The soil conservation district could be a partner on this project, but it would need evidence that the berms planned for the project would not adversely affect how the basin prevents flooding downstream or reduce the storage capacity of the basin.

The second impediment is aesthetics and current use. This site runs along a commonly used road and is easily visible from the road. Local residents may resist the project because they may prefer the look of the basin with mowed turf grass and landscaped shrubs rather than the more natural look proposed in the project. During a site visit, lacrosse and golf balls were found in the basin. Local residents may not want any changes made to the basin because of its recreational value.

<u>Possible Funding Sources:</u>
319(h) grants from the NJDEP

<u>Possible Partners/Stakeholders:</u>
Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA

Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Remove old and install new vegetation (assumes volunteer work)	$0.25/sq. ft.	54,885 sq. ft.	$13,721
	Supervision of Volunteers	$2,000	1	$2,000
	Install berms	$5,000	1	$5,000
	Contingency (20%)	$4,144	1	$4,144

	Total BMP installation cost	$24,865
Estimated total project cost		**$29,865**
Annual operation and maintenance cost		$500

7.4.3.5. Coventry Circle in Raritan Township

Project Name: Detention Basin Retrofit of Detention Basin MDB-0150	
Location: Outside of Coventry Circle in Raritan Township	Subwatershed Priority: High
BMP Type and Description: Bioretention Basin	
Issues and Concerns: Residential neighborhoods can be a source of sediment, phosphorus and bacteria for local waterways. All the surfaces of a residential neighborhood (streets, sidewalks, roofs and lawns) are potential sources of one or more of these pollutants. Pollutants accumulate on roofs, sidewalks and streets. Local wildlife and domestic pet wastes are sources of bacteria and nutrients. Fertilizer used on residential lawns is a source of phosphorus and nitrogen. Accumulated pollutants are carried to local waterways via stormwater runoff.	
Existing Conditions: Detention Basin MDB – 0150 has an estimated drainage area of 17.5 acres. The drainage area is a residential neighborhood in Raritan Township. The detention basin is approximately 0.92 acres in size. It has two inlets that each has their own low flow channel. One channel is comprised of concrete and the other channel is comprised of stone. Accumulation of sediment in the concrete low flow channel suggests that it is not maintained on a regular basis. The basin is approximately three to four feet deep with a side slope of 5 to 10 percent. It does not have a water quality outlet structure, but the outlet has a large concrete weir (see Figure below). The detention basin is in clear view of a commonly used roadway near a residential neighborhood.	
Proposed Solutions: The solution for this project is in two parts. The first part is re-vegetating the basin. Clusters of turf grass will be replaced with native warm season grasses, herbaceous plants, sedges, ferns and a minimum of woody vegetation. Over time, the new vegetation will expand past the boundaries of the clusters to cover the entire basin. The new vegetation will increase the infiltration rate of the basin. The basin will not be mowed on a weekly basis as it is now. Vegetation will be allowed to grow tall, increasing its ability to filter nutrients and sediment from stormwater runoff. Tall vegetation has a deeper and more complex root structure, allowing the basin to infiltrate greater amounts of water during storm events. The second part of the solution is a small berm or series of berms surrounding the outlet of the basin. Each berm would only be about one foot high and constructed using a permeable material, such as coconut fiber logs or ¾ inch clean stone secured with fabric. The berm will increase the amount of time runoff remains in the basin. In addition, the berm would constrict the flow of runoff for small, frequent storms, but not interfere with the capacity of the basin to prevent flooding from larger storms because the runoff would flow over the berm. Runoff from smaller storms would inundate a larger surface area, increasing infiltration and treatment of runoff.	

Anticipated Benefits:
The detention basin is expected to increase infiltration of water and remove more nutrients and sediment from runoff during storm events. Native vegetation will be allowed to grow tall, which results in a larger root structure. Taller plants are expected to increase infiltration of stormwater runoff and remove sediment and nutrients from runoff. The more extensive root structure will make the soil at the bottom of the basin more porous and increase the infiltration rates. Increased infiltration rates of the basin will allow less water to leave the basin after storms, which would prevent sediment and nutrients from the entering local water ways. After the retrofits are complete, the basin will be very similar to a bioretention basin with the same pollutant removal rates. Bioretention basins typically remove 90 percent of TSS, 60 percent of TP and 30 percent TN. Removal rates for bioretention basins and wetlands are at or above 90 percent for fecal coliform (Rusciano and Obropta, 2007 and Karathanasis et al., 2003). Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.6 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project would reduce TSS by 1,575 pounds per year, TP by 6.3 pounds per year and TN by 26.3 pounds per year.

Major Implementation Issues:
There two impediments to the implementation of this project. The first is permitting. This project requires a permit from the local conservation district, which indicates the district approves the proposed alterations of the basin. The soil conservation district could be a partner on this project, but it would need evidence that the berms planned for the project would not adversely affect how the basin prevents flooding downstream or reduce the storage capacity of the basin.

The second impediment is aesthetics. This detention basin handles the drainage for the stormwater

runoff of a residential neighborhood. Local residents may resist the project because they may prefer the look of the basin with mowed turf grass and landscaped shrubs rather than the more natural look proposed in the project. The Water Resources Program would work with township officials and local residents to develop a design that is acceptable to the neighborhood.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Possible Partners/Stakeholders: Raritan Township; NJRC&D; HCSCD; RCE; NJIT; and NJWSA				
Task	Task Description			Estimated Cost
1	Apply for Soil Erosion and Sediment Control Permit			$500
2	Complete Topographic Survey and soils test			$1,000
3	Prepare Final Design			$2,000
4	Prepare Maintenance Plan			$500
5	Prepare construction Documents and Solicit Quotes from contractors			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Remove old and install new vegetation (assumes volunteer work)	$0.25/sq. ft.	40,075 sq. ft.	$10,018
	Supervision of Volunteers	$2,000	1	$2,000
	Install berms	$5,000	1	$5,000
	Contingency (20%)	$3,404	1	$3,404
	Total BMP installation cost			$20,422
Estimated total project cost				**$25,422**
Annual operation and maintenance cost				$500

7.4.4. Vegetative Buffers for Non-agricultural Developed Lands

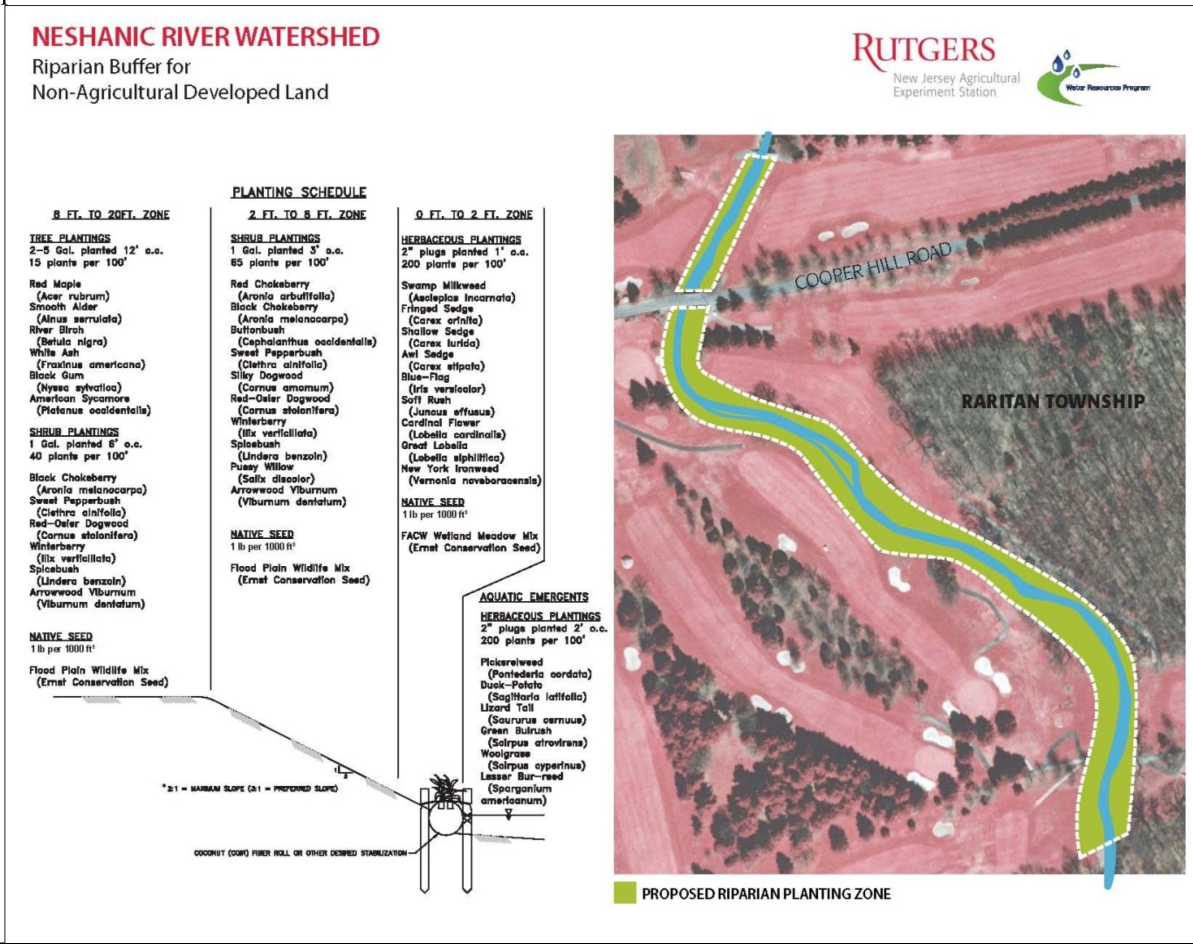
7.4.4.1. Copper Hill Country Club (Golf Course) in Raritan Township

Project Name: Non-Agricultural Developed Land Vegetative Buffer	
Location: Copper Hill Country Club (Golf Course) in Raritan Township	Subwatershed Priority: High
BMP Type and Description: Vegetative Buffer	
Issues and Concerns: Golf courses are considered potential sources of nutrients, bacteria and sediment in a watershed. The amount of fertilizer used at these facilities greatly increases the potential for golf courses to become a source of phosphorus and nitrogen. Additionally, geese that feed in these large grassed areas deposit feces, which is high in nutrients and pathogens. Accumulated pollutants can be carried to the local waterways via stormwater runoff.	
Existing Conditions: The proposed site for this project is a small tributary in Raritan Township that runs through the Copper Hill Country Club. The stream is approximately 1,900 feet long at this site. Despite a few trees and small shrubs along the edge of the shoreline, there is no buffer along either side of the tributary. The portion of the tributary in the golf course has an approximate drainage area of 44.15 acres. Vegetation on both sides of the tributary is mostly turf grass, which does not provide a high level of treatment for stormwater runoff from the golf course. In addition, turf grass attracts geese, which leave behind feces high in nutrients and pathogens. Golf courses are mowed every day and heavily fertilized. Stormwater	

runoff carries the lawn cuttings, excess fertilizer and waste from wildlife to the stream.

Proposed Solutions:

The golf course does not have any subsurface drainage system; stormwater from the site travels as runoff over the land until it reaches the tributary. The landscape of the golf course cannot be altered drastically without interfering with its architecture. This drastically limits the BMPs options for to improving water quality of the stormwater runoff generated onsite. While the landscape cannot be drastically changed, there is flexibility to add vegetation along the shoreline of the tributary. The recommended solution for this site is a vegetated buffer between 30 and 50 feet wide. The buffer would have a dynamic design that integrates it into the existing vegetation and landscape design of the golf course. Vegetation in the buffer will be diverse, comprised of warm season grasses, herbaceous plugs, woody shrubs and trees. This buffer will treat all of the stormwater runoff that passes through it. Vegetation will reduce the velocity of the stormwater runoff passing through the buffer, causing sediment, nutrients and bacteria to fall out of suspension and be deposited in the buffer. Deposited pollutants will be used by the vegetation to grow, thereby increasing the filtering and treatment potential of the buffer.



Anticipated Benefits:

The vegetative buffer is expected to treat and filter the stormwater runoff from every storm event. Vegetative buffers typically remove 60 to 80 percent of TSS, 30 percent of TP and 30 percent TN. Based upon aerial loading calculations for the drainage area of 100 pounds of TSS per acre per year, 0.2 pounds of TP per acre per year and 5 pounds of TN per acre per year, the project would reduce TSS by 2,649 to 3,532 pounds per year, TP by 2.65 pounds per year and TN by 66.23 pounds per year.

Major Implementation Issues:

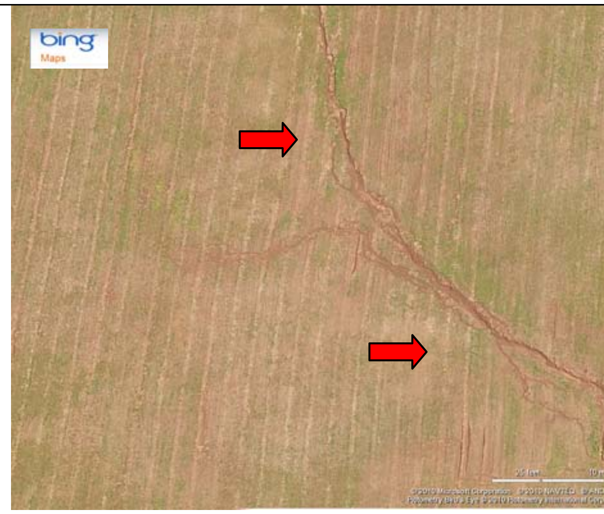
A major obstacle to implementing a vegetative buffer is convincing the golf course to install this BMP

on its property. Once funding is secured, the golf course owner can be approached about installing the vegetative buffer. The golf course owner has to agree to keep and maintain the vegetative buffer for a long period of time. If the vegetative buffer is not maintained, it will not achieve the potential water quality benefits. This problem can be overcome by incorporating the property owner's ideas in the design of the buffer. The golf course owner is likely to require that the buffer design match the existing landscape of the golf course, which could raise the total cost of the project.				
Possible Funding Sources: 319(h) grants from the NJDEP				
Partners/Stakeholders: NJRC&D; HCSCD; RCE; NJIT; NJDEP and NJWSA				
Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$500
2	Prepare final design			$1,000
	Activities for BMP installation	Unit Cost	Quantity	
	Install vegetative buffer (assumes most work completed by volunteers)	$5,000	1	$5,000
	Supervision of volunteers	$1,000	1	$1,000
	Contingency (20%)	$200	1	$200
	Total BMP installation cost			$6,200
Estimated total project cost				**$7,700**
Annual operation and maintenance cost				$100

7.4.5. Project for Agricultural Lands

7.4.5.1. Cover Crops

Project Name: Cover Crops
Location: Watershed wide
BMP Type and Description: Cover crops include grasses, legumes, forbs or other herbaceous plants established for seasonal cover and other conservation purposes.
Issues and Concerns: Exposed soil particles are vulnerable to being dislodged by rainfall and swept away. Eroded soil particles may carry phosphorus and other adsorbed contaminants to local waterways.
Existing Conditions: The images shown below illustrate some of the current crop field conditions in the Neshanic River Watershed that contribute to water quality degradation. Seasonally, some crop fields have inadequate vegetative cover. Bare soil is susceptible to becoming dislodged and carried into streams by runoff during storm events. Suspended soil particles contain phosphorus and other contaminants. Erosion is indicated in the images below by the red arrows. Cover crops protect the soil particles from becoming dislodged, helping to reduce erosion and retain soil nutrients for future crop use.



Proposed Solutions:

Cover crops would be planted on fields that are seasonally barren. Examples of cover crops are: Hairy Vetch (*Visa villosa Roth),* Winter Wheat (*Triticum vulgare),* Sorghum-sudangrass (*Sorghum bicolor*), Rye Grass (*Lolium spp.*) and Buckwheat (*Fagopyrum esculentum Moench*). The NRCS New Jersey Field Office Technical Guide (FOTG) practice code for cover crops is 340.

Anticipated Benefits:

Planting cover crops on barren fields reduces runoff, and wind and water erosion. Such crops absorb nutrients left from previous fertilizer and manure applications to the soil, making them unavailable for runoff. In addition, cover crops enhance overall soil health, reduce compaction and increase infiltration. Cover crops are especially beneficial in areas of the watershed where streams run dry during the summer.

The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 4,011 acres of row crops in the watershed, yielding on average approximately 1.3 pounds of TP per acre annually for a watershed total of 5,223 pounds per year. The Chesapeake Bay Water Quality Model showed that early planting of cover crops reduced TP by 15 percent. Based on reduction rates determined by the Chesapeake Bay Model and assuming row crop acres are beneficial, indicates that cover crops would reduce TP loading in the watershed by 0.195 pounds per acre or 769 pounds per year for the watershed.

The 4,011 acres of row crops in the watershed have an annual average sediment yield of approximately 0.10 tons of per acre or 396 tons for the watershed. The Chesapeake Bay Water Quality Model showed that early planting of cover crops reduces sediment yield by 20 percent. Based on reduction rates determined by the Chesapeake Bay Model and assuming row crop acres reduce sediment loads, indicates that cover crops would reduce annual sediment loads by 0.02 tons per acre or 99 tons per year for the watershed.

Major Implementation Issues:

Use of cover crops involves a cost for materials and time. The time period between the harvesting of row crops and seeding of cover crops is very short, which may be problematic for some farmers. State and federal agencies have cost-share programs that cover some of the implementation cost of cover crops. In some cases, a cover crop can be harvested to generate additional revenue. There is also a cost savings when a cover crop provides nutrient credits for the subsequent crop.

Possible Funding Sources:

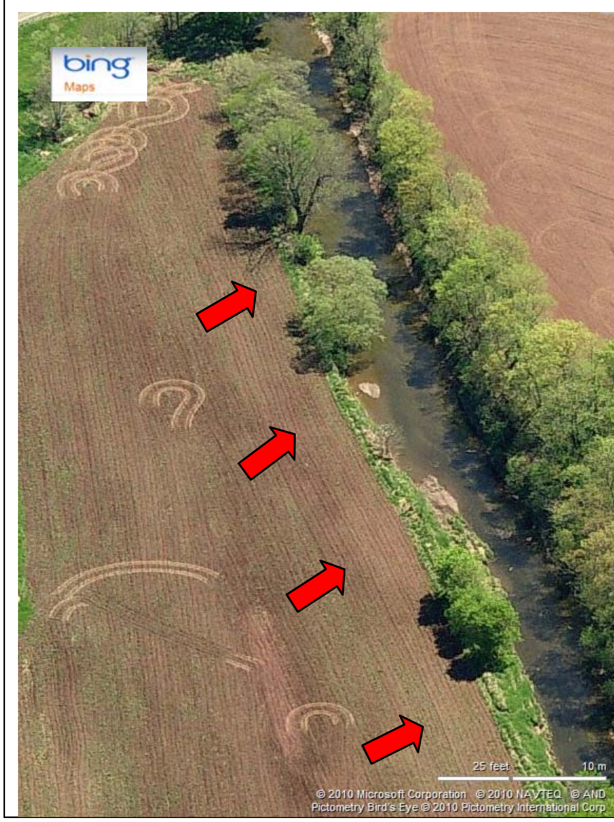
EPA 319(h) through NJDEP, Private, NJDA State Cost share, USDA Farm Bill Programs such

as CREP, EQIP, AWEP, and other cost share programs.				
Partners/Stakeholders: NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA and SBWA				
Task Description for a "Sample" Farm*				
Task	Task Description			Cost
1	Outreach to Producer			$550
2	Technical Assistance			$250
3	Project Plan			$100
4	Implementation oversight			$100
5	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Cover crop seeding	$83 average per acre for three years	62	$15,438
	Contingency (20%)			$3,088
	Total BMP Installation Cost			$18,526
Estimated total project cost				$19,526
* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementing cover crops. It is assumed that the sample farm has the equipment needed for field preparation and seeding of cover crops. The acreage for the sample farm is 62 acres, which is the average farm size in Hunterdon County (NASS, 2007). Cost of BMP installation was estimated using cost data from the New Jersey Farm Bill Program 2011 Practice Catalog. The unit cost is an average over five different seed types and plantings from the NRCS AWEP practice catalog. If program eligibility requirements are met, tasks 2, 3 and 4 may be provided at no cost to the landowner through NRCS technical assistance.				

7.4.5.2. Conservation Buffers

Project Name: Conservation Buffers
Location: Watershed wide
BMP Type and Description: A conservation buffer is an area of grasses, grass-like plants, forbs, trees and/or shrubs located adjacent to and up-gradient from streams or HSAs prone to generating runoff and other pollutants. Buffers help to protect these areas by trapping, slowing, filtering and uptaking potential pollutants. Whenever possible, vegetation in conservation buffers should be native plants, which provide good wildlife habitat. Examples of native plants used in buffers are Red Maple (*Acer rubrum*), Serviceberry (*Amelanchier arborea*), Silky Dogwood (*Cornus amomum*) and Reed Grass (*Calamagrostis canadensisx*).
Issues and Concerns: Runoff in streams and/or from HSAs with insufficient buffer areas is likely to have more phosphorus, pathogens and other contaminants than runoff in streams and/or from HSAs that have conservation buffers. Additionally, lack of conservation buffers makes these areas more susceptible to soil erosion. Streams without forested riparian buffers are likely to have higher water temperature than streams with forested riparian buffers. Higher water temperatures can impair aquatic species, particularly trout.
Existing Conditions: Streams in the Neshanic River Watershed have riparian areas or borders that have either insufficient or non-existent buffers. Some of those streams are adjacent to pastures, heavy livestock-use areas and crop fields, making them susceptible to agricultural runoff containing phosphorus, bacteria and

sediment; these pollutants are of concern in the watershed. The images below illustrate some of the current riparian conditions in the Neshanic River Watershed. Streams adjacent to agricultural crop fields and pastures lacking riparian buffers are indicated by the red arrows. Conservation buffers would trap sediment and filter out phosphorus, bacteria and other contaminants in runoff from agricultural lands before that runoff reaches a stream. To compound the issue, a stream without a proper buffer adjacent to pasture can be further degraded by livestock trampling of streambanks. Riparian buffers can be planted and a healthy riparian corridor established. Conservation buffers should, at a minimum, extend 35 feet on both sides of the streambank and contain suitable vegetation.



Proposed Solutions: Creating conservation buffers on HSAs and/or in riparian areas of streams adjacent to agricultural land will reduce water quality contamination from agricultural runoff. Buffers need to be designed, installed and maintained. Some of the NRCS New Jersey FOTG standards that may apply to conservation buffers are Riparian Forest Buffer (391), Riparian Herbaceous Cover (390), Critical Area Planting (342), Grassed Waterway (412) and Filter Strip (393).
Anticipated Benefits: Conservation buffers can reduce TP in runoff by up to 75 percent, protect waterbodies from pesticide drift and stabilize streambanks and shorelines. In addition, conservation buffers can reduce water temperatures, improve fish and wildlife habitat and improve groundwater quality. The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 7,645 acres of hay, pasture and croplands in the watershed. These acres produce annual average TP loads of approximately 0.97 pounds per acre and 7,400 pounds for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers reduce TP by at least 50 percent. Assuming all streams located in hay land, pastures and croplands have conservation buffers, annual TP loading in the Neshanic River Watershed would decrease by 0.484 pounds per acre or 3,700 pounds for the watershed. These estimates assume that all runoff from these lands enter the buffer as sheet flow as opposed to concentrated flow. Many areas of the watershed have concentrated flow whose reduction would require implementation of other erosion control practices. Runoff entering buffer areas as concentrated flow will not achieve the phosphorus reduction levels indicated above. The 7,645 acres of hay, pasture and row crops in the watershed yield approximately 0.066 tons of sediment per acre per year or 500.9 tons per year for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers can reduce sediment by at least 50 percent. Based on reduction rates determined by the Chesapeake Bay Model, installing conservation buffers in the watershed would reduce annual sediment loading by 0.033 tons per acre or 250.4 tons for the watershed. These estimates assume that all runoff entering conservation buffers is from sheet flow as opposed to concentrated flow. Some areas of the watershed generate concentrated flow whose control would require the implementation of other erosion control practices. Runoff entering buffer areas as concentrated flow will not achieve the expected sediment reduction given above.
Major Implementation Issues: There are multiple landowner costs associated with the installation of conservation buffers, including both time and material costs. Initial installation cost is often cost shared, sometimes up to 100 percent, through various state and federal programs. Establishing conservation buffers can also be challenging due to intense deer pressure. Precautions have to be taken to discourage and prevent deer from browsing when establishing conservation buffers. Maintenance costs vary by sites and are not always cost shared. In cases where the streams are the primary water source for livestock, there is the challenge as well as cost of providing alternative water sources. Often, the land in the conservation buffers is taken out of production and no longer generates revenue for the farmer. Some programs compensate for the production loss on an annual basis. Also, landowners are concerned about losing farmland tax assessment status of lands converted to conservation buffers. Obtaining the permits from NJDEP and other agencies needed to establish buffers is a complicated process that often discourages farmers from participating in programs that support installation of conservation buffers.
Possible Funding Sources: EPA 319(h) through NJDEP, National Fish and Wildlife Foundation's Five Star Restoration Challenge Grants, NJDEP Corporate Business Tax, Private Sources, NJDA State Cost share, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, USDA Farm Bill Programs such as CREP, EQIP,

AWEP, WHIP and other cost share programs.				
Partners/Stakeholders: NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA; NJDEP and SBWA				
Task Description for a "Sample" Farm*				
Task	Conservation Buffer Task Description			Cost
1	Outreach to Producer			$1,000
2	Technical Assistance			$2,000
3	Project Design			$1,000
4	Applicable permits			$200
5	Implementation oversight			$1,000
6	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Invasive Removal	$1,250 per acre	1	$1,250
	Site Preparation	$250 per acre	1	$250
	Planting	$4,000 per acre	1	$4,000
	Plant protection/weed suppression	$1,000 per acre	1	$1,000
	First year monitoring and maintenance	$750 per acre	1	$750
	Filter Strip with cool season grass	$180 per acre	2	$360
	Contingency (20%)			$1,522
	Total BMP Installation Cost			$9,132
Estimated total project cost				$14,332
Annual Operation and Maintenance Cost				$250
* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementing conservation buffers. The size of buffers, plant selection, protection from livestock and deer browse, and invasive control varies from site to site. These cost estimates assume the use of five-gallon containerized plant material to reduce plant mortality. Costs of BMP installation were estimated from cost data provided by North Jersey RC&D, which are based on past implementation projects. If program eligibility requirements are met, tasks 2, 3 and 5 may be provided at no cost to the landowner through NRCS technical assistance. Increased permanent easement incentive payments should be considered to encourage participation and implementation from landowners.				

7.4.5.3. Prescribed Grazing

Project Name: Prescribed Grazing
Location: Watershed wide
BMP Type and Description: Prescribed grazing is a system that allows agricultural producers to manage grazing and browsing of animals so as to ensure adequate ground cover and proper livestock nutrition.
Issues and Concerns: Over grazing and overstocked pastures lead to conditions of bare or inadequately covered and compacted soil. These conditions are conducive to soil erosion, nutrient runoff and fecal contamination of surface water.
Existing Conditions: Some pastures in the Neshanic River Watershed show signs of over grazing and overstocking.

Pastures need to rest between grazing to allow vegetation to recover. Grazing that is too frequent leaves the soil in a bare condition. Bare soil is more likely to be dislodged and eroded during storm events. Further exacerbating the situation is the fact that unprotected soil becomes compacted by livestock traffic making post-grazing recovery of vegetation even more difficult. Trampled areas may eventually experience gully erosion if channels are created by livestock paths. The images below illustrate some of the current conditions in the Neshanic River Watershed. The two pastures illustrate areas of poor vegetative cover and bare earth due to overgrazing and overstocking of livestock. Such conditions are likely to increase erosion and runoff.

Proposed Solutions:
Prescribed grazing systems developed by a grazing specialist and implemented by an agricultural producer is a possible solution to poor pasture conditions. Such prescribed grazing plans may include reducing the number of livestock, more frequent rotation of livestock, and using temporary fencing to exclude livestock from pastures recovering from frequent grazing activity. Some of the NRCS New Jersey FOTG standards that may apply to a prescribed grazing system are Prescribed Grazing (528), Watering Facility (614), Pest Management (595), Brush Management (314) and Pasture Planting (512).

Anticipated Benefits:
The use of well-designed prescribed grazing plans will help maintain healthy and productive pastures. Healthy pastures protect soil from erosion and reduce the resultant phosphorus and fecal in runoff. In

addition, an actively growing pasture has greater uptake of nutrients and water infiltration. A prescribed grazing plan designates stocking numbers, the timing of field rotations, and actions to restore pasture health. Benefits of healthy pastures include high quality forage and healthy livestock.

The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 892 acres of pasture in the watershed, yielding, on average, approximately 1.70 pounds of TP per acre annually or 1,521 pounds per year for the watershed. The Chesapeake Bay Water Quality Model showed that prescribed grazing reduces TP by 25 percent. If implemented in all pasture lands in the watershed, prescribed grazing would reduce annual TP loading by 0.425 pounds per acre or 380 pounds for the watershed.

The 890 acres of pasture in the watershed yield approximately 0.08 tons of sediment per acre per year, which amounts to 70 tons per year for the watershed. The Chesapeake Bay Water Quality Model showed that prescribed grazing reduces sediment by 25 percent. Prescribed grazing could reduce annual sediment loading in the watershed by 0.02 tons per acre or 17.5 tons for the watershed.

Major Implementation Issues:

A prescribed grazing plan often requires a farmer to make operational changes. Implementing these changes may make the operation more labor intensive. Fencing, alternate watering sources and other costs are typically incurred when implementing a prescribed grazing plan. In addition, a plan may require a farmer to graze fewer animals, which could reduce farm revenue. Some of the cost of prescribed grazing may be offset by a lower need for supplemental feed. Such costs and benefits are likely to vary by farming operation.

Possible Funding Sources:

EPA 319(h) through NJDEP, Private, NJDA State Cost share, USDA Farm Bill Programs such as CREP, EQIP, AWEP, and other available cost share.

Partners/Stakeholders:

Township officials; NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA and SBWA

Task Description for a "Sample" Farm*

Task	Task Description			Cost
1	Outreach to Producer			$1,000
2	Technical Assistance			$1,500
3	Grazing plan			$750
4	Implementation oversight			$500
5	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Managed system including polywire fence, forage monitoring every other day, relocation of livestock, and necessary documentation based on 30 acres as described by NRCS practice 528	$93 per acre	30 acres	$2,790
	Over-seeding	$173 per acre	30 acres	$5,190
	Contingency (20%)			$1,596
	Total BMP Installation Costs			$9,576
Estimated total project cost				$13,326

* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementing cover crops. Acreage will vary from farm to farm. This example does not include alternative water sources, permanent fencing or other practices that might be necessary to implement prescribed grazing on some farms. Cost of BMP installation was estimated using cost data

from the New Jersey Farm Bill Program 2011 Practice Catalog. If program eligibility requirements are met, tasks 2, 3 and 4 may be provided at no cost to the landowner through NRCS technical assistance.

7.4.5.4. Livestock Access Control

Project Name: Livestock Access Control

Location: Watershed wide

BMP Type and Description:
Access control is temporary or permanent exclusion of animals from riparian areas of streams.

Issues and Concerns:
Livestock with direct access to streams often deposit manure to those streams that causes nutrient and bacteria contamination, causes soil erosion of streambanks and elevates TSS concentrations in streams. Grazing in riparian areas of streams compacts soils and prevents the establishment of vegetation that can potentially filter the runoff.

Existing Conditions:
In some livestock operations, streams are the primary watering source for livestock, causing frequent, uncontrolled livestock access to and defecation in those streams. Livestock access to streams also degrades and creates channels for concentrated runoff. Soil compaction from grazing in riparian areas stifles growth of riparian vegetation; the latter filters pollutants from runoff in pastures.

Oblique aerial photos from Microsoft Bing Maps illustrate some of the current conditions in the Neshanic River Watershed. Livestock have open access to streams as indicated by the red arrows, which allows for direct deposit of manure in streams and streambank degradation. Access control fencing or a similar barrier would prevent livestock from defecating in streams. Re-establishment of riparian vegetation would reduce pasture runoff into streams. For such regeneration to occur, the fencing or barrier should be placed a minimum of 35 feet from the streambanks or more depending on site-specific conditions.

Proposed Solutions:
Exclusion fences should be used to eliminate livestock from access to streams and riparian zones in pastures. NRCS recommends the fencing be at least 35 feet from the streams. A greater distance may be required depending on site-specific conditions, such as land slope and intensity of adjacent land uses. NRCS New Jersey FOTG standards that may apply to livestock access control are Access Control (472), Fence (382), Stream Crossing (578), Watering Facility (614), Riparian Forest Buffer (391), Riparian Herbaceous Cover (390) and Filter Strip (393).

Anticipated Benefits:
Exclusion fencing will completely eliminate livestock manure from entering streams and permit the re-establishment of riparian vegetation that will filter runoff from adjacent pastures.

The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 892 acres of pasture within the watershed, yielding approximately 1.70 pounds of TP per acre annually or 1,521 pounds per year for the watershed. The Chesapeake Bay Water Quality Model showed that access control fencing reduces TP by 60 percent. Applying access control fences along all streams that cross pastures would reduce TP loading by 1.02 pounds per acre or 913 pounds per year for the watershed.

The 892 acres of pasture in the watershed yield approximately 0.08 tons of sediment per acre annually or 70 tons per year for the watershed. The Chesapeake Bay Water Quality Model showed that access control fencing reduces sediment by 75 percent. This suggests that access control fencing could potentially reduce sediment loading in the watershed by 0.06 tons per acre or 52.4 tons per year for the watershed.

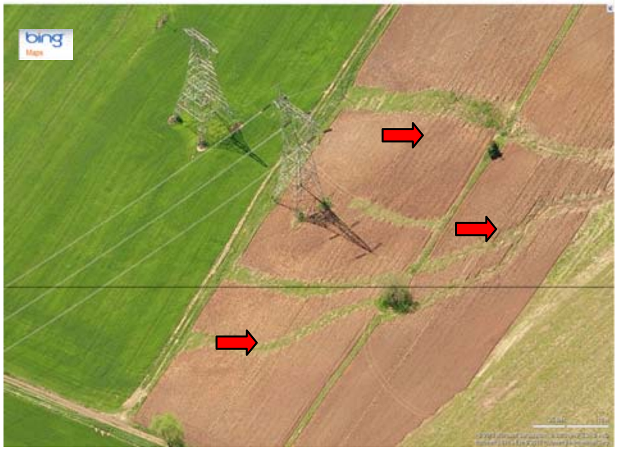
Major Implementation Issues:
This BMP will create new challenges for landowners in terms of requiring extra labor and learning how to maintain the BMP. Fencing must be routinely inspected and maintained, especially after flood events. Installing fencing would reduce the size of pastures, possibly resulting in a reduction in the number of livestock on pasture. In addition, excluding livestock from streams requires developing an alternative water source.

Possible Funding Sources: EPA 319(h) through NJDEP, Private Sources, NJDA State Cost share, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, USDA Farm Bill Programs such as CREP, EQIP, AWEP, and other cost share programs.				
Partners/Stakeholders: Township officials; NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA and SBWA				
Task Description for a "Sample" Farm*				
Task	Task Description			Cost
1	Outreach to Producer			$1,000
2	Technical Assistance			$500
3	Project Plan			$200
4	Implementation oversight			$200
5	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Fencing Installation	$4.78 per ft.	500 ft	$2,500
	Contingency (20%)			$478
	Total BMP Installation Cost			$2,868
Estimated total project cost				$4,768
Annual Operation and Maintenance Cost				$100
* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementing access control fencing. The "sample" farm assumes that the only fencing needed is on one side of the stream and that there is an alternate, pre-existing water source for livestock. See the Livestock BMP sheet for a more detailed account of possible additional measures that may be needed when implementing access control fencing. Costs of BMP installation were estimated from the cost data in the New Jersey Farm Bill Program 2011 Practice Catalog. If program eligibility requirements are met, tasks 2, 3 and 4 may be provided at no cost to the landowner through NRCS technical assistance.				

7.4.5.5. Contour Farming

Project Name: Contour Farming
Location: Watershed wide
BMP Type and Description: Contour Farming uses ridges and furrows formed by tillage, planting and other farming operations to change direction of runoff from directly downslope to around the hill slope.
Issues and Concerns: Crop planting without regard to the topography of the landscape can create conditions that lead to erosion and excessive nutrient runoff.
Existing Conditions: Currently, some crops in the Neshanic River Watershed are planted in straight rows without regard to the contour of the land or slope direction. This condition is conducive to increased erosion and fertilizer runoff. The situation can be improved by contour farming. The images below illustrate some of the current conditions in the watershed. The photo on the left shows crops planted in straight rows without regard to the topography of the landscape. The red arrows indicate points where water flows and soil erodes during storm events. The photo on the right is an example of contour farming, which negates or

reduces soil erosion in agricultural fields.



Proposed Solutions:
Use contour farming when field conditions allow. The NRCS New Jersey FOTG standards that may apply to contour farming are Contour Farming (330) and Field Border (386).

Anticipated Benefits:
Contour farming can reduce sediment from gully erosion and slow down surface water runoff. This will effectively reduce the transport of phosphorus and other contaminants to streams.

The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 4,011 acres of croplands in the watershed of which 1,846 acres have slopes from 2 to 10 percent making them ideal sites for contour farming. SWAT modeling results indicate that cropland produces approximately 1.3 pounds of TP per acre annually in the watershed. Potter et al. (2006) estimated that contour farming reduced TP by 20 percent. It is estimated that contour farming would reduce annual TP loads by 0.26 pounds per acre or 480 pounds when implemented on 1,846 acres of cropland in the watershed.

Cropland in the watershed produces approximately 0.10 tons of sediment per acre per year. Potter et al. (2006) estimated that contour farming reduced sediment runoff by 40 percent. Assuming contour farming is implemented on the 1.846 acres of suitable cropland, contour farming would reduce annual TP loading by 0.04 tons per acre or 73.84 tons for the watershed.

Major Implementation Issues:
Contour farming will pose new challenges to operators. Initially, farmers may need assistance in using contour farming. Such assistance is available from NRCS. There are currently no federal financial incentive programs for farmers who practice contour farming. Farmers are less likely to change their cropping practices without financial incentives. Future incentive payments for contour farming might encourage adoption.

Possible Funding Sources:
EPA 319(h) through NJDEP, Private and other available cost share. Cost share funding is not available for this practice. This practice does require a learning curve, requires effort on the part of farmers to implement, and can result in revenue loss. Future incentive payments should be considered to promote contour farming.

Partners/Stakeholders:
NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA and SBWA

Task Description for a "Sample" Farm*

Task	Task Description	Cost
1	Outreach to Producer	$1,000

2	Technical assistance			$250
3	Project plan			$200
4	Implementation oversight			$200
5	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Incentive payment ($25.00/acre/year for three years)	$75.00	62	$4,650
	Contingency (20%)			$930
	Total BMP Installation Cost			$5,580
Total estimated project cost				$7,230

* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementation contour farming. The "sample" farm assumes that the necessary equipment is available and that no additional practices are necessary to implement contour farming. There are no out-of-pocket costs to install this BMP because installation only involves changing the direction of tillage and planting of fields (i.e., crops are planted along the contour lines of the landscape). Currently, there are no incentive payments to farmers for the practice. Considering the benefits of contour farming, future incentive payments should be explored as described above. The sample farm size of 62 acres is the average farm size in Hunterdon County (NASS, 2007). If program eligibility requirements are met, NRCS technical assistance would allow tasks 2, 3 and 4 to be performed at no cost to landowners.

7.4.5.6. Integrated Crop Management

Project Name: Integrated Crop Management

Location: Watershed wide and applicable to crop, hay and pastures.

BMP Type and Description:
ICM is a soil test-based agricultural assistance program that allows farmers to better manage nutrients in crop production so as to achieve both environmental and economic goals.

Issues and Concerns:
Agricultural operations take place on a significant portion of the lands in the Neshanic River Watershed. These operations contribute to water quality problems in the watershed, including sedimentation, bacterial contamination, thermal pollution and nutrient enrichment. Sediments from agricultural operations result from agricultural tillage, lack of riparian buffers, animals with direct access to the streams and/or over-grazing on pasture. Bacterial contamination results when livestock have direct access to waterways, animal manure is improperly applied to croplands and concentrated manure runoff is carried into the streams. Thermal pollution results when riparian areas lack sufficient vegetative cover to provide shade to streams. Nutrient enrichment occurs when the timing, amount and methods of fertilizer application are such that excessive fertilizers (chemical or organic) enter streams.

Some farms in the watershed are small operations with limited capital and knowledge to implement current agronomic BMPs such as nutrient management, pest management, conservation buffers, access control, manure management and erosion control practices.

Existing Conditions:
Soil nutrients are critical to crop growth. Crop growth could deplete and/or enrich certain nutrients in soils and causes imbalance in soil nutrients. Fertilizers are often used to correct such imbalances and promote crop growth. Ideally, fertilizer application should be based on nutrient availability in soils.

However, most fertilizer application rates are determined without soil testing in the Neshanic River Watershed and many other regions in New Jersey. Many continually farmed fields are over limed with pH levels above the optimum level. Other fields require lime, indicating that lime is applied without evaluating crop requirements for lime. Optimizing pH levels maximizes nutrient availability and crop growth, while reducing the amount of nutrients in runoff. Balanced nutrient levels reduce nutrient runoff by maximizing crop growth. Phosphorus is usually found at or above optimal levels. Yet, farmers still apply fertilizers that contain it. Potassium, which aids in nutrient uptake, is seldom found near optimal levels and is either very low or excessive. Manure is often applied without a soil test and without knowledge of nutrient levels in soil and/or crop needs for nutrients. Use of herbicides and pesticides is typically based on the presence of a pest or a weed rather than the economic and biological damage thresholds.
Possible Solutions: A comprehensive targeted agricultural assistance program is recommended to address agricultural water quality problems in the watershed. The program should be voluntary for landowners, but provide funding to initiate planning and implementation of efforts to minimize the impacts of agriculture on streams. The comprehensive agricultural assistance program would include: nutrient management plans; pest management services; an implementation coordinator; focused outreach; conservation planning; and use of a secondary fund source to augment existing farm bill assistance programs for the implementation of complementary BMPs. Many features of the proposed comprehensive agricultural assistance program are already present in the Neshanic River Watershed. Providing additional funding and coordinated effort would allow proper administration of the proposed program. The program would have several phases and sufficient resources would be allocated to the different phases of the program as dictated by the conditions in the watershed. Phase 1: Property Identification and Initial Outreach Agricultural properties must be identified within the watershed so that initial outreach can be conducted. Once identified using hydrological modeling, agricultural properties can be further prioritized according to runoff potential. Owners of prioritized properties would be contacted using a door-to-door approach. Phase 2: Free Soil Testing, Nutrient Management, ICM and River-Friendly Farm Certification Program Identified agricultural properties will be offered free soil testing with an accompanying ICM Plan. Farmers that accept free soil testing will be required to participate in the River-Friendly Farm Program. A free ICM Plan is currently offered in the Mulhockaway watershed, a nearby watershed. A similar project could be initiated in the Neshanic River Watershed. Free plans are valuable to agricultural producers because they allow producers to identify agricultural fields that are high in nutrients. Plans have been shown to help producers reduce costs of both nutrient and pesticide applications. After the first year, producers would receive these services at a reduced rate over the course of the next three years depending on funding availability. Implementation funding would be sought through EQIP and other Farm Bill assistance programs and supplemented by secondary funding sources. The River-Friendly Farm Certification Program is available in the Raritan River Basin, which includes the Neshanic River Watershed. The River-Friendly Farm Program conducts property assessments that help producers identify areas with potential resource problems. The program will help farmers to

develop strategies and find funding to address these problems. Phase 3: Soil Test Results, Property Assessments, Model Comparison and BMP Selection By combining the soil testing results, River-Friendly Assessment results and VSA Hydrology modeling results, project partners can determine which areas within the watershed to consider for CSAs. These CSAs are HSAs are more likely to generate pollutant contaminated runoff. Once these areas are identified, suitable BMPs can be identified for reducing or eliminating pollutant runoff. Phase 4: BMP Prioritization and Secondary Implementation Funding Source Identified CSAs and corresponding BMPs will be prioritized according to pollutant reduction potential. By prioritizing CSAs and BMPs, it can be determined which projects offer the greatest pollution reduction per dollar. A common barrier to the implementation of BMPs is the lack of sufficient funding available to producers and landowners. In many cases, existing cost share is sufficient for a landowner to recapture the costs of implementing a BMP. High ranking BMP projects offer the greatest opportunity for achieving water quality benefits in a cost effective manner. Creation of secondary funding sources and use of those sources to fund high priority projects will ensure cost effective on-the-ground implementation of conservation efforts. The goal is to increase the cost share rate to 90 to 100 percent of the installation costs for targeted practices that improve water quality in the watershed. Eligible practices that should be funded include: fencing animals from the stream; establishing or improving riparian buffers; manure management; and erosion control
Anticipated Benefits: The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 4,010 acres of cropland in the watershed that produces approximately 1.3 pounds of TP per acre per year or 5,213 pounds per year for the watershed. Gitau et al. (2005) indicated that nutrient management reduces TP by 47 percent. This suggests that active nutrient management would reduce annual TP loading by 0.61 pounds per acre or 2,450 pounds for the watershed. Considering nutrient management plans are only Phase 1 of the program. If this comprehensive agricultural assistance program was successful, the pollutant loading reduction potential would be significant. A successful nutrient management program would build positive relationships between the agricultural community and conservation community. Such relationships would nurture and promote the future success of both agriculture and agricultural conservation in the region, ensuring the lasting effects of conservation efforts.
Major Implementation Issues: The success of the program depends largely on the willingness of landowners and agricultural operations to participate in the program. Agricultural operations are often a part of a family's heritage and tradition. Frequently, a producer lives on his/her farm. Time is needed to build trust and relationships with farmers.
Possible Funding Sources: EPA 319(h) through NJDEP, National Fish and Wildlife Foundation's Five Star Restoration Challenge Grants, NJDEP Corporate Business Tax, Private Sources, NJDA State Cost share, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, USDA Farm Bill Programs, such as CREP, EQIP, AWEP, WHIP and other available cost share.

Partners/Stakeholders: NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA and SBWA				
Task Description for a "Sample" Farm*				
Task	Task Description			Cost
1	Outreach to Producer			$1,000
2	Technical assistance			$250
3	Project plan			$200
4	Implementation oversight			$200
5	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Nutrient Management ($25.00/acre/year for three years)	$75.00	62	$4,650
	Contingency (20%)			$930
	Total BMP Installation Cost			$5,580
Total estimated project cost				$7,230
* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to define estimate the cost of implementing ICM. The acreage in the sample farm is 62 acres, which is the average farm size in Hunterdon County (NASS, 2007). If program eligibility requirements are met, it would be possible to do tasks 2, 3 and 4 at no cost to landowners by using the NRCS technical assistance program.				

7.4.5.7. Application of Multiple BMPs for Row Crop Farm

Project Name: Multiple BMPs for Row Crop Farm
Location: Watershed wide
BMP Type and Description: A cover crop includes grasses, legumes, forbs or other herbaceous plants established for seasonal cover and other conservation purposes. Contour farming uses ridges and furrows formed by tillage and planting and other farming operations that change direction of runoff from directly downslope to around the hill slope. Riparian buffers are areas of grasses, grass-like plants, forbs, trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies that help protect surface water from runoff and contaminants. Nutrient management manages the amount, source, form and timing of application of nutrients and soil amendments. The above image illustrates how these practices could be implemented.
Issues and Concerns: Row crops planted without proper BMPs in place can potentially lead to nutrient rich soil becoming dislodged and eroding into streams. These particles carry with them phosphorus, bacteria and other pollutants which contribute to poor water quality.
Existing Conditions: Some crop fields in the watershed may be over fertilized, sometimes with manure, and planted without using BMPs that protect streams. These conditions can contribute to phosphorus and bacterial contamination in the Neshanic River Watershed.

Proposed Solutions:

By applying proper BMPs to row crops in the watershed, the potential for phosphorus and bacterial runoff can be reduced or eliminated. BMPs have been shown to work better in tandem. Streams can be protected by implementing a nutrient management plan designed to avoid over application of fertilizer, followed by cover crops that protect the land, contour farming that reduce erosion and riparian buffers that filter agricultural runoff.

Anticipated Benefits:

Proper fertilizer application reduces fertilizer application costs and excess nutrient runoff to streams. In addition to reducing soil erosion, cover crops have a myriad of other benefits. Cover crops promote healthy soils by increasing microbial activity, infiltration and nutrient absorption, and can increase farm revenue. Cover crops enhance water quality by reducing dislodgement of soil particles from the landscape. Contour farming reduces erosion and channelization on farm fields, which in turns reduces the transport of pollutants to streams. Riparian buffers act as the final barrier to filter agricultural runoff.

The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 4,011 acres of cropland in the watershed that produces approximately 1.3 pounds of TP per acre per year or 5,223 pounds per year of TP for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers reduce TP by at least 50 percent. Provided conservation buffers are applied to all cropland in the watershed, annual TP loading would decrease by 0.975 pounds per acre or 3,910 pounds for the watershed. This estimate assumes that all runoff enters conservation buffers as sheet flow as opposed to concentrated flow. Many properties in the watershed have areas of concentrated flow. Those areas would require further erosion control practices. Any runoff entering the buffer area as concentrated flow will not undergo the same phosphorus reduction as expected for sheet flow.

The 4,011 acres of cropland produce approximately 0.10 tons of sediment per acre per year or 396 tons per year for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers reduce sediment runoff by at least 50 percent. This suggests that conservation buffers could reduce annual sediment loads by 0.05 tons per acre or 200.5 tons for the watershed assuming that all runoff enters the buffers as sheet flow as opposed to concentrated flow. Areas of the watershed that experience concentrated flow would require further erosion control practices. Any runoff entering the buffer area as concentrated flow will undergo the same sediment reduction as expected for sheet flow.

While it is difficult to determine the total load reduction when multiple BMPs are used in concert, the SWAT model indicate that using multiple BMPs improves water quality. This implies that a row crop system using multiple BMP's will reduce loading more than the reductions achieved by conservation buffers alone as listed above.

Major Implementation Issues:

Changing farm operations is often difficult for farmers. There is a learning curve and a cost associated with the implementation and maintenance of BMPs. Use of some BMPs requires land to be taken out of production (e.g., riparian buffers). Although cost share and technical assistance available are from the Natural Resources Conservation Service and other state, local and non-profit agencies, not all farms qualify for these programs. Continual outreach, educational and promotion of BMPs will be required to facilitate the transition to environmentally sound farming practices in the watershed.

Possible Funding Sources:

EPA 319(h) through NJDEP, National Fish and Wildlife Foundation's Five Star Restoration Challenge Grants, NJDEP Corporate Business Tax, Private Sources, NJDA State Cost share, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, USDA Farm Bill Programs, such as CREP, EQIP, AWEP, WHIP and other available cost share programs. In the case of contour farming, cost share funding is not available. Farmers would need to learn how to use the practice and make the effort to implement the practice and absorb an initial loss in farm revenue. Future incentive payments should be considered to help promote contour farming.

Partners/Stakeholders:

NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA; NJDEP and SBWA

Task Description for a "Sample" Farm*

Task	Task Description			Cost
1	Outreach to Producer			$1,000
2	Technical Assistance			$3,000
3	Project design			$2,000
4	Applicable permits			$200
5	Implementation oversight			$1,750
6	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Riparian Buffer	$12,750 per acre	1	$7,750
	Cover Crop	$113 per acre	62	$7,006
	Contour Farming	No cost	No cost	
	Nutrient Management	$22.00 per acre	62	$1,364
	Total BMP Installation Cost			$16,120
	Contingency (20%)			$4,814
Total estimated project cost				$28,884
Annual Operation and Maintenance Cost				$250

* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to

estimate the cost of implementing contour farming. The 62-acre size of the sample farm is the average farm size in Hunterdon County (NASS, 2007). Costs for BMP installation were estimated based on cost data from the New Jersey Farm Bill Program 2011 Practice Catalog and provided by North Jersey RC&D. The latter costs are based on past implementation projects. If program eligibility requirements are met, tasks 2, 3 and 5 could be done at no cost to landowners by using NRCS technical assistance.

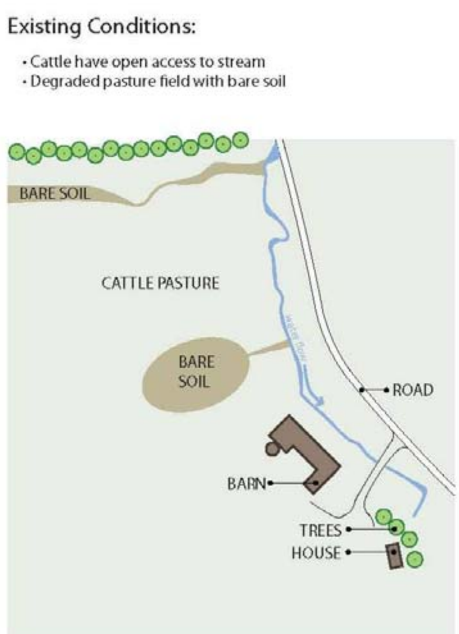
7.4.5.8. Application of Multiple BMPs for Livestock Farm

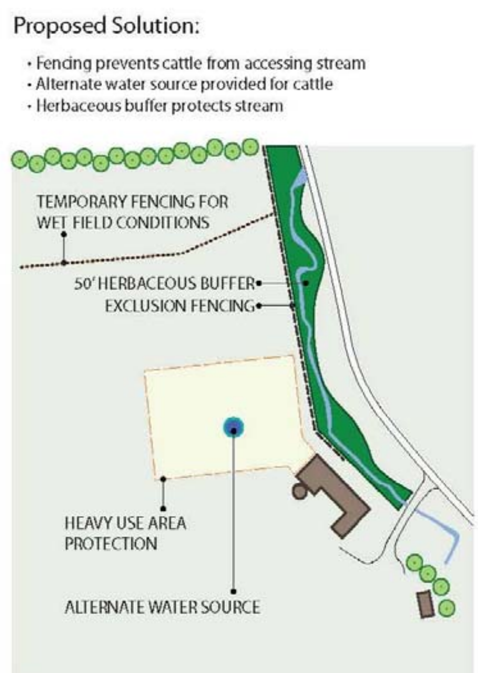
Project Name: Livestock Operation

Location: Watershed wide

BMP Type and Description:

Livestock access control is a temporary or permanent exclusion of animals from streams and their riparian areas. A riparian buffer is an area of grasses, grass-like plants, forbs, trees and/or shrubs located adjacent to and up-gradient from streams that protect streams from runoff and contaminants. Prescribed grazing is a plan that manages grazing and browsing of animals to ensure adequate ground cover and proper livestock nutrition.





Issues and Concerns:

Livestock with direct access to streams, runoff from overgrazed pasture, streambank erosion and poor pasture condition are conducive to manure being directly deposited into streams and being washed into streams as runoff. The picture on the left illustrates a livestock operation that generates erosion, degrades the stream bed and pastures conditions, and allows cattle to enter the stream.

Existing Conditions:

Pastures show signs of over grazing and damage indicative of high animal stocking numbers. Livestock directly access streams for water. There are areas where animals congregate in high numbers causing bare earth in pastures and signs of erosion.

Proposed Solutions: Install exclusion fence along the streams in the pasture to eliminate direct access of livestock to streams. The fence would be installed at least 35 feet away from both sides of the streams or more depending on site-specific conditions. Such fencing would also protect riparian areas of the streams. Create alternative watering sources for livestock. To allow rotational grazing, stream crossing structures for livestock may need to be installed along some stream segments. A pasture management plan should be created to ensure that overgrazing is eliminated. A manure management strategy should be implemented. Manure management measures include establishing and maintaining manure storage structures and/or composting facilities. Farms are encouraged to participate in the River-Friendly Farm Program. NRCS New Jersey FOTG has numerous standards for implementing the proposed BMPs on livestock farms.		
Anticipated Benefits: The exclusion fence would completely eliminate direct deposits of manure into streams. Pasture management will reduce manure runoff and erosion. Buffers will further reduce and treat any runoff. The SWAT model was used to simulate pollution loads in the Neshanic River Watershed. There are approximately 890 acres of pastures that produce approximately 1.7 pounds of TP per acre per year or 1,513 pounds of TP per year for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers reduce TP by at least 50 percent. This suggests that conservation buffers can reduce annual TP loading by 0.85 pounds per acre or 756 pounds on pastures in the watershed if conservation buffers are installed along all streams in pastures. This estimate assumes that runoff enters the buffer as sheet flow as opposed to concentrated flow. Some areas of the watershed generate concentrated flow; erosion control in such areas requires implementing other erosion control practices. Runoff entering buffer areas as concentrated flow will have the same phosphorus reduction as expected for areas with sheet flow. The 890 acres of pasture produce approximately 0.08 tons of sediment per acre per year or 71.2 tons per year for the watershed. The Chesapeake Bay Water Quality Model showed that conservation buffers reduce sediment at least 50 percent. If buffers are installed along all streams flowing through pastures, annual sediment load would decline by 0.04 tons per acre or 35.6 tons per year for pastures in the watershed. It is difficult to determine total load reduction when multiple livestock BMPs are used in concert. Preliminary results of the SWAT model indicated water quality improves when BMPs are used together. A livestock farm using multiple BMPs will experience greater reductions in pollutant loads than those achieved by conservation buffers alone as listed above.		
Major Implementation Issues: Use of these BMPs will be challenging form farmers. It will require more labor and learning how to use the practices. Use of conservation buffers will require taking land out of production. In order to maintain water quality, farmers may need to reduce the number of livestock on pasture. These challenges will affect farmers' willingness and ability to implement some or all of the recommended BMPs.		
Possible Funding Sources: EPA 319(h) through NJDEP, Private Sources, NJDA State Cost share, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, National Fish and Wildlife Foundation's Five Star Restoration Challenge Grants, NJDEP Corporate Business Tax, USDA Farm Bill Programs, such as CREP, EQIP, AWEP and other available cost share.		
Partners/Stakeholders: Township officials; NRCS; NJRC&D; HCSCD; RCE; NJIT; NJWSA; NJDEP and SBWA		
Task Description for a "Sample" Farm*		
Task	Task Description	Cost
1	Outreach to Producer	$1,000

2	Technical Assistance			$4,000
3	Project Design			$3,000
4	Applicable permits			$1,000
5	Implementation oversight			$1,500
6	BMP Installation			
	Activities for BMP Installation	Unit Cost	Quantity	
	Access control fencing	$4.78 per ft.	500 feet	$2,390
	Riparian Buffer establishment	$7750 per acre	1 acres	$7,750
	Prescribed grazing	$7980 per 30 acres	1	$5,190
	Alternate Livestock Water Source	$12.68 per animal unit	30 AU	$380
	Heavy use area protection	$14.00 per sf	3000 sf	$42,000
	Filter Strip	$285 per acre	1 acre	$285
	Composting facility	$2.85 per sf	7500 sf	$21,375
	Total BMP Installation Cost			$79,370
	Contingency (20%)			$17,974
Total estimated project cost				$107,844
Annual operation and maintenance cost				$500
* This "sample" farm is not indicative of every farm in the watershed. It is only a guideline used to estimate the cost of implementing multiple BMPs for a livestock farm. Costs for BMP installation were estimated using cost data from the New Jersey Farm Bill Program 2011 Practice Catalog and North Jersey RC&D. The latter costs are based on past implementation projects. If program eligibility requirements are met, tasks 2, 3 and 5 could be done at no cost to landowners by using NRCS technical assistance There are multiple manure management strategies applicable to livestock. Composting livestock manure has been shown to significantly reduce bacterial contamination.				

7.5. **Project Prioritization**

Section 7.4 presents detailed information about individual BMPs at specific sites in the watershed or for representative farms. Information for individual BMP projects is scaled up to estimate watershed reductions in TP and sediment, and the total and annual costs at the watershed scale. The cost effectiveness of these BMPs in reducing TP and sediment is calculated by dividing the annual watershed cost by the reduction in TP and sediment.

Table 7.11 summarizes the water quality effects, the costs and cost-effectiveness of the agricultural BMPs in Neshanic River Watershed assuming each BMP is individually applied to suitable land types in the watershed. The scale-up for cover crops, riparian buffers, prescribed grazing, livestock access control, contour farming and nutrient management are based on the information in Section 7.4.5. Information on the assessment unit, reduction in TP and sediment, assessment costs and land type suitable for BMP implementation are taken from the agricultural project descriptions given in Section 7.4.5. Reductions in TP and sediment for the agricultural BMPs are based on the reduction rates from literature, the SWAT-estimated pollutant loads, and the land suitable for BMP implementation as specified in Table 7.11. Total watershed costs are the product of total assessment costs and the applicable unit divided by the assessment unit. The assessment unit is the acreage of a representative farm used for estimating the BMP implementation cost. The applicable unit is the total acreage of the agricultural lands the BMP can be potentially applied to.

Table 7.11: Water quality effects, costs and cost-effectiveness of agricultural BMPs in the Neshanic River Watershed

		Cover Crop	Presc. Grazing	Access Control	Contour Farming	Nutrient Mgmt.	Conser. Buffers
1	Assessment Unit	62 acres	30 acres	500 feet	62 acres	62 acres	3 acres
2	TP Reduction Rate (%)	15	25	60	20	47	50
3	Sediment Reduction Rate (%)	20	25	75	40	0	50
4	Installation Cost ($)	18,526	9,576	2,868	5,580	5,580	9,132
5	Maintenance Cost ($)			1,000			3,750
6	Other Costs ($)	1,000	3,750	1,900	1,650	1,650	5,200
7	Total Assessment Unit Cost ($)	19,526	13,326	5,768	7,230	7,230	18,082
8	Land Type Suitable for BMP	Row crops	Pasture	Riparian areas of pasture	Row Crops	Crops, hay, pasture	HASs
9	Applicable Unit	4,011 acres	892 acres	24,663 feet	1,846 acres	7,645 acres	988 acres
10	Annual TP Reduction (lbs)	784	380	913	507	3,478	3,700
11	Annual Sediment Reduction (tons)	79	16	52	73	0	250
12	Total Watershed Cost ($)	1,263,180	396,226	284,512	215,267	891,548	5,955,005
13	Lifespan of BMP (years)	3	5	10	3	3	15
14	Annual Watershed Cost ($)	421,060	79,245	28,451	71,756	297,183	397,000
15	Cost-eff. of TP Reduction (lbs/$1,000)	1.861	4.799	32.083	7.066	11.703	9.320
16	Priority Rank for TP Reduction	6	5	1	4	2	3
17	Cost-eff. of Sed. Reduction (T/$1,000)	0.188	0.198	1.842	1.016		0.630
18	Priority Rank for Sed. Reduction	5	4	1	2	6	3

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

The annual watershed cost equals the total watershed cost divided by the years in the effective assessment period plus annual operation and maintenance costs, if any. Cost-effectiveness for TP reduction equals the annual average TP reduction divided by the annual watershed cost. Cost-effectiveness for sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Therefore, cost-effectiveness measures the reduction in TP or sediment per $1,000 spent on the BMP in the watershed. For example, every $1,000 of expenditure would reduce TP by 1.86 pounds if spent on cover crops and 32.08 pounds if spent on livestock access control. BMPs were prioritized based on their cost-effectiveness with BMPs resulting in a larger reduction in pollutant load receiving a higher priority for implementation.

Table 7.11 gives the priority ranks for BMPs in reducing TP and sediment. Livestock access control is ranked first in reducing both TP and sediment. Nutrient management is ranked second in reducing TP and contour farming is ranked second in reducing sediment. Conservation buffer and contour farming are ranked third and fourth, respectively, in reducing TP whereas conservation buffers and prescribed grazing are ranked third and fourth, respectively, in reducing sediment. The cost-effectiveness indicates the order in which BMPs should be selected to reduce pollutant loads when there is a limited budget for watershed restoration. Pollution load reductions are estimated assuming BMPs are applied individually. When multiple BMPs are applied to the same fields, the pollutant reduction from those fields will increase, but the total reduction in pollutant loads at the watershed scale is expected to be smaller because of the overlapping effects.

Table 7.12 presents the resulting water quality effects, costs and cost-effectiveness for stormwater BMPs in Neshanic River Watershed. Estimation of the effects assumes each BMP is individually applied to suitable agricultural lands in the watershed. The watershed has 3,545 potential sites for rain gardens and 27,603 feet of riparian segments suitable for vegetative buffers in the non-agricultural, developed lands. The stormwater infrastructure inventory identified 853 segments of roadside swales and ditches with an average length of 240 feet and 153 detention basins with the average size of 0.68 acres. The scale-up for rain gardens, roadside ditch retrofitting, detention basin retrofitting and vegetative buffers in developed lands is based on the information in Section 7.4 on the site specific projects. Information on the assessment unit, reduction rates for TP and sediment, and assessment costs come from the project descriptions given in Section 7.4. Specifically, the information on individual rain gardens given in Section 7.4.1.1 is used to estimate the water quality impacts and watershed costs for all 3,545 rain gardens in the watershed. Because its size is close to the average size of ditches in the watershed, information for retrofitting roadside Ditch_SD_389 in Section 7.4.2.3 was scaled up to estimate the impacts of retrofitting all ditches. The scale-up for detention basins is adjusted using the information on retrofitting DB_MDB_0035 in Section 7.4.3.1. Information on the vegetative buffer project in Section 7.4.4 was used to scale up to the watershed effects of installing 27,603 feet of buffers in the non-agricultural developed lands. Total annual reductions in TP and sediment are the products of the reductions achieved by individual projects and the applicable units divided by the assessment unit. The total watershed cost is the product of the total assessment cost and the applicable units divided by the assessment unit. The lifespans for all stormwater BMPs are assumed to be 15 years. Annual watershed cost is total watershed cost divided by 15 years, which is the life span of the BMPs.

Table 7.12: Water quality effects, costs and cost-effectiveness of stormwater BMPs in Neshanic River Watershed

		Rain Garden	Roadside Ditch Retrofitting	Detention Basin Retrofitting	Vegetative Buffers on Developed Lands
1	Assessment Unit	1 unit	1 unit	1 unit	1,900 feet
2	TP Reduction Rate (%)	50	30	50	30
3	Sediment Reduction Rate (%)	90	60	90	60
4	Installation Cost ($)	1,650	13,000	17,000	6,200
5	Maintenance Cost ($)	1,500	7,500	7,500	1,500
6	Other Costs ($)	1,000	3,000	5,000	1,500
7	Total Assessment Cost ($)	4,150	23,500	29,500	9,200
8	Applicable Unit	3,545 units	853 units	153 units	27,603 feet
9	Annual TP Reduction (lbs.)	44	196	1102	38
10	Annual Sediment Reduction (tons)	4	33	138	19
11	Total Watershed Costs ($)	14,711,750	20,045,500	4,513,500	133,657
12	Life span of BMP (years)	15	15	15	15
13	Annual Watershed Cost ($)	980,783	1,336,367	300,900	8,910
14	Cost-eff. for TP Reduction (lbs./$1,000)	0.045	0.147	3.661	4.321
15	Priority Rank for TP Reduction	4	3	2	1
16	Cost-eff. for Sediment Reduction (T/$1,000)	0.004	0.025	0.458	2.160
17	Priority Rank for Sediment Reduction	4	3	2	1

Similarly, the cost-effectiveness of TP reduction is the annual average TP reduction divided by the annual watershed cost for each stormwater BMP. Cost-effectiveness of sediment reduction is the annual average sediment reduction divided by the annual watershed cost. Cost-effectiveness measures the average reduction in TP or sediment per $1,000 of expenditure on each stormwater BMP in the watershed. For example, if $1,000 is spent on vegetative buffers on developed lands, TP would decrease by 4.32 pounds and sediment would decline by 2.16 tons. Rain gardens would only reduce TP by 0.045 pounds and sediment by 0.004 tons per $1,000 spent on each practice. BMPs were prioritized based on their cost-effectiveness. The BMPs resulting in a larger reduction in pollutant load are given a higher priority for implementation.

Table 7.12 gives the priority ranks for these stormwater BMPs in reducing TP and sediment, respectively. Priority ranks for reducing TP and sediment are the same for the four stormwater BMPs. Vegetative buffers and the detention basin retrofitting are ranked first and second, respectively, and the roadside ditch retrofitting and rain gardens are ranked third and fourth, respectively, in reducing TP and sediment. There are dramatic differences in the cost-effectiveness of the four stormwater BMPs. Detention basin retrofitting is almost as cost-effective as the vegetative buffers in reducing TP. Rain gardens are almost 100 times more cost effective than vegetative buffers in reducing TP. A comparison of the cost effectiveness of stormwater and agricultural BMPs indicated that all stormwater BMPs except vegetative buffers are much more expensive than the agricultural BMPs in reducing TP and sediment.

All BMPs have other hydrological and water quality benefits. For example, stormwater BMPs, such as rain gardens, result in large reductions in the amount of stormwater runoff and runoff velocity in receiving streams. As discussed in Section 7.1.1, one of the most significant water quality issues in the Neshanic River Watershed is pathogenic contamination. The SWAT model indicates that failing OSDSs contribute 46 percent of the pathogenic load, animal manure applied to row-crop fields contributes 31 percent of the annual pathogenic load to Neshanic streams, and livestock access to streams contributes 19 percent of the annual pathogenic load in the Neshanic River Watershed. Fate and transport of pathogens are not as well understood as fate and transport of TP and sediment. Therefore, the effectiveness of the BMPs in reducing pathogenic loads to the streams cannot be assessed as precisely as reductions in TP and sediment. Cost-effectiveness of BMPs for reducing the pathogenic loads was assessed differently.

Table 7.13: Costs of three major BMPs for reducing pathogenic loads in Neshanic River Watershed

Types of BMPs	Applicable Units	Unit Costs ($/unit)	Life span (years)	Total Cost ($)	Annual Cost ($/year)
OSDS Management					
System Inspection and Maintenance	1,490 units	600	3	894,000	298,000
Retrofitting on Failed Systems	447 units	15,000	15	6,705,000	447,000
Subtotal				7,599,000	745,000
Manure Management					
Regional Anima Waste Storage and composting Structure	5 units	90,000	10	450,000	45,000
Manure Application Incorporation Technology	330 acres	156	1	51,480	51,480
Subtotal				501,480	96,480
Livestock Stream Access Control					
Livestock Access Control	24,663 feet	11.54	10	284,512	28,451
Subtotal				284,512	28,451

Table 7.13 gives the costs of three BMPs for reducing pathogenic loads: OSDS management, manure management and livestock stream access control. OSDS management involves two integral components of the OSDS education and management strategies discussed in Section 7.1.1.1: system inspection and maintenance; and failing system retrofitting. Total cost

of OSDS management is $7.6 million and annual cost is $745,000. Improving OSDS management in the watershed will reduce pathogenic loads to streams by 46 percent at an annual average cost of $16,196 for each 1 percent reduction in pathogenic load. Manure management includes establishing and operating 5 regional animal waste storage and composting structures and implementing manure application incorporation technology for row-crop fields in the watershed, in addition to being compliant with the New Jersey Animal Waste Rules. Total cost for the two BMP projects for manure management is $501,480 and the annual cost is $96,480. Manure management is expected to reduce pathogenic loads to streams from manure application by 31 percent. The cost of reducing pathogenic loads by 1 percent is $3,112 for manure management. As discussed before, the annual cost of livestock stream access control is $28,451; such control will reduce pathogenic loads to streams in the watershed by 19 percent. The cost of reducing pathogen loads to streams by 1 percent is $1,497 for the livestock access control practice. In summary, livestock access control, manure management and OSDS management are the highest, second highest and lowest cost-effective BMPs for reducing the pathogenic loads, respectively.

Table 7.14 summarizes the priority ranks of all BMP projects in terms of their cost-effectiveness in reducing TP, sediment and pathogens in the Neshanic River Watershed. The highest-ranked BMP in terms of cost-effectiveness has the highest priority for implementation.

Table 7.14: Priority ranks for all BMP projects in Neshanic River Watershed

BMP Project		Priority Rank in Reducing		
		TP	Sediment	Pathogens
1	Cover Crops	8	7	
2	Prescribed Grazing	5	6	6
3	Livestock Access Control	1	2	1
4	Contour Farming	4	3	
5	Nutrient Management	2		9
6	Conservation Buffers in Agricultural Lands	3	4	10
7	Livestock Waste Storage and Composting Structure	12		2
8	Manure Application Incorporation Technology	11		4
9	Rain Gardens	10	9	
10	Road Ditches	9	8	11
11	Detention Basin Retrofitting	7	5	7
12	Vegetative Buffers on Developed Lands	6	1	8
13	OSDS Inspection and Maintenance	13		3
14	Failed OSDS Retrofitting	14		5

Note: A shaded area indicates the BMP has an insignificant impact on the reduction of the pollutant.

The top 5 ranked BMPs for reducing TP loads are:

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

The top 5 ranked BMPs for reducing sediment are:

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

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

1. Livestock access control;
2. Livestock waste storage and composting structures;
3. OSDS inspection and maintenance;
4. Manure application incorporation technology; and
5. Failed OSDS retrofitting.

Additional criteria can be used to rank BMP projects. These criteria may include

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

Use of those criteria needs more site-specific information. Although they cannot be used in the plan to rank the BMPs due to the limited site-specific information, they can be used to rank any proposed implementation projects when more site-specific information is collected for implementation.

8. Estimated Budget, Sources of Funding and Technical Assistance

8.1. Estimated Budget

Table 8.1 summarizes the size of the applicable area and costs of BMP projects recommended for achieving water quality goals in the watershed.

Table 8.1: Applicable units and costs of recommended BMP projects in Neshanic River Watershed

BMP Project	Applicable Units	Unit Cost ($/unit)	Life span (years)	Total Cost ($)	Annual Cost ($/year)
	Agricultural BMP Projects				
Cover Crops	4,011 acres	315	3	1,263,180	421,060
Prescribed Grazing	892 acres	444	5	396,226	79,245
Livestock Access Control	24,663 feet	11.54	10	284,512	28,451
Contour Farming	1,846 acres	117	3	215,267	71,756
Nutrient Management	9,645 acres	117	3	891,548	297,183
Conservation Buffers on Agricultural Lands	988 acres	6,027	15	5,955,005	397,000
Regional Animal Waste Storage and Composting Structure	5 units	90,000	10	450,000	45,000
Manure Application Incorporation Technology	330 acres	156	1	51,480	51,480
Subtotal for Agricultural BMP Projects				*$9,507,219*	*$1,391,175*
	Stormwater BMP Projects				
Rain Gardens	3,545 units	4,150	15	14,711,750	980,783
Roadside Ditch Retrofitting	853 units	23,500	15	20,045,500	1,336,367
Detention Basin Retrofitting	153 units	29,500	15	4,513,500	300,900
Vegetative Buffers on Developed Lands	27,603 feet	4.84	15	133,657	8,910
Subtotal for Stormwater BMP Projects				*$39,404,407*	*$2,626,960*
	OSDS BMP Projects				
OSDS Inspection and Maintenance	1,490 units	600	3	894,000	298,000
Failed OSDSs Retrofitting	447 units	15,000	15	6,705,000	447,000
Subtotal for OSDS BMP Projects				*$7,599,000*	*$633,250*
Total				*$56,510,626*	*$4,763,136*

There are eight agricultural BMP projects, four stormwater BMP projects and two OSDS BMP projects. The first column lists the recommended BMPs. The second column gives the applicable units in terms of the size of the application area, or length or units to which the BMP could potentially be applied. The third column lists the unit application costs, including BMP installation, maintenance and other costs estimated by the project team from the best available information about implementing those BMPs in the watershed and surrounding regions. The fourth column is the life span of 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 projects if they are applied to all applicable units in the watershed. It is the product of the applicable unit and the unit cost. The last column is the annual cost, which is the total cost divided by the life span of the BMP.

The total cost of implementing the eight agricultural BMP projects is about \$9.5 million, of which more than half is for conservation buffers on agricultural lands. Total cost of the four stormwater BMP projects is estimated to be \$39.4 million. Retrofitting roadside swales and ditches in the watershed accounts for half of the costs. Total cost of establishing the comprehensive OSDS inspection and maintenance programs and eliminating the failing OSDSs in the watershed is \$7.6 million. Implementing all recommended BMP projects is estimated to cost \$56.5 million and is expected to achieve or exceed the load reduction targets for TP, sediment and pathogens and restore the hydrology of the Neshanic River Watershed.

It is probably not realistic to implement all 14 recommended BMP projects at the same time. Natural resource conditions may restrict the application of BMPs to suitable lands in the watershed. Some farms or landowners may resist implementing any BMPs on their lands. For example, although cover crops are suitable for use on 4,011 acres of row-crop fields in the watershed, it is not realistic to expect 100 percent landowner participation to use cover crops. Nevertheless, it may be possible to achieve the required pollutant load reduction by implementing some of the recommended BMP projects in suitable areas. Any implementation plan should balance the physical restrictions of natural resource conditions, stakeholders' willingness and ability to act, and financial feasibility. Table 8.2 gives implementation targets for the recommended BMP projects in terms of the percentage or physical units to which BMP projects are applied and target reductions in TP and sediment. Targets are based on the cost-effectiveness of BMPs, feasibility of implementation and the need to achieve the required reduction targets. Expected annual load reductions in TP and sediment achieved by reaching the targeted reductions are 6,632 pounds and 324 tons, respectively, which should be sufficient to achieve 49 percent reduction in TP and more than 9 percent reduction in sediment. Estimated total implementation cost of achieving the targeted reductions in TP and sediment is \$14.6 million. Of the total implementation cost, 52 percent is for inspecting and maintaining OSDSs and retrofitting failing OSDSs in the watershed and 20 percent is for installing conservation buffers on 494 acres of agricultural lands.

The estimated reduction in TP is conservative for several reasons. First, almost all of the BMP projects for reducing the pathogenic loads also reduce TP loads. Second, implementation of the newly enacted Fertilizer Control Law and 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 Source Areas (CSAs) should reduce pollutant loads much more than the average reduction rates used in the estimates reported in Table 8.2. Third, although quantification of pathogenic load reduction is difficult, the required 89 percent reduction in pathogens (both fecal coliform and *E. coli*) should be achieved by eliminating failing OSDSs, improving manure application and completely excluding livestock from accessing the streams in the watershed.

Table 8.2: Implementation targets and costs for recommended BMP projects in Neshanic River Watershed

Types of BMP Projects		Area Implementation Target		Reduction Target		Implementation Cost	
		%	Unit	TP (lbs)	Sed. (tons)	$	%
1	Cover Crops	50	2,006 acres	392	40	631,590	4.3
2	Prescribed Grazing	50	446 acres	190	8	198,113	1.4
3	Livestock Access Control	100	24,663 feet	913	52	284,512	2.0
4	Contour Farming	75	1,385 acres	380	55	161,451	1.1
5	Nutrient Management	75	5,734 acres	2,608		668,661	4.6
6	Conservation Buffers on Agricultural Lands	50	494 acres	1,850	125	2,977,503	20.5
7	Livestock Waste Storage and Composting Structure	100	5 units			450,000	3.1
8	Manure Application Incorporation Technology	75	248 acres			38,610	0.3
9	Rain Gardens	1	35 units			147,118	1.0
10	Road Ditches	1	9 units	2		200,455	1.4
11	Detention Basin Retrofitting	25	39 units	277	35	1,135,750	7.8
12	Vegetative Buffers on Developed Lands	50	13,802 feet	19	10	66,828	0.5
13	OSDS Inspection and Maintenance	100	1,490 units			894,000	6.1
14	Failed OSDS Retrofitting	100	447 units			6,705,000	46.1
Total				6,632	324	14,559,591	100.0

8.2. **Existing Sources of Funding and Technical Assistance**

There are various funding programs landowners, homeowners and businesses can use to implement various BMPs to improve water quality in the watershed. Some programs offer technical and cost share assistance up to 100 percent of the project cost.

8.2.1. Natural Resources Conservation Service

8.2.1.1. Wildlife Habitat Incentives Program (WHIP)

WHIP is a voluntary USDA program for landowners who want to improve or develop fish and wildlife habitat on nonfederal lands. The program provides both technical and financial assistance to establish and enhance habitat for priority species and habitat types. Landowners work with NRCS to prepare and implement a wildlife habitat development plan that becomes the basis for a contract. If a contract is funded through a competitive bidding process, the landowner receives payments for completed practices that create or improve wildlife habitat. There is a $50,000 per year limit ($200,000 total over four years) on WHIP contracts, although most average around $15,000. Partnering agencies and organizations may provide additional technical and financial assistance.

The NRCS and their wildlife partners in New Jersey have developed a state plan to direct WHIP financial and technical assistance to several areas. Applications are accepted year-round for individual projects that meet one of the following objectives.

- Early Successional Priority Habitat – Create, restore or manage for early successional habitats, such as grasslands, savannahs and emergent wetlands, which provide habitat for declining wildlife species. Emphasis is on establishing native plant species, including species that provide nectar, pollen and larval food sources for pollinators that benefit agriculture in New Jersey.
- Wetland Priority Habitat **–** Create, restore and manage wetland habitats, including forested wetlands, coastal wetlands and riparian habitats. Stream restoration and enhancement projects are covered under this category. The focus is on land not likely to be funded by the Wetlands Reserve Program.
- Disturbance-dependent Priority Habitat **–** Manage habitats that depend upon a natural or human-induced disturbance in order to create conditions suitable for regenerating or maintaining these unique habitats. Examples of habitats include Atlantic white cedar forests, scrub/shrub habitats and fire dependent plant communities.
- Bog Turtle Priority Species **–** Enhance or maintain habitat for this federally threatened species that occurs infrequently on farms throughout most of New Jersey.

Conservation buffers provide water quality and wildlife benefits. WHIP offers producers many opportunities to implement conservation buffers in the watershed. Applications are accepted year-round, which allows producers to apply when it is most convenient for them. On average, payments for conservation practices are 60 - 90 percent of the total cost. One of the most attractive features of the WHIP is that the contract agreement lasts approximately five years. This allows a reasonable time frame for tenant producers to implement conservation buffers. On the negative side, WHIP does not offer annual payments to producers that take land out of production. Conservation buffers fall under the wetland priority habitat objective. This objective focuses on land not likely to be funded by the Wetlands Reserve Program.

8.2.1.2. Environmental Quality Incentives Program (EQIP)

EQIP is a voluntary conservation program for persons engaged in livestock or agricultural production. It offers financial and technical assistance to implement conservation practices on eligible agricultural land. The NRCS professionals work with producers to develop conservation plans for their operation, design conservation practices, and provide guidance in plan implementation.

EQIP is designed to assist producers in adopting conservation practices that address existing resource concerns on farms and improve environmental quality on and off farms. Resource concerns addressed by EQIP include reducing soil erosion and improving soil quality, increasing water quality and quantity, improving air quality and protecting animal and plant species of concern. The NRCS, with input from the State Technical Committee, determines the eligible practices that address state and local resource concerns. The EQIP program provides cost share and technical assistance for almost all eligible agricultural BMPs.

The NRCS FOTGs provide more detailed information on each type of practice and specifications for eligible BMPs. They are localized meaning they apply to the geographic area for which they are prepared.

Applications can be submitted anytime during the year. The first step in the application process is submitting to the local NRCS office a signed application indicating interest in developing a conservation plan. During the annual evaluation period, NRCS makes contract offers to landowners based on approved conservation plans. Plans are ranked based on how well they meet national, state and local environmental objectives as well as their cost-efficiency.

EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practice and a maximum term of ten years. Contracts provide pre-determined program payments to the producer for the implementation of planned practices according to a schedule developed in conjunction with the producer. The schedule identifies the conservation practice extent (amount), date to be installed, and payment. Practices are subject to NRCS technical standards, which are adapted to local conditions. Any deviation from the contract schedule is considered a contract violation unless approved in advance.

Program payment rates in New Jersey are between 45 and 60 percent of the typical cost of implementing the practice, except when the applicant is a beginning farmer or limited resource producer, in which case the rates are between 75 and 90 percent of the typical cost. Payments are made after conservation practices are fully implemented.

Applicants must be compliant with all conservation provisions of the 2002 farm bill and have current crop and producer records on file with USDA's Farm Service Agency. In addition, applicants must own or control the land, agree to implement specific eligible conservation practices according to the contract schedule, and qualify for farmland assessment.

All the agricultural BMPs proposed here are eligible for EQIP funding. However, there are some implementation barriers. In Hunterdon County, over 40 percent of all farmed acres are operated by tenant farmers; those farmers are ineligible for EQIP funding. On average, half the cost of implementation must be paid by the producer. Many small farms in New Jersey may not be able to pay even half the cost of implementing approved practices. A higher cost-share rate would encourage more farmers to enroll in the program.

8.2.2. Farm Service Agency

8.2.2.1. Conservation Reserve Program (CRP)

The CRP is a voluntary program for agricultural landowners. Successful CRP applicants receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. Annual rental payments are made by the Commodity Credit Corporation. Payments are based on the agricultural rental value of the land and provide cost-share assistance for up to 50 percent of the participant's cost of establishing approved conservation practices. Participants enroll in CRP contracts for 10 to 15 years. The Farm Service Agency (FSA) administers CRP. Technical assistance is provided by NRCS, USDA's Cooperative State Research, Education, and Extension Service, state forestry agencies, local soil and water conservation districts and private technical service providers.

Producers can offer land only during CRP general sign-up periods. Environmentally desirable land devoted to certain conservation practices may be enrolled at any time under CRP's continuous sign-up. The latter focuses on smaller portions of a farm field rather than the entire field as does the traditional CRP. There are certain eligibility requirements for the continuous CRP signup.

To be eligible for CRP enrollment, a producer must have owned or operated the land for at least 12 months prior to close of the CRP sign-up period, unless:

- The new owner acquired the land due to the previous owner's death;
- The ownership change occurred due to foreclosure where the owner exercised a timely right or redemption in accordance with state law; or
- The circumstances of the acquisition present adequate assurance to FSA that the new owner did not require the land for the purpose of placing it in CRP.

For land to be eligible for enrollment in the CRP, one of two conditions must be satisfied:

- Cropland (including field margins) must have been planted or considered for planting to an agricultural commodity in four of the previous six crop years from 1996 to 2001, and cropland must be physically and legally capable of being planted in a normal manner to an agricultural commodity; or
- Certain marginal pastureland that is suitable for use as a riparian buffer or for similar water quality purposes.

In addition to the eligible land requirements, cropland must meet one of the following criteria: have a weighted average erosion index of 8 or higher; be expiring CRP acreage; or be located in a national or state CRP conservation priority area.

FSA provides CRP participants with the following:

- Rental Payments - In return for establishing long-term, resource-conserving covers, FSA provides annual rental payments to participants. FSA bases rental rates on the relative productivity of the soils within each county and the average dry land cash rent or cash-rent equivalent. The maximum CRP rental rate for each offer is calculated in advance of enrollment. Producers may offer land at that rate or offer a lower rental rate to increase the likelihood that their offer will be accepted.
- Maintenance Incentive Payments - CRP annual rental payments may include an additional amount up to $4 per acre per year as an incentive to perform certain maintenance obligations.
- Cost-share Assistance - FSA provides cost-share assistance to participants who establish approved cover on eligible cropland. The cost-share amount cannot be more than 50 percent of the participant's costs in establishing approved practices.
- Other Incentives - FSA may offer additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices.

Offers for CRP contracts are ranked according to the Environmental Benefits Index. FSA collects data for each of the affecting factors that determine the relative environmental benefits for the land offered. Each eligible offer is ranked in comparison to all other offers and selections made from that ranking. FSA uses the following affecting factors to assess the environmental benefits that can be achieved by enrolling land in the CRP: wildlife habitat benefits resulting from covers on contract acreage; water quality benefits from reduced erosion, runoff and leaching; on-farm benefits from reduced erosion; benefits that are likely to endure beyond the contract period; air quality benefits from reduced wind erosion; and cost.

The combination of cost share for practice implementation and annual payment for land taken out of production is attractive to many landowners and farm operators. Unfortunately, the application process and program requirements often discourage interested applicants from submitting bids for enrolling land in the program. Landownership and enrollment for a minimum contract period of 10 years are other obstacles to participation. The application process for farm rental land must involve both the owner and farm operator. The crop history requirement is another hurdle since the farmers may not be able to document the crop history.

8.2.2.2. Conservation Reserve Enhancement Program (CREP)

CREP is a voluntary land retirement program for agricultural producers that protects environmentally sensitive land, decreases erosion, restores wildlife habitat and safeguards ground and surface water.

CREP is a joint, voluntary state-federal conservation program targeted to reducing environmental impacts of agricultural production. The program co-sponsors, NJDA and NJDEP, offer financial incentives to encourage farmers to create stream buffers on existing farmland. Program objectives are to: maintain and improve water quality by reducing agricultural pollutants into streams; enhance farm viability; and contribute to the State's open space goals.

The agricultural community supports the CREP program because it provides a way for New Jersey farmers to be recognized and compensated for their environmental stewardship. The industry also supports the voluntary nature of the program and its ability to enhance farm viability.

Like CRP, farmland enrolled in the CREP is a under rental contract for 10-15 years or placed into both a permanent easement contract and a 10-15 year contract agreement designed to reduce nonpoint source pollution through the preservation of stream buffers and implementation of conservation practices on existing farmland. Through a combination of cost share and incentive payments, the program pays 100 percent of the cost of establishing conservation practices and annual rental and maintenance payments to the landowner. To be eligible for CREP, land must be owned or leased for at least one year prior to enrollment, and must be physically and legally capable of being cropped in a normal manner. Like the CRP, CREP-enrolled land must meet cropping history and other eligibility requirements. Marginal pastureland is eligible for enrollment provided it is suitable for use as a buffer practice. Enrollment is on a continuous basis, permitting farmers and ranchers to join the program at any time.

Eligible CREP practices in New Jersey include Grass Waterways, Establishment of Permanent Vegetative Cover, Filter Strips and Riparian Buffers. Filter strips and forested buffers on farmland are specifically supported by the program. Annual rental rates and cost share for CREP projects are significantly greater than for the traditional and continuous CRP. Like the CRP program, the combination of cost share for practice implementation and annual payment for land taken out of production is attractive to many landowners and farm operators. Unfortunately, the application process and program requirements often discourage interested applicants from applying to the program. Like the CRP, the application process for rental farm land must involve both the owner and farm operator. Providing a crop history is another hurdle. Another obstacle to potential applicants for this program is the requirement that applicants limit activities on their land for a minimum of ten years. Tenant farmers may have a lease agreement that does not permit them to enroll leased land the CRP. Enrolling in a long-term contract can be a deterrent even for owner-operators.

8.2.3. US Fish & Wildlife Service

8.2.3.1. Partners for Fish and Wildlife (PFW)

PFW, a national program implemented by the U.S. Fish & Wildlife Service, is designed to protect, enhance and restore important fish and wildlife habitats on private lands through partnerships. The PFW program has the potential to protect some of America's most important natural resources. It is a voluntary cost-share program that builds on the strength and interest of committed individuals and organizations to accomplish shared conservation goals. Traditionally, the PFW program focused on wetland restoration. It has been expanded to include aquatic, upland and riparian (natural stream and river bank) restoration. Since the program's New Jersey debut in 1991, the Service's New Jersey Field Office and partners have worked to restore 6,499 acres of wetlands, 3,009 acres of uplands and 49 miles of riparian areas.

Areas with the highest restoration potential in New Jersey include: disturbed coastal and bay salt marshes; grazed and urban riparian areas; farmed or drained wetlands; drained vernal (recurring or temporary) ponds; former cranberry bogs; wetlands in the Hackensack Meadowlands; abandoned mining sites; shrub/dune communities; grasslands; and fragmented forests. Private, county, municipal or tribal lands meeting the program's goals and guidelines are eligible to apply to the PFW program.

Proposed projects are evaluated for their restoration potential and ability to meet the program's goals and guidelines. For qualifying projects, the Service provides plans and recommendations, assistance with implementation and funds for restoration work. Landowners must sign an agreement to maintain a restored site for at least 10 years (commitments of greater than 20 years are preferred). Because of federal funding limitations, cost sharing is an integral part of the program. In-kind services (e.g., labor, machinery, materials) and funds from partners are essential to the PFW program.

The application and contract process for the PFW program is far less involved than many other federal programs and, as such, is attractive to producers and landowners. The in-kind services offered by agencies and communities encourage landowners to implement such practices on their lands. As with other programs, an obstacle for many landowners is the minimum 10-year commitment to maintain the restored site.

8.2.3.2. Bring Back the Natives (BBN)

The BBN program includes projects that restore aquatic species to their historic range, improve and enhance aquatic and riparian habitats to support native fish species, restore the health of aquatic systems to benefit native species in the Nation's waters and watersheds and develop conservation partnerships between federal and non-federal entities for restoration of aquatic systems.

The BBN is a cooperative effort between the National Fish and Wildlife Foundation (NFWF), U.S. Fish & Wildlife Service, Bureau of Land Management, USDA Forest Service, Bureau of Reclamation and Trout Unlimited to restore native aquatic species and their habitats through local and regional partnerships. The New Jersey Field Office implements this program throughout the state. Under BBN, the Foundation matches federally funded challenge grants with contributions from private foundations, corporations, individuals, state and local governments and non-profit organizations for conservation projects.

Areas with the highest restoration potential in New Jersey include: waterways with dams or spillways currently impeding migratory fish passage; fish nursery areas; grazed and urban riparian areas; native trout streams; state reservoirs; and previously disturbed waterways that support native fish species. Any project meeting the program's goals and guidelines is eligible. In addition to native fish species, BBN provides opportunities to restore habitat for native mussel, invertebrate and amphibian species.

Proposed projects are evaluated for restoration potential, available matching funds and consistency with program's goals and guidelines. The US Fish & Wildlife Service helps develop and submit grant proposals for qualifying projects, but projects selected by the NFWF must match or exceed federal funding with non-federal contributions. Matching funds can be monetary contributions or in-kind services such as labor, machinery or materials. If the NFWF selects the project, the US Fish & Wildlife Service administers the grant and provides technical assistance. The NFWF accepts BBN project proposals on a continuing basis.

BBN funding to successful applicants is given as grants rather than contracts. The application process may discourage landowners from applying to the program. Although, the BBN program is an excellent resource for community projects that improve water quality and restore native habitat, it provides little incentive for producers. Neither rental rates nor cost share for establishment and long-term maintenance costs are provided to producers.

8.2.4. U.S. Environmental Protection Agency

8.2.4.1. Five Star Restoration Challenge Grants

The Five Star Restoration Program (FSRP) brings together students, conservation corps, other youth organizations, citizen groups, corporations, landowners and government agencies to provide environmental education through projects that restore streambanks and wetlands. The program provides challenge grants, technical support and opportunities for information exchange to enable community-based restoration projects.

The FSRP was established by EPA to facilitate collaboration with its partners in advancing education through community-based wetlands restoration projects in watersheds across the U.S. The National Association of Counties, National Fish and Wildlife Foundation, and Wildlife Habitat Council are partners with EPA in this effort. Funding for selected projects in coastal areas is provided by EPA's Office of Wetlands, Oceans and Watersheds, and National Marine Fisheries Service's Community-based Restoration Program.

The FSRP develops knowledge and skills in young people through restoration projects that involve multiple and diverse partners, including local government agencies, elected officials, community groups, businesses, schools, youth organizations and environmental organizations. The objective of the program is to engage five or more partners in each project and contribute funding, land, technical assistance, workforce support or other in-kind services that match the program's funding assistance. Consideration for project funding is based upon the educational and training opportunities for students and at-risk youth, ecological benefits, and social and economic benefits to the community.

EPA's funding levels are modest, averaging about $10,000 per project. However, when combined with the contributions of partners, it is possible to have projects that make a meaningful contribution to communities. It is expected that, at the completion of Five Star projects, each partnership will have experience and a demonstrated record of accomplishment, and will be well-positioned to take on other projects. Having multiple projects over time and space is expected to generate significant benefits for environmental landscapes and advance understanding of the importance of healthy wetlands and streams in communities.

8.2.5. NJ Department of Environmental Protection

8.2.5.1. U.S. E.P.A 319(h) Nonpoint Source Pollution Control Grants

The purpose of this program is to provide grants to regional comprehensive planning or health organizations and coalitions of municipal and county governments and/or local and county environmental commissions, watershed and water resource associations and nonprofit 501(c)(3) organizations. Potential beneficiaries of this program include, but are not limited to: municipal planning departments or boards; health departments or boards; county planning departments; designated water quality management planning agencies; state and regional entities entirely within New Jersey; state governmental agencies; universities and colleges; federal government; interstate agencies of which New Jersey is a member; and intrastate regional entities. Funds are used to conduct nonpoint source management in the 20 watershed management areas in New Jersey through the Section 319(h) federal Clean Water Act. There is approximately $3 million in federal funds available for the program, which can vary depending upon the annual federal budget.

319(h) funding is available for a wide variety of agricultural and stormwater BMPs identified in the watershed restoration plan. An applicant must submit a project that meets the administrative requirements, objectives and project criteria as outlined in the 319(h) grant guidelines outlined by the NJDEP. 319(h) projects are funded as grants. The application process may discourage some landowners from applying to the program. However, it is an option for community-based large scale projects that control NPS and generate multiple water quality benefits.

8.3. **Alternative Funding Sources**

Existing federal and state funding programs offer opportunities to implement various stormwater and agricultural BMPs to reduce pollutant loads and improve water quality. Unfortunately, such programs do not necessarily provide a reliable source of funding for watershed restoration efforts. Given the current budget crises faced by all level of governments, continued governmental funding is uncertain and the likelihood of less or no funding is high. In general, the demand for funds exceeds the supply of funds for watershed restoration. For that reason, development of alternative funding sources is necessary to ensure the continuation of watershed restoration efforts. To meet the increasing demand for funds in watershed restoration, alternative funding sources are proposed to support the watershed BMPs contained in the proposed plan. These funding sources can be used separately or in combination.

8.3.1. Stormwater Mitigation Fund

Raritan Township currently operates a stormwater mitigation fund that collects funds from new developments on forest land in the township. The funds are used to implement stormwater management projects that mitigate the impacts of increased stormwater runoff. Such programs should be expanded to all new development projects in the watershed that increase impervious land surfaces. The funding amount for each new development will be based on the scale and location of the projects, the ratio of impervious surface to pervious surface in the developments and the use of stormwater management practices in the developments. The expanded stormwater mitigation fund will be used exclusively to implement proposed stormwater BMPs in the watershed.

8.3.2. Stormwater Utility Fund

Just like water and sewer utilities, a stormwater utility fund is a mechanism that allows municipalities to collect a fee from homeowners and businesses that discharge stormwater into the stormwater system. A stormwater utility fund has been authorized and used by many county and municipal governments to finance stormwater management. The Morris County Planning Board (2005) outlined several alternative financial mechanisms that municipalities can use to finance stormwater management. These financial mechanisms include:

- A general fund consisting of property tax revenues, state and federal revenue sharing, municipal state aid, franchise fees, fines/penalties, etc;
- Local improvement assessments imposed on properties that benefit from the improved stormwater management facilities or projects;
- Homeowners associations for improving the stormwater management in residential neighborhoods;
- Fees/Licenses/Permits that cover the cost of permit review, enforcement and the inspection of construction;
- Penalties and fines;
- Bonds for large capital improvement projects/programs;
- Pay-as-you-go sinking fund that is used as an adjunct to revenue bond financing;
- Developer contributions to construct stormwater management facilities within developments that are dedicated to the local government upon completion;
- Developer contributions for off-tract improvements needed to serve their and other developments in complying with stormwater management requirements;
- Developer incentives to use proper stormwater management planning techniques; and

- Stormwater utility fund for operating stormwater management programs, including administration, routine operation and maintenance, renewal/replace, capital improvement and monitoring.

These mechanisms can be used to finance watershed restoration. The Morris County Planning Board (2005) compared the advantages and disadvantages of the mechanisms listed above and concluded that a stormwater utility fund is the most equitable means of generating funds to pay for stormwater management. A stormwater utility fund has proven effective in financing and improving stormwater management in many other states in the U.S. Such a fund has not been authorized in New Jersey. In March 3, 2008, assemblymen John S. Wisniewski and John F. McKeon introduced Assembly Bill No. 2411 to the 213th State Legislature. The purpose of bill was to establish a stormwater utility fund. The bill failed to pass. Additional effort is needed to move the bill through the State Legislature.

Implementation of a stormwater utility fund should not be considered as an additional financial burden on homeowners and businesses, but rather as a financial framework that motivates homeowners and businesses to be better environmental stewards. Credits should be given to homeowners and businesses that invest in stormwater management and control stormwater runoff from their properties. Such credits could offset their payment obligations to the stormwater utility fund. The stormwater utility fund collected from the properties with poor stormwater management practices could be used to finance large capital stormwater improvement projects.

8.3.3. Water Quality Trading

Water quality trading uses the market to efficiently achieve an overall load reduction for water quality and watershed restoration goals. Different stakeholders face different costs for reducing pollutant loads into the streams in the watershed by the same amount. Water quality trading allows the stakeholders facing higher pollutant load reduction costs to meet their regulatory requirement in load reduction by purchasing the equivalent amount of pollution load reduction from other stakeholders who have lower pollutant load reduction costs. A result, the total pollutant load reduction goal for the watershed is achieved at least cost to stakeholders.

Ideally, a water quality trading market operates at large geographic scale, such as the Raritan River Basin. The Neshanic River Watershed may be too small for effective operation of a water quality trading market. However, the economic principle behind water quality trading can be applied to minimize the overall cost of achieving the watershed restoration goal. For example, the unit cost of reducing the phosphorus load from urban land is higher than from agricultural land. One way of apply the economic principle is to collect funds from the stakeholders in urban land and use the funds to pay farmers to implement agricultural BMPs to reduce the equivalent amount of phosphorus load from agricultural land. A regional water quality trading program in the Raritan River Basin would help implement the proposed BMPs in the watershed.

8.3.4. Low-interest or No-interest Loans for Capital Improvement Projects

Implementing some BMPs proposed in the Plan requires a large amount of capital. Examples of such BMPs include the stormwater detention basin retrofitting and OSDSs replacement/retrofitting. Financial arrangements should be available that allow property owners to easily access the financial capital needed to carry out those projects. One way to do it is to provide low-interest or no-interest loans to qualified landowners who are interested in and/or under regulatory obligations to carry out those projects. Such a program would be similar to various incentive programs for renewable energy and energy efficiency under the New Jersey Clean Energy Program run by the Board of Public Utilities. One particular example is the Home Performance with Energy Star program that offers financial incentives on energy efficient improvement packages for private homes such as air sealing, insulation, HVAC (heating, ventilation and air conditioning), DHW (domestic hot water) and other eligible measures. The program offers convenient, zero-interest financing or cash incentives are available to help pay for such home improvements made by participating BPI accredited contractors. There are no application fees or closing costs, and the loans do not require a down payment. As the old energy inefficient homes waste energy and generate larger carbon footprint, the failing OSDSs in private homes causes public health and environmental hazards, and thereby should be addressed in a similar manner. There is currently no such program available to assist homeowners who undertake OSDS retrofitting projects. A funding source needs to be identified and developed to implement such program.

9. Information and Education

Although agricultural and stormwater BMPs discussed above have the potential to improve water quality, there are substantial implementation barriers facing farmers, homeowners and businesses. Those barriers range from lack of knowledge to high implementation costs. The North Jersey RC&D interviewed 16 farmers in the Raritan River Basin during 2009-2010 for the purpose of evaluating potential barriers to the adoption of conservation buffers, one of the agricultural BMPs discussed in Chapter 7. Farmers were presented with a list of potential barriers and were asked to rank each barrier from 1 to 5, one being the least concern and 5 being a major concern. Table 9.1 tallies the average scores for potential barriers to implementation. Overall, maintaining farmland tax assessment was a major concern for producers in the Raritan River Basin. The fear is that any land converted from agricultural production to a buffer will result in loss of farmland tax assessment on the converted area. The next major concern was the cost of implementation. Damage to crops from deer is a major deterrent towards implementing riparian buffers especially forest riparian buffers, as the deer are attracted to the riparian buffer plantings and hence to the farmers crops. Few producers have experience with cost sharing and rental rates. For that reason, they were unable to answer the question on cost sharing and rental rates. Interviewed producers were least concerned about the decrease in land value which may be associated with riparian buffer implementation.

Table 9.1: Potential barriers to BMP implementation

Barriers	Average Score	Rank
Maintaining Farmland Tax Assessment	3.63	1
Cost of Implementation	3.31	2
Damage From Deer	3.25	3
Loss of Productive Land	3.25	4
Maintenance Requirements	3.13	5
Inadequate Incentives	3.00	6
Inconvenience	2.63	7
Cost Sharing Rate Too Low	2.57	8
Rental Rate Too Low	2.57	9
Aesthetics	2.56	10
Control of the Land	2.44	11
Not Interested	2.44	12
Doesn't Work in this Area	2.19	13
Not Familiar With What is Involved	2.19	14
Decrease in Land Value	2.06	15

Similar barriers may exist for agricultural and stormwater BMPs. Practical barriers, such as cost of implementation and inadequate incentive, should be addressed by the governmental programs for implementing those BMPs. There are also perceived barriers associated with the lack of information and understanding or the fear of working with governmental agencies. One way to overcome such perceived barriers is to initiate effective outreach and educational efforts to help relevant stakeholders to overcome those barriers.

There are several educational and outreach programs that would be appropriate to implement in the Neshanic River Watershed. Such programs would educate people about water quality problems in the watershed and actions needed to resolve those problems with the long-term goal of promoting behavioral changes that ultimately result in improvements in water quality. Below is a description of several programs that should immediately be implemented throughout the Neshanic River Watershed.

9.1. **River-Friendly Programs: Golf Courses, Businesses, Residences and Farms**

The NJWSA offers River-Friendly programs to golf courses, residents, businesses, farms and schools. The goals of these programs are to improve water quality by implementing actions in four categories:

- Water Quality Management and NPS Management;
- Water Conservation;
- Native Habitat and Wildlife Enhancement; and
- Education and Outreach.

The certification process provides opportunities for landowners to become local stewards, showcasing positive environmental actions they have already taken and new practices that they can begin implementing as part of the program. The NJWSA provides technical information, support and guidance for implementing environmental practices tailored to particular locations.

For more information, go to www.njriverfriendly.org.

9.2. **Rain Garden Program: Residences, Schools and Landscapers**

The RCE Water Resources Program offers several outreach programs whose goal is to help local groups build capacity to install rain gardens throughout their community to improve water quality. One such program, called *Stormwater Management in Your Backyard*, has the general public as its target audience. The program focuses on educating the public about stormwater management and provides alternatives for improving stormwater management at home. As part of this program, participants are taught how to design and build a rain garden.

Stormwater Management in Your Backyard has been adapted for use with school children, under the program *Stormwater Management in Your School Yard.* This program focuses on educating K-12 students on stormwater management and includes instruction on how to design and build a rain garden. Often this program is accompanied by the construction of a demonstration rain garden designed by the students on the school grounds.

Two rain garden certificate programs are available from the RCE Water Resources Program. One is a certification program for individuals providing intensive instruction on how to design, build and maintain rain gardens. The second program is for landscapers and is very similar to the other program except that it includes much more detail on how landscapers could offer rain garden construction as a service. Once landscapers complete the course, their names are posted on the RCE Water Resources Program web site. People looking for help with rain gardens are referred to these landscapers.

For more information on these programs, go to www.water.rutgers.edu.

9.3. **Sustainable Jersey™**

Sustainable Jersey™ is a certification program for municipalities in New Jersey that want to go green, save money and take steps to sustain their quality of life over the long term. Sustainable Jersey™ identifies actions communities can take to become "certified" as leaders on the path toward sustainability and provides the tools, guidance and incentives to enable communities to make progress toward sustainability. The certification is a prestigious designation for municipal governments in New Jersey. Municipalities that achieve the certification are considered by their peers, state government, experts and civic organizations in New Jersey to be among the leading municipalities.

All four towns within the Neshanic River Watershed are registered with Sustainable Jersey™. Several of the actions that are required under the certification process help improve water quality of the Neshanic River and achieve the goals of the plan. Three Sustainable Jersey actions fall into this category: (1) Community Education and Outreach; (2) Water Conservation Education Program; and (3) Innovative Demonstration Projects - Rain Gardens. As towns strive to achieve their Sustainable Jersey™ certification, they should focus on tailoring the three actions to help improve water quality within the Neshanic River Watershed.

For more information, go to www.sustainablejersey.com.

9.4. **Soil Testing Program**

Understanding soil nutrients will help farmers, residents and businesses better manage their fertilizer applications. An educational program that includes a comprehensive soil testing program should be put in place in the Neshanic River Watershed. The program should provide free soil testing to farmers, residents and businesses. A soil test is less than $20 and typically needs to be done once every three years. The test provides fertilizer recommendations to the property owner based upon the crop they are growing or the type of turf grass they wish to establish and maintain. Blanketing the watershed with soil testing results will help municipalities and watershed groups target areas that are more susceptible to high phosphorus loads in stormwater runoff. A partnership among North Jersey RC&D, HCSCD and RCE should be created to implement this program. This partnership would not only administer the soil test program, educate property owners on how to interpret soil testing results, and provide recommendations on actions that should be taken and technical assistance in implementing those recommendations. Recently, New Jersey Water Savers developed the *Turf Management for a Healthier Lawn* program. This program could be implemented in the Neshanic River Watershed, serving as the educational component for homeowners described above.

For more information on *Turf Management for a Healthier Lawn* program, go to www.njwatersavers.rutgers.edu.

9.5. **Ordinance Review and Development**

The ordinances for the four municipalities in this watershed should be reviewed to identify opportunities for incorporating a wider range of environmental practices. For example, many ordinances require new developments to use specific design standards many of which do not allow for deviations. These ordinances could be expanded to allow green infrastructure to be used in place of traditional infrastructure, which would improve water quality within the Neshanic River Watershed. Additionally, new ordinances could be developed and adopted for the towns that would help achieve the goals of the Plan, such as for stream corridor protection, water conservation, and/or low-phosphorus fertilizer. In the past, various watershed groups or other watershed oriented organizations have provided this service for municipalities. The NJWSA (2008) reviewed ordinances for municipalities in the Lockatong and Wickecheoke Creek watersheds and recommended improvements in conservation planning and ordinances in those municipalities. The review covered Raritan and Delaware townships. The recommendations to both municipalities are presented in Section 7.1.4.3. One of the recommendations specifically calls for information sharing and education: conducting on-going outreach and education programs through the environmental commissions to inform local residents of the value of water resource protection and engage local schools to participate in activities that are protective of water resources (NJWSA, 2008). The NJWSA could provide similar services for other municipalities in the watershed.

9.6. **Roadside Rain Gardens**

The RCE Water Resources Program has been working with municipalities to help them address the water quality impacts of roadside drainage swales or ditches. This program focuses on retrofitting existing ditches with rain gardens or other natural systems that improve water quality and reduce maintenance costs to the municipality. The RCE Water Resources Program designs the systems and work with the local DPWs to implement the design. The ultimate goal is to teach the DPW how to implement a series of standard green retrofit designs that they could implement in suitable ditches throughout the watershed, reducing maintenance costs and improving water quality.

9.7. **Detention Basin Retrofits**

Over the last twenty years, it has been standard practice for developers to build detention basins to manage stormwater runoff. These detention basins originally were designed to control the increases in peak runoff flows that result from new developments, thereby minimizing downstream flooding. Over the years, these stormwater facilities evolved to also address water quality by installing a three-inch diameter orifice in the detention basin outlet structure to increase detention time and allow more pollutants to settle out. The detention basin designs began to incorporate concrete low flow channels for the purpose of preventing small flows from remaining in the basins for extended periods of time and thereby reduce habitat for mosquito breeding.

Most of the detention basins that have been built are vegetated with turf grass. The maintenance for these basins is typically weekly mowing during the growing season and regular sediment removal from the concrete low flow channels. Additionally, many of the basins have outlet structures that can easily be clogged with debris, which has to be removed on a regular basis.

As local operating budgets become more limited, municipalities are looking for ways to reduce maintenance costs for their detention basins. Additionally, as more waterways become identified as impaired (i.e., not meeting water quality standards), municipalities also are examining methods to improve the pollutant removal capabilities of their existing stormwater facilities that discharge to these waterways. With these two goals in mind, municipalities are beginning to retrofit their existing stormwater facilities to be more water quality friendly and to reduce maintenance demands. The most popular method of retrofitting stormwater facilities is to "naturalize" the basin to mimic natural systems found in nature. This typically results in converting the detention basin into one of two natural systems: a stormwater wetland or a bioretention system.

This program works with municipalities and homeowner associations to retrofit basins with native vegetation to enhance their pollutant removal efficiency, promote groundwater recharge and reduce maintenance costs.

9.8. Nonpoint Education for Municipal Officials (NEMO)

This program would provide educational programs for municipal officials, engineers and Department of Public Works employees. The goal of the program is to educate these groups on water quality issues associated with NPS, possible solutions to mitigate NPS and how land use decisions can impact the pollutant loading to streams. The NEMO program includes low impact development training. Although there currently is not an official NEMO program in New Jersey, the RCE Water Resources Program is currently working to develop such a program for New Jersey.

For more information, visit the http://nemo.uconn.edu/.

9.9. Greening of Department of Public Works (DPW)

A greening program is currently being developed by Pat Rector, RCE Environmental and Resource Management Agent, and the NJWSA. The goal of the program is to work with DPWs to green their facilities. Many of the DPW yards have a high potential to be a pollutant source and often can easily be retrofitted with management strategies to minimize water quality impacts. From implementing natural stormwater management systems to installing pervious pavement, these facilities typically have the land to incorporate various BMPs into their yards. Furthermore, the DPW has the ability and expertise to install many of these systems.

9.10. Agriculture Mini-Grant Program

The goal of this on-going program is to increase implementation of agricultural conservation practices in four priority watersheds of the Raritan Basin: Spruce Run; Mulhockaway Creek; Neshanic River; and South Branch/Long Valley. The NJWSA developed this program to provide cost-share funding to agricultural producers in order to increase conservation practice implementation. The program is intended to expand the ability of farmers to implement conservation practices by providing a funding source to either serve as a complement to USDA Farm Bill programs, or be a sole source of funding. There is considerable benefit to continuing to support this program in the Neshanic River Watershed. Although farmers may be willing to install BMPs that could improve water quality of the Neshanic River, many of these farmers have limited financial resources and often cannot afford the cost-share associated with receiving US Farm Bill funding for BMP implementation. This program helps pay for the cost share, thereby allowing many more farmers to implement BMPs.

10. Implementation Plan and Milestones

The implementation plan refers to how the agricultural and stormwater BMPs discussed in Chapters 7 and 8 will be implemented in the watershed over time. The planning time horizon for implementing the plan is 10 years. The implementation plan will be discussed in several timeframes: 1-2 years; 5 years; and 10 years. Milestones are measurements of the expected decreases in pollutant loads from implementing these BMPs. The implementation plan and milestones are discussed together in different timeframes during the planning time horizon.

10.1. Implementation Plan and Milestones in First Two Years

During the first two years after the Plan is adopted, the four municipalities in the watershed should:

- Educate residents, farmers and businesses on water quality of the Neshanic River and responsible stewardship in land use and management;
- Establish concrete steps for implementing the New Jersey State Rules for improving water quality and/or preventing water quality from continuous deterioration. These rules include the New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program rules (N.J.A.C. 7:14A), the Stormwater Management Rules (N.J.A.C. 7:8), the Flood Hazard Area Control Act rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Criteria and Standards for Animal Waste Management (N.J.A.C. 2:91) and the newly enacted Fertilizer Control Law for commercial and residential lawn care and management.
- Refine their open space and farmland preservation plan that addresses the protection of hydrologically sensitive areas from future developments.
- Develop the municipal ordinance on OSDS inspection, maintenance and operation that requires a 3-year certification program.
- Work with federal, state and county governmental agencies, universities, non-governmental and non-profit agencies and local environmental consulting firms to apply and secure the necessary funding and technical assistance needed to implement the proposed BMP projects in the watershed.

Table 10.1 describes the implementation goals, expected pollutant load reduction in TP and sediment and the implementation costs in the first two years of the plan implementation. The implementation goal is expressed as a percentage of full implementation and in physical units, such as acres and feet. For example, 25 percent of livestock exclusion fence, which is equivalent to 6,166 feet, must be installed to reduce livestock access to streams in the watershed. The inspection of all OSDSs in the watershed must be conducted in the first two years of the plan implementation. The expected load reductions for TP and sediment assume BMP projects are implemented individually. The expected total load reduction from all BMP projects is 1,770 pounds for TP and 75 tons for sediment. In reality, several BMP projects might be implemented in the same field, and therefore the load reduction level could make the load reductions smaller than the sum of the expected load reductions from all BMPs. However, if all the BMP projects are implemented in high priority areas, the load reduction could be even greater than the load reduction given in Table 10.1, which is estimated from average reduction rates. The total implementation cost is estimated at $3.4 million.

Table 10.1: Implementation goals, expected pollutant load reductions and implementation costs of BMP projects for the first two years of plan implementation

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
				TP (lbs.)	Sed. (tons)		
		%	Unit			$	%
1	Cover Crops	10	401 acres	78	8	126,318	3.7
2	Prescribed Grazing	10	89 acres	38	2	39,623	1.2
3	Livestock Access Control	25	6,166 feet	228	13	71,128	2.1
4	Contour Farming	25	462 acres	127	18	53,817	1.6
5	Nutrient Management	25	1,911 acres	869	0	222,887	6.6
6	Conservation Buffers in Agricultural Lands	10	99 acres	370	25	595,501	17.6
7	Livestock Waste Storage and Composting Structure	20	1 units	0	0	90,000	2.7
8	Manure Application Incorporation Technology	25	83 acres	0	0	12,870	0.4
9	Rain Gardens	0.1	4 units	0	0	14,712	0.4
10	Road Ditches	0.1	1 units	0	0	20,046	0.6
11	Detention Basin Retrofitting	5	8 units	55	7	227,150	6.7
12	Vegetative Buffers in Developed Lands	10	2,760 feet	4	2	13,366	0.4
13	OSDS Inspection	100	1,490 units	0	0	223,500	6.6
14	Failed OSDS Retrofitting	25	112 units	0	0	1,676,250	49.5
Total				1,770	75	3,387,166	100.0

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

- Prevent the continuous deterioration in water quality and watershed hydrology;
- Reduce annual TP load by 1,770 pounds, which is close to 30 percent of the required annual load reduction in TP;
- Reduce annual sediment load by 75 tons, which is equivalent to 50 percent of the required annual load reduction in sediment; and
- Reduce annual pathogenic loads by 5 percent of the goal.

10.2. **Implementation Plan and Milestones in First Five Years**

Table 10.2 shows the cumulative implementation goals, expected pollutant load reduction in TP and sediment and implementation costs during the first five years of plan implementation. In addition to expanding the BMP projects started in the first two years of implementation, the first five years involves substantial work to reduce pathogenic loads to the streams, including retrofitting all failed OSDSs in HSAs found through OSDS inspection, completing regular OSDS maintenance, establishing and operating the small regional animal waste storage and composting structure facilities and improving manure application efficiency. A total cumulative cost of plan implementation for the first five years is $8 million.

Table 10.2: Implementation goals, expected pollutant load reductions and implementation costs of BMP projects in first five years of plan implementation

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
		%	Unit	TP (lbs.)	Sed. (tons)	$	%
1	Cover Crops	25	1,003 acres	196	20	315,795	3.9
2	Prescribed Grazing	25	223 acres	95	4	99,057	1.2
3	Livestock Access Control	50	12,332 feet	456	26	142,256	1.8
4	Contour Farming	50	923 acres	253	36	107,634	1.3
5	Nutrient Management	50	3,823 acres	1,739	0	445,774	5.6
6	Conservation Buffers in Agricultural Lands	25	247 acres	925	63	1,488,751	18.5
7	Livestock Waste Storage and Composting Structure	60	3 units	0	0	270,000	3.4
8	Manure Application Incorporation Technology	50	165 acres	0	0	25,740	0.3
9	Rain Gardens	0.5	18 units	0	0	73,559	0.9
10	Road Ditches	0.5	4 units	1	0	100,228	1.2
11	Detention Basin Retrofitting	15	23 units	166	21	681,450	8.5
12	Vegetative Buffers in Developed Lands	25	6,901 feet	10	5	33,414	0.4
13	OSDS Inspection and Maintenance	100	1,490 units	0	0	894,000	11.1
14	Failed OSDS Retrofitting	50	224 units	0	0	3,352,500	41.7
Total				3,842	175	8,030,157	100.0

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

- Improve the water quality and watershed hydrology;
- Reduce annual TP load by 3,800 pounds, which is equivalent to 60 percent of the required annual load reduction for TP;
- Reduce sediment load by 175 tons, which exceeds the required annual load reduction in sediment; and
- Reduce annual load of pathogens by 60 percent of the goal.

10.3. **Implementation Plan and Milestones in First Ten Years**

Table 10.3 gives the cumulative implementation goals, estimated costs and expected pollutant load reduction for TP and sediment during the first ten years of plan implementation. In the second five years, the BMP projects implemented during the first five years are expanded to cover more areas of the watershed. Total cost of accomplishing the implementation goal for the first ten years is $14.6 million.

Table 10.3: Implementation goals, expected pollutant load reductions and implementation costs of BMP projects in 10 years

Types of BMP Projects		Implementation Goal		Reduction Goal		Implementation Costs	
		%	Unit	TP (lbs.)	Sed. (tons)	$	%
1	Cover Crops	50	2,006 acres	392	40	631,590	4.3
2	Prescribed Grazing	50	446 acres	190	8	198,113	1.4
3	Livestock Access Control	100	24,663 feet	913	52	284,512	2.0
4	Contour Farming	75	1,385 acres	380	55	161,451	1.1
5	Nutrient Management	75	5,734 acres	2,608		668,661	4.6
6	Conservation Buffers in Agricultural Lands	50	494 acres	1,850	125	2,977,503	20.5
7	Livestock Waste Storage and Composting Structure	100	5 units			450,000	3.1
8	Manure Application Incorporation Technology	75	248 acres			38,610	0.3
9	Rain Gardens	1	35 units			147,118	1.0
10	Road Ditches	1	9 units	2		200,455	1.4
11	Detention Basin Retrofitting	25	39 units	277	35	1,135,750	7.8
12	Vegetative Buffers in Developed Lands	50	13,802 feet	19	10	66,828	0.5
13	OSDS Inspection and Maintenance	100	1,490 units			894,000	6.1
14	Failed OSDS Retrofitting	100	447 units			6,705,000	46.1
Total				6,632	324	14,559,591	100.0

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

- Continuously improve water quality and restore watershed hydrology;
- Reduce annual TP load by 6,000 pounds, which exceeds the required annual load reduction in TP and attains the water quality standard for TP;
- Reduce annual sediment load by 324 tons, which exceeds the required annual load reduction in sediment and attains the water quality standard for TSS;
- Achieve 89 percent of the required annual load reduction for pathogens and attain the water quality standard for pathogens.

11. Monitoring and Evaluation

As discussed in Section 5.3.2, NJDEP assessed the impairment of the Neshanic River and its tributaries based on surface water quality monitoring at the USGS Reaville Gage Station near the stream-road crossing between the Reaville Road and the main Neshanic River denoted as N1 as well as AMNET monitoring at biological monitoring stations AN0330, AN0331, AN0332 and AN0333 as represented by FN1, SN1, TN3 and N1, respectively (see Figure 5.6). In order to understand the causes and sources of water pollution in the watershed, this project expanded the surface water quality monitoring to include seven monitoring stations in the watershed (see in Figure 5.6). Additional water quality monitoring was done at stations FN1, SN1, TN3, TN3a, UNT1 and UNT2. The project conducted another round of biological monitoring at all four biological monitoring stations. As discussed in Section 5.6.2, the project documented the stream conditions at seven monitoring stations using the Rosgen Stream Classification System and the channel conditions in 15 locations across the watershed following the Schumm's five-stage channel evolution model. In addition, the project organized and trained volunteers to assess the physical and biological conditions of instream and riparian areas of the 40 stream reaches located at the road-stream crossings using SVAP. The resulting monitoring data were used in setting the water pollutant reduction targets and establishing a reliable baseline for evaluating water quality changes after implementing the BMP projects in this Plan.

Monitoring is a necessary step in assessing water quality improvements resulting from the installation and implementation of the various BMPs in this Plan. Long-term monitoring of water quality and stream conditions is generally expensive and funding for such monitoring is limited and hard to find. It is not realistic to expect the same intensive monitoring conducted in the project to be continued in the long run.

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

11.1. BMP Documentation Database

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

- Educational materials being developed by municipalities and relevant agencies and organizations to educate stakeholders on NPS control and stormwater management in the watershed;

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

11.2. **Water Quality Monitoring**

It is expected that the NJDEP and USGS will continue their streamflow and water quality monitoring work at the USGS Reaville Gage Station (i.e., monitoring station N1). The NJDEP and USGS should compare their routine monitoring procedures to the dry weather monitoring plan specified in the Neshanic River Watershed Quality Assurance Project Plan and make necessary adjustments in their monitoring plan to improve water quality assessment in the watershed. The water quality parameters that should be monitored include NH3-N, NO3-N, NO2-N, TK), TP, dissolved orthophosphate phosphorus, TSS and *E. coli*. Annual water quality and bacteria sampling results should be sufficient for assessing changes in water quality in streams in the Neshanic River Watershed. Although the drainage area to the Reaville Gage Station only contains the upper portion of the Neshanic River Watershed, monitoring results would indicate how water quality can be improved through active land use management in the watershed.

11.3. **Biological Monitoring**

The NJDEP should continue biological monitoring at biological monitoring stations AN0330, AN0331, AN0332 and AN0333 as represented by monitoring stations FN1, SN1, TN3 and N1 in this project. Biological monitoring at selected biological monitoring stations is usually conducted once every five years. This frequency of monitoring should be sufficient to determine whether improvements in water quality and watershed hydrology eventually translate into improvements in biological conditions in the streams in the Neshanic River Watershed.

11.4. **Stream Visual Assessment**

Stream visual assessment uses visual inspection of the physical and biological characteristics of instream and riparian segments of stream reaches to assess the health of the stream, identify pollutant sources and identify potential management measures to reduce pollutant sources. Local watershed and environmental organizations should continue to use stream visual assessment as an educational tool for encouraging community volunteers to document changes in stream and riparian area conditions.

The NJDEP (August 2007) has developed a protocol for stream visual assessments that must be utilized for any 319 grant, namely the Visual Assessment Project Plan (VAPP). This project did not utilize this protocol because it was not available at the time the 319 grant contract was finalized. Instead, the SVAP developed by NRCS and modified by Rutgers University Cooperative Extension was used in this grant project. Since the VAPP is available, it should be used by the local watershed and environmental organizations in their stream visual assessment activities.

12. **Conclusions and Discussion**

The water quality monitoring data indicates the Neshanic River is severely impaired by sediment, nutrients and pathogens resulting from land use and landscape changes in the Neshanic River Watershed. This Plan analyzes the causes and sources of various kinds of water quality impairments, sets pollutant load reduction targets, discusses management measures for reducing pollutant loads and presents a road map for how management measures can be applied in various parts of the watershed to achieve the desired water pollutant load reduction targets for restoring water quality and watershed hydrology in the watershed.

This Plan also presents several BMPs for reducing the identified water quality impairments in the watershed. Each BMP varies by cost, physical and cost effectiveness, ease of use and applicability. Local communities often experience difficulties in choosing BMPs. The economic concept of cost-effectiveness was used to evaluate the efficacy of BMPs and select BMPs for implementation. Cost-effective analysis of BMPs is an important tool for developing a watershed restoration plan. As demonstrated in the Plan recommended here, the cost and cost-effectiveness of BMPs is highly variable. For example, some BMPs are a hundred times more expensive than others. Such information is valuable to watershed managers in allocating scarce financial resources to watershed restoration.

Many stormwater BMPs can improve water quality. Rain garden and roadside ditch retrofitting are examples. Selection and the cost of a stormwater best management practice will vary based on the volume of water to be drained the location and size of the drainage and the size of the area that the measure can be installed. For example, the total project costs for retrofitting a 250 feet long roadside ditch is estimated at $16,000 (see Section 7.4.2) with annual maintenance cost of $500. In some cases, basin retrofitting and vegetative buffers for developed lands can be more or as cost effective for controlling NPS.

Section 7.4.1 provides some information on estimates for installing rain gardens. These estimates should be observed by the acreage of the property which the rain garden will be draining. Total project costs for installing a rain garden can vary from $200 for a residential rain garden to $14,900 for Shoprite Parking Lot. The costs will vary based on the size of the rain garden, the type of materials chosen for construction and whether the work is completed by the homeowner, volunteers or paid labor. The annual operation and maintenance cost can be either negligible or vary dependant on material chosen at time of construction and if the performer of maintenance is volunteer or paid.

This Plan shows that BMPs for reducing NPS from agricultural lands are generally more cost-effective than stormwater BMPs, such as rain gardens and roadside ditch retrofitting. However, most of the agricultural BMPs have to be adopted by farmers through changes in agricultural practices. There are substantial barriers to implementing BMPs on private and active agricultural lands. Efforts should be undertaken to reduce implementation barriers for BMPs and encourage their adoption by farmers.

12.1. **EPA's Nine Minimum Elements of a Watershed Restoration Plan**

The Neshanic River Watershed Restoration Plan, November 2011 addresses the nine minimum elements as specified in the NJDEP "Request for Proposals for the SFY 2006 319(h) Grants for Nonpoint Source Pollution Control." The details are summarized below.

1. *An identification of the causes of impairment and pollutant sources or groups of similar sources that need to be controlled*

Water quality and quantity issues in the Neshanic River Watershed are the result of substantial land use changes in the watershed. There are dramatic increases in urban land uses and decreases in agricultural lands due to rapid suburbanization during the last two decades. The percentage of urban land in the watershed increased from 16.6 percent in 1986 to 25 percent in 1995, and was 31.2 percent in 2002 and 35.1 percent in 2007. The increases in urban land resulted primarily from the loss in agricultural land in the watershed. Agricultural lands in the watershed decreased from 51.4 percent in 1986 to 43 percent in 1995, and continued to decrease to 36.4 percent in 2002 and 35 percent in 2007. Other land uses were relatively steady with forest around 20-21 percent, wetlands at 10-11 percent, water at 0.2-0.5 percent and barren at 0.3-1.6 percent.

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

Water quality and quantity are affected by not only quantitative changes in land use, but also the nature of the land use changes and where those changes occur on the landscape. Many intensive land uses, such as agriculture and urban development, took place in hydrologically sensitive areas, hydric soils and riparian areas of the streams, which intensifies the water quality and quantity issues in the watershed. Other sources of water quality degradation include: intensive uses of fertilizer and pesticides in agricultural production and lawn management; livestock production, such as cattle and horses; failing on-site wastewater treatment systems, such as OSDSs; animal manure mismanagement; and deposition of excrement of wildlife, such as deer and geese.

The SWAT watershed model was used to assess how various sources of water quality degradation affect water quality in the watershed. The SWAT modeling results were used to characterize the sources and root causes of water quality degradation.

Both fecal coliform and E. coli in water are indicators of pathogen contamination. In general, human and animal wastes are sources of pathogens in the Neshanic streams. Failing

OSDSs, which are the largest source of pathogens in the watershed, contribute 46 percent of the pathogen loads in the Neshanic streams. The second largest source is manure that is applied to the field for row-crop production, which accounts for 31 percent of the annual load of pathogens in the Neshanic streams. Livestock in the watershed is a significant contributor of pathogens to streams, including animals grazed on pasture and/or animals that enter streams. Livestock account for 19 percent of annual pathogen loads in the watershed, which make it the third largest contributor to pathogen loads. Another minor contributor is wildlife, such as geese and deer.

Nutrients include TN and TP. Water quality monitoring efforts by USGS, NJDEP and the project team indicate that TP is a significant source and TN is an insignificant source of water pollution in the watershed. The SWAT assessment shows that 229,119 pounds of TN and 12,282 pounds of TP leave the watershed through streamflow each year. The primary source of nutrients in the Neshanic River Watershed is agricultural land that is used for row-crop production, pasture and hay, accounting for 76 percent of the TN and 60 percent of the TP loads in the watershed. Fertilizers on urban lands are the second largest sources of nutrients, contributing 11 percent of the TN load and 29 percent of the TP load.

Sediment in streamflow is measured by TSS. Results of the SWAT model indicate that, each year, streamflow carries 1,715 tons of sediment out of the watershed. Streams are the primary source of sediments and contribute 1,021 tons of sediment per year, which accounts for 60 percent of the total annual sediment load. The source of sediments from the streams is soil eroded from the streambanks and resurfaced from the deposited sediments in the stream bed due to the high energy streamflow. The remaining 40 percent of sediments, roughly 694 tons, come from various land uses in the watershed, including row-crop agriculture (i.e., corn, soybean, wheat and rye production), which accounts for almost 57 percent of the sediment, urban land (27 percent) and other agricultural lands, such as pasture and hay (15 percent).

2. *An estimate of the load reductions expected from the management measures*

The NJDEP (2010a) designated the Neshanic River and its tributaries as FW2-NT. According to this designation from the New Jersey Surface Water Quality Standards (NJAC 7:9B) amended January 4, 2010 (42 N.J.R. 68a), the following surface water quality standards are applicable to the pollutants of concern in the Neshanic River and its tributaries:

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

The NJDEP approved and adopted a TMDL for fecal coliform for the Neshanic River, which requires a 87 percent reduction in fecal coliform from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands (NJDEP, 2003). A nutrient TMDL for the Raritan Basin was developed and is still under review by NJDEP. However, the adopted fecal coliform TMDL and the nutrient

TMDL are based on the water quality monitoring data at the USGS Reaville Gage Station, and therefore cover only the upper portion of the Neshanic River Watershed. The project team developed its own load reduction targets for the pollutants of concern that enable the streams in the Neshanic River Watershed to meet the water quality standards for their designated uses. This project uses a more robust load duration curve method for setting TMDL targets. A duration curve is a graph representing the percentage of time during which the value of a given parameter (e.g. flow, load) is equaled or exceeded.

The load reduction target for the Neshanic River Watershed is defined as the total pollutant load reductions that are required to satisfy the water quality standards for the non-trout FW2 streams in the watershed as defined by NJDEP. A 10 percent margin of safety (MOS) and less than 10 percent exceedance threshold were adopted to determine the pollutant load reduction targets. The 10 percent MOS indicates the more stringent water quality targets at the 90 percent of the regulatory water quality standards. For example, the TN target is 9 mg/L instead of 10 mg/L when considering the MOS. Given the stochastic nature of water contamination, it is not practical to require the water quality standard to be achieved daily. The less than 10 percent exceedance threshold requires a frequency of violating the water quality standards and their MOS of less than 10 percent.

Three sets of load duration curves were developed for the watershed. Each set contains five load duration curves for TSS, TN, TP, fecal coliform and *E. coli*. The first set of load duration curves is based on observed streamflow and water quality data at the USGS Reaville Gage Station (N1 Station), above which is the upper portion of the watershed. Both TSS and TN satisfy the TMDL water quality goals at the N1 Station. The load reduction targets of 48, 90 and 91 percent for TP, fecal coliform and E. coli, respectively, are required to achieve the specified TMDL goals including MOS and the threshold for the frequency of exceedance at the N1 Station. The second set of load duration curves are based on the streamflow and water quality results simulated by the SWAT watershed model at the N1 station. To satisfy the TMDL requirements, the load reduction targets are 48 percent for TP, 90 percent for fecal coliform and 91 percent for *E. coli*. It is not necessary to reduce TN and TSS at the N1 station. These pollutant load reduction targets are essentially the same as those based on the monitoring data at the same station. Since there is no observed streamflow and water quality data at the watershed outlet, the third set of load duration curves are based on the streamflow and water quality results simulated by the SWAT model. The load reduction targets required to meet the TMDL goals at the watershed outlet are 9 percent for TSS, 49 percent for TP and 89 percent for both fecal coliform and *E. coli*.

3. A description of the NPS management measures that will need to be implemented to achieve the estimated load reductions and an identification (using a map and description) of the critical areas in which those measures will be needed to implement this plan

The Plan recommends 14 management measures to reduce pathogen, nutrients and sediment loads from various sources to the streams and to achieve the estimated load reductions. The 14 management measures include eight types of agricultural BMPs, four types of stormwater BMPs and two types of OSDS BMPs. The eight agricultural BMPs are:

- Cover Crops – are grasses, legumes, forbs or other herbaceous plants established for seasonal cover and other conservation purposes. Cover crops reduce soil erosion, help maintain soil moisture and improve nutrient and organic content of soils. Other potential benefits of cover crops include decreased farm operation costs, reduced tillage, less herbicide use and better overall soil health.

- Prescribed Grazing – is a system that helps agricultural producers to manage grazing and browsing of animals to ensure adequate ground cover and proper livestock nutrition. A prescribed grazing plan may require reducing the number of livestock in a given pasture, more frequent rotation of livestock across pastures, and using temporary fencing to exclude livestock from pastures recovering from past grazing activity. Prescribed grazing helps to maintain healthy and productive pastures. Healthy pastures have lower soil erosion rates, lower phosphorus and fecal matter in runoff, greater absorption of nutrients, and higher water infiltration.
- Livestock Access Control – livestock should be completely excluded from direct access to streams and their immediate riparian areas along pastures. The exclusion primarily focuses on the streams that pass through pasture and does not apply to temporary stream crossings for livestock. Livestock access control eliminates the chance of directly dropping livestock waste to the streams and therefore substantially reduces the pathogen loads into streams. The exclusion also eliminates livestock disturbances to streambanks and maintains streambank stability. A stable streambank results in less soil erosion and, therefore, less TSS load to the streams in the watershed.
- Contour Farming – uses ridges and furrows formed by tillage, planting and other farming operations to change the direction of runoff from directly downslope to around the hill slope. Contour farming reduces sediment from gully erosion, surface water runoff, and the transport of phosphorus and other contaminants to streams.
- Integrated Crop Nutrient Management – requires the amount of fertilizers applied to crops to be based on reasonable crop yield goals and available nutrients in soils as determined by soil testing. Such soil-testing based nutrient management reduces the farmers' fertilizer costs and at the same time eliminates the excess nutrients in soil and therefore reduces the nitrogen and phosphorus runoff.
- Conservation Buffers – are planned vegetative mixtures of trees, shrubs and grasses placed in landscapes to influence ecological processes and enhance ecosystem goods and services. There are many types of conservation buffers, such as contour buffer strips, field borders, grassed waterways, filter strips and riparian forest buffers. Conservation buffers have multiple water quality benefits and reduce both sediments and nutrient loads to streams. As runoff flows through a conservation buffer, dense vegetation in the buffer acts as a filter, blocking sediments and sediment-absorbed nutrients, pesticides and pathogens and preventing them from entering streams. Their efficiency in improving water quality can be significantly improved by strategically placing the conservation buffers in the critical source areas in a watershed.
- Animal Manure Management – in addition to implementing 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, small scale regional manure composting and storage facilities should be established and operated to eliminate improper manure disposal.
- Manure Management – cropland should not be used as a dumping ground for animal manure. Manure application should be rotated among numerous fields to avoid

concentrating manure in a limited area. To protect water resources and promote crop growth and soil health, manure should be tested for nutrient content and applied according to crop needs. Manure incorporation technology should be developed and implemented when applying manure as fertilizer in row-crop and hay production.

Land use changes and associated stormwater infrastructure have significantly altered the hydrology of the Neshanic River Watershed. Watershed restoration should mitigate the negative impacts of land use changes on watershed hydrology. Stormwater BMPs not only help restore watershed hydrology, but also improve water quality in the watershed. The four stormwater BMPs are:

- Rain Gardens – traditional stormwater infrastructure is designed to quickly deliver stormwater from the sources to the streams. Rain gardens are designed to retain the stormwater first and then discharge it to the stormwater systems and/or the stream if necessary. These systems are designed to treat the retained stormwater to achieve substantial water quality benefits through various biological processes embedded in the system. The stormwater retained in those systems could also be infiltrated though the soils to recharge groundwater, thus reducing the amount of stormwater entering streams. Rain gardens include a series of bio-retention facilities that are maintained under different situations such as residential and commercial properties and along the roadsides.
- Roadside Ditch Retrofitting – roadside ditches in the watershed are actively eroding, thus adding sediment to stormwater that flows through them. Roadside ditch retrofitting can transform ditches into bio-retention systems that are very similar to constructed wetlands.
- Detention Basin Retrofitting – detention basins capture a large amount of stormwater runoff from medium and low density urban development where sediment, nutrients and pathogen sources could exist. Depending on the final design of a detention basin, the retrofitted detention basin can function like a bio-retention basin or a constructed wetland that removes sediment, nutrient and pathogen loads to the streams.
- Vegetated Buffers in Developed Lands – developed land uses such as residential, commercial, industrial, barren lands and park lands contribute to the phosphorus and TSS loads entering streams. Sources of pollutants are typically roadway sediment and lawn fertilizer, as well as soil erosion from unstable areas. A vegetated buffer is an area designed to remove suspended solids and other pollutants, as well as associated pollutants, such as hydrocarbons, heavy metals, and nutrients, from stormwater runoff. Pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake and microbial activity. Vegetated buffers are designed to receive stormwater runoff as sheet flow for maximum pollutant removal. Pollutant removal rates for vegetated buffers depend upon the type of vegetative cover in the buffer.

Failing OSDSs are one of the major pathogen sources in the watershed. The Plan calls for a comprehensive education campaign on OSDS operation and maintenance, a three-year inspection and certification program, and technical assistance and financial incentive programs to retrofit the failing OSDSs in the watershed. The two OSDS BMPs are:

- OSDS Inspection and Maintenance – technical assistance shall be offered one time to inspect all the existing OSDSs to help establish the three-year inspection and certification program. The subsequent OSDS inspection and maintenance shall be implemented through the operation of the three-year inspection and certification program.
- OSDS Retrofitting – the effective way to eliminate the pathogen loads from the failing OSDSs in the watershed is to repair and replace them and bring them up to the current state and local regulatory standards. OSDS repair and replacement could be expensive and the financial burden to the homeowners with the failing OSDS is the major obstacle to maintain the functioning OSDS. A financial incentive program shall be provided to motivate residents and businesses to properly maintain and care for their OSDSs. The program could include cost-sharing and low or no interest loan to homeowners to install OSDSs that comply with current state and local regulations, replace or repair failing systems, and inspect and maintain existing systems. These financial incentives could be combined with fines for failing to maintain properly functioning OSDSs in the watershed.

Table 12.1 presents the priority rankings for all the BMPs in term of reducing TP, sediment and pathogen loads to the streams. The priority rankings are based on the cost-effectiveness of these BMPs in reducing TP, sediment and pathogen. Cost-effectiveness measures the average reduction in the loading of pollutant achieved by a BMP per dollar spent on implementing that BMP. It is measured by the annual pollutant load reduction divided by the annual cost of implementing the BMP in the watershed.

Table 12.1: Priority ranks for all BMP projects in the Neshanic River Watershed

Type of BMP Project		Priority Rank in Reducing		
		TP	Sediment	Pathogen
1	Cover Crop	8	7	
2	Prescribed Grazing	5	6	6
3	Livestock Access Control	1	2	1
4	Contour Farming	4	3	
5	Nutrient Management	2		9
6	Conservation Buffers in Agricultural Lands	3	4	10
7	Livestock Waste Storage and Composting Structure	12		2
8	Manure Application Incorporation Technology	11		4
9	Rain Garden	10	9	
10	Road Ditches	9	8	11
11	Detention Basin Retrofitting	7	5	7
12	Vegetative Buffers in Developed Lands	6	1	8
13	OSDS Inspection and Maintenance	13		3
14	Failed OSDS Retrofitting	14		5

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

Table 12.2 presents the implementation targets for all of the recommended BMPs for achieving the desired pollutant load reduction. Targets are described in terms of physical dimensions of the applicable units for each BMP (implementation goal) and the amount or reduction achieved (reduction goal). The expected annual load reductions for the implementation plan are 6,632 pounds of TP and 324 tons of sediment, which is sufficient to achieve a 49 percent reduction in TP and greater than 9 percent of reduction in TSS. It is expected that the required 89 percent reduction in pathogen (both fecal coliform and *E. coli*) can be achieved by eliminating the failing OSDSs, improving manure application and completely excluding livestock access to streams in the watershed.

The estimated reduction in TP is on the conservative side for several reasons. First, almost all BMPs for reducing pathogen loads also reduce TP loads, but the reductions from some BMPs are difficult to quantify and are not included in the calculation. Second, the implementation of the newly enacted Fertilizer Control Law and the municipal low-phosphorus ordinances for lawn care should substantially reduce TP loads from the urban lands that contribute 28 percent of TP loads to the streams in the watershed. Third, targeting the application of BMPs in the critical pollution source areas should reduce pollutant loads much more than the average reduction rates used in this estimation.

Table 12.2: Implementation targets for the recommended BMPs in the Neshanic River Watershed

Types of BMP Projects		Implementation Goal	Reduction Goal		
			Pathogen (%)	TP (lbs)	Sed. (tons)
1	Cover Crop	2,006 acres		392	40
2	Prescribed Grazing	446 acres		190	8
3	Livestock Access Control	24,663 feet	Up to 19	913	52
4	Contour Farming	1,385 acres		380	55
5	Nutrient Management	5,734 acres		2,608	
6	Conservation Buffers in Agricultural Lands	494 acres		1,850	125
7	Livestock Waste Storage and Composting Structure	5 units	Up to 31		
8	Manure Application Incorporation Technology	248 acres			
9	Rain Garden	35 units			
10	Road Ditch Retrofitting	9 units		2	
11	Detention Basin Retrofitting	39 units		277	35
12	Vegetative Buffers on Developed Lands	13,802 feet		19	10
13	OSDS Inspection and Maintenance	1,490 units	Up to 46		
14	Failed OSDS Retrofitting	447 units			
Total			89	6,632	324

4. *An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan*

The total cost for achieving implementation goals is about $14.6 million. That cost can be broken down into three components: (1) outreach and technical assistance costs for reaching out to stakeholders and designing BMP implementation plans, and obtaining the necessary permits to install the BMPs; (2) BMP installation costs for related materials, labor, equipment and other items; and (3) BMP maintenance costs that ensure proper operation of BMPs. Of the $14.6 million of implementation costs, $1.5 million is for outreach and technical assistance, $10.9 is for installation and $2.2 million is for maintenance.

The funding available for BMP implementation depends on the types of BMPs and the nature of the costs. USDA NRCS and Farm Service Agency (FSA) support installation of agricultural BMPs (1-8) through outreach, technical assistance and cost-sharing of installation costs. There are no consistent funding sources for implementing stormwater BMPs and no public funding sources available to support the OSDS inspection and maintenance and retrofitting because OSDSs are generally viewed as private properties.

The funding and technical assistance for the implementation plan are based on the following recommendations. First, all maintenance costs for installed BMPs should be the responsibility of stakeholders. For example, homeowners should pay for the maintenance cost for installed rain gardens. Local homeowners associations should be responsible for maintaining retrofitted detention basins in their neighborhoods. Residents should be responsible for operating their own OSDSs. Second, 50 percent of the outreach and technical assistance and installation costs for agricultural BMPs (1-8) 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). Third, to jump start the comprehensive OSDS certification and maintenance program and completely eliminate water pollution from the failing OSDSs, the implementation plan should consider funding the OSDS inspection and cost-share the retrofitting cost for failing OSDSs in the watershed.

Table 12.3: Potential sources of funding for implementation of BMPs

	Types of BMP Projects	Total Cost	Stake-holders	USDA	Other Sources	
					BMP Inst.	Tec. As.
1	Cover Crop	631,590	0	315,795	299,622	16,173
2	Prescribed Grazing	198,113	0	99,057	71,182	27,875
3	Livestock Access Control	284,512	49,326	117,593	70,733	46,860
4	Contour Farming	161,451	0	80,725	62,303	18,423
5	Nutrient Management	668,661	0	334,330	258,031	76,299
6	Conservation Buffers in Agricultural Lands	2,977,503	617,500	1,180,001	751,868	428,133
7	Livestock Waste Storage and Composting Structure	450,000	250,000	100,000	100,000	
8	Manure Application Incorporation Technology	38,610	0	19,305	19,305	
9	Rain Garden	147,118	53,175		58,493	35,450
10	Road Ditches	200,455	63,975		110,890	25,590
11	Detention Basin Retrofitting	1,135,750	288,750		654,500	192,500
12	Vegetative Buffers in Developed Lands	66,828	10,896		45,036	10,896
13	OSDS Inspection and Maintenance	894,000	670,500		223,500	
14	Failed OSDS Retrofitting	6,705,000	3,352,500		3,352,500	
Total		14,559,591	5,356,622	2,246,807	6,077,962	878,200

Table 12.3 summarizes the potential sources of funding for implementation of BMP projects. Stakeholders, such as farmers and residents, could pay $5.4 million of the total implementation costs. Of this amount, 50 percent is for retrofitting failing OSDSs and OSDS inspection and maintenance. The remaining stakeholders' costs are for the time and labor required for maintenance of installed BMPs. The USDA could contribute $2.25 million for agricultural BMPs. An additional $7 million is needed from other sources, of which $6.1 million is for BMP installation and $0.88 million is for outreach and technical assistance.

Other sources of funding for BMP projects include:

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

In addition to the standard funding that could be provided by the above agencies, there are alternative funding sources that can be developed for watershed restoration. Raritan Township currently operates a stormwater mitigation fund that collects funds from new developments on forest land in the township. The funds are used to implement stormwater management projects that mitigate the impacts of increased stormwater runoff. Such programs should be expanded to all new development projects in the watershed that increase impervious land surfaces.

A stormwater utility fund is a mechanism that allows municipalities to collect a fee from homeowners and businesses that discharge stormwater into the stormwater system. A stormwater utility fund has been authorized and used by many county and municipal governments to finance stormwater management and has proven effective in financing and improving stormwater management in many other states in the country. Implementation of a stormwater utility fund should not be considered as an additional financial burden on homeowners and businesses, but rather as a financial framework that motivates homeowners and businesses to be better environmental stewards. Credits should be given to homeowners and businesses that invest in stormwater management and control stormwater runoff from their properties. Such credits could offset their payment obligations to the stormwater utility fund. The stormwater utility fund collected from the properties with poor stormwater management practices could be used to finance large capital stormwater improvement projects.

Water quality trading uses the market to efficiently achieve an overall load reduction for water quality and watershed restoration goals. Different stakeholders face different costs for reducing same amount of pollutant loads into the streams. Water quality trading allows the stakeholders facing higher pollutant load reduction costs to meet their regulatory requirement in load reduction by purchasing the equivalent amount of pollution load reduction from other stakeholders who have lower pollutant load reduction costs. The Neshanic River Watershed may be too small for effective operation of a water quality trading market. However, the economic principle behind water quality trading can be applied to minimize the overall cost of achieving the watershed restoration goal. One way to apply the economic principle is to collect funds from the stakeholders in urban land and use the funds to pay farmers to implement agricultural BMPs to reduce the equivalent amount of phosphorus load from agricultural land. A regional water quality trading program in the Raritan River Basin would help implement the proposed BMPs in the watershed.

Implementing some BMPs proposed in the Plan requires a large amount of capital. Examples of such BMPs include the stormwater detention basin retrofitting and OSDSs replacement/retrofitting. Financial arrangements should be available that allow property owners to easily access the financial capital needed to carry out those projects. One way to do it is to provide low-interest or no-interest loans to qualified landowners. Such a program would be similar to various incentive programs for renewable energy and energy efficiency under the New Jersey Clean Energy Program. As the old energy inefficient homes waste energy and generate larger carbon footprint, the failing OSDSs in private homes causes public health and environmental hazards, and thereby should be addressed in a similar manner. There is no such program available to assist homeowners who undertake OSDS retrofitting projects. A funding source needs to be identified and developed to implement such program.

5. An information/education component used to enhance public understanding of the project

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

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

The ultimate goal of education is to improve stakeholders' awareness and promote behavior changes that are beneficial in achieving watershed restoration.

6. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious

The implementation schedule considers how the BMPs are implemented in the watershed over space and time. Table 12.4 presents the implementation schedule within 2, 5 and 10 years in terms of the 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 the high priority areas identified in the project.

The assumption of a 10-year planning horizon does not mean it takes 10 years to achieve the required pollutant load reduction targets. Depending on funding availability and the stakeholders' willingness to act, many recommended BMPs can be implemented at a much faster pace. However, attaining the required pollutant load reduction targets does not guarantee the restoration of water quality and biological integrity of the streams in the watershed because it takes time for reductions in pollutant loads to affect water quality.

Table 12.4: BMP implementation schedule in the Neshanic River Watershed

	Types of BMP Projects	In 2 Years		In 5 Years		In 10 Years	
		%	Unit	%	Unit	%	Unit
1	Cover Crop	10	401 acres	25	1,003 acres	50	2,006 acres
2	Prescribed Grazing	10	89 acres	25	223 acres	50	446 acres
3	Livestock Access Control	25	6,166 feet	50	12,332 feet	100	24,663 feet
4	Contour Farming	25	462 acres	50	923 acres	75	1,385 acres
5	Nutrient Management	25	1,911 acres	50	3,823 acres	75	5,734 acres
6	Conservation Buffers in Agricultural Lands	10	99 acres	25	247 acres	50	494 acres
7	Livestock Waste Storage and Composting Structure	20	1 unit	60	3 units	100	5 units
8	Manure Application Incorporation Technology	25	83 acres	50	165 acres	75	248 acres
9	Rain Garden	0.1	4 units	0.5	18 units	1	35 units
10	Road Ditches	0.1	1 unit	0.5	4 units	1	9 units
11	Detention Basin Retrofitting	5	8 units	15	23 units	25	39 units
12	Vegetative Buffers in Developed Lands	10	2,760 feet	25	6,901 feet	50	13,802 feet
13	OSDS Inspection and Maintenance	25	373 units	10 0	1,490 units	100	1,490 units
14	Failed OSDS Retrofitting	25	112 units	50	224 units	100	447 units

7. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented

During the first two years after the Plan is adopted, the four municipalities in the watershed should:

- Educate the residents, farmers, and businesses on the water quality status of the Neshanic River and responsible stewardship in land use and management;
- Where applicable, establish concrete steps for implementing the New Jersey State Rules for improving water quality and/or preventing water quality from continuous deterioration. These rules includes New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program rules (N.J.A.C. 7:14A), the Stormwater Management Rules (N.J.A.C. 7:8), the Flood Hazard Area Control Act rules (N.J.A.C. 7:13), the Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), the Criteria and Standards for Animal Waste Management(N.J.A.C. 2:91), and the newly

enacted Fertilizer Control Law for commercial and residential lawn care and management.

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

The implementation of the BMPs for the first two years are estimated to cost $3.4 million 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 annual TP load by 1,770 pounds, which is close to 30 percent of the required annual load reduction for TP;
- Reduce annual sediment load by 75 tons, which is equivalent to 50 percent of the required annual load reduction for sediment; and
- Reduce annual load of pathogens by 5 percent.

Implementation of the BMP projects during the first five years is estimated to cost $8 million and achieve the following milestones toward the pollutant reduction goals and the attainment of the water quality standards:

- Improve water quality and watershed hydrology;
- Reduce annual TP load by 3,800 pounds, which is equivalent to 60 percent of the required annual load reduction in TP;
- Reduce annual sediment load by 175 tons, which exceeds the required annual load reduction for sediment; and
- Reduce annual load of pathogens by 60 percent.

The completion of the 10-year implementation of the BMP projects is estimated to cost $14.6 million and achieve the following milestones toward the pollutant reduction goals and the attainments of the water quality standards:

- Improve the water quality and restore watershed hydrology;
- Reduce annual TP load by 6,000 pounds, which exceeds the required annual load reduction in TP and attains the water quality standard for TP;
- Reduce annual sediment load by 324 tons, which exceeds the required annual load reduction for sediment and achieves the water quality standard for TSS;
- Achieve an 89 percent annual load reduction for pathogens and attain the water quality standard for pathogens.

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

Two criteria can be used to evaluate whether watershed restoration is successful. The first criterion relates to changes in land use management practices. This criterion evaluates whether: (1) the proposed BMP projects are implemented in the watershed; (2) stakeholders are more aware of the impacts of their land use and management decisions; and (3) stakeholders continue to practice environmentally friendly BMPs after initial BMP funding ends. The second criterion relates to the outcomes observed in streams and their riparian areas. This criterion evaluates whether such things as: (1) water quality and biological conditions in streams improve over time; and (2) stream channels become stabilized.

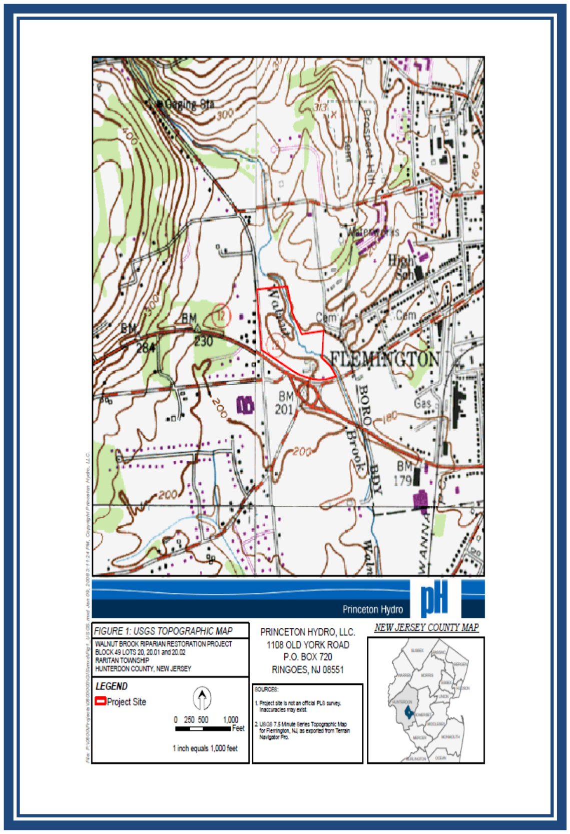
9. *A monitoring component to evaluate the effectiveness of the implementation efforts over time*

Based on these two criteria, a monitoring program can be used to determine the success of watershed restoration efforts. Such a program would involve the following elements:

- Establish a database to document the BMPs being implemented in different locations of the watershed and estimate their water quality impacts using quantitative models and tools, such as Spreadsheet Tool for Estimating Pollutant Load (STEPL) model;
- Continue the comprehensive streamflow, water quality and biological monitoring program at the USGS Reaville 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 the long-term biological monitoring in four biological monitoring stations in the watershed to determine long-term changes in biological conditions in the Neshanic streams; and
- Use volunteers to periodically conduct stream visual assessment using VAPP to assess physical changes in the streams and their riparian zones.

The Plan demonstrates that it is possible to achieve the required pollutant load reductions and restore water quality and watershed hydrology through implementing various BMPs. Moreover, watershed restoration is not simply about adopting the proposed BMPs, but, in addition, a process of encouraging and stimulating stakeholders including municipalities, residents, businesses and farmers to permanently use those environmental friendly land use and management practices. Through the implementation of these BMPs and continuous education and outreach activities, the ultimate goal of this Plan to help the stakeholders develop new types of awareness, perception and behaviors with respect to using the lands and managing their water resources that lead to the permanent improvement in water quality in the Neshanic River Watershed.

13. **Implementation Showcase: Walnut Brook Streambank Stabilization and Riparian Restoration Project**



The Walnut Brook watershed is located on the eastern side of the Route 12 and C.R. 523 circle and north of Mine Street (C.R. 523), in Raritan Township, Hunterdon County, New Jersey and is currently identified as Block 49, Lots 2, 2.01 and 2.02 on the Raritan Township Tax Maps. Lot 2 and 2.02 are owned by the Hunterdon Land Trust Alliance and is currently operated as a farm and future plans to operate as an educational facility. Lot 2.01 is owned by Raritan Township and is operating as a public park, Mine Brook Park.

Walnut Brook is designated as Freshwater 2 Trout Maintenance (FW2-TM), headwater stream of the First Neshanic River. The First, Second and Third Neshanic rivers join together to form the main stem of the Neshanic which flows to the South Branch of the Raritan River.

The two streambank reaches that were proposed for stabilization are located along the mainstem of the Walnut Brook. The site is traversed by three watercourses: (1) the mainstem of the Walnut Brook, which generally flows in a north to south direction across the site; (2) an unnamed tributary of the Walnut Brook, which generally flows in a north to east direction before entering the Walnut Brook mainstem on the site; and (3) a small drainage ditch that drains into the unnamed tributary of the Walnut Brook on the site, which runs in a southwesterly direction.

13.1. **Project Overview**

In early 2007, North Jersey Resource Conservation and Development (RC&D) Council received funding to continue the streambank stabilization work along the Walnut Brook as it flows through Mine Brook Park and the Hunterdon County Land Trust (HLTA) owned Dvoor Farm in Raritan Township, Hunterdon County and to create 2.97 acres of forested wetland. The project was managed by North Jersey RC&D. The streambank stabilization portion of the project was part of this large watershed management grant ‘Developing the Neshanic River Watershed Restoration Plan’ led by New Jersey Institute of Technology and funded by the Office of Policy Implementation and Watershed Restoration (formerly the Division of Watershed Management) of the NJ Department of Environmental Protection (DEP). Additional funding for the streambank stabilization and wetland creation portion of the project was provided by the New Jersey Wetland Mitigation Council. The RC&D received $126,000 in funds from the NJDEP and $566,260 in funds from the New Jersey Wetland Mitigation Council to complete the three phases of the riparian restoration project.

Initial restoration work along the Walnut Brook began in fall 2005 in Mine Brook Park. The project funds received for this work totaled $21,250 in grant fund and cash towards the project which came from The National Fish & Wildlife Foundation (5-Star Restoration Program), NRCS-Wildlife Habitat Incentives Program, and from two Raritan Township committees, additionally over $30,000 of in-kind services and material were donated to this initial project.

Mine Brook Park is a 15.8 acre property which is heavily utilized as it supports a playground, soccer and baseball fields plus walking trails. The HLTA Dvoor Farm is a 42 acre preserved farm that abuts Mine Brook Park. Continuous stream-flow monitoring data shows that peak flows in the Walnut Brook have greatly increased since much of the housing development occurred in the watershed in the 1960s – 70's. These increased flows have negatively impacted the stream resulting in serious stream bank erosion, excess sediment, and related impacts to native flora and fauna.

The objectives of the project, as stated in the initial Scope of Work, are outlined below:

- To restore the riparian functions and values of the Walnut Brook
- Reconnect 1,000 feet of stream to 2 acres of floodplain for the 2-year storm event and restore an additional 11 acres of floodplain functions and values.
- Establish 8 acres of new riparian buffer plantings along with the enhancement of 3 acres of existing buffer through invasive exotic vegetation removal and replanting of native species.
- To transfer the restoration process and techniques used on the site to other interested parties.
- Transfer technology to 1,000 people through outreach efforts such as workshops, newsletters and presentations.

North Jersey RC&D and the project partners can successfully state that the above outlined objectives were achieved. The original timeline for the scope of work as presented to the New Jersey Wetland Mitigation Council was off by a few years as it took that long to work out the details of permitting and in locating and securing the full financial support required to complete the project. Thanks to the additional funding support obtained through the New Jersey Institute of Technology funded *Developing the Neshanic River Watershed Restoration Plan* 319(h) grant.

The riparian buffer planting started in April 2009. The riparian buffer planting occurred in phases throughout the length of the project through August 2011. One hundred and thirty-five volunteers, from within the community up to corporate groups accounted for almost 600 hours of work at the site. They helped to establish the riparian buffer corridor. The volunteers worked to plant, mulch and place protective caging around the material. Throughout the course of two years the volunteers also assisted with watering the plants as necessary by lack of rainfall during the planting period.

In June 2009, streambank stabilization practices were constructed along Meander #1 and Meander #2 along approximately 1,000 feet of bank preventing additional scour and erosion of the streambanks and thereby reducing the stream's pollutant load. The construction of the entire stream project was completed in less than two weeks by two local excavating contractors. Construction costs were minimized by using day rates for the equipment onsite and material costs were reduced by donations from private companies. During the US Army Corps *Working Workshop,* which was one week of active construction, 40 people contributed about 540 hours of labor to the installation of the streambank stabilization practices. With the guidance and additional oversight obtained from Linda Peterson, PE USDA-NRCS, Mary Paist-Goldman PE, Princeton Hydro and Dave Derrick, US Army Corps of Engineers Research Hydraulic Engineer, North Jersey RC&D was able to have volunteers, both near and far, construct rock vanes, LPSTP (longitudinal peaked stone toe protection), ERR (engineered rock riffle), LL (locked logs), SSBW (single stone bendway weirs), smooshed riprap, angle slam, and boulder-log revetment.

Once completed the streambank stabilization utilized 980 tons of rock; 4,400 willow and sycamore cuttings; 2.98 acres of area was treated for the removal of multi-flora rose along with a 5 acre riparian buffer containing 2,061 trees and shrubs and a 1.18 acre of native warm season grasses.

The wetland component construction started in September 2009 and concluded in March 2010. It will further improve stream water quality through retention of stormwater and will increase sediment removal functions associated with the establishment of additional vegetative cover and adjacent 6 acres of native riparian buffer. With the streambank stabilization practices in place and the constructed wetland, this project is achieving the reconnection of the floodplain to the brook, in turn helping to reduce downstream flooding.

13.2. **Installation**

13.2.1. Streambank Stabilization

At the onset of the project, it was determined that a detailed stream survey was necessary. A tooth-pick survey was conducted to establish some of the key characteristics of the stream channel including the Rosgen classification of the stream reaches. Researching the historic photos of the site revealed that the stream channel was straightened sometime prior to 1956, hence the extreme instability in the channel. A detailed topographic survey of the channel and the floodplain was performed. The riffle-pool sequence proved to be a Type C3 meandering stream. The project team had several meetings to discuss the stream stabilization techniques and several additional field meetings were held.

Willows harvested in March, taken out of cold storage days prior to use and allowed to “soak” in nearby pond.

The hydrology for the stream project was established using HydroCAD Software Solutions’ Stormwater Modeling System and hydraulic modeling of the stream was completed using the United States Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS). The hydraulic model established in-stream velocities and shear stresses and provided the basis for the rock sizes specified in the stream stabilization measures proposed.

Root growth after being soaked for few days

Meander #1: May 2009

Due to fisheries concerns, construction could not commence until after June 15th. This meant that dormant plant materials needed to be harvested and kept dormant until we could install the bio-engineering practices. Willow cuttings were harvested in March and kept cool (33-35 degrees) and moist in large, walk-in coolers. In mid-June the plants were taken out of the coolers and allowed to soak for 2-4 days in a nearby pond prior to installation.

Equipment used in June 2009

Meander #1: Triangulating Vane construction June 2009

Meander #1: Looking Up Stream at completed Grade Control (Engineered Rock Riffle) July 2009

Construction for the access/haul road was delayed by rain storms that had been hitting the area throughout the entire month of June.

Meander #1's proposed design as constructed in June 2009 included both resistive and re-directive measures to address several problems, including head-cuts and severe bank erosion. The head-cut movement and channel migration from the time of survey to the time of construction was startling. To address the changes, a large grade control structure in the form of an engineered rock riffle was added during construction. Treatments of Meander #1 included several rock vanes with large keyways and scour pools and longitudinal peaked stone toe protection (LPSTP). The downstream outside bend was stabilized with additional LPSTP and smooshed riprap beneath existing exposed tree roots.

After Construction: Looking Down Stream July 2009

Meander #1: one of the Vanes completed with willows placed in keyway

Meander #2 although shorter than Meander #1 presented challenges as well. Most severe in this reach was the headcutting in the stream channel and severe bank erosion at the inside bend at the upstream limits and at the outside bend on the downstream limits. The proposed design included the use of single stone bendway weirs (SSBW) and slit trenches to be planted with willow cuttings. The weirs were placed with LPSTP between them and a grade control structure immediately downstream of the weirs. The downstream limit had a boulder-log revetment locked log structure.

Meander #2: Looking Up Stream
October 2008

Unique to Meander #2 is the t-shaped single-stone bendway weirs. Again, adaptive management during the June 2009 construction required innovative use of some of the irregular boulder sizes and shapes available at the time of construction.

All design elements were selected to maximize the use of vegetative techniques wherever possible; however, the velocities and shear stresses anticipated in the channel indicated that some armoring would be required.

Looking Up Stream: May 2010 (after)

Construction of the stream project was completed in large part with the aid of volunteers who were led by Linda Peterson PE, USDA-Natural Resources Conservation Service, David Derrick, US Army Corps of Engineers and Mary Paist-Goldman PE, Princeton Hydro LLC. The construction of the entire stream project was completed in less than two weeks by two local excavating contractors. Construction costs were minimized by using day rates for the equipment onsite and material costs were reduced by donations from private companies.

Equipment used to complete the streambank stabilization included: Cat 924 Loader, Case 9020 Excavator, Cat D4 Bulldozer, 621 Loader, Skid Steer, CAT 416 Backhoe, York Rake and probably one of the most important machines was an Excavator with a thumb to properly place the rock for the grade control structures.

June 2009: Dave Derrick installing willow cuttings with use of yellow machine above LPSTP

In spring 2010 the project team had to conduct adaptive management along Meander #1. In mid-June, an additional grade control structure in the form of an engineered rock riffle was installed above Vane #1. This additional structure was submitted to amend the exiting permit and it was approved by NJDEP Land Use for installation. In April and May, the project team worked with the stream contractor to adjust some of the rocks and boulders that had gotten displaced during the past major storm events. It was anticipated that with the installation of the upstream grade control the velocity of the brook would get dissipated prior to hitting Meander #1's vane structures. At that time slit trenches were constructed to install additional willow material that would aid to capture the woody material that occurs due to the out of bank flows. The willows utilized were harvested in March 2010. In a similar fashion as had been completed in 2009, the willows were harvested while dormant. They were kept moist and in a walk-in cooler at 33-35 degrees. Once needed, they were removed from the walk-in cooler and placed in a near-by pond to soak for a few days prior to use. Unfortunately the 2010 spring and summer did not receive a lot of rainfall and the temperatures were considerably hotter than in 2009. A majority of the willows installed in the slit trenches did not survive.

13.2.2. Riparian Buffer Restoration

This portion of the project focused on the establishment and enhancement of the riparian corridor along a specific length of Walnut Brook and the surrounding land. The project goal was to restore natural stream function and improve overall water quality. This involved planting trees, shrubs and native grasses in areas immediately adjacent to the brook to strengthen its banks, increase shading on the brook, increase wildlife habitat, and help to reduce the volume of runoff over the landscape. Volunteers played a huge role in working to plant the trees and shrubs in the project area.

Approximately eight (8) acres of floodplain were restored by the increased flooding frequency, native planting and invasive exotic plant removal. The entire 8 acres of floodplain may not meet the jurisdictional definition of wetlands (due to soils and hydrology criteria) but will provide many of the ecological functions discussed previously. Eight acres of riparian buffer were established on farm fields on each side of Walnut Brook to protect the stream from any agricultural runoff or other nonpoint source pollutants such as lawn fertilizers and pesticides, and road runoff. Buffers were planted to native floodplain trees, shrubs, grasses and forbs. A total of 13 acres of riparian restoration represents approximately 30% of the Hunterdon Land Trust Alliance property at the Dvoor Farm. A small portion of the riparian buffer restoration took place at the upstream end of the HLTA property in Mine Brook Park owned by Raritan Township (lot 2.01).

Meadow/field off Shield's Ave
October 2008 (pre)

Over the course of three years, North Jersey RC&D lead the riparian buffer restoration process along the Walnut Brook. The RC&D had the contacts, experience and knowledge to secure volunteers, material and professional services which translated into planting 2,061 native trees and shrubs in 2009, 2010 and 2011. To date 135 people have volunteered to assist with planting or caring for the riparian buffer plantings. The volunteers were invaluable in helping to plant trees and shrubs along both sides of the Walnut Brook. In working with Hunterdon County Roads, Bridges and Engineering Department, North Jersey RC&D was able to secure mulch that was placed around the newly planted trees and shrubs in an attempt to reduce the amount of competitive vegetation and grasses from growing around the buffer plants. The volunteers put mulch around all the plants and placed protective caging around the newly planted material in an attempt to protect the plant from

Machine removing multi-flora rose
from buffer planting off Shield's Ave

Volunteers from Ethicon Planting
Buffer: April 2009

wildlife damage.

As designed the buffer installation was completed in phases. The importance to phase the installation of the plantings was multi-faceted. The benefits were that plantings could occur prior to the proposed major construction activities, the plantings could be completed when volunteer groups were more readily available, the project spread out the risk of losing trees and shrubs to drought or wildlife damage, and areas could be reassessed to make sure that an adequate buffer was planted once the majority of the project was completed. North Jersey RC&D was able to initiate the buffer phase of the project in March 2009. Volunteers planted 660 trees and shrubs along the Walnut Brook prior to the active construction of the streambank stabilization work or the wetland being started. Throughout the spring, summer and fall of 2009 additional plantings occurred with assistance from volunteers. In 2010 another way of plantings occurred focused on the streambank side of the buffer. Plantings were installed between the completed wetland and the constructed streambank stabilization practices. In 2010, due to drought conditions volunteers were enlisted to help water the trees and shrubs. In early 2011 causalities of the drought-like conditions were noted in the buffer. Some reasons why the causalities occurred were from wildlife damage, even on trees and shrubs that were caged, since there were so many plants a handful of them did not have the proper caging around them to protect from deer browse, buck rub or girdling; poor plant material received from nurseries; and plants that did not get enough watering during the drier/drought conditions. The majority of the plantings survived and are thriving.

Warm Season Grass seed being poured into no-till grass drill: April 2009

Teaching Moment: EvanMadlinger, USDA-NRCS speaking to June 2009 Construction volunteers about establishment of Warm Season Grass planting

A unique quality of the project was the ability for the riparian buffer restoration to occur on both sides of the Walnut Brook. The use of the properties was also diversified prior to the restoration work being completed. The bulk of the riparian buffer plantings as noted above occurred along the brook, referred to as the Shield’s Avenue side of the project. This portion of the property has historically been maintained as an open field/meadow. It was mowed every so often to help control the multi-floral rose growth. The project partners felt the Shield’s Avenue side of the restoration project would be a great place to establish a native warm season grass area. In April 2009, 1.18 acres of the field was prepared to have warm season grasses planted on it. North Jersey RC&D worked with the USDA-NRCS Wildlife Biologist to establish an area along side of the shrub planting area. The farmer that the Hunterdon Land Trust Alliance works with to mow the field on Shield’s Avenue planted the seed with a no-till seeder. Since the warm season grass seed is lighter and fluffier than typical seed a specific no-till seeded was utilized.

13.3. **Water Quality Benefits**

The **Spreadsheet Tool for Estimating Pollutant Load** (STEPL) employs simple algorithms to calculate nutrient and sediment loads from different land uses and the load reductions that would result from the implementation of various best management practices (BMPs). STEPL provides a user-friendly Visual Basic (VB) interface to create a customized spreadsheet-based model in Microsoft (MS) Excel. It computes watershed surface runoff; nutrient loads, including nitrogen, phosphorus, and 5-day biological oxygen demand (BOD5); and sediment delivery based on various land uses and management practices.

Total load by subwatershed(s)

Watershed	N Load (no BMP)	P Load (no BMP)	BOD Load (no BMP)	Sediment Load (no BMP)
	lb/year	lb/year	lb/year	t/year
W1	13740.9	2152.3	52610.2	399.9
Total	13740.9	2152.3	52610.2	399.9

Total load by subwatershed(s)

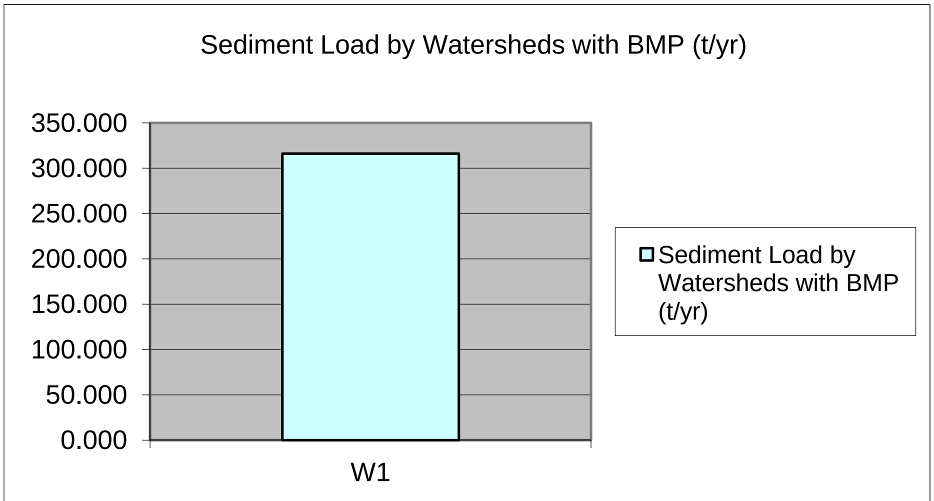
Watershed	N Reduction	P Reduction	BOD Reduction	Sediment Reduction
	lb/year	lb/year	lb/year	t/year
W1	154.2	59.4	308.3	83.8
Total	154.2	59.4	308.3	83.8

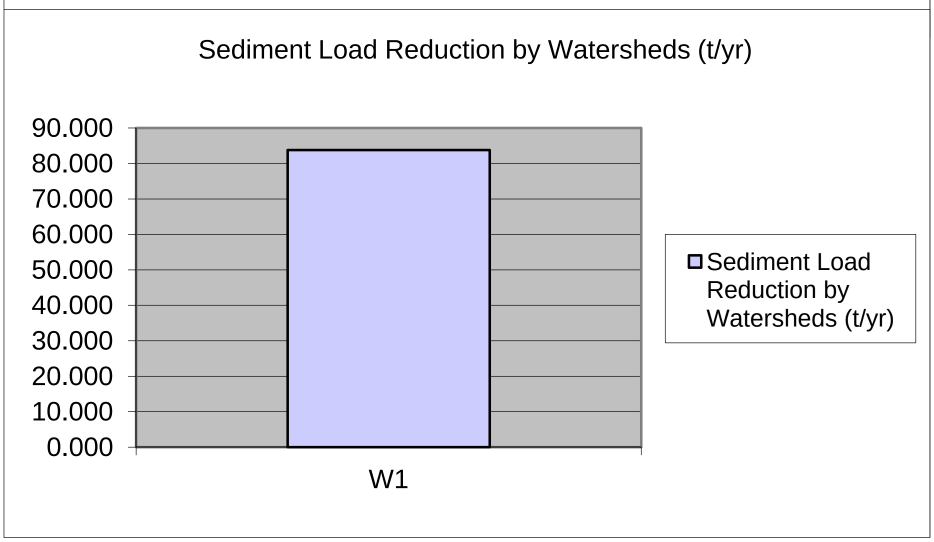
Total load by subwatershed(s)

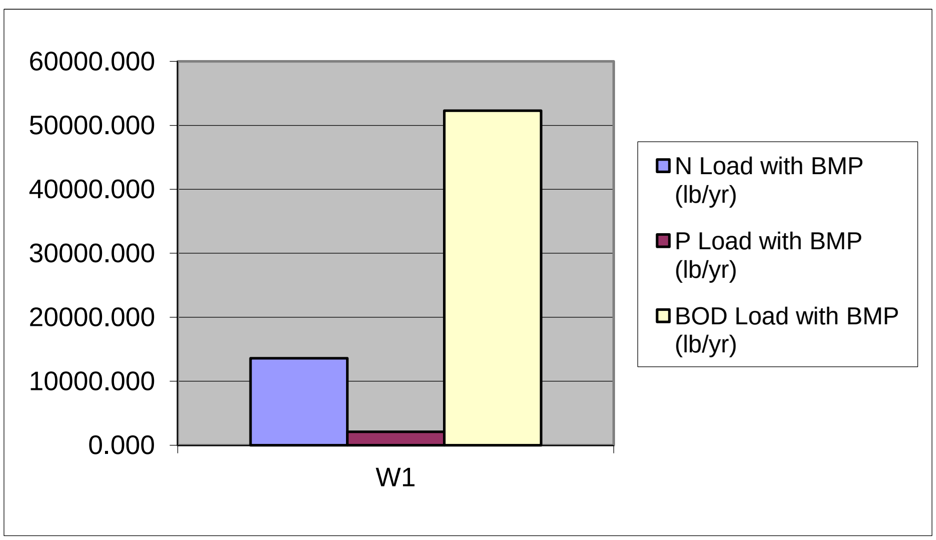
Watershed	N Load (with BMP)	P Load (with BMP)	BOD (with BMP)	Sediment Load (with BMP)	%N Reduction	%P Reduction	%BOD Reduction	%Sediment Reduction
	lb/year	lb/year	lb/year	t/year	%	%	%	%
W1	13586.7	2092.9	52301.9	316.1	1.1	2.8	0.6	21.0
Total	13586.7	2092.9	52301.9	316.1	1.1	2.8	0.6	21.0

Total load by land uses (with BMP)

Sources	N Load (lb/yr)	P Load (lb/yr)	BOD Load (lb/yr)	Sediment Load (t/yr)
Urban	13578.63	2089.82	52285.62	311.72
Streambank	8.11	3.12	16.23	4.41
Total	13586.74	2092.94	52301.85	316.13


Sediment Load by Watersheds with BMP (t/yr)
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0.000
W1
Sediment Load by Watersheds with BMP (t/yr)


Sediment Load Reduction by Watersheds (t/yr)
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
W1
Sediment Load Reduction by Watersheds (t/yr)


60000.000
50000.000
40000.000
30000.000
20000.000
10000.000
0.000
W1
N Load with BMP (lb/yr)
P Load with BMP (lb/yr)
BOD Load with BMP (lb/yr)

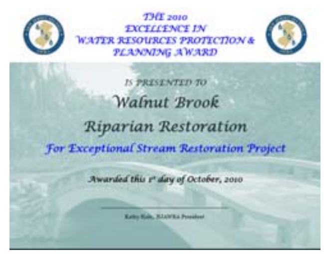
13.4. **Recognitions and Awards**

After many years of planning, permitting and construction, the Walnut Brook Riparian Restoration project has been fortunate enough to receive six major awards and accolades.

13.4.1. 2010 NJ Section American Water Resources Association: Excellence in Water Resources Protection and Planning

The New Jersey Section American Water Resources Association presented the first annual "Excellence in Water Resources Protection and Planning Awards" on October 1st 2010. The award recipients selected exemplified outstanding projects which are designed to protect and enhance water resources management. The three categories of awards recognized included Storm water management projects, Stream restoration projects, Exceptional water resources management and planning initiatives. The Walnut Brook Riparian Restoration project was given the award for the "stream restoration project". The project was selected because it meets the following criteria:

- Planning and design using a creative new or innovative approach to water resources management and planning
- Innovative site design demonstrating a unique approach in the physical characteristics, representing high standards in site planning and engineering
- Demonstrated cooperation between local officials, applicants, and public thus promoting sound planning and engineering. Significant consideration will be given to nominations that demonstrate public / private partnerships.
- Projects that embody the essence and mission of the NJ section American Water Resources Association.



13.4.2. 2010 NJ Governor's Environmental Excellence Award: Healthy Ecosystems


NJDEP Commissioner Bob Martin, Grace Messinger, Linda Peterson (NRCS), Margaret Waldock (Hunterdon Land Trust), Mark Gallagher (Princeton Hydro), Governor (former) James Florio

This awards program was established in 2000 by the New Jersey Department of Environmental Protection to recognize outstanding environmental performance, programs and projects in the state. Since its inception, over 100 businesses, individuals, municipalities and institutions have received recognition.

Healthy Ecosystems Category: this award is presented to a nominee demonstrating a commitment to and experience in programs or techniques that have resulted in the restoration, protection and enhancement of the State's ecological resources: including wetlands, estuaries, coastal areas; and non-game and endanagered species.

13.4.3. 2010 Hunterdon County Planning and Design Award: Hermia Lechner Award

Each year Hunterdon County Planning Board and staff recognize outstanding planning accomplishments in Hunterdon County and the people responsible for them. The Hermia Lechner Award is given to an individual or organization for exceptional planning efforts that promote the conservation of natural resources; may include ordinances, environmental programs, open space plans or other projects that protect the natural environment. The Walnut Brook Riparian Restoration Project secured this award in the winter of 2010.

13.4.4. 2011 Sustainable Raritan Awards: Remediation and Redevelopment Award

The Walnut Brook Riparian Restoration Project received an award at the June 16, 2011 Sustainable Rivers Conference for the outstanding streambank restoration work completed.

13.4.5. 2011 Bowman's Hill Wildflower Preserve Land Ethics Award: Nomination of Excellence

The North Jersey RC&D nominated the Walnut Brook Riparian Restoration Project for this award because they felt it was in line with the goal of the award, which honors and recognizes individuals, organizations, government agencies, community groups and business professionals who have made significant contributions to the promotion of native plants and have exhibited a strong land ethic while promoting sustainable designs that protect the environment. Ultimately the project was given the award; in addition, the review committee felt that the project deserved to be recognized as a 'Nomination of Excellence'. The full nomination was shared on the Bowman's Hill Wildlife Preserve website.

13.4.6. 2011 Soil and Water Conservation Society Firman E Bear Chapter Environmental Excellence Award

Each year, the Firman E. Bear Chapter awards an individual contractor, construction company, designer or organization that displays excellence in an ecological restoration project, unique soil and water conservation stabilization project, or innovative habitat development or enhancement project. The presentation of the award to the Walnut Brook Riparian Restoration Project will occur at the SWCS annual meeting at the end of November 2011.

14. **References**

1. Abu-Zreig, M., R.P. Rudra, M.N. Lalonde, H.R. Whitely, N.K. Kaushik. 2004. Experimental Investigation of Runoff Reduction and Sediment Removal by Vegetated Filter Strips. Hydrological Processes 18(11): 2029-2038.
2. American Society of Agricultural Engineers (ASAE). 2003. Manure Production and Characteristics. American Society of Agricultural Engineers, St. Joseph, MI.
3. Arnold, J. G., J.R. Williams, R. Srinivasan, K.W. King, and R.H. Griggs. 1994. SWAT: Soil and Water Assessment Tool. Temple, Texas: USDA Agricultural Research Service.
4. Arnold, J.G. and P.M. Allen. 1999. Automated Methods for Estimating Baseflow and Ground Water Recharge from Streamflow Records. J Am Water Resour Assoc 35(2): 411-424.
5. Ballesteros, F. Jr. 2008. Projecting Land Use Changes Using Parcel-Level Data: Model Development and Application to Hunterdon County, New Jersey. Unpublished Ph.D. Dissertation, New Jersey Institute of Technology, Newark, New Jersey.
6. Bentrup, G. 2008. *Conservation buffers: design guidelines for buffers, corridors, and greenways*. Gen. Tech. Rep. SRS-109. Asheville, NC: Department of Agriculture, Forest Service, Southern Research Station. 110 p.
7. Brown, E., D. Caraco, and R. Pitt. 2004. Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments. Center for Watershed Protection. Ellicott City, Maryland.
8. Cantlon, J.E. 1953. Vegetation and microclimates of north and south of Cushetunk Mountain, New Jersey. Ecological Monograms 23:241-270.
9. Charles, E.G., J. Schooley, C. Behroozi, and J.L. Hoffman. 1993. A Method for Evaluation of Ground-Water-Recharge Areas in New Jersey. NJ Geological Survey Report GSR-32, NJ Geological Survey, Trenton, New Jersey.
10. Clark, R.B., I.F. Creed, and G.Z. Sass. 2009. Mapping hydrologically sensitive areas on the Boreal Plain: a multitemporal analysis of ERS synthetic aperture radar data. International Journal of Remote Sensing 30(10):2619-2635.
11. Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. December 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. The U.S. Department of the Interior, Washington D.C.
12. Davis, J.S., A.C. Nelson and K.J. Dueker. 1994. The New 'Burbs': the Exurbs and Their Implications for Planning Policy. Journal of American Planning Association 60(1): 45-59.
13. Dillaha T.A., R.B. Reneau, S. Mostaghimi, D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Transaction of the American Society of Agricultural Engineers 32:491-496.
14. Dosskey M.G., M.J. Helmers, D.E. Eisenhauer, T.G. Franti, K.D. Hoagland. 2002. Assessment of concentrated flow through riparian buffers. Journal of Soil and Water Conservation 57(6):336-343.

15. Dosskey M.G., M.J. Helmers, D.E. Eisenhauer. 2006. An approach for using soil surveys to guide the placement of water quality buffers. Journal of Soil and Water Conservation 61(6):344-354.

16. Driver, N.E. and G.D. Tasker. 1988. Techniques for Estimation of Storm-Runoff Loads, Volumes, and Selected Constituent Concentrations in Urban Watersheds in the United States. U.S. Dept. Of The Interior, U.S. Geological Survey: Books and Open-File Reports Section 88-191.

17. Forman, R.T.T. and B. A. Elfstrom. 1975. Forest structure comparison of Hutcheson Memorial Forest and eight old woods on the New Jersey Piedmont. Forest Bull. 3: 44-51.

18. Gitau, M.W., W.J. Gburek, and A.R. Jarrett. 2007. A Tool for Estimating Best Management Practice Effectiveness for Phosphorus Pollution Control. Journal of Soil and Water Conservation 60(1):1-10.

19. Herron, N. F., and P. B. Hairsine. 1998. A Scheme for Evaluating the Effectiveness of Riparian Zones in Reducing Overland Flow to Streams. Australian Journal of Soil Research 36 (4): 683-698.

20. http://www.nj.gov/dep/watershedmgt/DOCS/TMDL/june2006/Raritan%20FC.pdf.

21. Iowa Department of Natural Resources (IDNR). 2006. TMDL for Pathogens in Beeds Lake Franklin County. Watershed Improvement Section, Iowa Department of Natural Resources, Des Moines, Iowa.

22. Karathanasis, A. D., C. L. Potter, and M. S. Coyne. 2003. Vegetation Effects on Fecal Bacteria, BOD, and Suspended Solid Removal in Constructed Wetlands Treating Domestic Wastewater. Ecological Engineering 20(2): 157-69.

23. Krivak, J.A. 1978. Best Management Practices to Control Nonpoint Source Pollution from Agriculture, J. of Soil and Water Conservation 33(4): 161-166.

24. Lowrance R.R., J.K. Sharpe, J.M. Sheridan. 1986. Long-term Sediment Deposition in the Riparian Zone of a Coastal Plain Watershed. Journal of Soil Water Conservation 41:266-271.

25. Lynch, L. and C. Brown. 2000. Landowner Decision-making about Riparian Buffers. Journal of Agriculture and Applied Economics, 32(3):585-596.

26. Morris County Planning Board. 2005. Recommendations for Stormwater Utility Implementation in New Jersey. Prepared by Camp Dresser & McKee Inc. (CDM). Morris County Planning Board, Morristown, New Jersey.

27. National Agricultural Statistics Service (NASS). 2007. The 2007 Census of Agriculture for Hunterdon County, New Jersey. NASS, the U.S. Department of Agriculture.

28. Natural Resources Conservation Service (NRCS). 2008. Highly Erodible Land Definitions. NRCS, U.S. Department of Agriculture. [online] http://www.pr.nrcs.usda.gov/technical/Soil_Survey/HELdefs.htm.

29. Neitsch, S.L., J.G. Arnold, J.R. Kiniry, J.R. Williams, and K.W. King. 2005. Soil and Water Assessment Tool Theoretical Documentation, Version 2005. Temple, Texas, USA: USDA-ARS Grassland, Soil and Water Research Laboratory.

30. Nelson, A.C. 1992. Characterizing Exurbia. Journal of Planning Literature 6(4): 350-368.

31. New Jersey Association of Conservation Districts (NJACD). 2009. On-farm Strategies to Protect Water Quality: an Assessment and Planning Tool for Best Management Practices on New Jersey Farms. Prepared by the NJACD in cooperation with State Soil Conservation Committee, New Jersey Department of Agriculture and Natural Resource Conservation Service, U.S. Department of Agriculture. Accessible by http://www.nj.gov/agriculture/divisions/anr/pdf/BMPManual.pdf .

32. New Jersey Audubon Society. 2005. Forest Health and Ecological Integrity: Stressors and Solutions. Policy White Paper. New Jersey Audubon Society, Bernardsville, New Jersey.

33. New Jersey Department of Agriculture (NJDA). 2009. N.J.A.C. 2:91 – Criteria and Standards for Animal Waste Management. Jersey Register 41(6): 1-75.

34. New Jersey Department of Environmental Protection (NJDEP). 1995. Ambient Biomonitoring Network, Raritan River Drainage Basin, 1993-94 Benthic Macroinvertebrate Data. http://www.nj.gov/dep/wms//bfbm/download/rar94.pdf.

35. New Jersey Department of Environmental Protection (NJDEP). 2000. Ambient Biomonitoring Network, Watershed Management Areas 7, 8, 9, and 10, Raritan Region, 1999 Benthic Macroinvertebrate Data. http://www.nj.gov/dep/wms//bfbm/download/rar99.pdf.

36. New Jersey Department of Environmental Protection (NJDEP). Division of Watershed Management. 2001. Management of Canadian Geese in Suburban Areas: A Guide to the Basics. http://www.state.nj.us/dep/watershedmgt/DOCS/BMP_DOCS/Goosedraft.pdf.

37. New Jersey Department of Environmental Protection (NJDEP). 2002. NJDEP GPS Data Collection Standards for GIS Data Development. Office of Information Resource Management, NJDEP, Trenton, New Jersey.

38. New Jersey Department of Environmental Protection (NJDEP). 2003. Total Maximum Daily Loads for Fecal Coliform to Address 48 Streams in the Raritan Water Region. Division of Watershed Management, NJDEP, Trenton, New Jersey.

39. New Jersey Department of Environmental Protection (NJDEP). 2004. Ambient Biomonitoring Network, Watershed Management Areas, Benthic Macroinvertebrate Data, Generalized Executive Summary. http://www.nj.gov/dep/wmm/bfbm/GenExecSum.html.

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

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

42. New Jersey Department of Environmental Protection (NJDEP). 2007. Visual Assessment Project Plan (VAPP) Guidance. http://www.nj.gov/dep/watershedmgt/DOCS/319%28h%29%20RfP/VAPPaug07.pdf.

43. New Jersey Department of Environmental Protection (NJDEP). 2008. The 2008 New Jersey Integrated Water Quality Monitoring and Assessment Report (Draft). Water Monitoring and Standards, Bureau of Water Quality Standards and Assessment, Division of Watershed Management, NJDEP, Trenton, New Jersey.

44. New Jersey Department of Environmental Protection (NJDEP). 2008a. Ambient Biomonitoring Network, Raritan Water Region, Watershed Management Areas 7, 8, 9, and 10, Round 3 Benthic Macroinvertebrate Data, Volume 1 and 2. http://www.nj.gov/dep/wms//bfbm/download/rarRnd3.pdf.

45. New Jersey Department of Environmental Protection (NJDEP). 2008b. Wildlife Populations: White-tailed Deer. Division of Fish and Wildlife, New Jersey Department of Environmental Protection, Trenton, New Jersey.

46. New Jersey Department of Environmental Protection (NJDEP). 2009. 2008 Integrated Water Quality Monitoring and Assessment Methods. http://www.state.nj.us/dep/wms/bwqsa/2008_Revised_Final_Methods_Document_&_RTC.pdf.

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

48. New Jersey Department of Environmental Protection (NJDEP). 2010. NJDEP 2007 Land Use/Land Cover Update. NJDEP, Trenton, New Jersey.

49. New Jersey Department of Environmental Protection (NJDEP). 2010a. Surface Water Quality Standards, N.J.A.C. 7:9B. Last Amended January 4, 2010 (42 N.J.R. 68(a)) http://www.nj.gov/dep/rules/rules/njac7_9b.pdf.

50. New Jersey Department of Environmental Protection (NJDEP). 2010b. Wildlife Populations: Canada Goose. Division of Fish and Wildlife, NJDEP, Trenton, New Jersey.

51. New Jersey Department of Environmental Protection (NJDEP). Division of Fish and Wildlife. Community Based Deer Management Manual for Municipalities. http://www.nj.gov/dep/fgw 2011.

52. New Jersey Department of Labor and Workforce Development (NJDLWD). 2006. Northern Regional Community Fact Book. Hunterdon County Edition. Trenton, New Jersey.

53. New Jersey Water Supply Authority (NJWSA). 2000. Water Budget in the Raritan River Basin: A Technical Report for the Raritan Basin Watershed Management Project. Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

54. New Jersey Water Supply Authority (NJWSA). 2002. Raritan Basin Watershed Management Project: Water Resources Protection Open Space Criteria. Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

55. New Jersey Water Supply Authority (NJWSA). 2002a. Raritan Basin watershed management plan. Raritan Basin Watershed Management Project Report, Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

56. New Jersey Water Supply Authority (NJWSA). 2007. Mulhockaway Creek Stormwater Management and Watershed Restoration Plan. Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

57. New Jersey Water Supply Authority (NJWSA). 2008. An Assessment of Municipal Plans, Policies and Regulations Effecting Water Quality in the Lockatong and Wickecheoke Creek Watersheds. Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

58. New Jersey Water Supply Authority (NJWSA). 2009. Lockatong and Wickecheoke Creek Watershed Restoration and Protection Plan. Watershed Protection Programs Unit, NJWSA, Somerset, New Jersey.

59. Niles, L.J., M. Valent, P. Winkler, and P. Woerner. 2008. New Jersey's Landscape Project, Version 2.1. NJ Department of Environmental Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program, Trenton, New Jersey.

60. North Jersey Resource Conservation & Development Council (North Jersey RC&D). 2011. Developing a Watershed Restoration Plan for the Neshanic River Watershed Task 6: Evaluate Agricultural Best Management Practices Report. North Jersey Resource Conservation & Development Counci, 54 Old Highway 22, Suite 201 Clinton, NJ 08809.

61. Pahl, R. 2002. Nevada's TMDL Program. The paper presented at U.S. Committee on Irrigation and Drainage Conference –"Helping Irrigated Agriculture Adjust to TMDLs", Sacramento, CA, October 23-27, 2002.

62. Potter, S.R., S. Andrews, J.D. Atwood, R.L. Kellog, J. Lemunyon, L. Norfleet, D. Oman. 2006. The Model Simulation of Soil Loss, Nutrient Loss, and Change in Soil Organic Carbon Associated with Crop Production. The Conservation Effects Assessment Project Report, Natural Resource Conservation Service, United States Department of Agriculture.

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

64. Qiu, Z. 2003. A VSA-based Strategy for Placing Conservation Buffers in Agricultural Watersheds. Environmental Management 32(3): 299-311.

65. Qiu, Z. 2009. Identifying Critical Source Areas in Watersheds for Conservation Buffer Planning and Riparian Restoration. Environmental Management 44(5): 968-980.

66. Qiu, Z., M.T. Walter and C. Hall. 2007. Managing Variable Source Pollution in Agricultural Watersheds. Journal of Soil and Water Conservation 62(3):115-122.

67. Reiser, R.G., 2004. Evaluation of Streamflow, Water Quality and Permitted and Nonpermitted Loads and Yields in the Raritan River Basin, New Jersey, Water Years 1991-98. Water-Resources Investigations Report 03-4207., U.S. Geological Survey, West Trenton, New Jersey.

68. Robichaud, Beryl and Karl H. Anderson. 1994. Plant Communities of New Jersey: A Study in Landscape Diversity. New Brunswick, New Jersey: Rutgers University Press.

69. Rosgen, D.L. 1994. A Classification of Natural Rivers, Elsevier Science - Catena 22: 169-199.

70. Rusciano, G.M. and C.C. Obropta. 2007. Bioretention Column Study: Fecal Coliform and Total Suspended Solids Reductions. Transactions of the ASABE 50(4): 1261-1269.

71. Schlische, R.W. 1992. Structural and Stratigraphic Development of the Newark Extensional Basin, Eastern North America: Implications for the Growth of the Basin and its Bounding Structures. Geological Society of America Bulletin 104:1246-1263.

72. Schueler, T. 1995. Site Planning for Urban Stream Protection Metropolitan Washington Council of Governments. Center for Watershed Protection, Ellicot City, MD

73. Schumm, S.A., M.D. Harvey, and C.C. Watson. 1984. Incised Channels: Morphology, Dynamics, and Control, Water Resources Publications, Littleton, CO.

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

75. Semple, A., S. Blick, F. Kelly and J. Skupien. 2004. New Jersey Stormwater Best Management Practices Manual. New Jersey Department of Environmental Protection, Trenton, New Jersey.

76. Snyder, J.P. 1969. The Story of New Jersey's Civil Boundaries, 1606-1968. Bureau of Geology and Topography, Trenton, New Jersey.

77. Soil and Water Conservation Society (SWCS). 2001. Realizing the Promise of Conservation Bugger Technology. Ankeny, IA: Soil and Water Conservation Society.

78. The Center for Neighborhood Technology. 2009. A Sustainable Community-Based Approach to Reducing Non-Point Source Pollution. The Center for Neighborhood Technology, Chicago, Illinois.

79. U.S. Department of Agriculture (USDA). 1974. Soil Survey Hunterdon County New Jersey. Soil Conservation Service, USDA.

80. U.S. Environmental Protection Agency (USEPA). 1994. National Water Quality Inventory: 1992 Report to Congress. Office of Water, USEPA, Washington DC, EPA 841-R-94-001.

81. U.S. Environmental Protection Agency (USEPA). Office of Watershed Management. 2000. Potential Roles for Clean Water State Revolving Fund Programs in Smart Growth Initiatives. EPA 832-R-00-010. Washington, DC 20460.

82. U.S. Environmental Protection Agency (USEPA). 2001. Managing Agricultural Fertilizer Application to Prevent Contamination of Drinking Water. Office of Water, USEPA, Washington, D.C.

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

84. U.S. Environmental Protection Agency (USEPA). 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006. Office of Wetlands, Oceans and Watersheds, USEPA, Washington, DC.

85. Virginia Department of Environmental Quality. 2002. Fecal coliform TMDL for Naked Vreek in Augusta and Rockingham Counties, Virginia, Virginia Department of Environmental Quality, Richmond, VA.

86. Walter, M.T., M.F. Walter, E.S. Brooks, T.S. Steenhuis, J. Boll, and K. Weiler. 2000. Hydrologically Sensitive Areas: Variable Source Area Hydrology Implications for Water Quality Risk Assessment. Journal of Soil and Water Conservation 55(3):277-284.

87. Walter, M.T., T.S. Steenhuis, V.K. Mehta, D. Thongs, M. Zion, and E. Schneiderman. 2002. A Refined Conceptualization of TOPMODEL for Shallow-subsurface Flows. Hydrological Processes 16(10): 2041-2046.

88. Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses: a guide to

conservation planning. Agriculture Handbook 282, USDA-ARS.

89. Wittman Hydro Planning Associates, Inc. (WHPA). 2004. Salt Creek E. coli TMDL. WHPA, Bloomington, Indiana.

90. Gregory, S.C., F.J. Swanson, W.A. McKee and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 42: 540–541.

91. National Resources Council (NRC), 2002. Riparian Areas: Functions and Strategies for Management. National Academy Press, Washington DC.

15. Appendices

15.1. Appendix 1: Residential Sites Suitable for Rain Gardens by Subwatershed in the Neshanic River Watershed

Potential Rain Garden Sites	Size of Neighborhood (acres)	Number of Houses in the Neighborhood
In Subwatershed SN1		
SN1_001	192.1	91
SN1_002	45.0	23
SN1_003	76.2	20
SN1_004	107.6	54
SN1_005	33.5	19
SN1_006	113.2	58
SN1_007	154.7	63
SN1_008	240.9	59
SN1_009	161.0	135
SN1_010	21.8	19
Others	NA	116
Subtotal	1,146	657
In Subwatershed TN3a		
TN3a_002	69.4	30
TN3a_001	84.2	13
Others	NA	352
Subtotal	154	405
In Subwatershed FN1		
FN1_001	21.1	16
FN1_002	30.7	25
FN1_003	53.5	18
FN1_004	35.6	16
FN1_005	38.5	22
FN1_006	40.7	132
FN1_007	31.2	133
FN1_008	150.9	91
FN1_009	21.3	19
FN1_010	7.3	42
FN1_011	8.3	16
FN1_012	97.9	59
FN1_013	36.5	10
Others	NA	154
Subtotal	573	753
In Subwatershed UNT2		

UNT2_001	286.4	146
UNT2_002	78.6	50
UNT2_003	40.1	27
UNT2_004	161.7	85
Others	NA	15
Subtotal	567	323
In Subwatershed UNT1		
UNT1_001	40.5	30
UNT1_002	204.5	135
UNT1_003	101.5	54
UNT1_004	39.8	21
UNT1_006	30.1	17
UNT1_005	16.2	13
UNT1_008	58.1	42
UNT1_009	11.4	8
UNT1_007	35.1	29
UNT_010	29.9	20
Others	NA	76
Subtotal	567	445
In Subwatershed N1		
N1_001	83.9	47
N1_002	37.0	69
N1_003	15.4	54
N1_004	63.3	156
N1_005	165.5	343
N1_006	167.1	108
N1_008	97.3	58
N1_007	32.7	16
N1_009	20.8	11
Others	NA	53
Subtotal	683	915
In Subwatershed TN3		
TN3_001	30.3	20
TN3_002	26.5	11
TN3_003	16.6	10
TN3_004	23.8	12
Others	NA	4
Subtotal	97	57
Total	3,787	3,545

15.2. **Appendix 2: Prioritization of Roadside Ditches by Subwatersheds in the Neshanic River Watershed**

N1			N1 (cont'd)		
Rank	Score	ID	Rank	Score	ID
1	17 HP	SD-382	28	13 MP	SD-189
2	17 HP	SD-389	29	13 MP	SD-190
3	16 HP	SD-187	30	13 MP	SD-371
4	16 HP	SD-373	31	13 MP	SD-372
5	16 HP	SD-375	32	13 MP	SD-374
6	16 HP	SD-376	33	13 MP	SD-1196
7	16 HP	SD-377	34	13 MP	SD-1198
8	16 HP	SD-378	35	13 MP	SD-1201
9	16 HP	SD-379	36	13 MP	SD-1203
10	16 HP	SD-380	37	12 MP	SD-860
11	16 HP	SD-381	38	9 MP	SD-183
12	16 HP	SD-383	39	9 MP	SD-185
13	16 HP	SD-384	40	9 MP	SD-186
14	16 HP	SD-385	41	9 MP	SD-447
15	16 HP	SD-386	42	9 MP	SD-830
16	16 HP	SD-387	43	9 MP	SD-832
17	16 HP	SD-388	44	9 MP	SD-1132
18	16 HP	SD-839	45	9 MP	SD-1200
19	16 HP	SD-840	46	5 LP	SD-829
20	16 HP	SD-900	47	5 LP	SD-919
21	15 MP	SD-184	48	5 LP	SD-1210
22	15 MP	SD-188	49	4 LP	SD-831
23	15 MP	SD-191	50	4 LP	SD-838
24	15 MP	SD-370	51	4 LP	SD-1199
25	15 MP	SD-1197	52	4 LP	SD-1202
26	14 MP	SD-920	53	4 LP	SD-1209
27	14 MP	SD-921			

SN1			SN1 (cont'd)		
Rank	Score	ID	Rank	Score	ID
1	18 HP	SD-361	41	15 MP	SD-456
2	17 HP	SD-134	42	15 MP	SD-457
3	17 HP	SD-211	43	15 MP	SD-458
4	16 HP	SD-125	44	15 MP	SD-459
5	16 HP	SD-133	45	15 MP	SD-467
6	16 HP	SD-217	46	15 MP	SD-468
7	16 HP	SD-220	47	15 MP	SD-828
8	16 HP	SD-221	48	15 MP	SD-971
9	16 HP	SD-224	49	15 MP	SD-973
10	16 HP	SD-225	50	15 MP	SD-975
11	16 HP	SD-227	51	15 MP	SD-1026
12	16 HP	SD-245	52	15 MP	SD-1213
13	16 HP	SD-246	53	15 MP	SD-1218
14	16 HP	SD-357	54	15 MP	SD-1219
15	16 HP	SD-358	55	15 MP	SD-1220
16	16 HP	SD-360	56	15 MP	SD-1221
17	16 HP	SD-362	57	15 MP	SD-1222
18	16 HP	SD-365	58	15 MP	SD-1253
19	16 HP	SD-366	59	15 MP	SD-1254
20	16 HP	SD-407	60	15 MP	SD-1257
21	16 HP	SD-463	61	15 MP	SD-1265
22	16 HP	SD-464	62	15 MP	SD-1266
23	16 HP	SD-465	63	14 MP	SD-229
24	16 HP	SD-965	64	14 MP	SD-232
25	16 HP	SD-1214	65	14 MP	SD-239
26	15 MP	SD-128	66	14 MP	SD-296
27	15 MP	SD-129	67	14 MP	SD-297
28	15 MP	SD-135	68	14 MP	SD-298
29	15 MP	SD-202	69	14 MP	SD-299
30	15 MP	SD-214	70	14 MP	SD-302
31	15 MP	SD-215	71	14 MP	SD-363
32	15 MP	SD-218	72	14 MP	SD-364
33	15 MP	SD-219	73	13 MP	SD-197
34	15 MP	SD-226	74	13 MP	SD-198
35	15 MP	SD-244	75	13 MP	SD-199
36	15 MP	SD-247	76	13 MP	SD-200
37	15 MP	SD-250	77	13 MP	SD-201
38	15 MP	SD-308	78	13 MP	SD-204
39	15 MP	SD-309	79	13 MP	SD-205
40	15 MP	SD-455	80	13 MP	SD-206

SN1 (cont'd)			SN1 (cont'd)		
Rank	Score	ID	Rank	Score	ID
81	13 MP	SD-207	121	13 MP	SD-1086
82	13 MP	SD-208	122	13 MP	SD-1089
83	13 MP	SD-209	123	13 MP	SD-1090
84	13 MP	SD-210	124	13 MP	SD-1217
85	13 MP	SD-212	125	13 MP	SD-1226
86	13 MP	SD-213	126	13 MP	SD-1227
87	13 MP	SD-222	127	13 MP	SD-1279
88	13 MP	SD-223	128	13 MP	SD-1280
89	13 MP	SD-228	129	13 MP	SD-1281
90	13 MP	SD-230	130	12 MP	SD-1170
91	13 MP	SD-231	131	12 MP	SD-1255
92	13 MP	SD-233	132	12 MP	SD-1256
93	13 MP	SD-238	133	12 MP	SD-1264
94	13 MP	SD-243	134	11 MP	SD-1282
95	13 MP	SD-248	135	9 MP	SD-130
96	13 MP	SD-249	136	9 MP	SD-355
97	13 MP	SD-251	137	9 MP	SD-367
98	13 MP	SD-252	138	9 MP	SD-368
99	13 MP	SD-300	139	9 MP	SD-452
100	13 MP	SD-301	140	9 MP	SD-453
101	13 MP	SD-303	141	9 MP	SD-454
102	13 MP	SD-305	142	9 MP	SD-460
103	13 MP	SD-306	143	9 MP	SD-462
104	13 MP	SD-307	144	9 MP	SD-466
105	13 MP	SD-310	145	9 MP	SD-967
106	13 MP	SD-356	146	9 MP	SD-972
107	13 MP	SD-359	147	9 MP	SD-1087
108	13 MP	SD-391	148	9 MP	SD-1088
109	13 MP	SD-450	149	9 MP	SD-1228
110	13 MP	SD-451	150	9 MP	SD-1251
111	13 MP	SD-461	151	8 MP	SD-1271
112	13 MP	SD-469	152	4 LP	SD-216
113	13 MP	SD-961	153	4 LP	SD-304
114	13 MP	SD-963	154	3 LP	SD-1269
115	13 MP	SD-964			
116	13 MP	SD-966			
117	13 MP	SD-968			
118	13 MP	SD-969			
119	13 MP	SD-970			
120	13 MP	SD-974			

TN3			TN3a			TN3a (cont'd)		
Rank	Score	ID	Rank	Score	ID	Rank	Score	ID
1	13 MP	SD-192	1	18 HP	SD-527	41	16 HP	SD-604
2	13 MP	SD-234	2	18 HP	SD-588	42	1 HP6	SD-617
3	13 MP	SD-235	3	18 HP	SD-612	43	16 HP	SD-646
4	9 MP	SD-236	4	18 HP	SD-618	44	16 HP	SD-649
5	9 MP	SD-237	5	17 HP	SD-525	45	16 HP	SD-651
6	8 MP	SD-861	6	17 HP	SD-583	46	16 HP	SD-664
			7	17 HP	SD-596	47	16 HP	SD-666
			8	17 HP	SD-679	48	16 HP	SD-681
			9	17 HP	SD-768	49	16 HP	SD-686
			10	17 HP	SD-942	50	16 HP	SD-702
			11	17 HP	SD-1273	51	16 HP	SD-723
			12	16 HP	SD-28	52	16 HP	SD-778
			13	16 HP	SD-32	53	16 HP	SD-935
			14	16 HP	SD-176	54	16 HP	SD-951
			15	16 HP	SD-177	55	16 HP	SD-953
			16	16 HP	SD-180	56	16 HP	SD-956
			17	16 HP	SD-195	57	16 HP	SD-960
			18	16 HP	SD-258	58	16 HP	SD-1120
			19	16 HP	SD-260	59	16 HP	SD-1272
			20	16 HP	SD-269	60	15 MP	SD-11
			21	16 HP	SD-275	61	15 MP	SD-33
			22	16 HP	SD-277	62	15 MP	SD-124
			23	16 HP	SD-294	63	15 MP	SD-175
			24	16 HP	SD-295	64	15 MP	SD-196
			25	16 HP	SD-339	65	15 MP	SD-240
			26	16 HP	SD-341	66	15 MP	SD-241
			27	16 HP	SD-404	67	15 MP	SD-261
			28	16 HP	SD-497	68	15 MP	SD-262
			29	16 HP	SD-499	69	15 MP	SD-263
			30	16 HP	SD-501	70	15 MP	SD-264
			31	16 HP	SD-503	71	15 MP	SD-268
			32	16 HP	SD-504	72	15 MP	SD-270
			33	16 HP	SD-506	73	15 MP	SD-271
			34	16 HP	SD-507	74	15 MP	SD-272
			35	16 HP	SD-536	75	15 MP	SD-274
			36	16 HP	SD-537	76	15 MP	SD-276
			37	16 HP	SD-566	77	15 MP	SD-291
			38	16 HP	SD-575	78	15 MP	SD-293
			39	16 HP	SD-585	79	15 MP	SD-340
			40	16 HP	SD-592	80	15 MP	SD-344

TN3a (cont'd)			TN3a (cont'd)			TN3a (cont'd)		
Rank	Score	ID	Rank	Score	ID	Rank	Score	ID
81	15 MP	SD-346	121	15 MP	SD-547	161	15 MP	SD-718
82	15 MP	SD-349	122	15 MP	SD-548	162	15 MP	SD-735
83	15 MP	SD-350	123	15 MP	SD-552	163	15 MP	SD-771
84	15 MP	SD-408	124	15 MP	SD-565	164	15 MP	SD-777
85	15 MP	SD-410	125	15 MP	SD-569	165	15 MP	SD-868
86	15 MP	SD-411	126	15 MP	SD-572	166	15 MP	SD-915
87	15 MP	SD-412	127	15 MP	SD-577	167	15 MP	SD-936
88	15 MP	SD-416	128	15 MP	SD-579	168	15 MP	SD-938
89	15 MP	SD-432	129	15 MP	SD-584	169	15 MP	SD-941
90	15 MP	SD-433	130	15 MP	SD-591	170	15 MP	SD-943
91	15 MP	SD-434	131	15 MP	SD-593	171	15 MP	SD-947
92	15 MP	SD-435	132	15 MP	SD-597	172	15 MP	SD-987
93	15 MP	SD-438	133	15 MP	SD-601	173	15 MP	SD-994
94	15 MP	SD-441	134	15 MP	SD-603	174	15 MP	SD-1020
95	15 MP	SD-442	135	15 MP	SD-607	175	15 MP	SD-1021
96	15 MP	SD-443	136	15 MP	SD-608	176	15 MP	SD-1121
97	15 MP	SD-445	137	15 MP	SD-631	177	15 MP	SD-1124
98	15 MP	SD-498	138	15 MP	SD-634	178	15 MP	SD-1125
99	15 MP	SD-500	139	15 MP	SD-635	179	15 MP	SD-1128
100	15 MP	SD-509	140	15 MP	SD-636	180	15 MP	SD-1129
101	15 MP	SD-512	141	15 MP	SD-637	181	15 MP	SD-1276
102	15 MP	SD-513	142	15 MP	SD-638	182	15 MP	SD-1277
103	15 MP	SD-515	143	15 MP	SD-640	183	15 MP	SD-1278
104	15 MP	SD-516	144	15 MP	SD-641	184	14 MP	SD-7
105	15 MP	SD-517	145	15 MP	SD-643	185	14 MP	SD-10
106	15 MP	SD-519	146	15 MP	SD-644	186	14 MP	SD-30
107	15 MP	SD-522	147	15 MP	SD-657	187	14 MP	SD-31
108	15 MP	SD-523	148	15 MP	SD-658	188	14 MP	SD-137
109	15 MP	SD-524	149	15 MP	SD-659	189	14 MP	SD-259
110	15 MP	SD-528	150	15 MP	SD-662	190	14 MP	SD-273
111	15 MP	SD-529	151	15 MP	SD-671	191	14 MP	SD-279
112	15 MP	SD-530	152	15 MP	SD-672	192	14 MP	SD-286
113	15 MP	SD-531	153	15 MP	SD-673	193	14 MP	SD-288
114	15 MP	SD-532	154	15 MP	SD-674	194	14 MP	SD-414
115	15 MP	SD-538	155	15 MP	SD-676	195	14 MP	SD-418
116	15 MP	SD-542	156	15 MP	SD-677	196	14 MP	SD-437
117	15 MP	SD-543	157	15 MP	SD-684	197	14 MP	SD-439
118	15 MP	SD-544	158	15 MP	SD-687	198	14 MP	SD-440
119	15 MP	SD-545	159	15 MP	SD-700	199	14 MP	SD-444
120	15 MP	SD-546	160	15 MP	SD-704	200	14 MP	SD-496

TN3a (cont'd)			TN3a (cont'd)			TN3a (cont'd)		
Rank	Score	ID	Rank	Score	ID	Rank	Score	ID
201	14 MP	SD-514	241	13 MP	SD-173	281	13 MP	SD-600
202	14 MP	SD-520	242	13 MP	SD-174	282	13 MP	SD-614
203	14 MP	SD-573	243	13 MP	SD-179	283	13 MP	SD-616
204	14 MP	SD-574	244	13 MP	SD-181	284	13 MP	SD-619
205	14 MP	SD-576	245	13 MP	SD-182	285	13 MP	SD-620
206	14 MP	SD-589	246	13 MP	SD-193	286	13 MP	SD-621
207	14 MP	SD-590	247	13 MP	SD-242	287	13 MP	SD-622
208	14 MP	SD-606	248	13 MP	SD-253	288	13 MP	SD-626
209	14 MP	SD-609	249	13 MP	SD-254	289	13 MP	SD-627
210	14 MP	SD-610	250	13 MP	SD-255	290	13 MP	SD-628
211	14 MP	SD-611	251	13 MP	SD-256	291	13 MP	SD-630
212	14 MP	SD-613	252	13 MP	SD-257	292	13 MP	SD-632
213	14 MP	SD-615	253	13 MP	SD-265	293	13 MP	SD-642
214	14 MP	SD-667	254	13 MP	SD-266	294	13 MP	SD-660
215	14 MP	SD-668	255	13 MP	SD-278	295	13 MP	SD-669
216	14 MP	SD-670	256	13 MP	SD-280	296	13 MP	SD-680
217	14 MP	SD-683	257	13 MP	SD-281	297	13 MP	SD-696
218	14 MP	SD-749	258	13 MP	SD-284	298	13 MP	SD-698
219	14 MP	SD-939	259	13 MP	SD-285	299	13 MP	SD-699
220	14 MP	SD-944	260	13 MP	SD-287	300	13 MP	SD-701
221	14 MP	SD-949	261	13 MP	SD-292	301	13 MP	SD-707
222	14 MP	SD-954	262	13 MP	SD-333	302	13 MP	SD-717
223	14 MP	SD-1134	263	13 MP	SD-347	303	13 MP	SD-722
224	13 MP	SD-2	264	13 MP	SD-348	304	13 MP	SD-724
225	13 MP	SD-3	265	13 MP	SD-351	305	13 MP	SD-725
226	13 MP	SD-4	266	13 MP	SD-353	306	13 MP	SD-726
227	13 MP	SD-5	267	13 MP	SD-429	307	13 MP	SD-727
228	13 MP	SD-6	268	13 MP	SD-446	308	13 MP	SD-729
229	13 MP	SD-8	269	13 MP	SD-508	309	13 MP	SD-730
230	13 MP	SD-9	270	13 MP	SD-521	310	13 MP	SD-747
231	13 MP	SD-12	271	13 MP	SD-533	311	13 MP	SD-748
232	13 MP	SD-14	272	13 MP	SD-535	312	13 MP	SD-750
233	13 MP	SD-26	273	13 MP	SD-571	313	13 MP	SD-767
234	13 MP	SD-34	274	13 MP	SD-580	314	13 MP	SD-770
235	13 MP	SD-35	275	13 MP	SD-582	315	13 MP	SD-910
236	13 MP	SD-136	276	13 MP	SD-586	316	13 MP	SD-914
237	13 MP	SD-169	277	13 MP	SD-587	317	13 MP	SD-934
238	13 MP	SD-170	278	13 MP	SD-594	318	13 MP	SD-940
239	13 MP	SD-171	279	13 MP	SD-598	319	13 MP	SD-948
240	13 MP	SD-172	280	13 MP	SD-599	320	13 MP	SD-955

TN3a (cont'd)			TN3a (cont'd)		
Rank	Score	ID	Rank	Score	ID
321	13 MP	SD-957	361	9 MP	SD-563
322	13 MP	SD-958	362	9 MP	SD-567
323	13 MP	SD-959	363	9 MP	SD-623
324	13 MP	SD-977	364	9 MP	SD-624
325	13 MP	SD-1015	365	9 MP	SD-625
326	13 MP	SD-1017	366	9 MP	SD-633
327	13 MP	SD-1018	367	9 MP	SD-682
328	13 MP	SD-1019	368	9 MP	SD-697
329	13 MP	SD-1122	369	9 MP	SD-703
330	13 MP	SD-1123	370	9 MP	SD-773
331	13 MP	SD-1127	371	9 MP	SD-774
332	13 MP	SD-1130	372	9 MP	SD-826
333	13 MP	SD-1131	373	9 MP	SD-874
334	12 MP	SD-29	374	9 MP	SD-875
335	12 MP	SD-343	375	9 MP	SD-945
336	12 MP	SD-595	376	9 MP	SD-946
337	11 MP	SD-39	377	9 MP	SD-1012
338	11 MP	SD-639	378	9 MP	SD-1013
339	11 MP	SD-869	379	9 MP	SD-1014
340	11 MP	SD-916	380	9 MP	SD-1022
341	10 MP	SD-436	381	9 MP	SD-1126
342	10 MP	SD-578	382	9 MP	SD-1135
343	10 MP	SD-581	383	8 MP	SD-178
344	10 MP	SD-605	384	8 MP	SD-194
345	10 MP	SD-629	385	8 MP	SD-203
346	9 MP	SD-13	386	7 MP	SD-161
347	9 MP	SD-27	387	7 MP	SD-1176
348	9 MP	SD-267	388	7 MP	SD-1177
349	9 MP	SD-282	389	7 MP	SD-1178
350	9 MP	SD-283	390	7 MP	SD-1179
351	9 MP	SD-289	391	5 LP	SD-345
352	9 MP	SD-290	392	4 LP	SD-160
353	9 MP	SD-332	393	4 LP	SD-827
354	9 MP	SD-334	394	4 LP	SD-931
355	9 MP	SD-342			
356	9 MP	SD-352			
357	9 MP	SD-518			
358	9 MP	SD-526			
359	9 MP	SD-539			
360	9 MP	SD-551			

FN1			FN1 (cont'd)			FN1 (cont'd)		
Rank	Score	ID	Rank	Score	ID	Rank	Score	ID
1	17 HP	SD-323	41	14 MP	SD-321	81	9 MP	SD-1207
2	17 HP	SD-325	42	14 MP	SD-324	82	9 MP	SD-1229
3	16 HP	SD-330	43	14 MP	SD-326	83	8 MP	SD-887
4	16 HP	SD-395	44	14 MP	SD-331	84	8 MP	SD-918
5	16 HP	SD-888	45	14 MP	SD-394	85	8 MP	SD-1098
6	16 HP	SD-889	46	14 MP	SD-398	86	8 MP	SD-1215
7	16 HP	SD-892	47	14 MP	SD-399	87	6 MP	SD-1007
8	16 HP	SD-893	48	14 MP	SD-400	88	5 LP	SD-448
9	16 HP	SD-895	49	14 MP	SD-962	89	5 LP	SD-899
10	16 HP	SD-1009	50	14 MP	SD-1115	90	5 LP	SD-1008
11	16 HP	SD-1099	51	13 MP	SD-318	91	4 LP	SD-390
12	16 HP	SD-1100	52	13 MP	SD-319	92	4 LP	SD-406
13	16 HP	SD-1101	53	13 MP	SD-320	93	4 LP	SD-897
14	16 HP	SD-1102	54	13 MP	SD-322	94	4 LP	SD-898
15	16 HP	SD-1103	55	13 MP	SD-354	95	4 LP	SD-1109
16	16 HP	SD-1104	56	13 MP	SD-397	96	4 LP	SD-1270
17	16 HP	SD-1105	57	13 MP	SD-999			
18	16 HP	SD-1106	58	13 MP	SD-1010			
19	16 HP	SD-1114	59	13 MP	SD-1084			
20	16 HP	SD-1118	60	13 MP	SD-1091			
21	16 HP	SD-1119	61	13 MP	SD-1107			
22	15 MP	SD-327	62	13 MP	SD-1108			
23	15 MP	SD-328	63	13 MP	SD-1111			
24	15 MP	SD-329	64	13 MP	SD-1113			
25	15 MP	SD-393	65	13 MP	SD-1117			
26	15 MP	SD-396	66	13 MP	SD-1206			
27	15 MP	SD-890	67	13 MP	SD-1208			
28	15 MP	SD-894	68	13 MP	SD-1224			
29	15 MP	SD-896	69	13 MP	SD-1225			
30	15 MP	SD-1003	70	12 MP	SD-315			
31	15 MP	SD-1006	71	12 MP	SD-1005			
32	15 MP	SD-1011	72	11 MP	SD-120			
33	15 MP	SD-1085	73	10 MP	SD-392			
34	15 MP	SD-1112	74	10 MP	SD-891			
35	15 MP	SD-1116	75	9 MP	SD-369			
36	15 MP	SD-1204	76	9 MP	SD-449			
37	15 MP	SD-1205	77	9 MP	SD-995			
38	15 MP	SD-1211	78	9 MP	SD-1004			
39	14 MP	SD-316	79	9 MP	SD-1110			
40	14 MP	SD-317	80	9 MP	SD-1175			

UNT1			UNT2		
Rank	Score	ID	Rank	Score	ID
1	16 HP	SD-780	1	16 HP	SD-311
2	16 HP	SD-793	2	16 HP	SD-314
3	15 MP	SD-794	3	15 MP	SD-862
4	15 MP	SD-795	4	15 MP	SD-865
5	14 MP	SD-781	5	15 MP	SD-877
6	14 MP	SD-792	6	15 MP	SD-878
7	14 MP	SD-796	7	15 MP	SD-879
8	14 MP	SD-809	8	13 MP	SD-313
9	14 MP	SD-810	9	13 MP	SD-863
10	13 MP	SD-482	10	13 MP	SD-864
11	13 MP	SD-779	11	13 MP	SD-866
12	13 MP	SD-782	12	11 MP	SD-1025
13	13 MP	SD-786	13	9 MP	SD-867
14	13 MP	SD-787	14	9 MP	SD-1180
15	13 MP	SD-788	15	9 MP	SD-1181
16	13 MP	SD-789	16	9 MP	SD-1195
17	13 MP	SD-790	17	8 MP	SD-1173
18	13 MP	SD-791	18	8 MP	SD-1267
19	13 MP	SD-808	19	5 LP	SD-312
20	13 MP	SD-812	20	4 LP	SD-1174
21	13 MP	SD-813	21	4 LP	SD-1190
22	13 MP	SD-814	22	4 LP	SD-1192
23	13 MP	SD-815	23	4 LP	SD-1268
24	13 MP	SD-816	24	3 LP	SD-1274
25	9 MP	SD-478	25	3 LP	SD-1275
26	9 MP	SD-479			
27	9 MP	SD-480			
28	9 MP	SD-481			
29	9 MP	SD-783			
30	9 MP	SD-784			
31	9 MP	SD-785			
32	9 MP	SD-833			
33	9 MP	SD-834			
34	9 MP	SD-835			
35	9 MP	SD-1212			
36	5 LP	SD-811			

N2			N2 (cont'd)		
Rank	Score	ID	Rank	Score	ID
1	18 HP	SD-903	43	13 MP	SD-846
2	17 HP	SD-473	44	13 MP	SD-845
3	16 HP	SD-904	45	13 MP	SD-841
4	16 HP	SD-901	46	13 MP	SD-825
5	16 HP	SD-851	47	13 MP	SD-824
6	16 HP	SD-844	48	13 MP	SD-821
7	16 HP	SD-843	49	13 MP	SD-806
8	16 HP	SD-842	50	13 MP	SD-801
9	16 HP	SD-823	51	13 MP	SD-800
10	15 MP	SD-902	52	13 MP	SD-798
11	15 MP	SD-886	53	13 MP	SD-797
12	15 MP	SD-885	54	13 MP	SD-492
13	15 MP	SD-880	55	13 MP	SD-490
14	15 MP	SD-856	56	13 MP	SD-488
15	15 MP	SD-854	57	13 MP	SD-487
16	15 MP	SD-853	58	13 MP	SD-475
17	15 MP	SD-852	59	13 MP	SD-471
18	15 MP	SD-850	60	13 MP	SD-470
19	15 MP	SD-848	61	13 MP	SD-1001
20	15 MP	SD-847	62	13 MP	SD-1
21	15 MP	SD-805	63	9 MP	SD-884
22	15 MP	SD-491	64	9 MP	SD-883
23	15 MP	SD-486	65	9 MP	SD-881
24	15 MP	SD-485	66	9 MP	SD-857
25	15 MP	SD-484	67	9 MP	SD-820
26	15 MP	SD-483	68	9 MP	SD-819
27	15 MP	SD-474	69	9 MP	SD-818
28	15 MP	SD-472	70	9 MP	SD-817
29	15 MP	SD-1263	71	9 MP	SD-807
30	15 MP	SD-1187	72	9 MP	SD-803
31	15 MP	SD-1000	73	9 MP	SD-799
32	14 MP	SD-822	74	9 MP	SD-489
33	14 MP	SD-804	75	9 MP	SD-477
34	14 MP	SD-802	76	9 MP	SD-1258
35	14 MP	SD-476	77	9 MP	SD-1185
36	13 MP	SD-906	78	9 MP	SD-1184
37	13 MP	SD-905	79	9 MP	SD-1183
38	13 MP	SD-882	80	8 MP	SD-493
39	13 MP	SD-859	81	4 LP	SD-1191
40	13 MP	SD-858			
41	13 MP	SD-855			
42	13 MP	SD-849			

HP = High Priority; MP = Medium Priority; LP = Low Priority

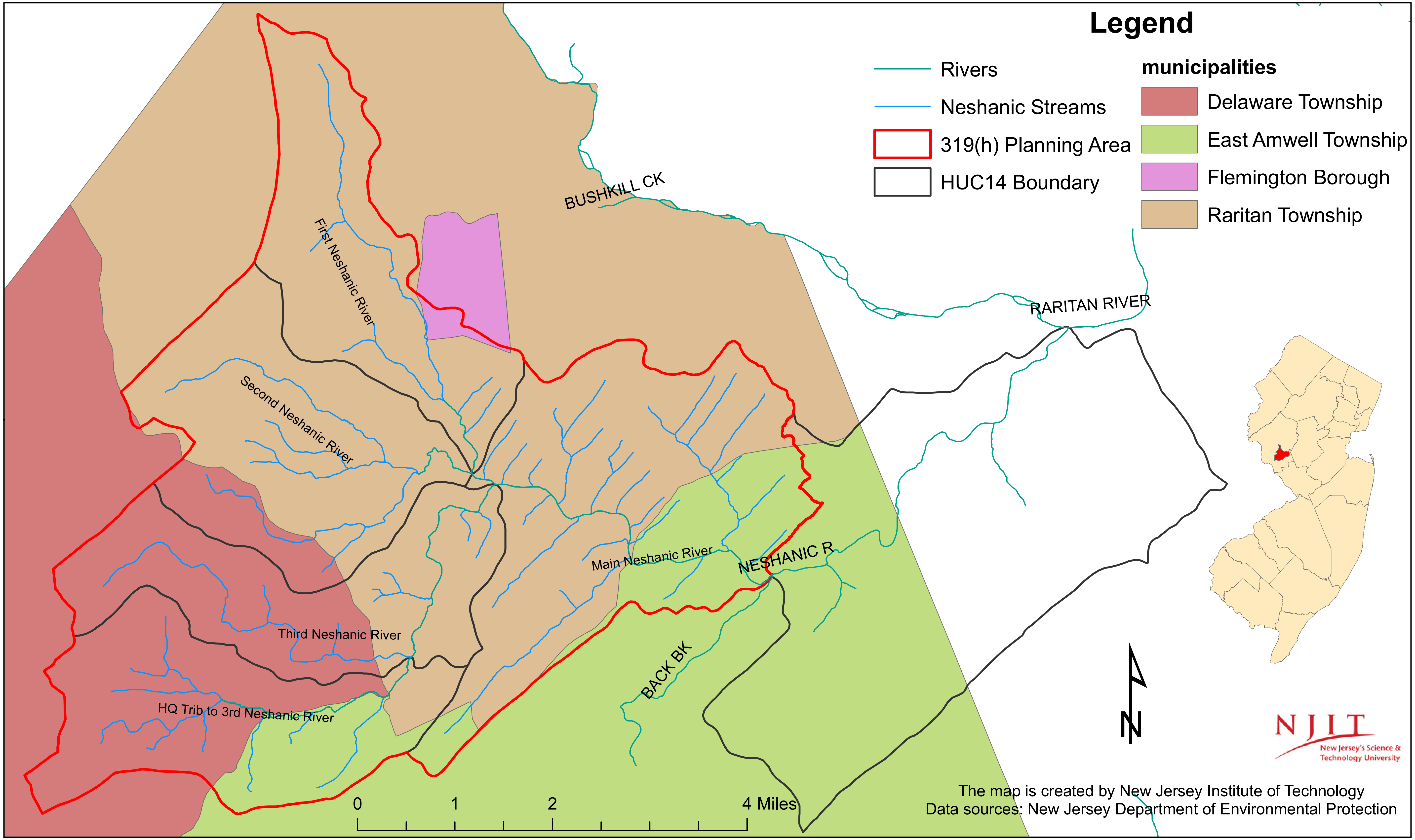
15.3. **Appendix 3: Prioritization of Detention Basins by Subwatersheds in the Neshanic River Watershed**

N1			SN1			TN3		
Rank	Priority	BASIN_ID	Rank	Priority	BASIN_ID	Rank	Priority	BASIN_ID
1	28 HP	MDB-0036	1	24 HP	MDB-0046	1	24 HP	MDB-0153
2	28 HP	MDB-0037	2	22 HP	MDB-0070	2	22 HP	MDB-0154
3	26 HP	MDB-0136	3	22 HP	MDB-0054	3	22 HP	MDB-0209
4	24 HP	MDB-0137	4	22 HP	MDB-0071	4	17 MP	MDB-0252
5	24 HP	MDB-0047	5	22 HP	MDB-0092	5	17 MP	MDB-0016
6	22 HP	MDB-0145	6	22 HP	MDB-0093	6	17 MP	MDB-0060
7	22 HP	MDB-0150	7	22 HP	MDB-0095	7	14 MP	MDB-0139
8	22 HP	MDB-0151	8	22 HP	MDB-0255	8	10 MP	MDB-0251
9	22 HP	MDB-0222	9	20 HP	MDB-0061			
10	21 HP	MDB-0013	10	19 MP	MDB-0256			
11	19 MP	MDB-0014	11	17 MP	MDB-0074			
12	19 MP	MDB-0217	12	17 MP	MDB-0075			
13	18 MP	MDB-0138	13	17 MP	MDB-0098			
14	17 MP	MDB-0149	14	17 MP	MDB-0156			
15	17 MP	MDB-0189	15	17 MP	MDB-0253			
16	17 MP	MDB-0215	16	17 MP	MDB-0254			
17	17 MP	MDB-0224	17	17 MP	MDB-0049			
18	17 MP	MDB-0250	18	17 MP	MDB-0069			
19	17 MP	MDB-0012	19	17 MP	MDB-0077			
20	14 MP	MDB-0259	20	17 MP	MDB-0078			
21	13 MP	MDB-0059	21	17 MP	MDB-0081			
22	11 MP	MDB-0218	22	17 MP	MDB-0094			
23	11 MP	MDB-0258	23	17 MP	MDB-0155			
24	9 MP	MDB-0246	24	17 MP	MDB-0239			
25	6 LP	MDB-0260	25	15 MP	MDB-0101			
26	5 LP	MDB-0131	26	15 MP	MDB-0080			
			27	14 MP	MDB-0203			
			28	13 MP	MDB-0115			
			29	13 MP	MDB-0210			
			30	12 MP	MDB-0082			
			31	12 MP	MDB-0242			
			32	10 MP	MDB-0240			
			33	8 LP	MDB-0159			
			34	5 LP	MDB-0157			

TN3a			FN1			UNT1		
Rank	Priority	BASIN_ID	Rank	Priority	BASIN_ID	Rank	Priority	BASIN_ID
1	22 HP	MDB-0035	1	28 HP	MDB-0143	1	22 HP	MDB-0072
2	19 MP	MDB-0043	2	22 HP	MDB-0231	2	22 HP	MDB-0086
3	19 MP	MDB-0125	3	22 HP	MDB-0229	3	22 HP	MDB-0087
4	17 MP	MDB-0045	4	22 HP	MDB-0110	4	22 HP	MDB-0089
5	14 MP	MDB-0241	5	22 HP	MDB-0064	5	22 HP	MDB-0091
6	8 LP	MDB-0208	6	22 HP	MDB-0226	6	19 MP	MDB-0135
			7	22 HP	MDB-0121	7	19 MP	MDB-0062
			8	22 HP	MDB-0118	8	19 MP	MDB-0084
			9	22 HP	MDB-0112	9	19 MP	MDB-0090
			10	22 HP	MDB-0111	10	18 MP	MDB-0128
			11	22 HP	MDB-0055	11	17 MP	MDB-0133
			12	22 HP	MDB-0146	12	17 MP	MDB-0134
			13	21 HP	MDB-0160	13	11 MP	MDB-0129
			14	20 HP	MDB-0113	14	6 LP	MDB-0130
			15	19 MP	MDB-0225			
			16	19 MP	MDB-0148			
			17	18 MP	MDB-0142			
			18	17 MP	MDB-0257			
			19	17 MP	MDB-0230			
			20	17 MP	MDB-0227			
			21	17 MP	MDB-0120			
			22	17 MP	MDB-0116			
			23	17 MP	MDB-0108			
			24	17 MP	MDB-0106			
			25	17 MP	MDB-0063			
			26	17 MP	MDB-0119			
			27	17 MP	MDB-0220			
			28	17 MP	MDB-0117			
			29	17 MP	MDB-0107			
			30	17 MP	MDB-0056			
			31	15 MP	MDB-0127			
			32	15 MP	MDB-0109			
			33	14 MP	MDB-0244			
			34	12 MP	MDB-0228			
			35	11 MP	MDB-0243			
			36	11 MP	MDB-0223			
			37	11 MP	MDB-0141			
			38	10 MP	MDB-0144			
			39	9 MP	MDB-0248			
			40	9 MP	MDB-0219			
			41	8 LP	MDB-0053			
			42	8 LP	MDB-0221			

UNT2			N2		
Rank	Priority	BASIN_ID	Rank	Priority	BASIN_ID
1	25 HP	MDB-0039	1	17 MP	MDB-0011
2	22 HP	MDB-0044	2	11 MP	MDB-0245
3	22 HP	MDB-0065			
4	22 HP	MDB-0066			
5	22 HP	MDB-0068			
6	22 HP	MDB-0009			
7	22 HP	MDB-0067			
8	22 HP	MDB-0158			
9	17 MP	MDB-0050			
10	17 MP	MDB-0247			
11	17 MP	MDB-0010			
12	17 MP	MDB-0051			
13	17 MP	MDB-0052			
14	17 MP	MDB-0008			
15	13 MP	MDB-0216			
16	8 LP	MDB-0140			

HP = High Priority; MP = Medium Priority; LP = Low Priority



Figutre 3.1: Neshanic River Watershed, New Jersey

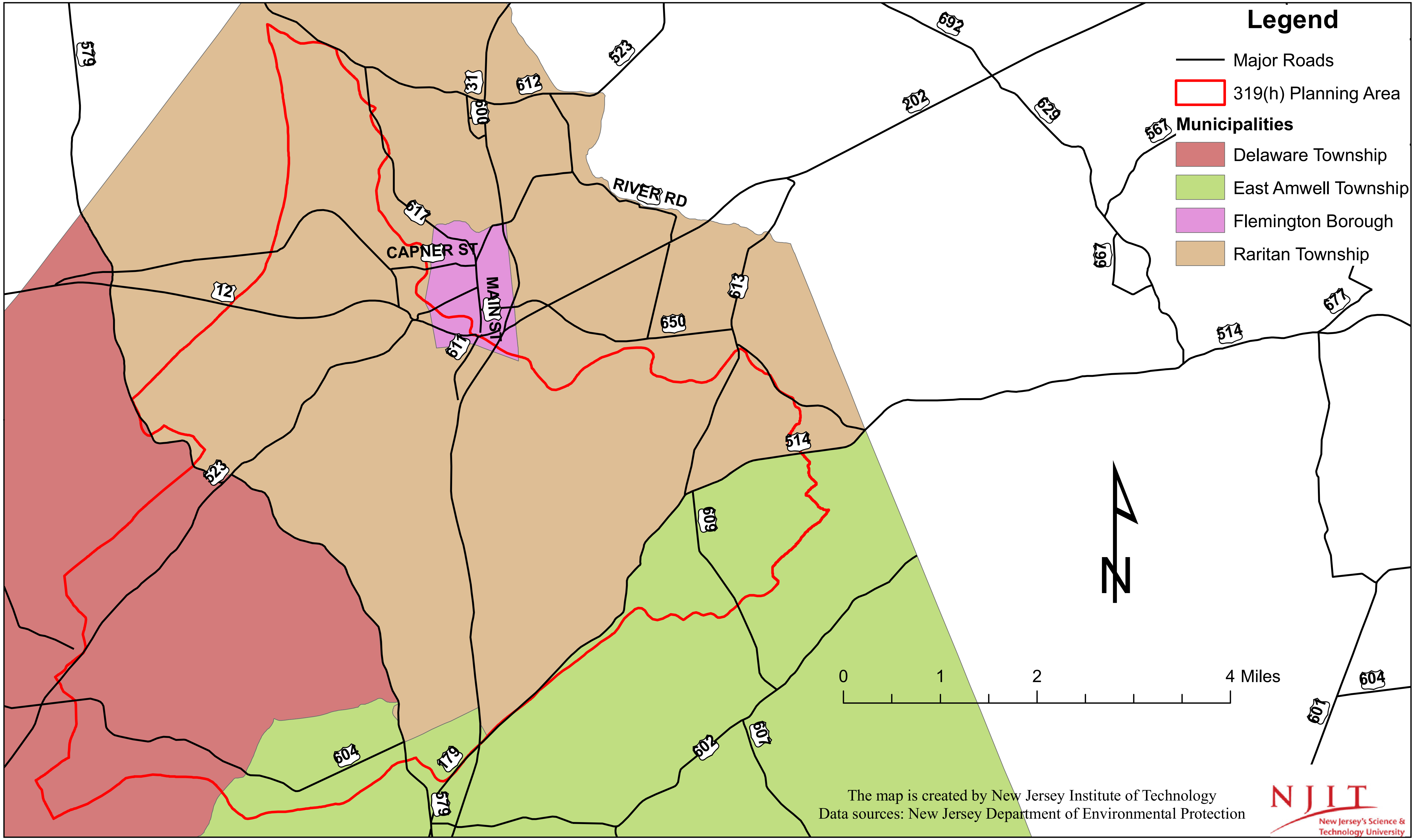


Figure 4.1: Transportation network in the Neshanic River Watershed

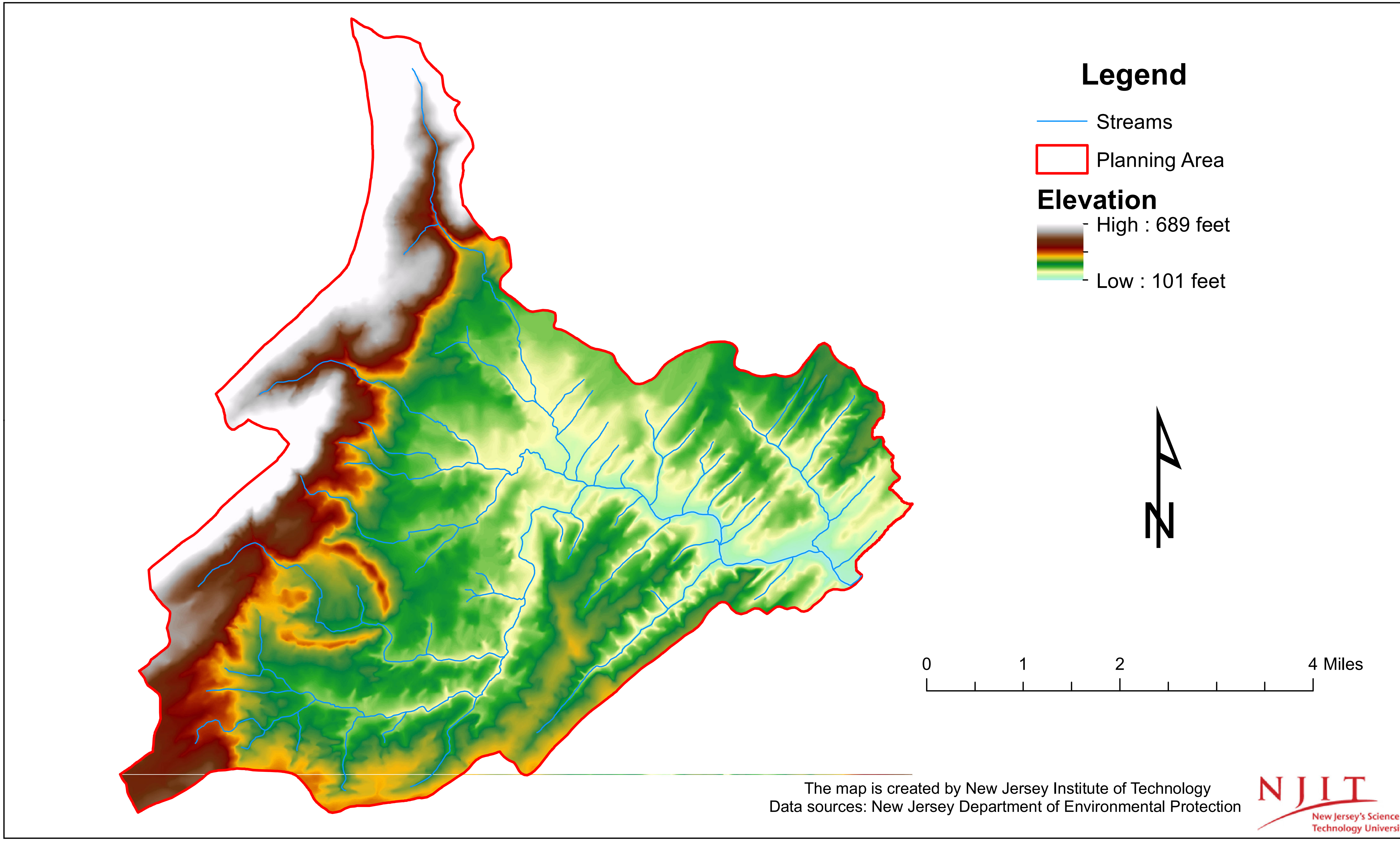


Figure 4.2: Topography in the Neshanic River Watershed

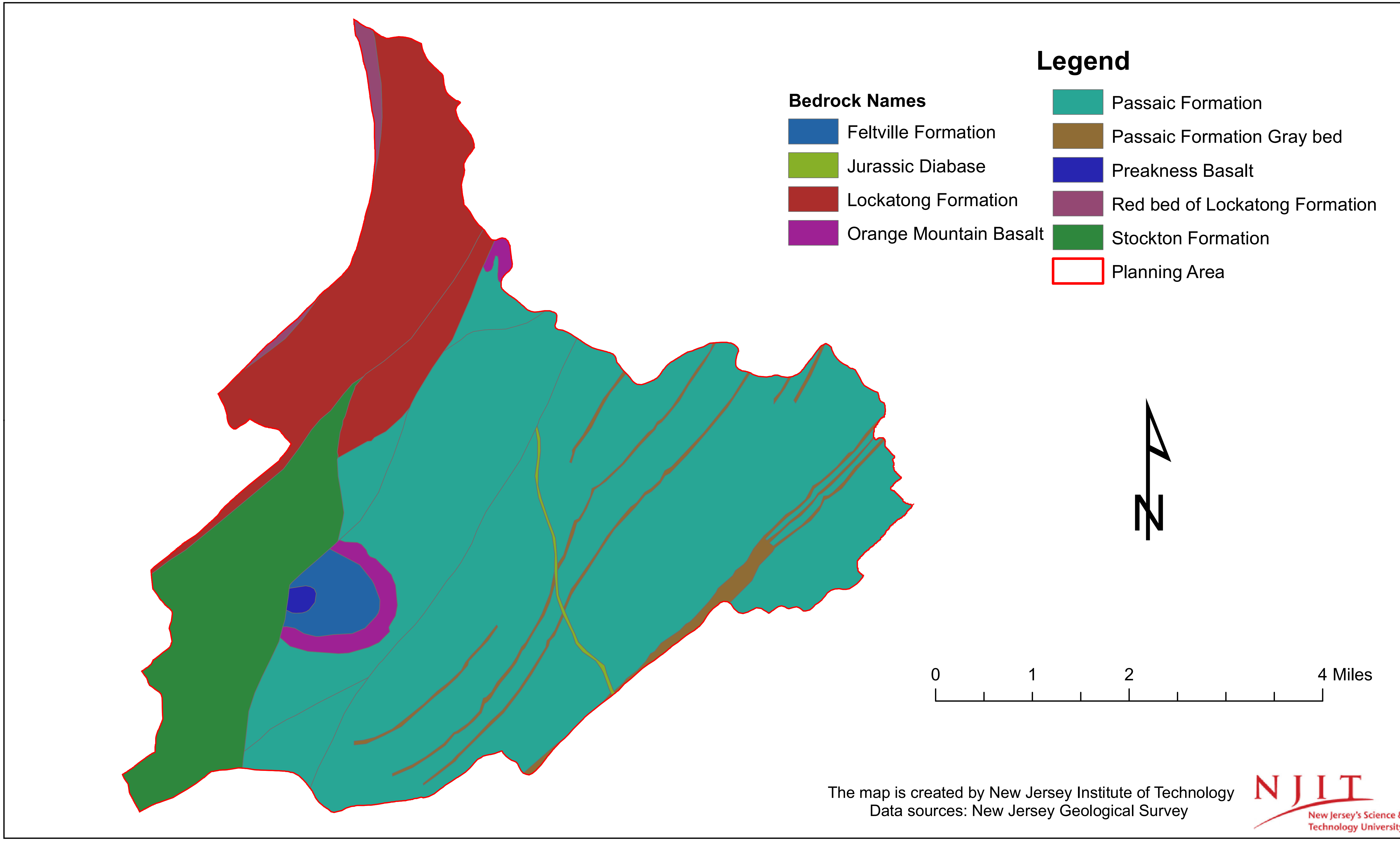


Figure 4.3: Spatial distribution of bedrock in the Neshanic River Watershed

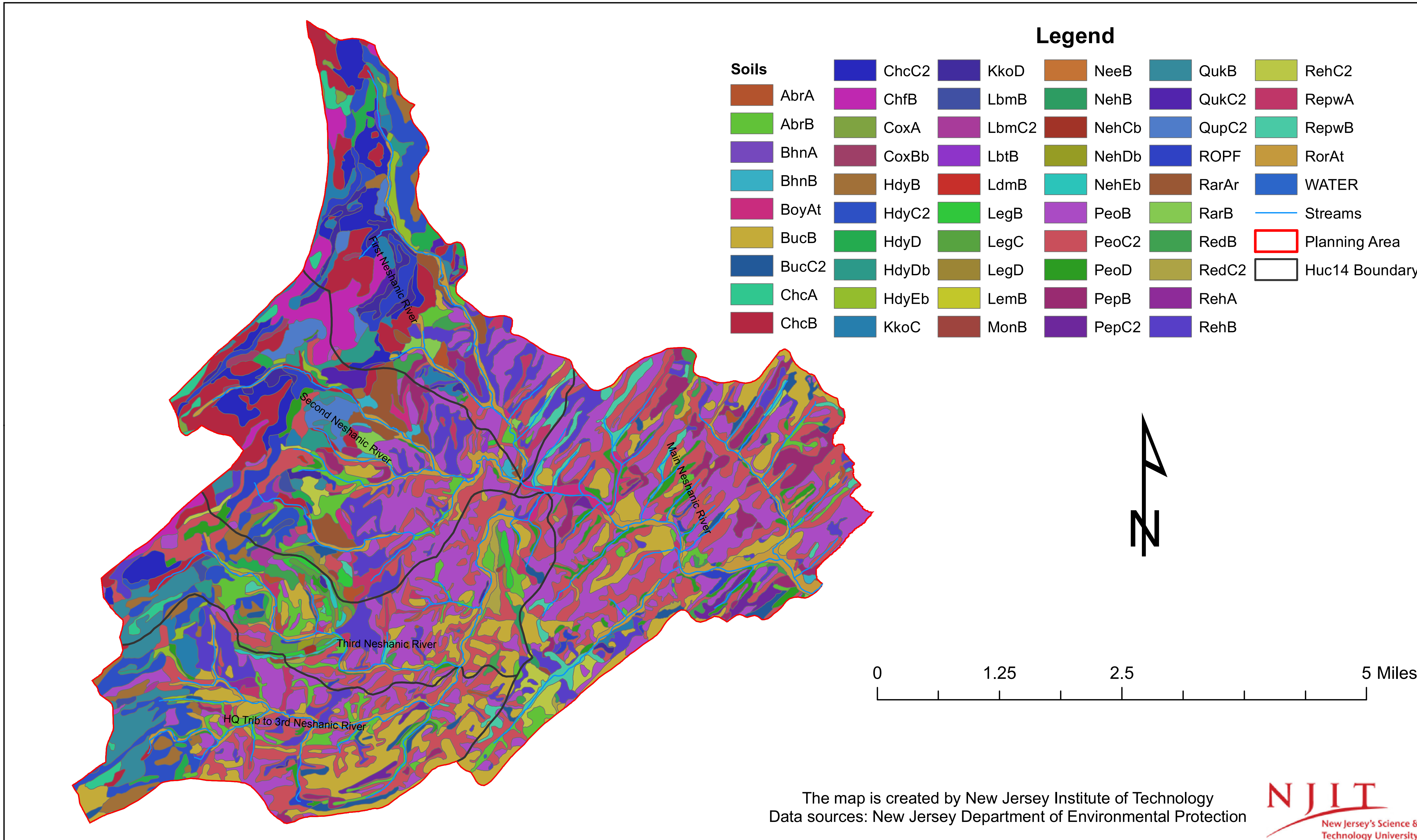


Figure 4.4: Distribution of soil types in the Neshanic River Watershed

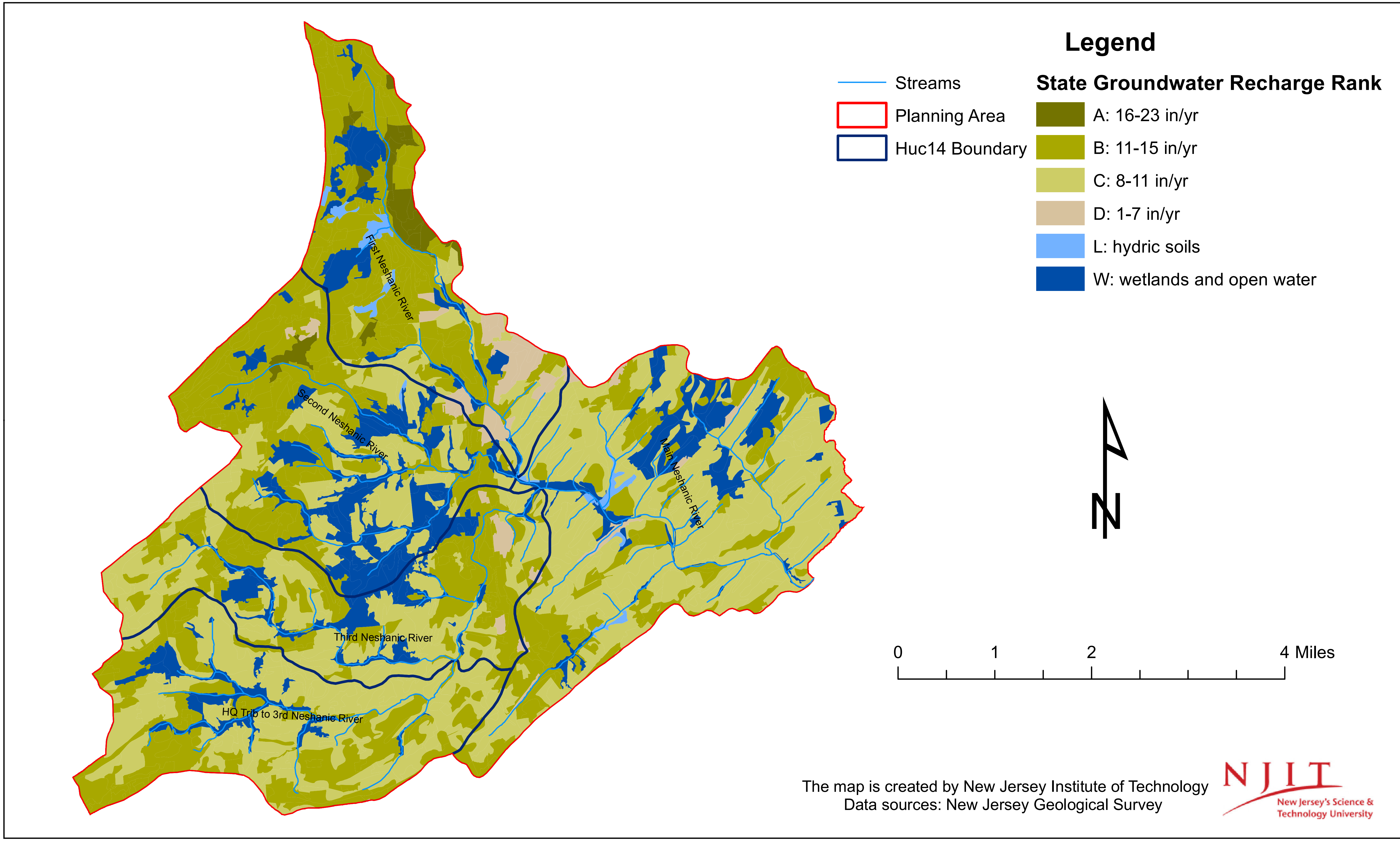


Figure 4.5: Spatial distribution of groundwater recharge in the Neshanic River Watershed

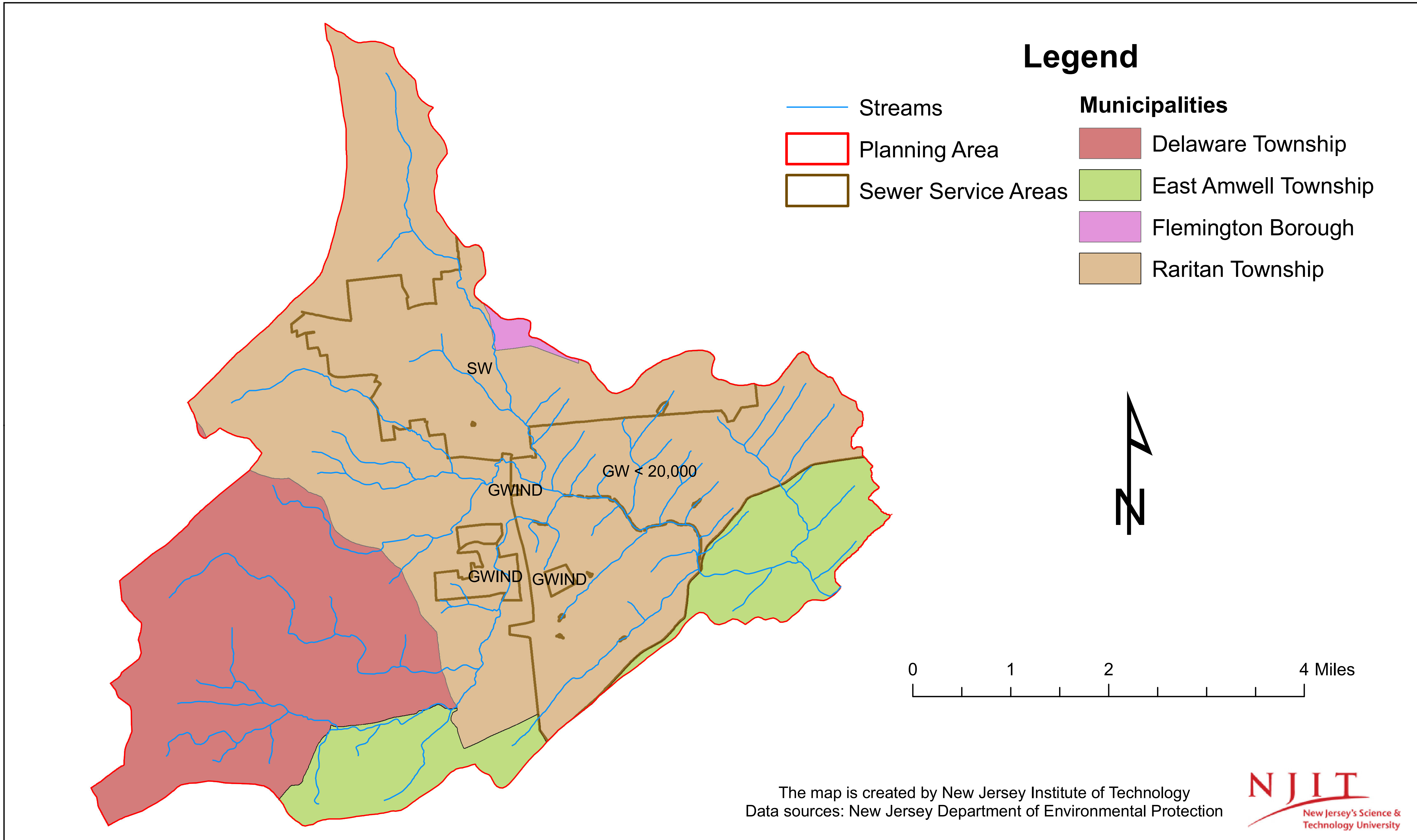


Figure 4.6: Spatial distribution of sewer service areas in the Neshanic River Watershed

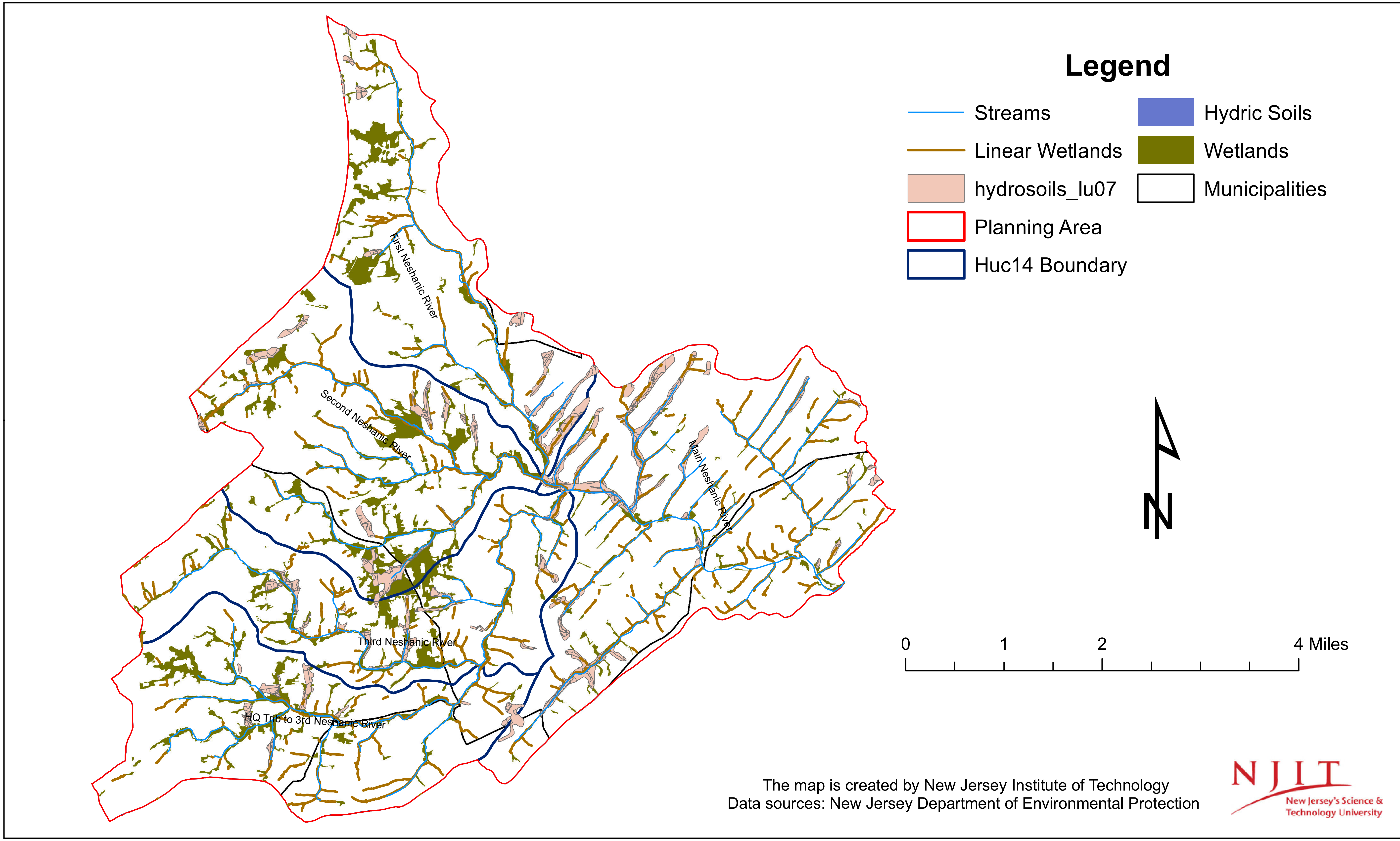


Figure 4.8: Spatial distribution of hydric soils, linear wetlands and wetlands in the Neshanic River Watershed

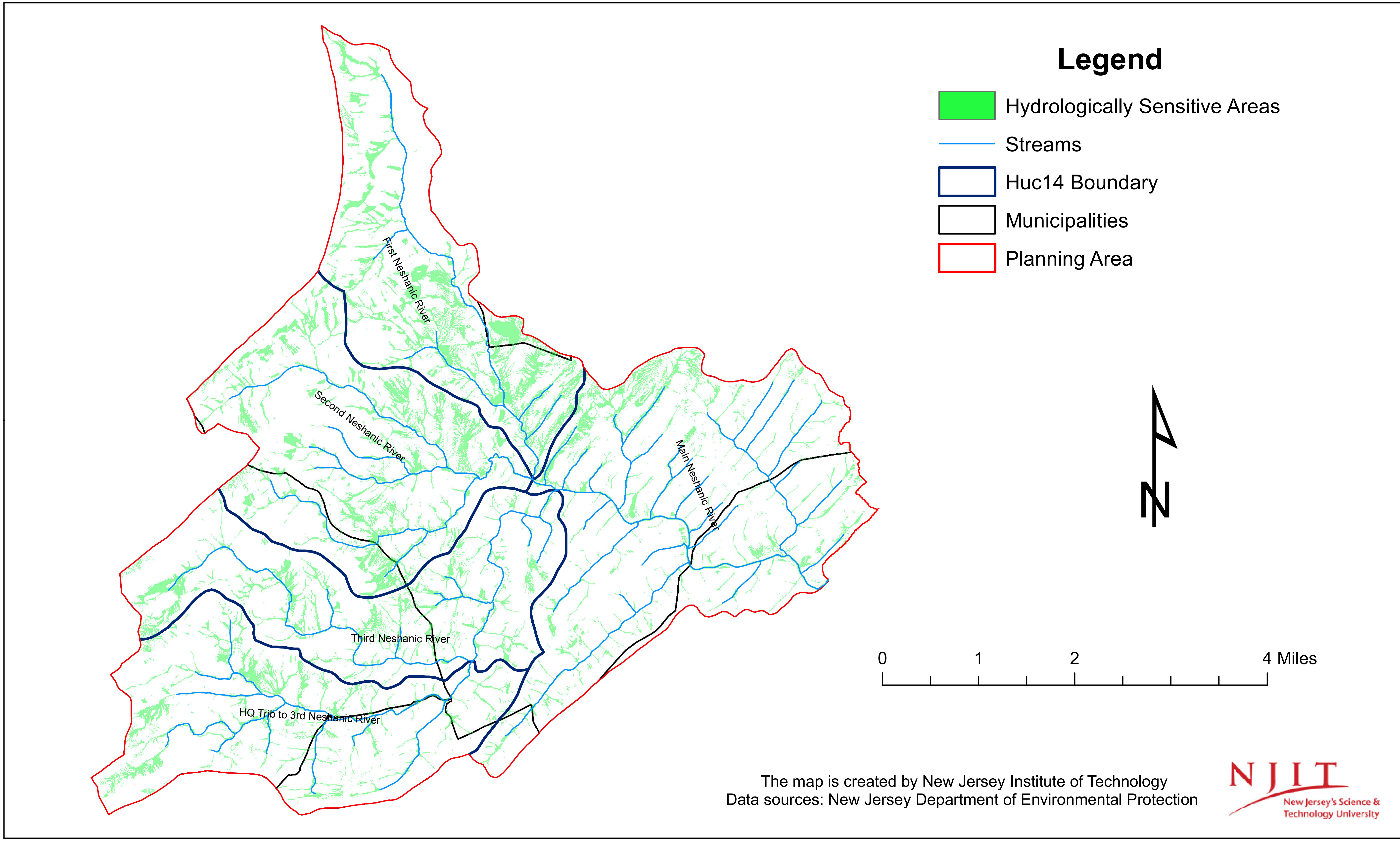


Figure 4.9: Spatial distribution of hydrologically sensitive areas in the Neshanic River Watershed

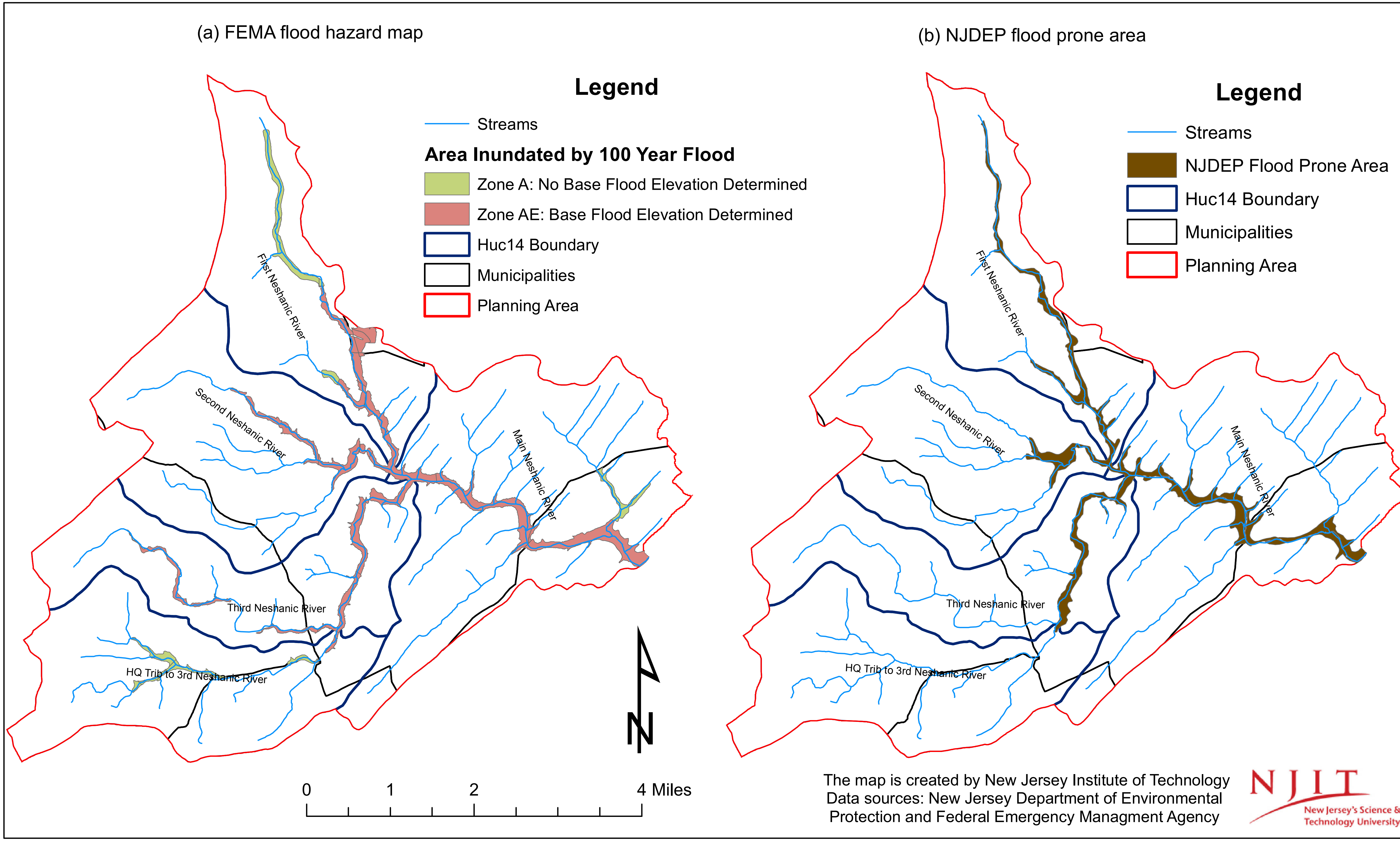


Figure 4.10: Comparison between (a) FEMA flood hazard map and (b) NJDEP flood prone area map in the Neshanic River Watershed

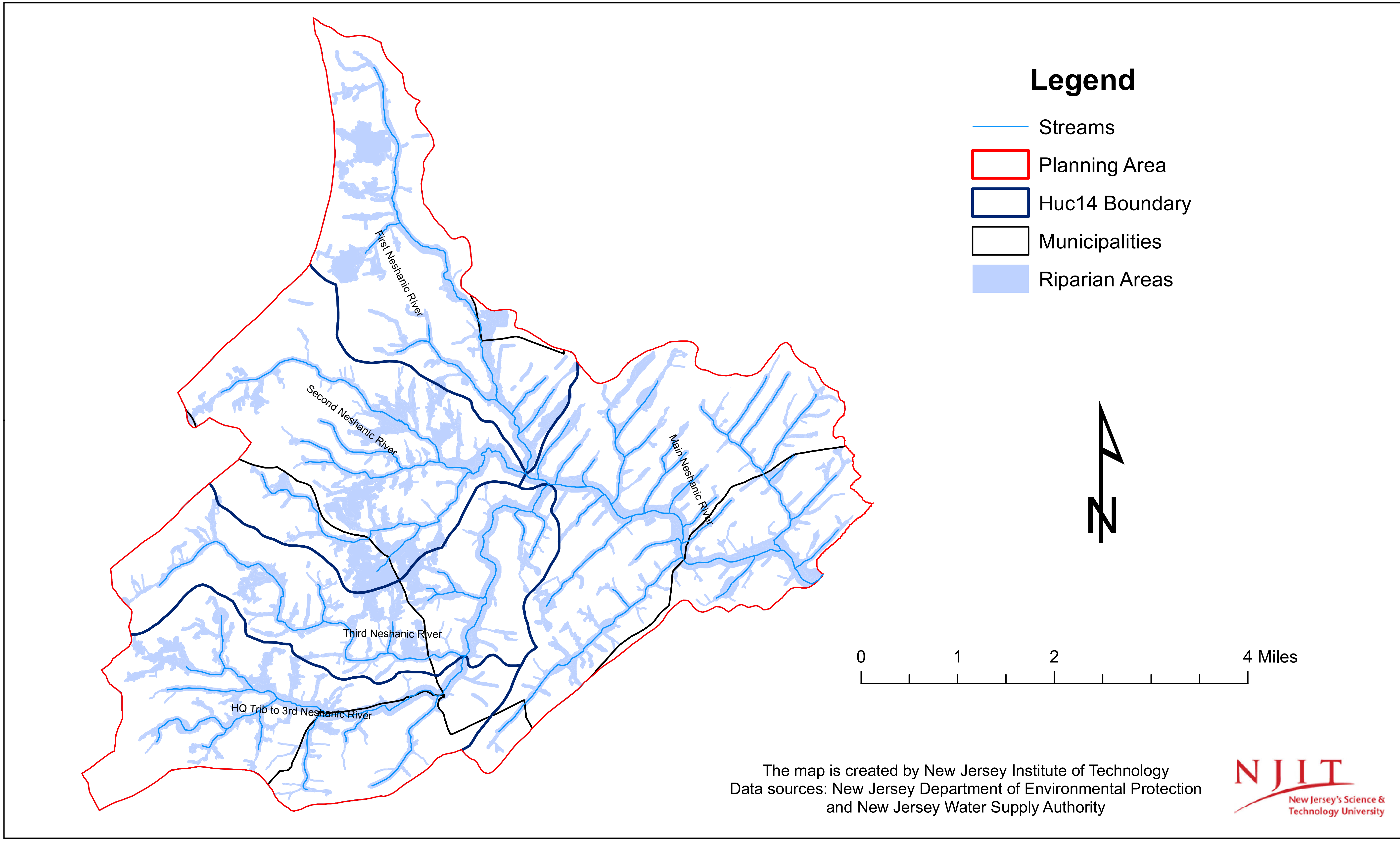


Figure 4.11: Spatial distribution of the riparian areas in the Neshanic River Watershed

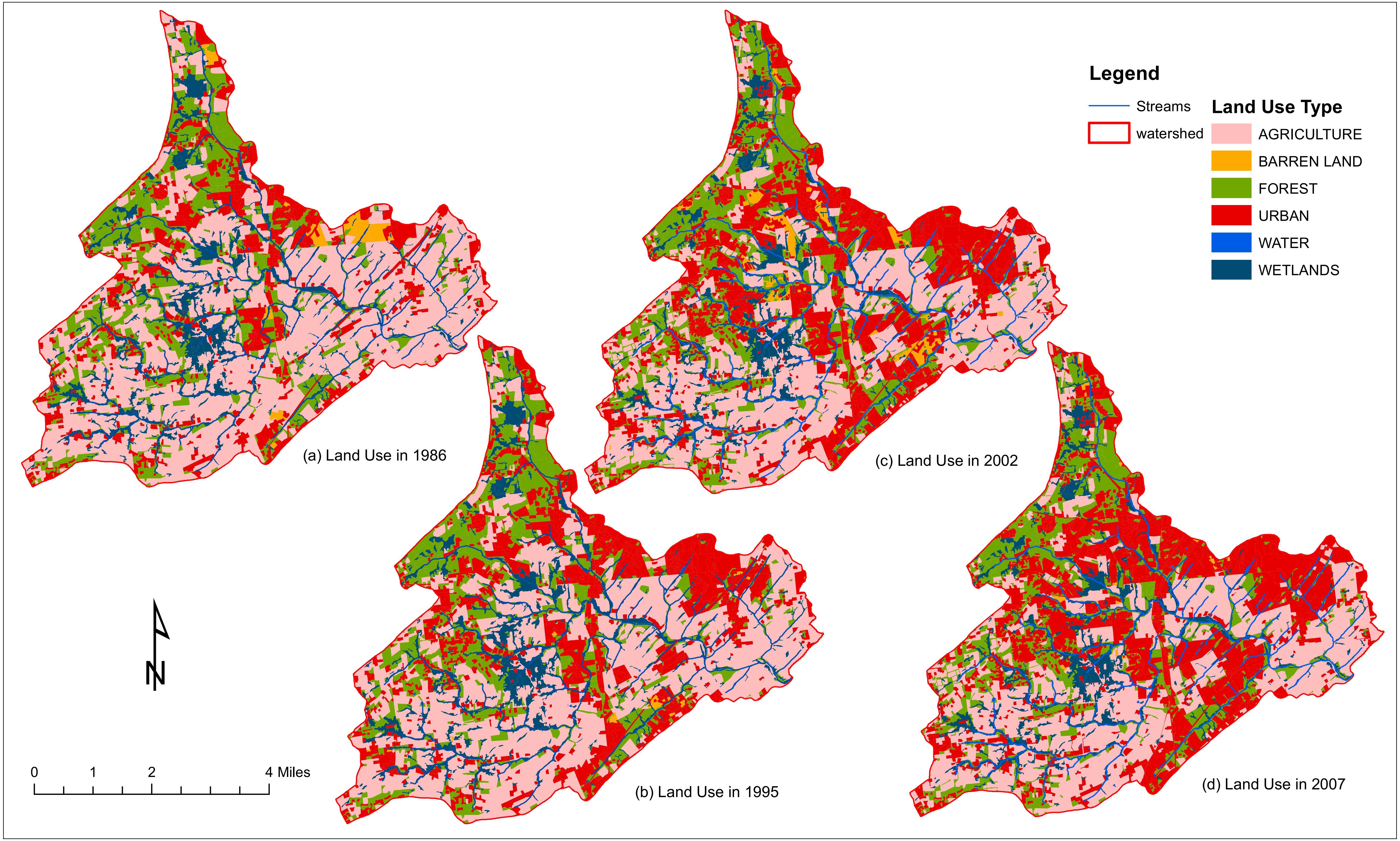


Figure 4.12: Spatial distribution of land uses in the Neshanic River Watershed, 1986,1995, 2002 and 2007

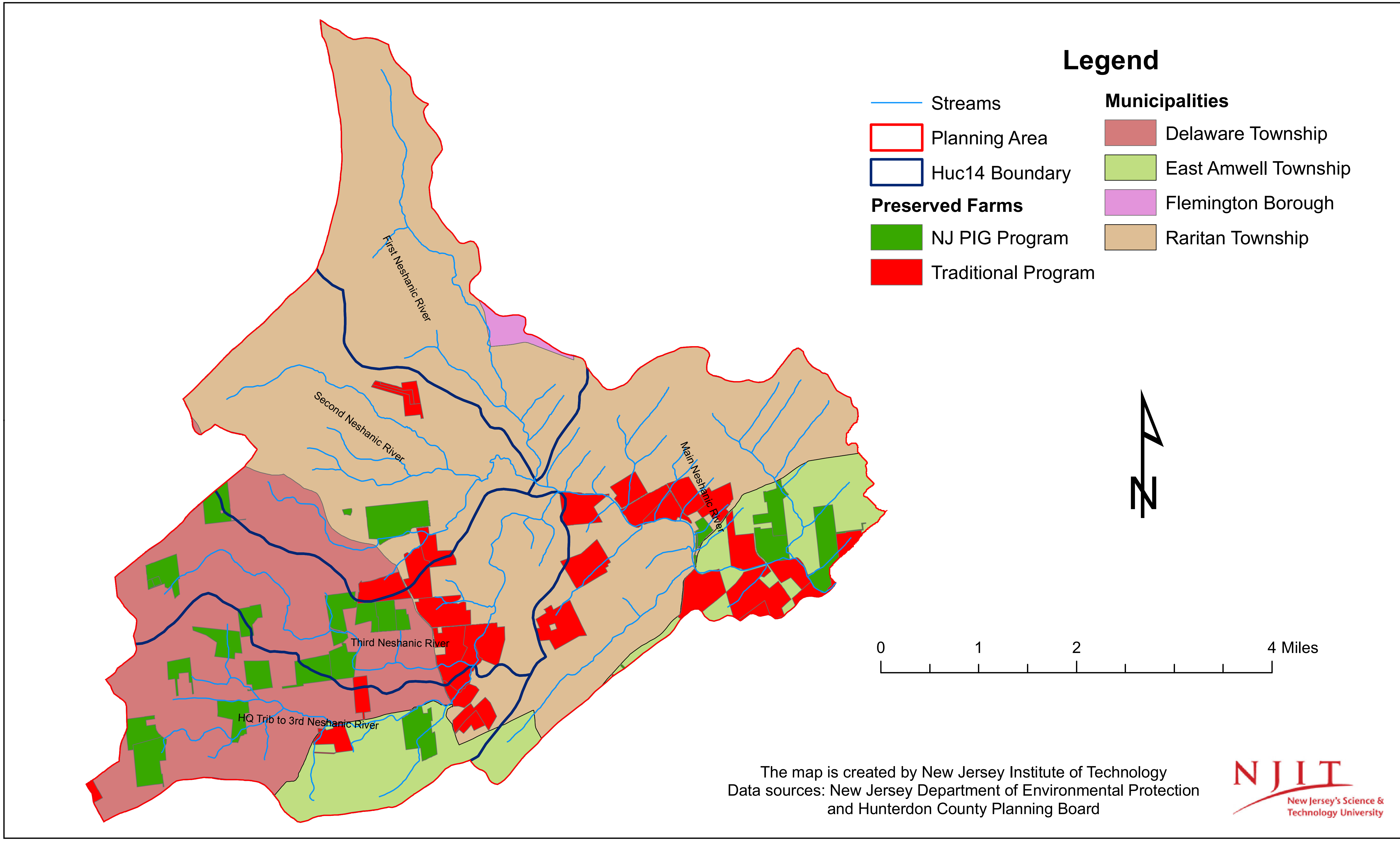


Figure 4.13: Spatial distribution of preserved farmlands in the Neshanic River Watershed

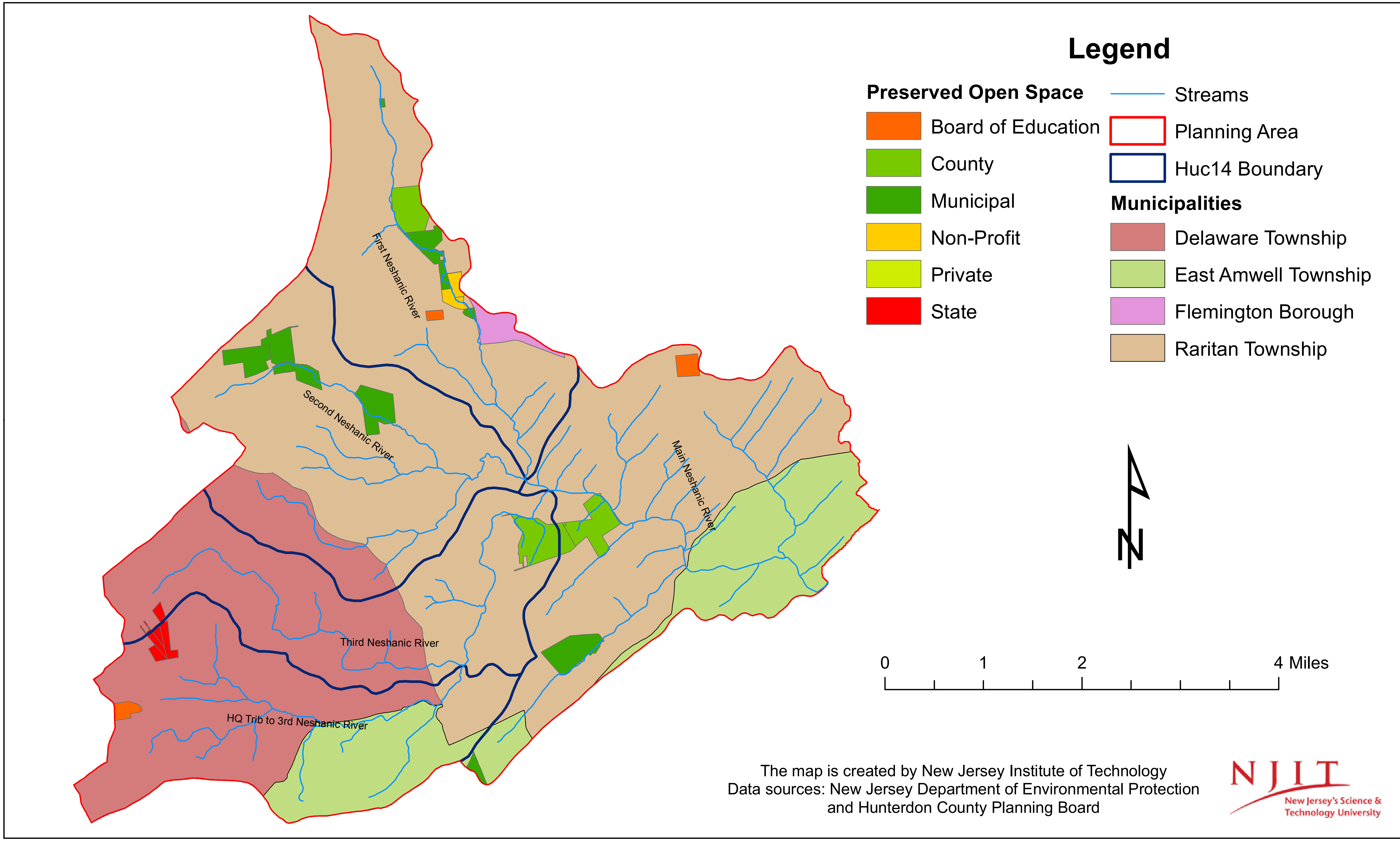


Figure 4.14: Spatial distribution of preserved open space in the Neshanic River Watershed

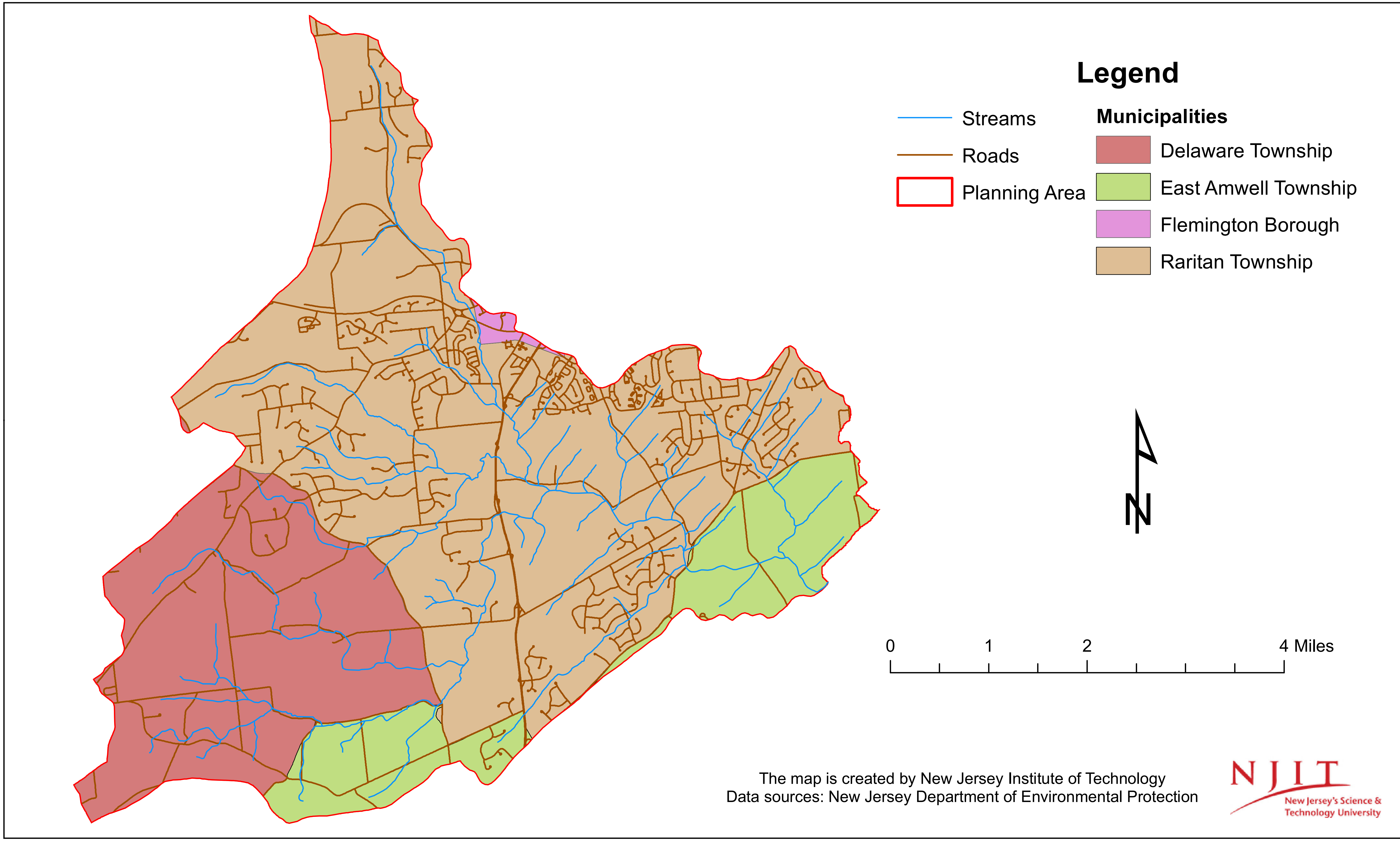


Figure 5.1: Distribution of streams and roads in the Neshanic River Watershed

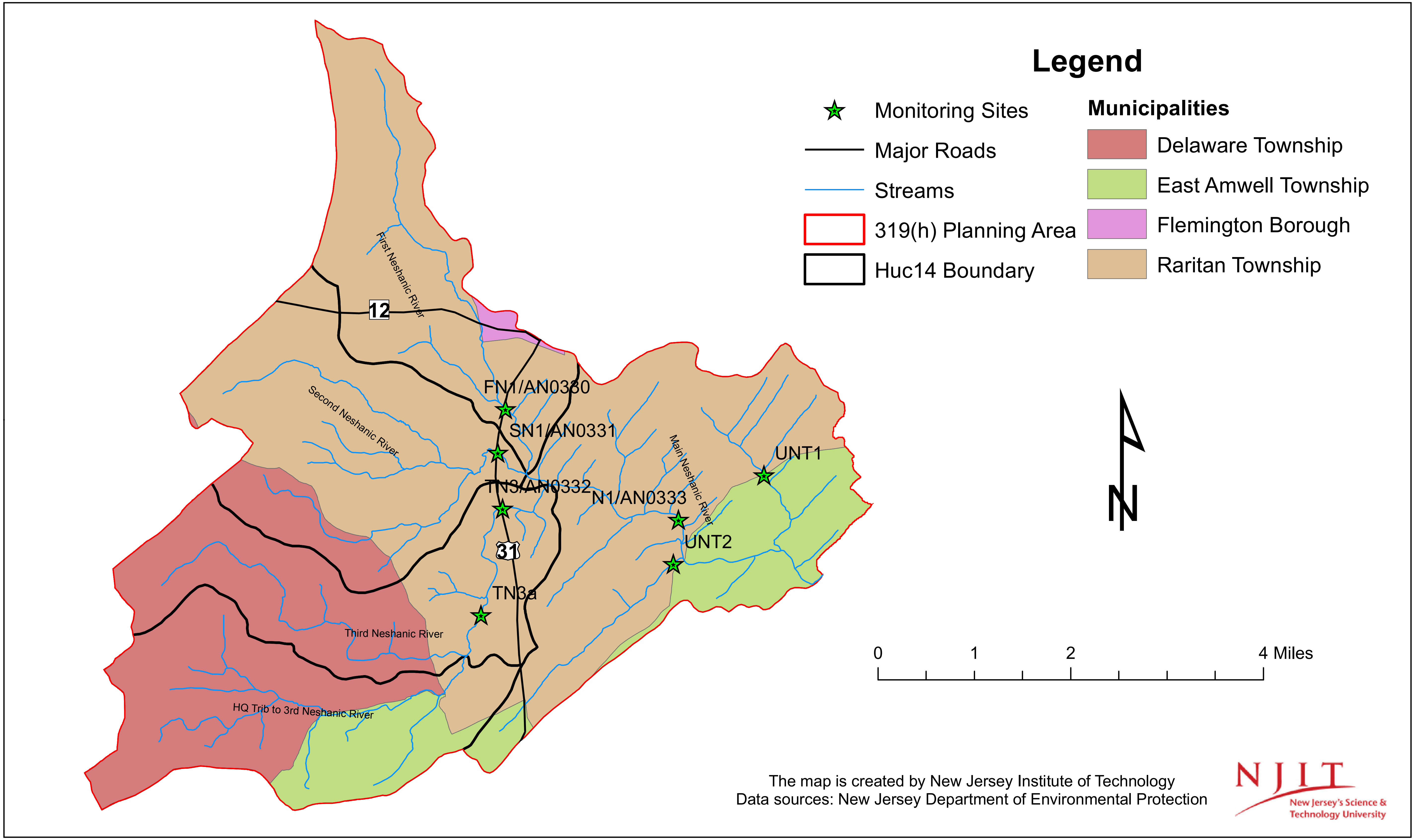


Figure 5.6: Location of seven monitoring stations in the Neshanic River Watershed

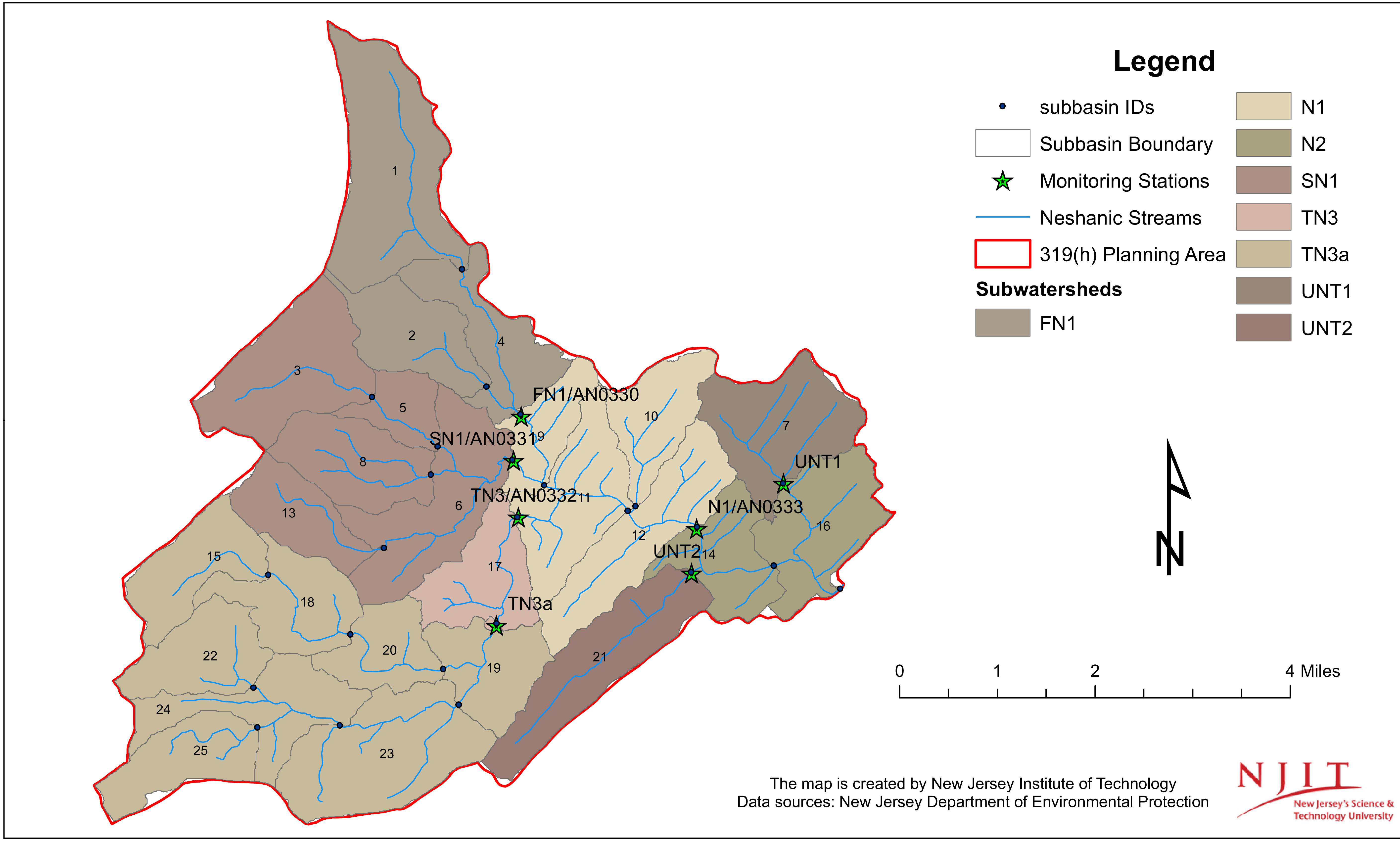


Figure 5.8: Water quality monitoring stations, subbasins and subwatersheds in the Neshanic River Watershed

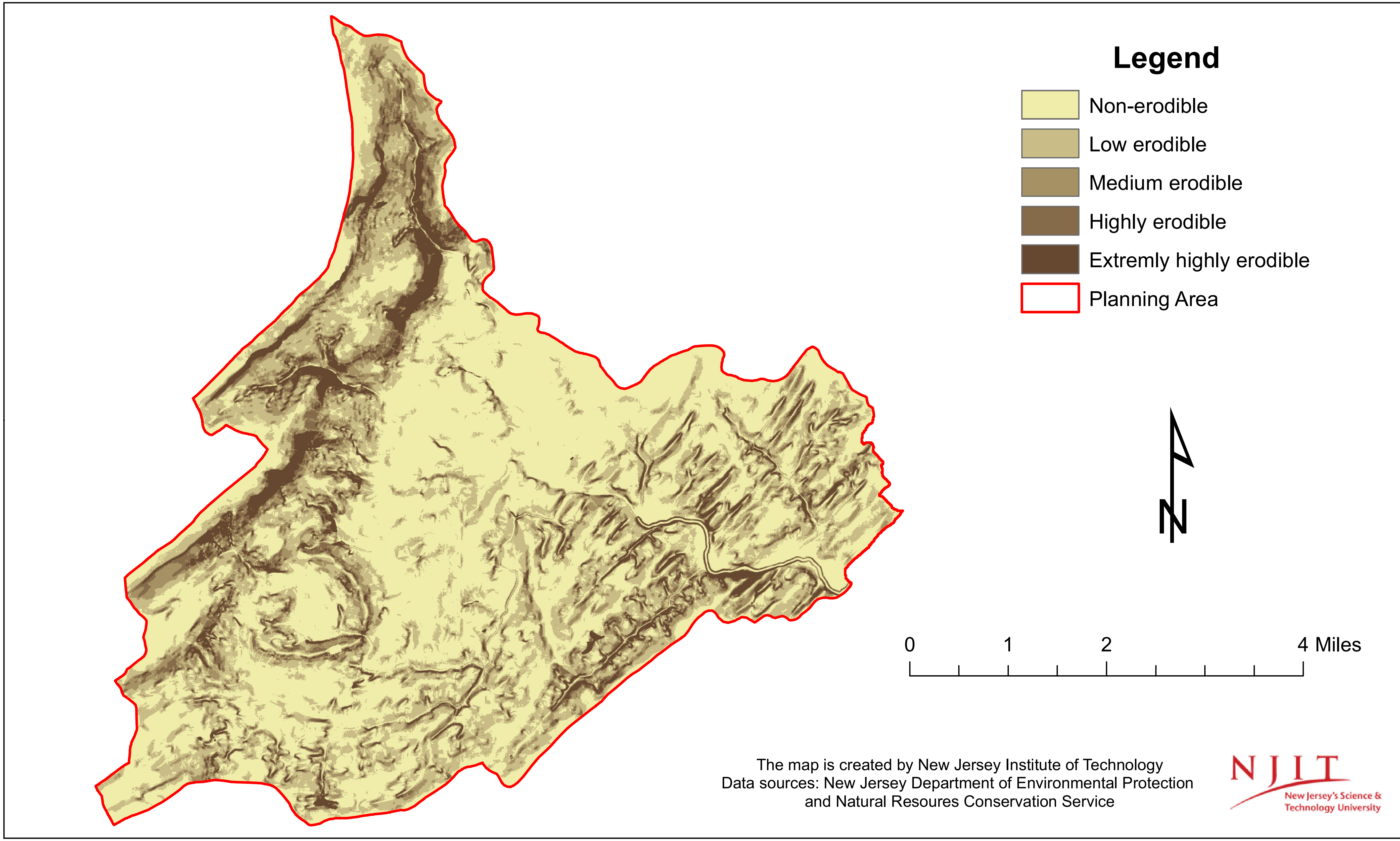


Figure 5.9: Distribution of soil erodibility classes in the Neshanic River Watershed

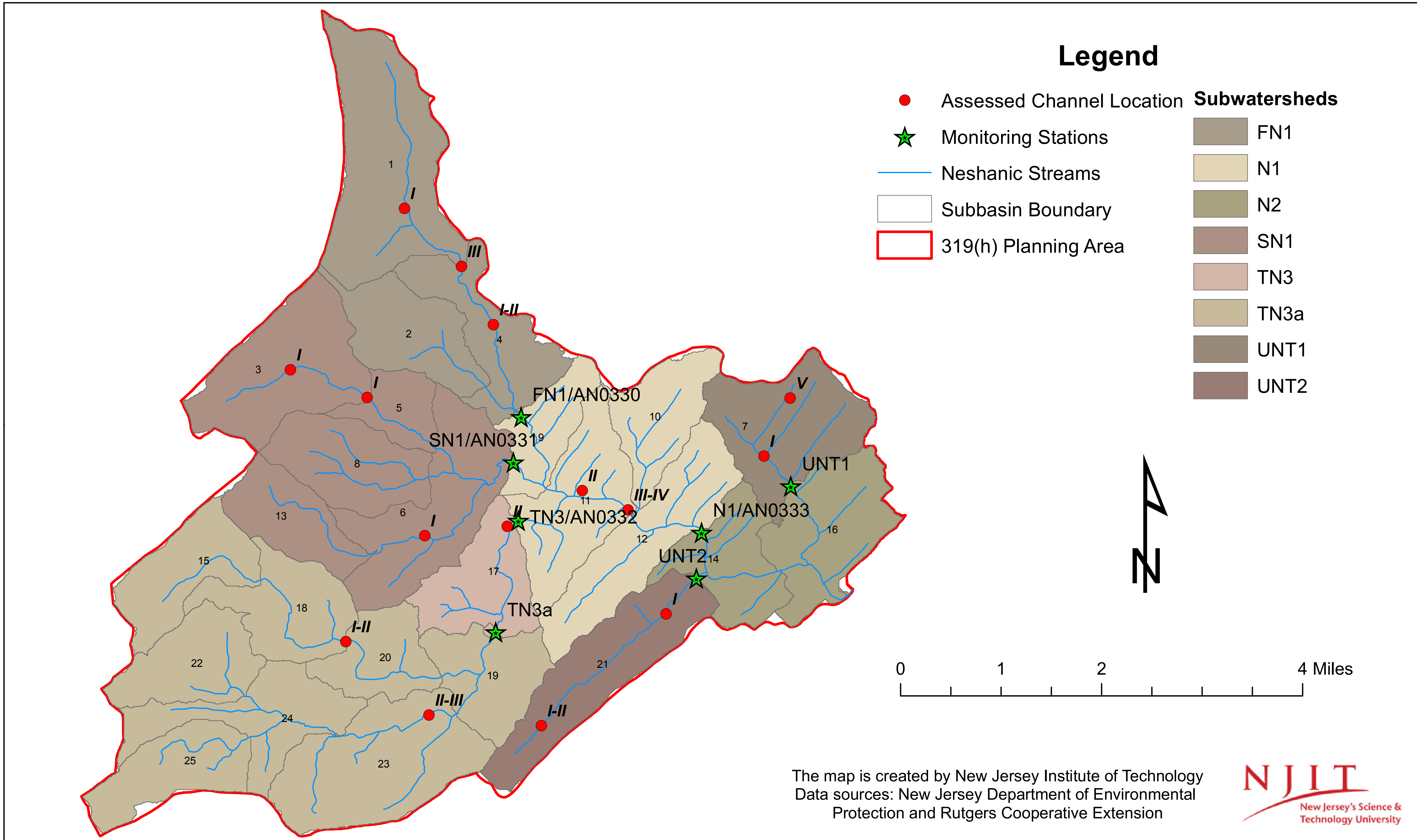


Figure 5.10: Channel stages at fifteen selected locations in the Neshanic River Watershed

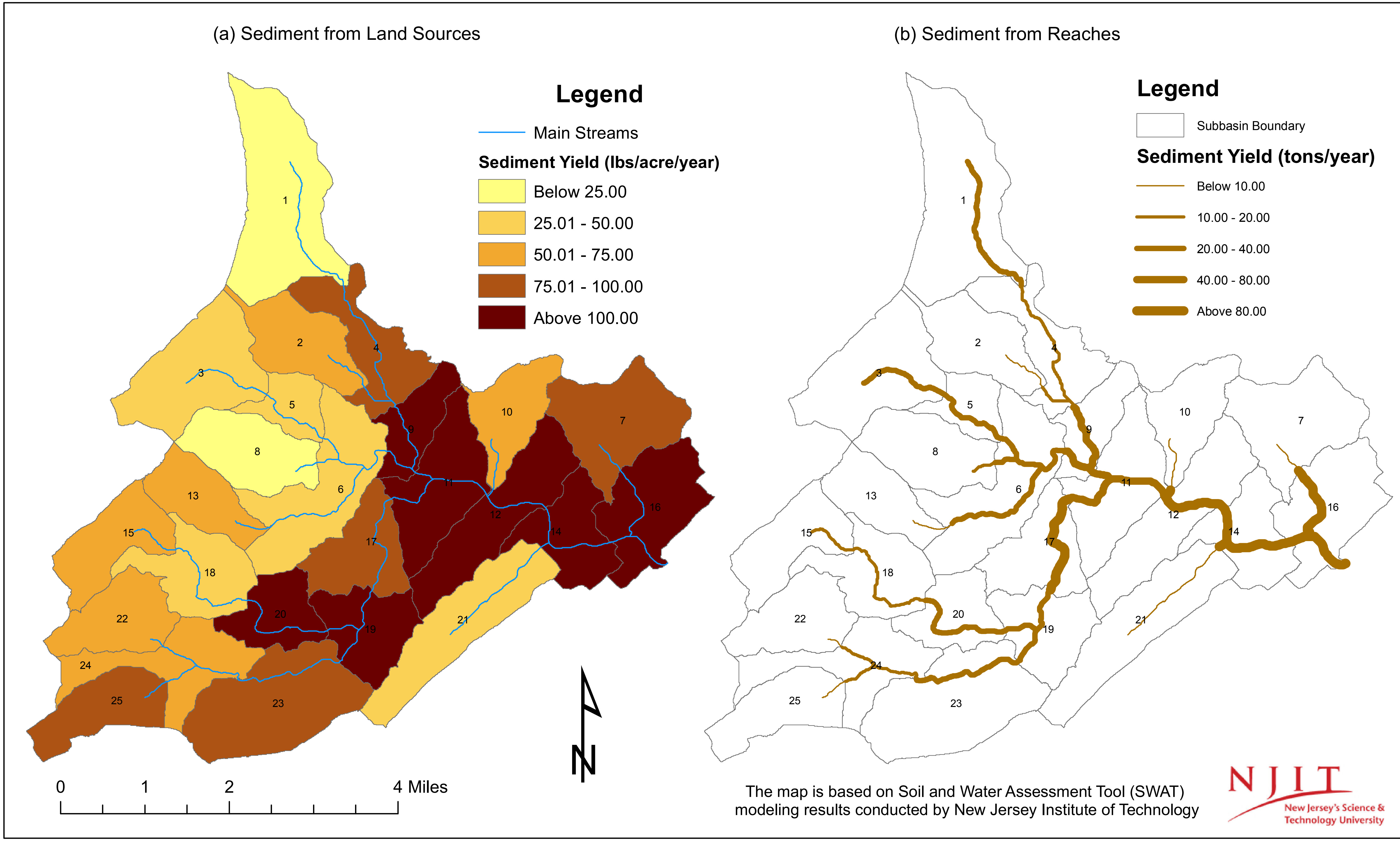


Figure 5.11: Sediment sources and yields in the Neshanic River Watershed

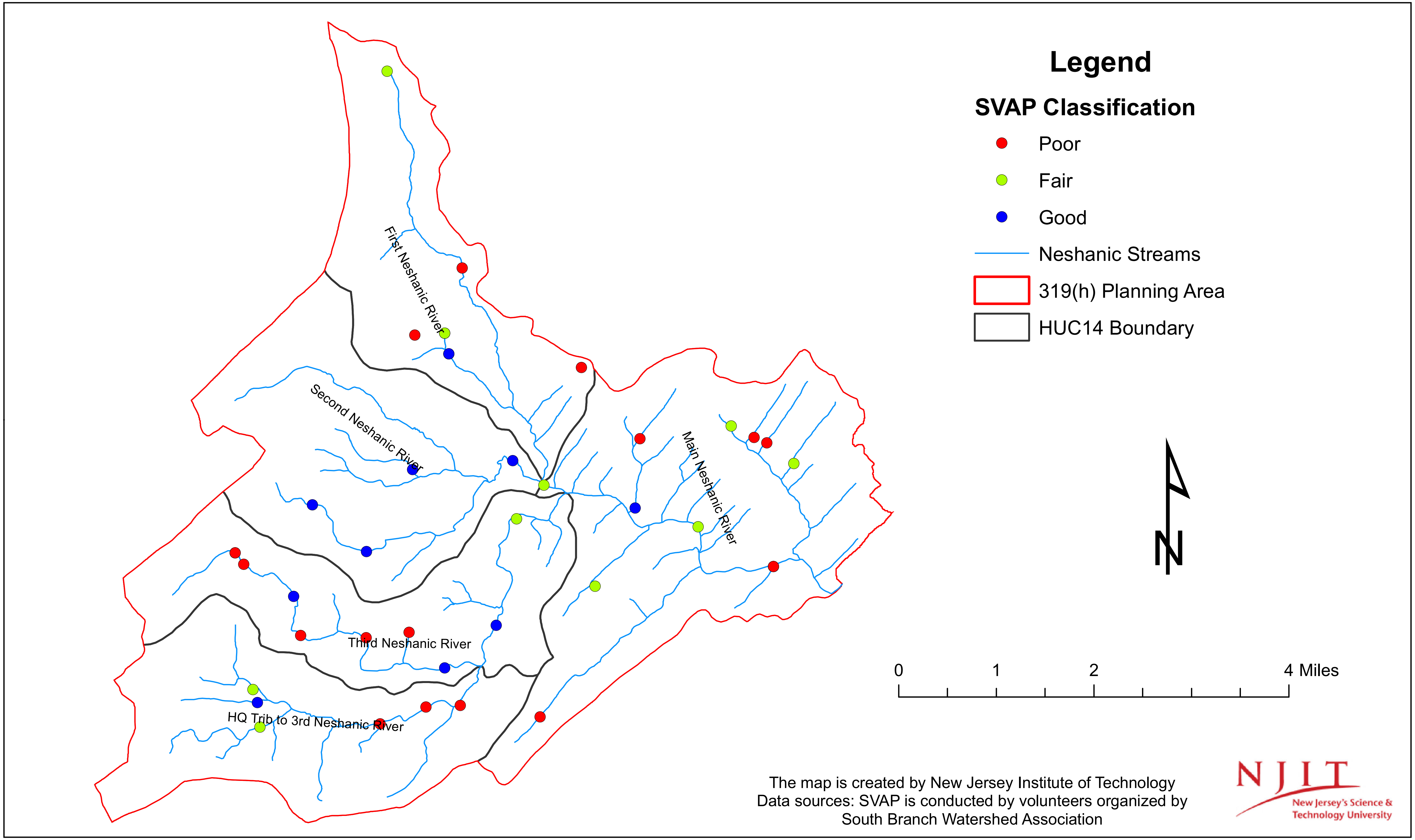


Figure 5.12: SVAP location and assessment results in the Neshanic River Watershed

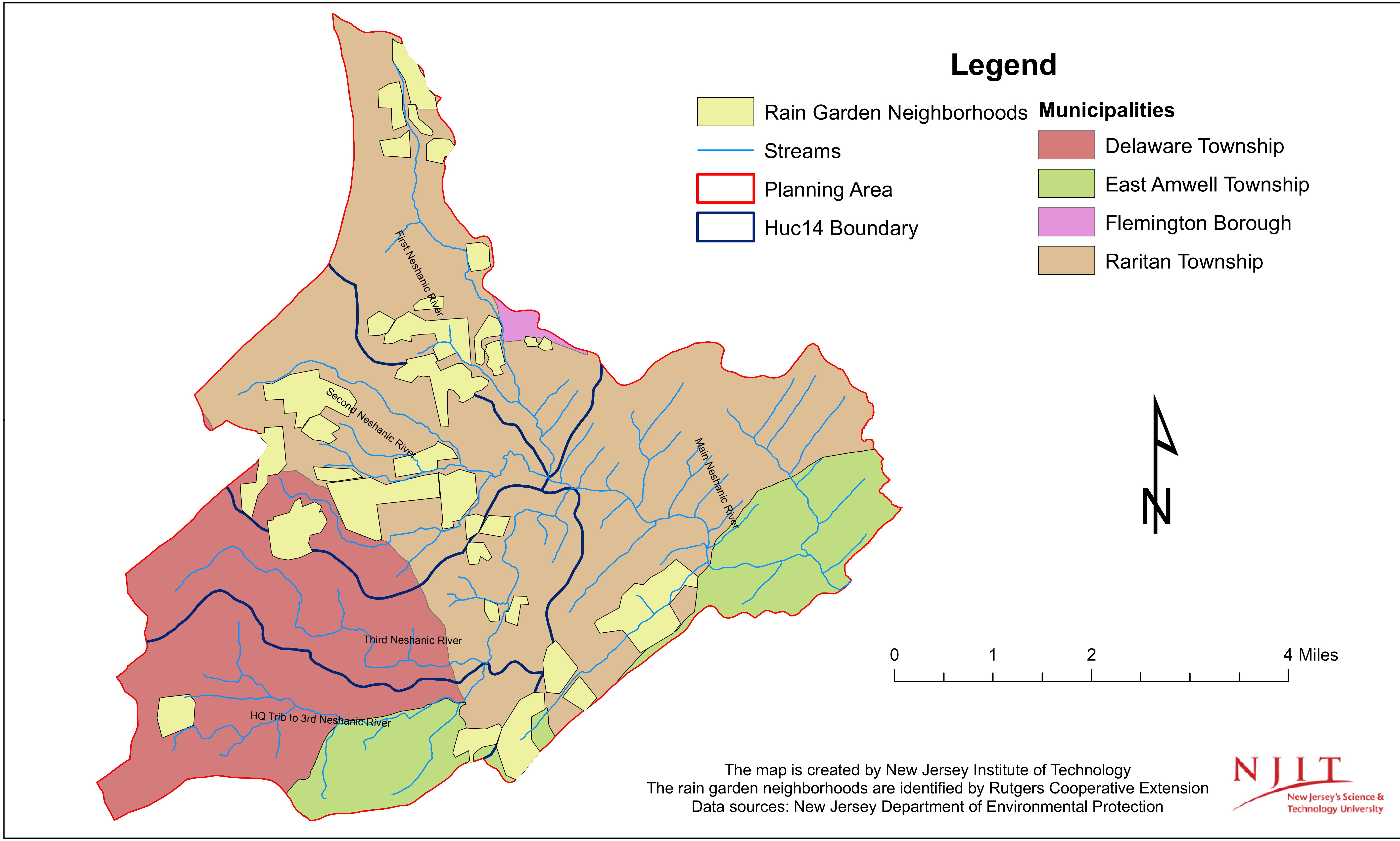


Figure 7.1: Location of potential neighborhoods for rain garden installation in the Neshanic River Watershed

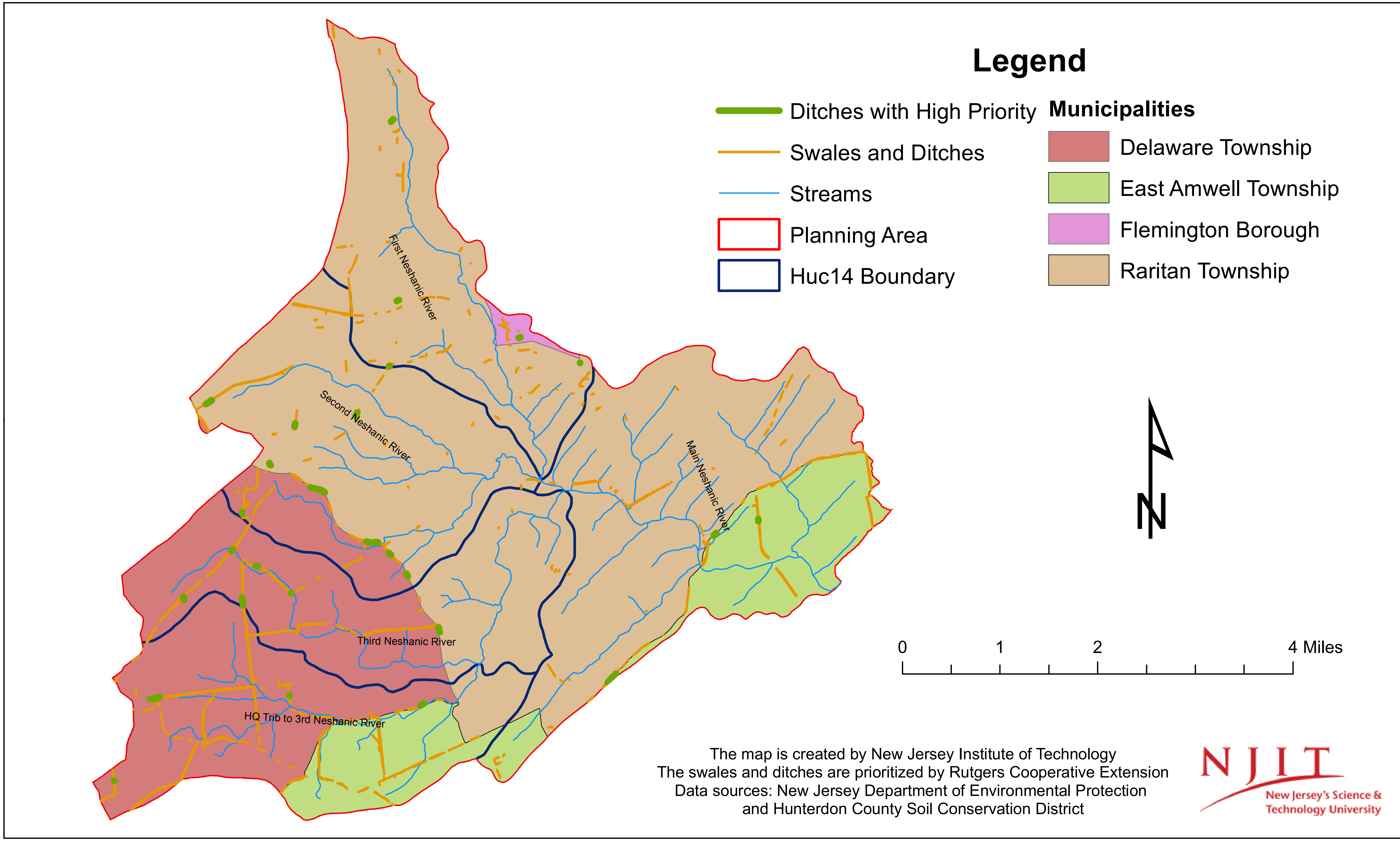


Figure 7.2: Location of swales and ditches in the Neshanic River Watershed

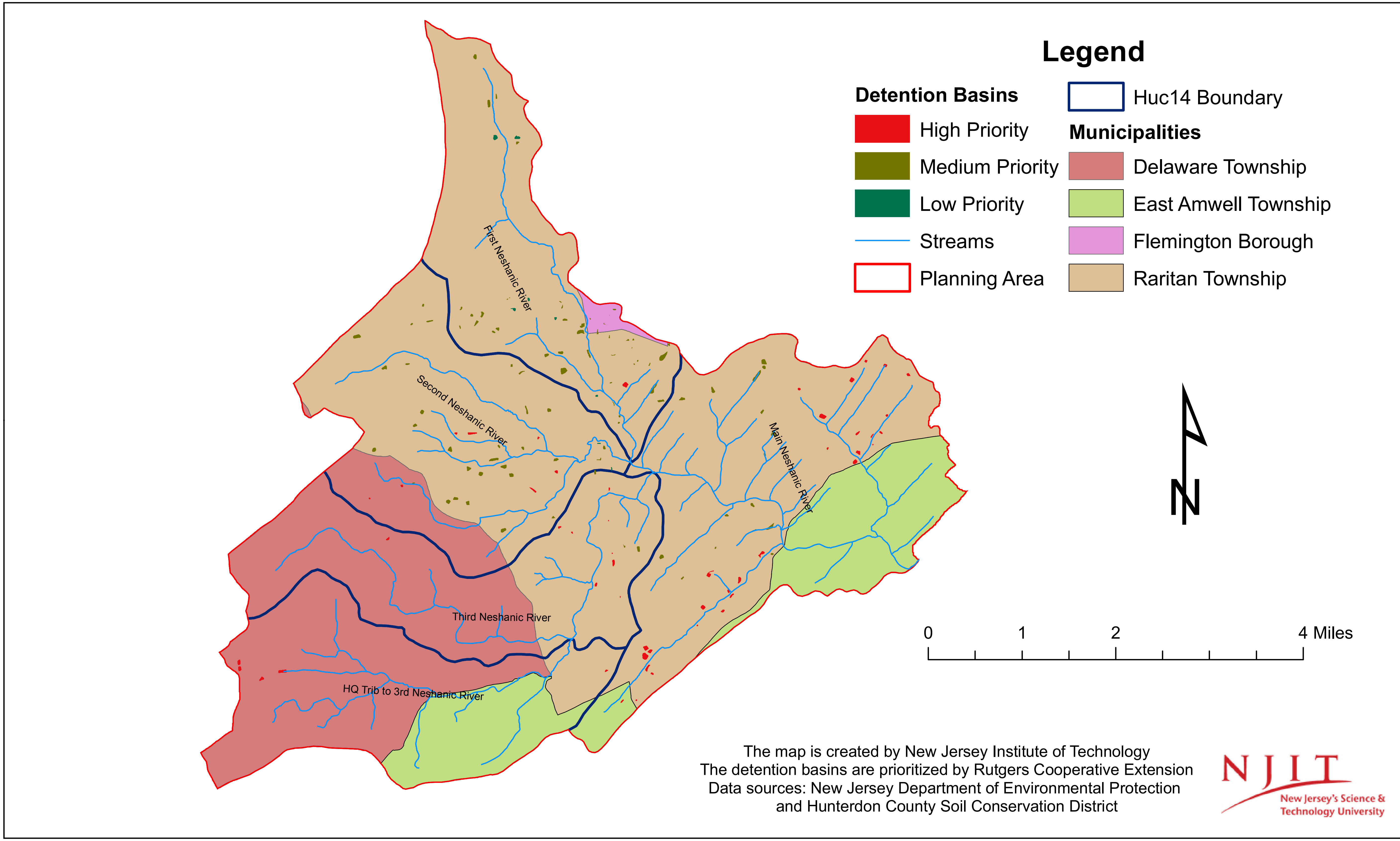


Figure 7.4: Location of detention basins with priority for retrofitting in the Neshanic River Watershed

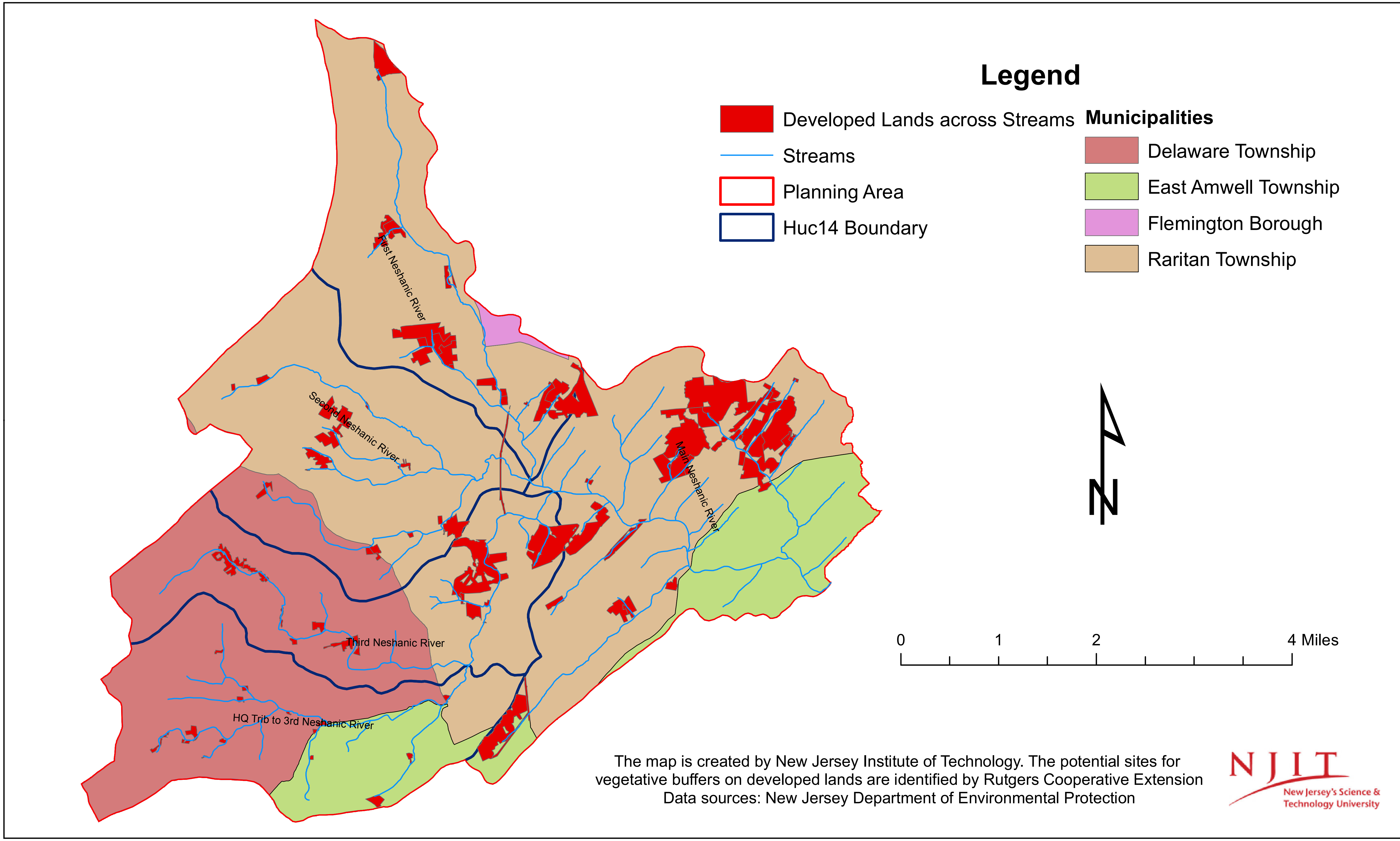


Figure 7.6: Potential sites for vegetative buffers on developed lands in the Neshanic River Watershed

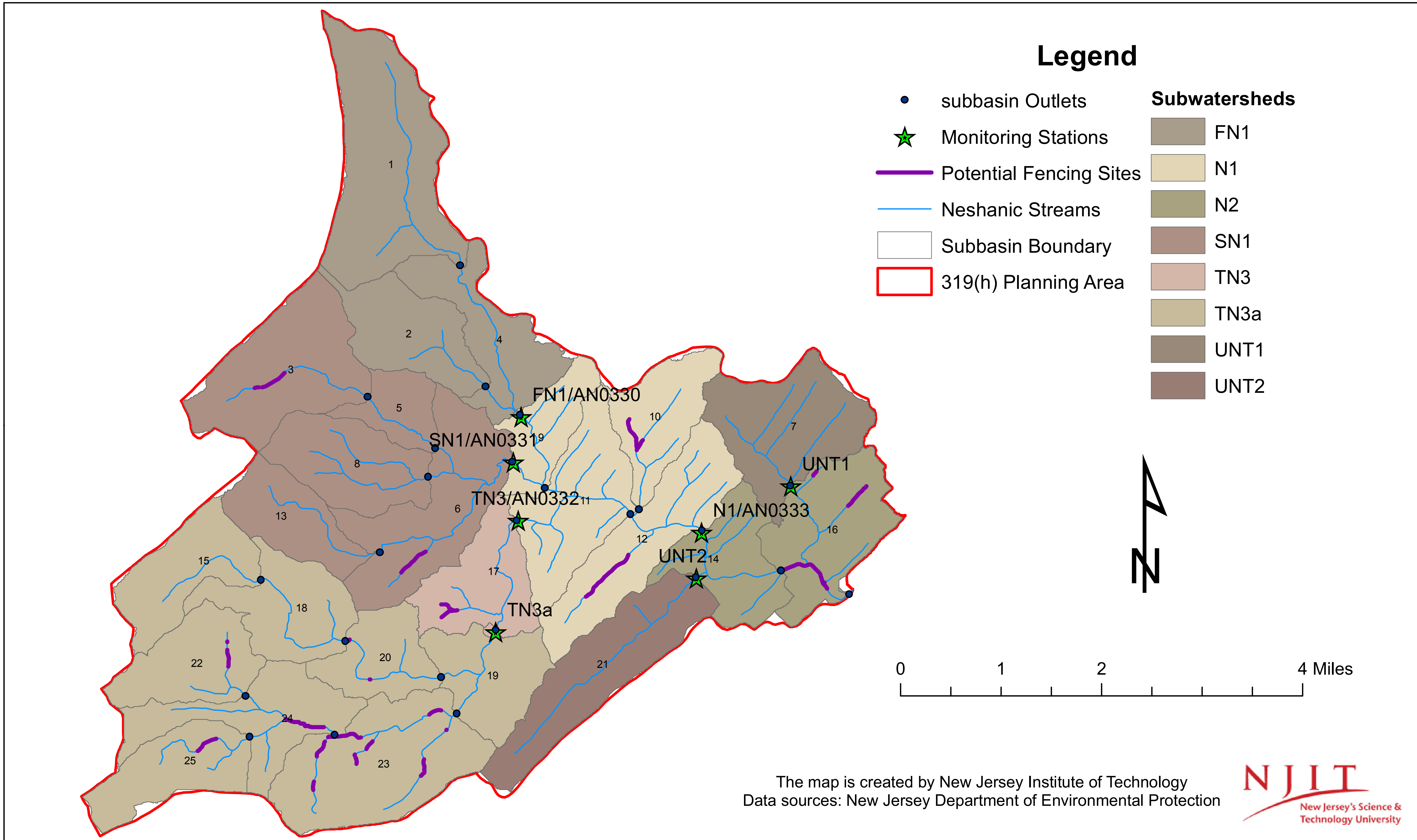


Figure 7.7: Potential sites for livestock exclusion fencing in the Neshanic River Watershed

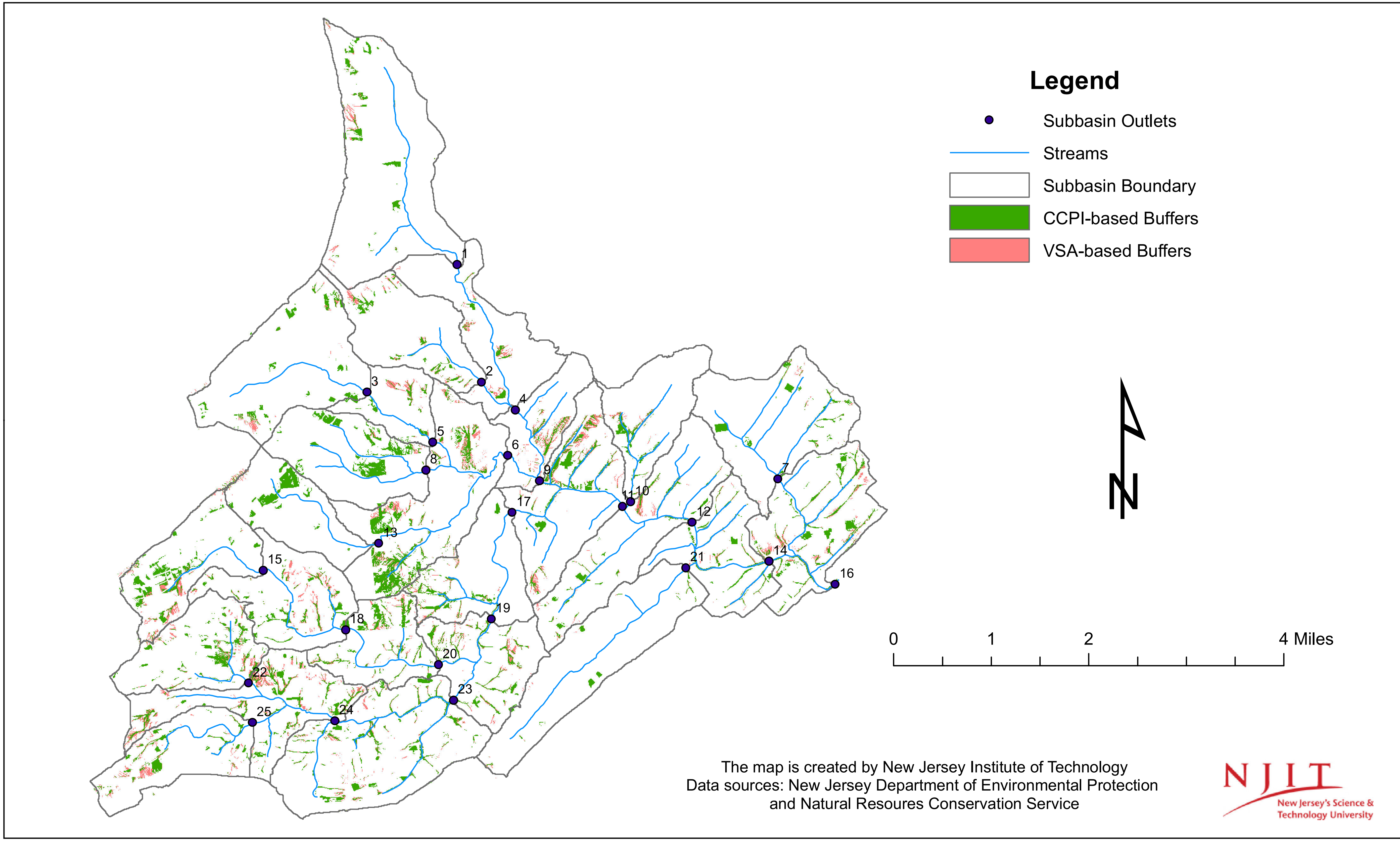


Figure 7.8: Location of the agricultural lands for conservation buffers under two targeting strategies

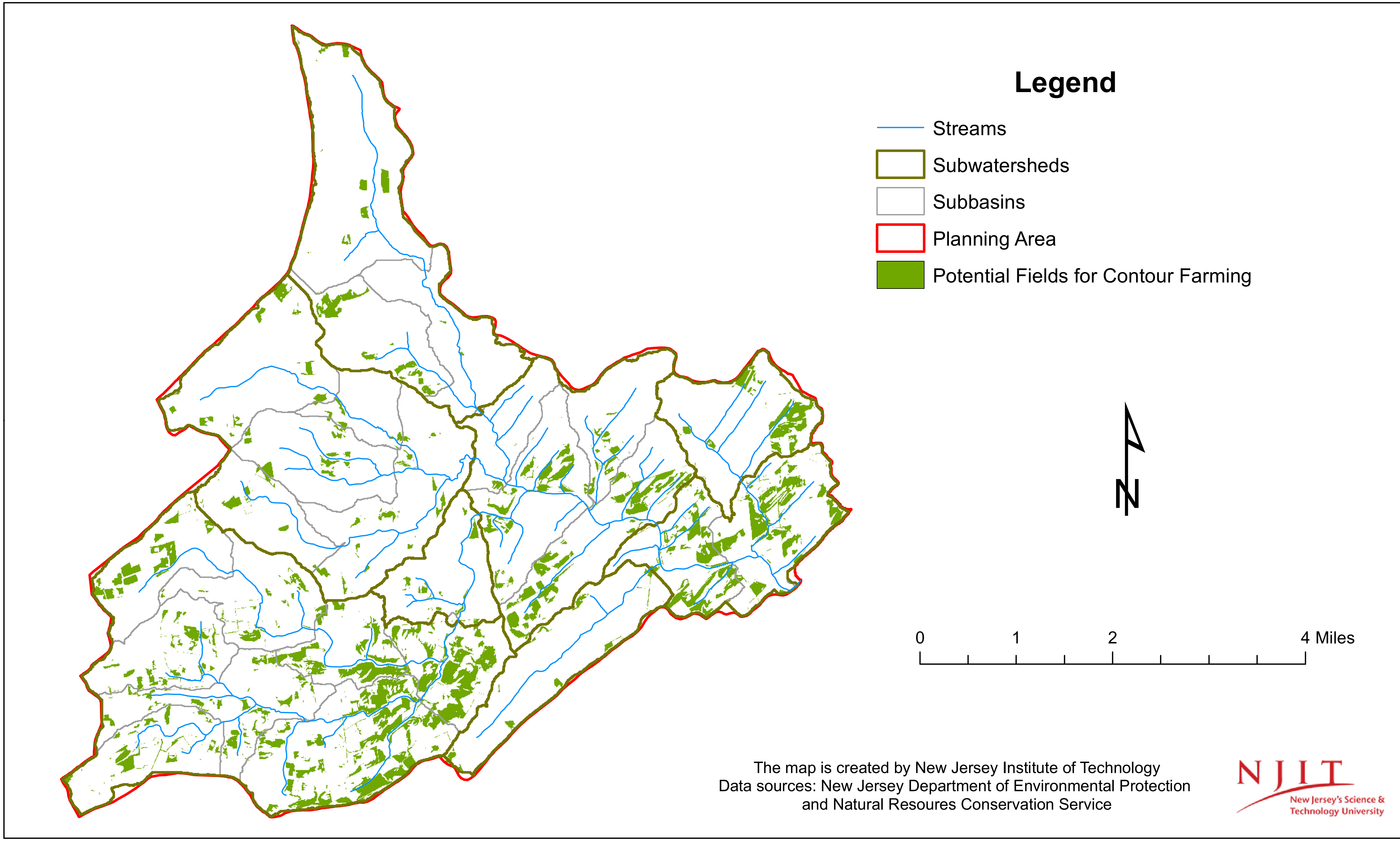


Figure 7.9: Location of the agricultural lands for contour farming in the Neshanic RIver Watershed