UPPER SALEM RIVER WATERSHED RESTORATION AND PROTECTION PLAN

Developed by the Rutgers Cooperative Extension Water Resources Program

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and the New Jersey Agricultural Experiment Station

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Acknowledgements

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Introduction

Project Background and the TMDL Development Process

The purpose of creating this Watershed Restoration and Protection Plan for the Upper Salem River Watershed is to ensure that the valuable uses that this freshwater system has provided the area in the past continue into the future. These uses include recreational activities and irrigation for agriculture, along with the ability of the river to provide a healthy ecosystem for aquatic species and surrounding wildlife. The Rutgers Cooperative Extension (RCE) Water Resources Program has undertaken the task of performing water quality testing, land surveillance, geographic information systems (GIS) analyses, and watershed modeling to provide stakeholders within the Upper Salem River Watershed with a Watershed Restoration and Protection Plan to ensure the quality of the watershed for the future.

To properly manage water quality, a total maximum daily load (TMDL) was developed based on data collected in the Salem River at U.S. Geological Survey (USGS) monitoring station 01482500 at Woodstown Borough (NJDEP, 2003a) to address fecal coliform impairment. TMDLs are developed by the New Jersey Department of Environmental Protection (NJDEP), and approval is given by the U.S. Environmental Protection Agency (USEPA). In accordance with Section 305(b) of the Clean Water Act, New Jersey addresses the overall water quality of the state's waters and identifies impaired waterbodies every two years through the development of a document referred to as the *New Jersey Integrated Water Quality Monitoring and Assessment Report*, a.k.a. the "Integrated List" (NJDEP, 2009a). Within this document are sublists that indicate the presence and level of impairment for each waterbody monitored. The lists are defined as follows:

- **Sublist 1 – "Full Attainment"** waterbodies are meeting water quality standards and attaining their designated uses.
- **Sublist 2 – "Attained"** states that a waterbody is attaining some of the designated uses, and no use is threatened. Furthermore, sublist 2 suggests that data are insufficient to declare if other uses are being met.
- **Sublist 3 – "Not Assessed"** waterbodies have insufficient data or information available to support an attainment determination.

- **Sublist 4 – "Not Attained"** listings are waterbodies where use attainment is threatened and/or a waterbody is impaired. However, a TMDL will not be required to restore the waterbody to meet its use designation.
    - **Sublist 4a** includes waterbodies that have a TMDL developed and approved by the USEPA.
    - **Sublist 4b** establishes that impaired waters will require pollutant control measurements taken by local, state, or federal authorities that will result in full attainment of designated uses.
    - **Sublist 4c** states that impairment is not caused by pollutants, but is due to factors such as in-stream channel condition, flow alteration, or habitat degradation.
- **Sublist 5 – "Not Attained"** clearly states that water quality standards are not being attained and a TMDL is required.

According to the 2002 Integrated List (NJDEP, 2002), the Upper Salem River at Woodstown Borough did not attain its designated uses and was therefore listed on Sublist 5 for fecal coliform and total phosphorus, requiring development of TMDLs. The TMDL for fecal coliform determined that an **84%** reduction in fecal coliform loading to the Salem River is needed to achieve water quality standards (NJDEP, 2003a). The TMDL was developed based on summer monitoring results (May through September) from 1994 to 2000. The TMDL further states that the load duration curve is consistent with storm-driven values of fecal coliform (NJDEP, 2003a).

The TMDL developed for total phosphorus (TP) at this location calls for a relatively high reduction in phosphorus loading. Since the Salem River drains to Memorial Lake (Figure 1), the applicable lake water quality criterion of 0.05 mg/L has been used for the TP TMDL, requiring a load reduction of **88%** (NJDEP, 2003b). This reduction must be met for the entire lakeshed, which is the Upper Salem River Watershed that this study addresses.

The purpose of this plan is to synthesize available data on the Upper Salem River Watershed, including previous studies and the work of the RCE Water Resources Program, and determine the potential sources and extent of any water quality problems in the Upper Salem River Watershed. Solutions to these problems will also be discussed with examples of such solutions for specific areas within the watershed.

Watershed Description

The Salem River Watershed above USGS gauge 01482500 (henceforth, the Upper Salem River Watershed) is approximately 15 square miles in size, includes 20 miles of river and streams, and is located in Watershed Management Area (WMA) 17 (Figure 1). The Upper Salem River Watershed is comprised of sections of Upper Pittsgrove Township, Pilesgrove Township, and Woodstown Borough in Salem County (Figure 1). Tributaries to the Upper Salem River are unnamed and one major surface waterbody, Memorial Lake, is located in Woodstown Borough (Figure 1). Smaller waterbodies are located throughout the watershed, and are primarily dammed impoundments used for flood control (Figure 1).

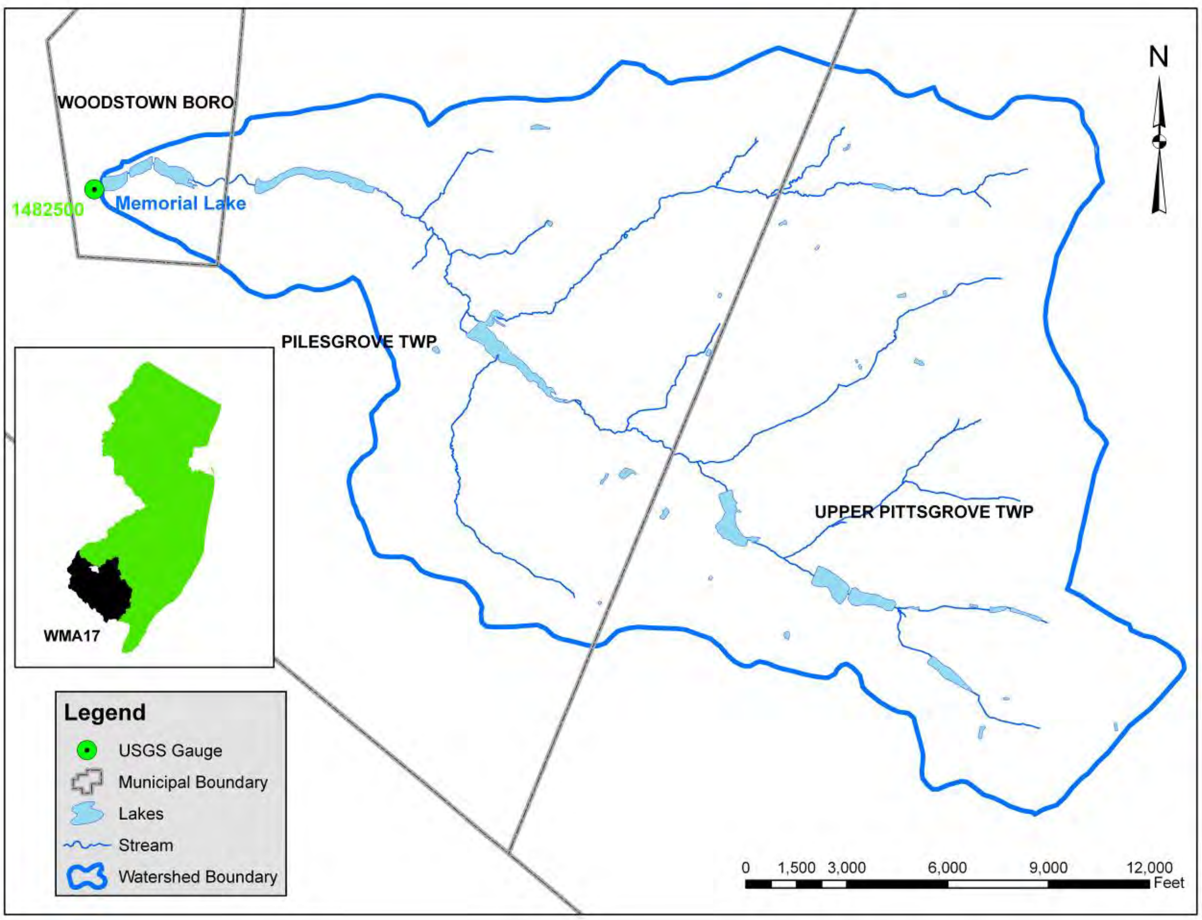


Figure 1: The Upper Salem River Watershed.

The watershed is dominated by agricultural land uses (Figure 2; Figure 3; Table 1). NJDEP land use data (NJDEP, 2010) categorizes agricultural land uses as cropland and pastureland, orchards/vineyards/nurseries/horticultural areas, confined feeding operations, and other agriculture (Figure 3). Forests, urban land uses, and wetlands comprise the majority of remaining land cover within the Upper Salem River Watershed (Figure 2; Figure 3).

Subwatersheds were delineated, based on the ten stations identified for monitoring, using ESRI ArcHydro (Version 1.1, August 2004) and the 10-meter digital elevation model available from the NJDEP (Figure 4). The largest of the subwatersheds is S3 covering 1,801 acres, which is approximately 60% agriculture (Table 1). The smallest subwatershed is S10, covering only 333 acres, which has the highest percentage of urban area (26.1%) when compared to other subwatersheds (Table 1). This is due to Woodstown Borough, which makes up the majority of its area. This subwatershed (S10) is also the one to contain sewer service, once again due to Woodstown Borough, while all other subwatersheds contain septic systems for wastewater treatment (Figure 5).

Table 1: Percent of land use per subwatershed.

Subwatershed	Total Area (Acres)	% Agriculture	% Barren Land	% Forest	% Urban	% Water	% Wetlands
S1	375	77.7%	0.0%	2.8%	10.3%	0.5%	8.7%
S2	837	56.8%	4.4%	6.7%	16.3%	4.6%	11.3%
S3	1,801	59.7%	0.0%	18.1%	8.9%	1.2%	12.0%
S4	670	68.2%	0.0%	15.4%	6.9%	0.7%	8.8%
S5	377	83.0%	0.0%	1.9%	2.8%	0.1%	12.2%
S6	578	76.0%	0.0%	5.8%	7.9%	0.0%	10.2%
S7	1,666	71.6%	0.0%	14.6%	3.5%	0.3%	10.0%
S8	1,262	66.7%	0.2%	10.3%	11.0%	2.7%	9.1%
S9	1,057	56.8%	0.1%	19.0%	14.7%	1.8%	7.6%
S10	333	43.1%	0.0%	12.78%	26.1%	7.4%	10.6%

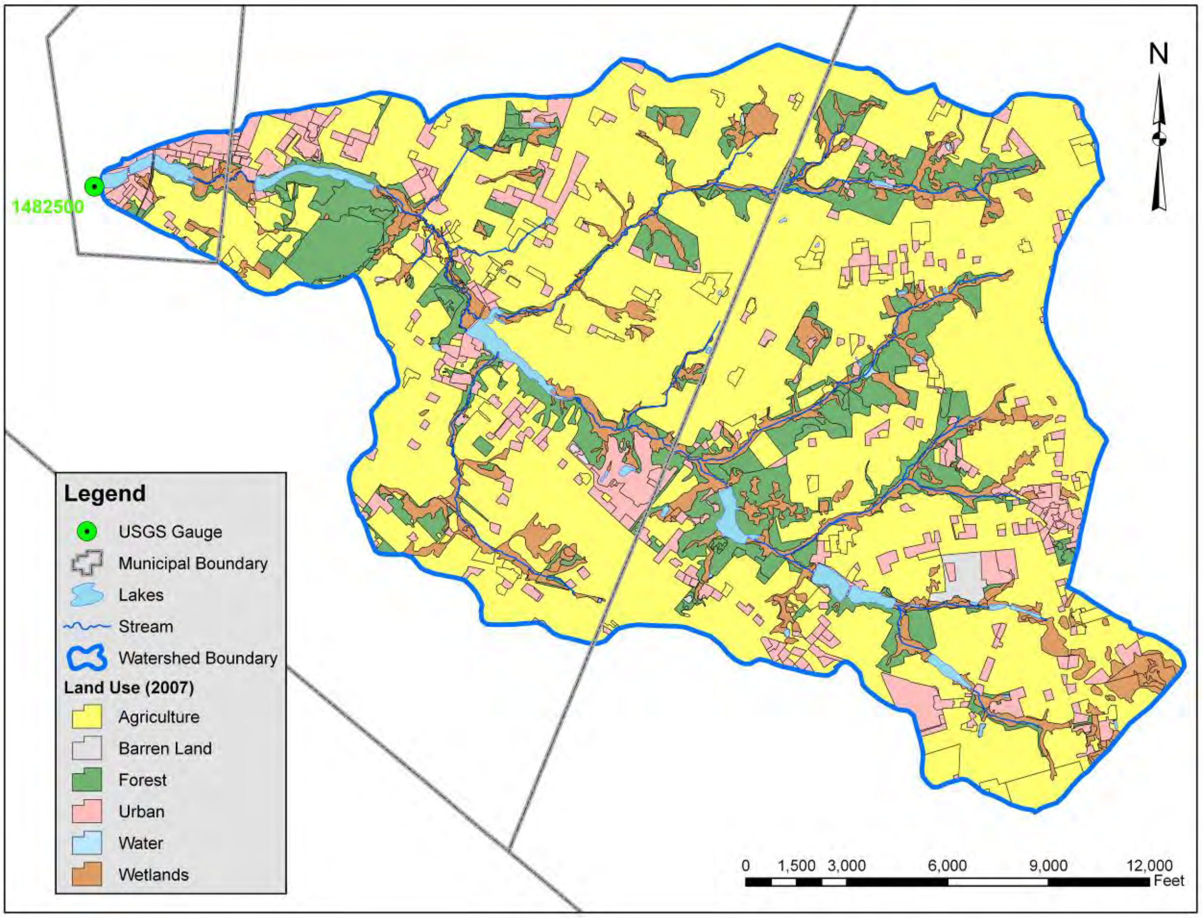
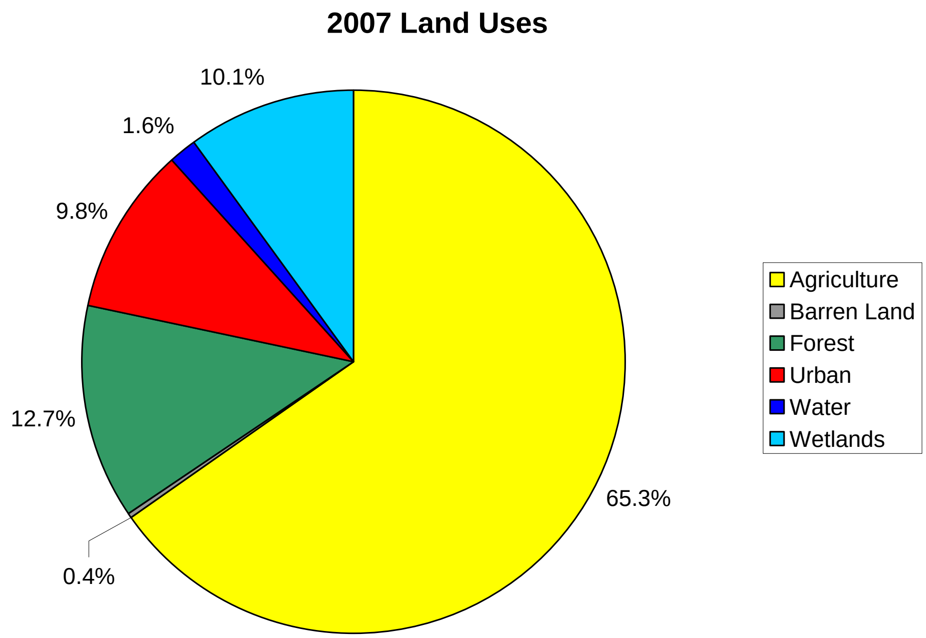


Figure 2: Land uses in the Upper Salem River Watershed.



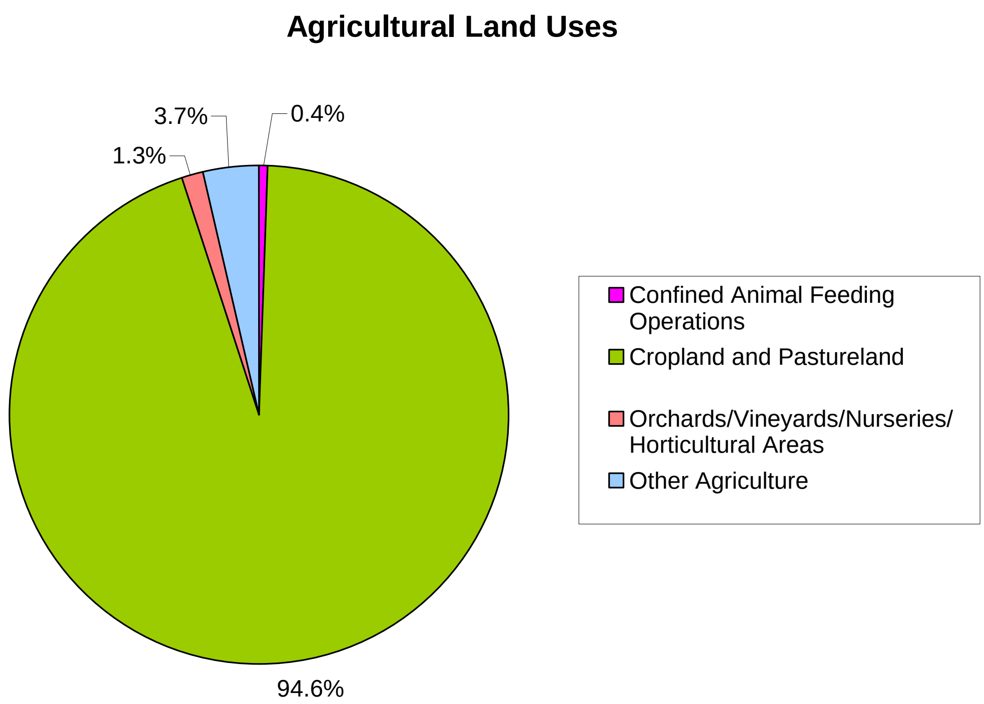


Figure 3: Land cover types and agricultural land uses in the Upper Salem River Watershed.

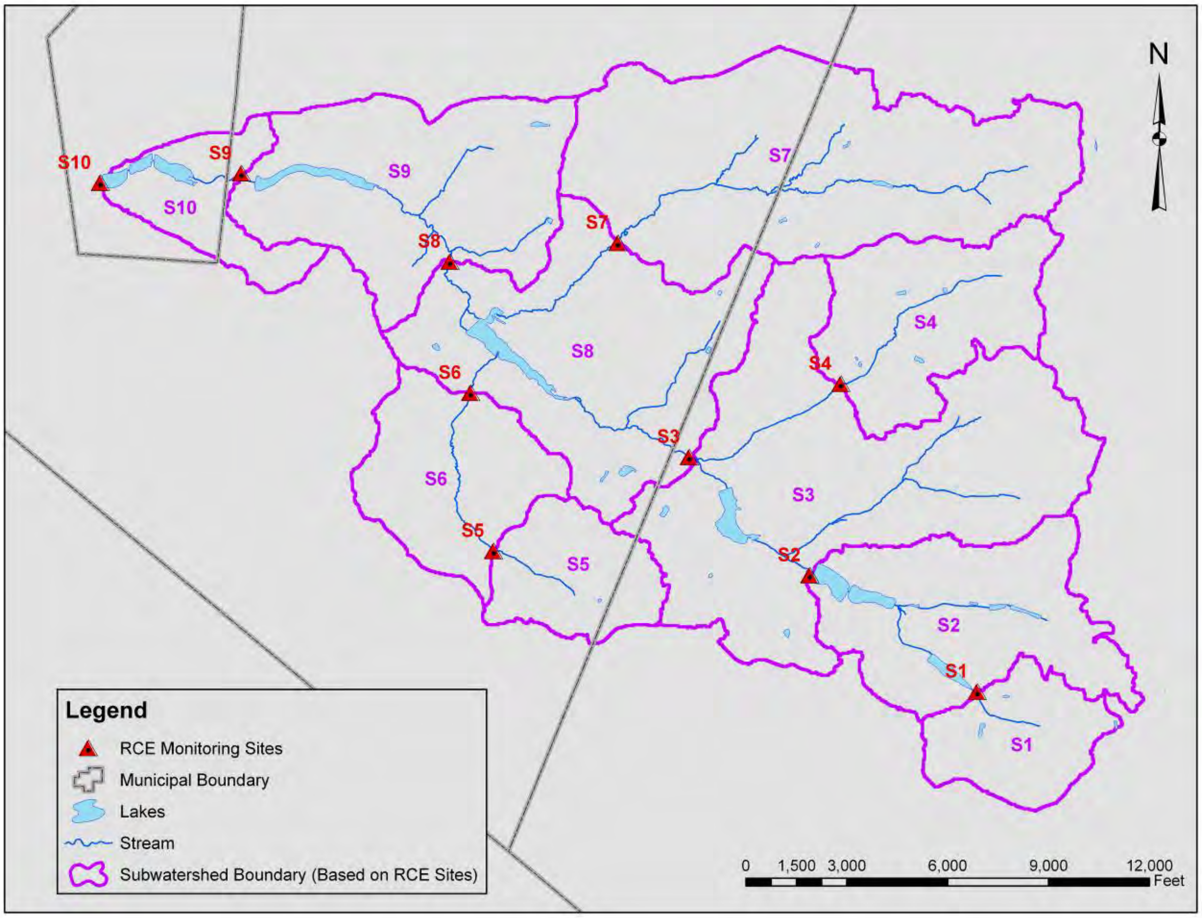


Figure 4: Delineated subwatersheds in the Upper Salem River Watershed.

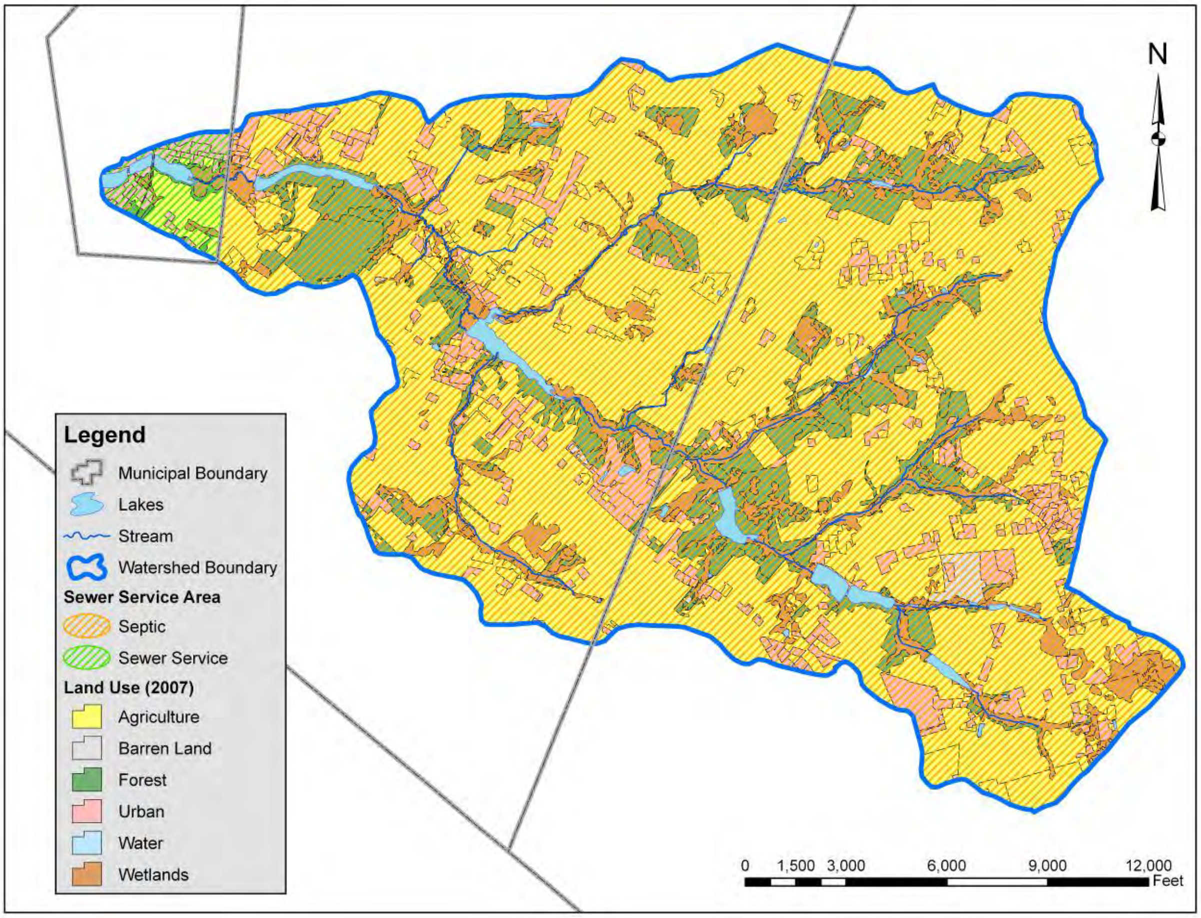


Figure 5: Sewer service areas in the Upper Salem River Watershed.

Since 1957, USGS has monitored flow on the Salem River at USGS gauge 01482500 (Figure 1). The mean discharge is 17.8 cubic feet per second (cfs) (Figure 6). The artificial lakes created by various impoundments along the main stem of the Upper Salem River are most likely keeping flow rates low (Figure 1).

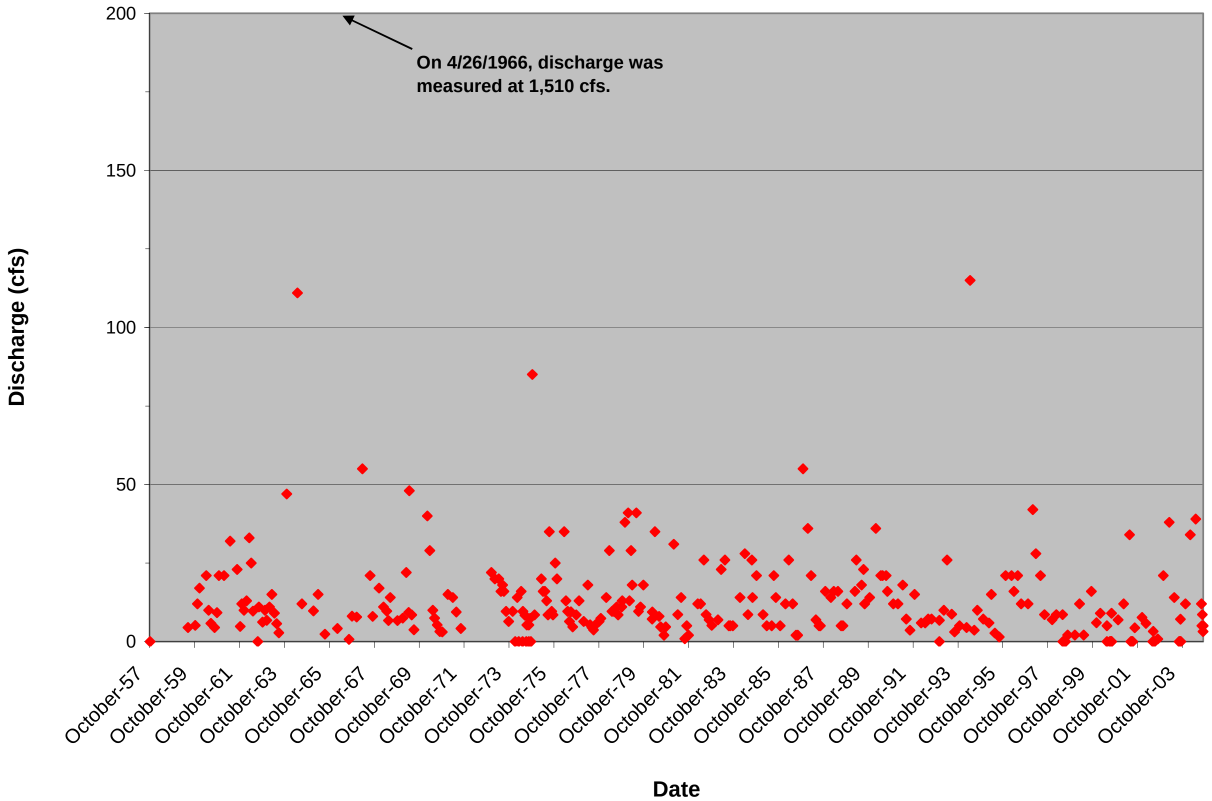


Figure 6: River discharge measurements at USGS gauge 01482500 (Salem River at Woodstown, NJ).

The NJDEP classifies waters within the state to properly manage their uses and quality. All waters within the Upper Salem River Watershed are classified as FW2-NT/SE1 (Figure 7). FW2-NT waters are freshwater systems that are subjected to man-made wastewater discharges or increases in runoff from anthropogenic activities and are not used for either the production or maintenance of trout populations (NJDEP, 2009b). FW2-NT/SE1 waters are located at a salt water and freshwater interface and combine the FW2-NT designation and the saline estuarine (SE) designation. The division between these two designations is determined through salinity measurements. Salinity below 3.5 parts per thousand (ppt) are governed by the FW2-NT classification and above 3.5 ppt are classified SE1 (NJDEP, 2009b). The waterways within this portion of the Upper Salem River Watershed have salinity concentrations less than 3.5 ppt, so all waters are considered FW2-NT.

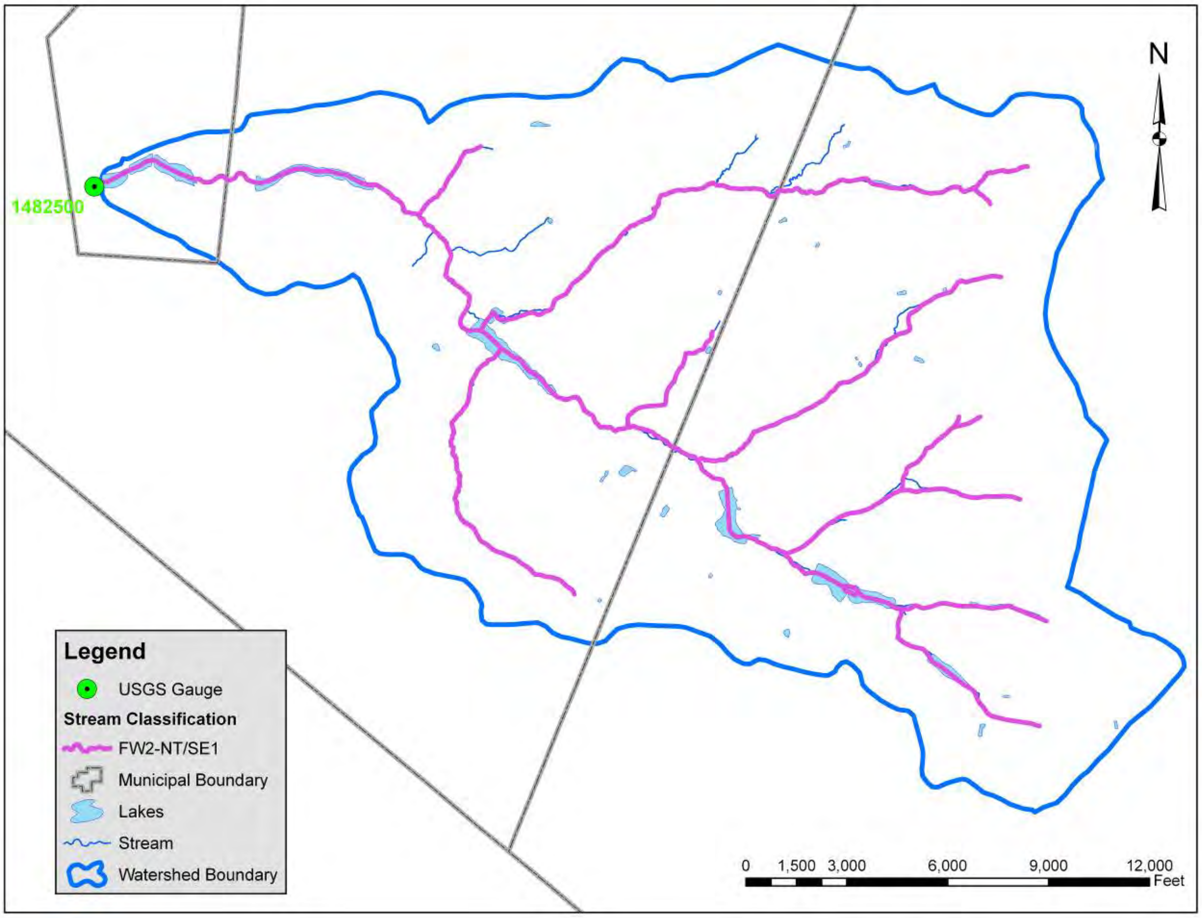


Figure 7: NJDEP stream classifications for Upper Salem River Watershed.

There is only one New Jersey Pollution Discharge Elimination System (NJPDES) permit allowing discharges to surface waters in the project watershed: Coastal Service Station #7224 (Figure 8). The Coastal Service Station (NJPDES Permit No. NJ0130915) has a minor industrial discharge and discharges to East Lake via a storm sewer system. There are no discharges to groundwater permitted in the Upper Salem River Watershed.

A complete description of the Upper Salem River Watershed can be found in the *Watershed Restoration Plan for the Upper Salem River Watershed: Phase I* report (RCE, 2006).

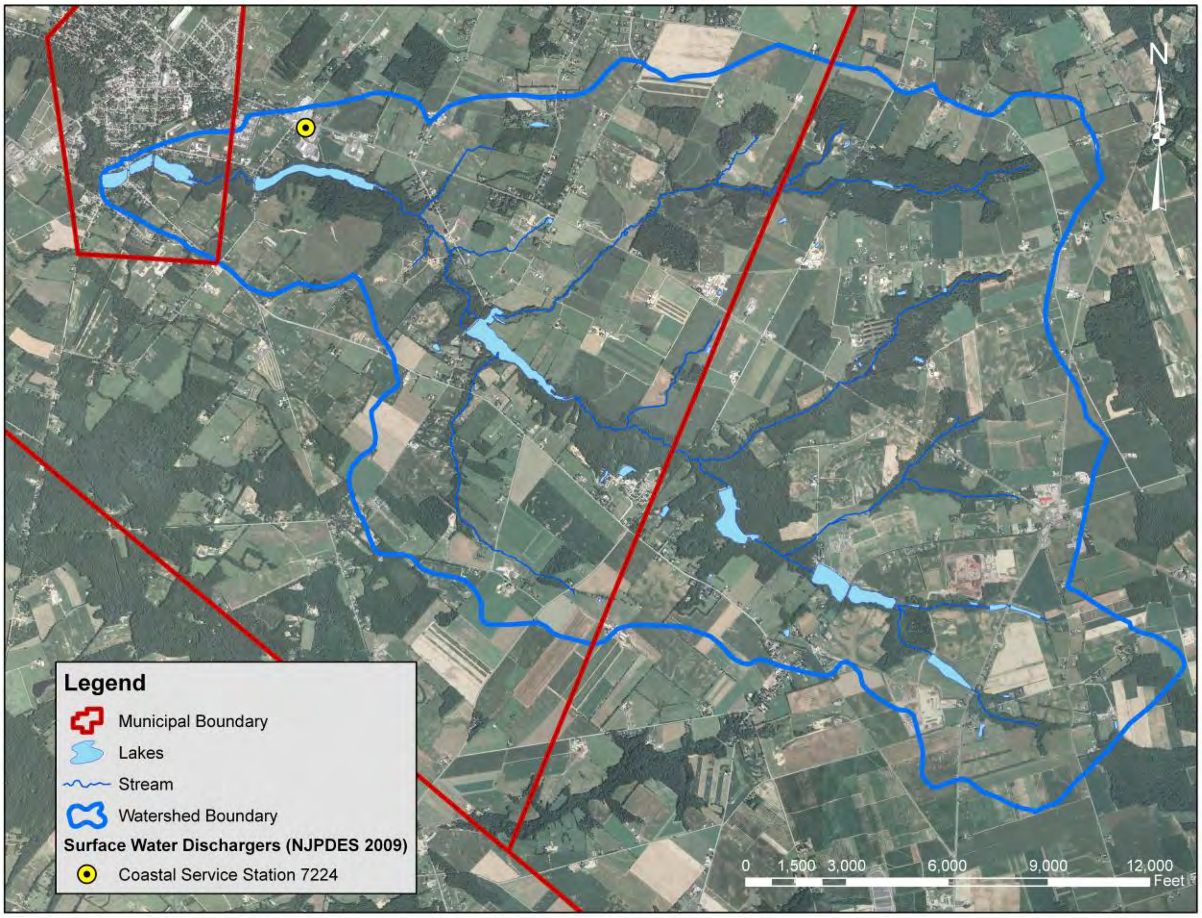


Figure 8: Surface water and groundwater dischargers in the Upper Salem River Watershed.

Problem Identification and Analysis

This report contains summaries and analyses of water quality data, stream assessments, and macroinvertebrate sampling conducted in the Upper Salem River Watershed. For a complete description of sampling programs and methods, see the *Upper Salem River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2011a).

Stream Visual Assessment Protocol (SVAP) Data

The USDA SVAP methodology was followed to gain an understanding of potential physical changes in the Upper Salem River Watershed's rivers and streams that may indicate water quality problems. The protocol provides an outline to quantitatively score in-stream and riparian qualities. Such assessed qualities include water appearance, channel condition, canopy cover, and riparian health.

Seventy-three stream reaches were evaluated in the Upper Salem River Watershed (Table 2). While only eight of the ten subwatersheds within the Upper Salem River Watershed were evaluated (Figure 9), SVAP assessment results provide an overall appraisal of watershed health. Access to river reaches was the major obstacle in completing visual assessments in the Upper Salem River Watershed. Many of the streams flow through privately-owned agricultural and residential lands and SVAP assessments were conducted in areas to prevent trespassing on these lands. Reaches reported here are either along public lands or in private lands where permission to enter was granted to evaluators. The overall mean SVAP assessment score for all seventy-three reaches was 7.24, a resulting watershed quality of "fair." Assessment scores ranged from 5.45 ("poor") to 8.59 ("good") (Figure 9; Table 2). The 'barriers to fish movement' element was scored at almost every reach and was the highest scored assessment element with an average score of 9.03 (Table 2). Other elements with high scores were 'canopy cover,' 'invertebrate cover,' and 'pools' (Table 2). 'Bank stability,' for both the right and left banks, was the lowest scoring assessment element with mean scores of 4.48 and 4.78, respectively (Table 2). None of the assessed stream reaches received a score of "excellent" (Figure 9; Table 2).

Table 2: SVAP assessment scores for the Upper Salem River Watershed.

Subwatershed	Date	Reach Location	Reference Location	Hydrologic Alteration	Channel Condition	Riparian Zone Left Bank	Riparian Zone Right Bank	Bank Stability Left Bank	Bank Stability Right Bank	Water Appearance	Nutrient Enrichment	Barriers to Fish Movement	Instream Fish Cover	Pools	Invertebrate Habitat	Canopy Cover	Manure Presence	Salinity	Riffle Embeddedness	Overall Site Average
S3	6/13/2005	GC3R002	just upstream of Commissioners Pike	na	9	9	9	5	3	6	7	8	10	8	10	10	5	na	8	7.8
S3	6/6/2005	GC3R003	About 300 yards below Daretown Lake dam	na	10	9	8	8	8	6	7	10	10	9	10	10	5	na	7	8.4
S3	6/13/2005	GC3R003	upstream of Commissioners Pike	na	5	7	8	7	4	7	7	8	7	7	8	10	5	na	6	6.9
S3	6/6/2005	GC3R004	Midway between Daretown Lake and Slabtown Lake	na	8	7	7	8	8	8	7	8	8	9	10	10	5	na	8	8.0
S3	6/13/2005	GC3R004	Salem River Tributary north of Slabtown Lake	na	5	8	7	6	2	7	7	8	7	8	9	10	5	na	7	7.0
S3	6/6/2005	GC3R005	About 100 yards above the head of Slabtown Lake	na	10	8	7	8	8	7	7	10	8	10	8	10	5	na	na	8.2
S3	6/13/2005	GC3R005	Salem River Tributary north of Slabtown Lake	na	7	9	9	6	3	6	6	8	10	9	10	10	5	na	8	7.7
S3	6/22/2005	GC3R005	east of Commissioner's Pike	na	4	9	9	1	3	6	6	8	9	9	9	10	5	na	8	7.1
S3	6/6/2005	GC3R006	Just above the head of Slabtown Lake	na	10	8	9	8	9	7	7	10	9	9	10	10	5	na	na	8.5
S3	6/13/2005	GC3R006	Salem River Tributary north of Slabtown Lake	na	4	8	7	4	2	6	5	8	9	8	10	10	5	na	5	6.7
S3	6/22/2005	GC3R006	east of Commissioner's Pike	na	8	9	9	4	5	6	5	8	7	7	8	10	5	na	3	6.7
S3	6/13/2005	GC3R007	Between cultivated field and horse pasture/residen	na	4	8	7	5	4	7	6	10	7	7	8	10	na	na	7	7.1
S3	6/22/2005	GC3R007	just below Slabtown Lake dam	na	5	9	9	3	7	5	5	10	10	10	9	7	5	na	3	6.9
S3	6/13/2005	GC3R008	Salem River Tributary north of Slabtown Lake	na	9	8	9	2	3	7	6	8	8	7	9	10	5	na	8	7.3
S3	7/7/2005	GD3R004	north of RT. 40	na	8	9	9	8	7	8	7	8	8	7	10	10	5	na	5	7.7
S3	7/7/2005	GD3R005	north of Rt. 40	na	5	8	9	2	3	8	7	8	7	8	9	10	5	na	7	7.1
S3	7/7/2005	GD3R006	at Rt. 40 bridge	na	6	9	9	3	6	6	7	8	9	8	10	7	5	na	7	7.2
S3	7/7/2005	GD3R007	south of Rt. 40	na	5	8	8	3	4	7	7	8	9	9	10	7	5	na	8	7.2
S3	7/7/2005	GD3R008	south of Rt. 40	na	8	9	9	4	5	8	8	8	7	7	8	7	5	na	8	7.3
S3	7/7/2005	GD3R009	south of Rt. 40	na	8	8	9	3	3	9	9	10	8	9	10	10	5	na	na	8.1
S3	6/1/2005	GD4R001	About 100 yards below Daretown Lake dam	na	10	9	9	7	8	8	6	9	9	9	9	10	na	na	8	8.6
S3	6/6/2005	GD4R001	About 200 yards below Daretown Lake dam	na	10	8	8	7	8	8	7	10	8	9	9	10	5	na	8	8.3
S3	6/1/2005	GD4R002	About 150+ yards below Daretown Lake dam	na	10	9	9	5	4	8	7	10	7	9	9	10	na	na	na	8.4
S4	7/7/2005	GD2R001	south of Glassboro Road	na	5	6	6	3	4	8	8	8	8	7	9	7	5	na	8	6.9
S4	7/7/2005	GD2R002	south of Glassboro Road	na	5	8	9	5	3	8	8	8	8	7	9	7	5	na	7	7.0
S4	7/7/2005	GD2R003	headwaters of creek; south of Glassboro Road	na	9	9	9	6	8	8	7	8	8	8	9	10	5	na	7	7.9
S5	8/17/2005	GB3R001	behind silos/barn	na	7	8	8	6	6	7	7	10	8	8	7	0	3	na	8	7.2
S5	8/17/2005	GB3R002	west of Davis Road @ bridge	na	7	8	7	7	7	7	7	10	6	7	6	10	5	na	na	7.2
S6	8/17/2005	GB3R003	west of Davis Road @ back of pasture	na	6	8	8	7	7	8	8	10	7	8	7	10	5	na	6	7.5
S7	7/5/2005	GC2R001	east of Commissioner's Pike	na	5	8	9	3	4	7	7	8	9	8	9	7	5	na	8	7.1
S7	7/5/2005	GC2R002	east of Commissioner's Pike	na	5	7	8	2	4	7	7	8	7	8	8	10	5	na	7	6.9
S7	7/5/2005	GC2R003	east of Commissioner's Pike, north of Rt. 40	na	5	8	7	6	2	8	8	9	7	9	7	10	5	na	na	7.2
S7	7/5/2005	GC2R004	at road in forest	na	3	1	3	2	2	7	7	5	6	7	6	10	5	na	na	5.5
S7	7/5/2005	GC2R005	north of Rt. 40	na	6	7	8	4	3	6	7	9	7	8	8	10	5	na	8	7.1
S7	7/5/2005	GC2R006	north of RT. 40	na	3	7	9	4	2	7	7	8	9	9	9	10	5	na	6	7.0
S7	7/5/2005	GC2R007	north of Rt. 40	na	5	5	8	3	2	6	7	8	7	7	8	7	5	na	6	6.3
S8	6/21/2005	GB2R001	Downstream from Avis Mill Pond	na	7	7	5	1	2	5	5	10	9	10	9	10	5	na	na	7.0
S8	6/22/2005	GB2R001	Below South dam of Avis Mill Pond	na	2	8	8	5	3	5	5	8	5	7	8	7	na	na	5	5.8
S8	6/21/2005	GB2R002	Downstream of Avis Mill Pond on state ground	na	8	7	7	2	1	5	5	10	8	9	9	10	5	na	na	7.0
S8	6/22/2005	GB2R002	Downstream of south dam of Avis Mill Pond	na	3	8	8	1	2	5	6	8	7	7	9	7	5	na	na	6.0
S8	6/1/2005	GB2R003	About 200 yards below Avis Mill Pond dam	na	5	7	7	7	2	6	6	10	9	8	8	10	5	na	na	7.1
S8	6/21/2005	GB2R003	Behind home off of Fox Road	na	5	7	7	1	2	5	6	8	9	10	9	10	5	na	3	6.5
S8	6/22/2005	GB2R003	parallel to Fox Road adjacent to field	na	4	7	8	4	1	6	5	8	9	8	10	10	na	na	3	6.6
S8	6/21/2005	GB2R004	behind white house off of Fox Road	na	7	5	7	1	3	6	5	8	8	9	8	10	5	na	3	6.4
S8	6/22/2005	GB2R004	at bridge over river off of Fox Road	na	6	8	8	3	4	6	6	10	8	9	9	10	5	na	3	7.0
S8	6/28/2005	GB3R005	between Avis Mill Pond and Woodstown-Daretown Road	na	8	9	9	5	4	7	7	8	8	8	8	10	5	na	na	7.5
S8	6/28/2005	GB3R006	just north of Woodstown-Daretown Road	na	5	3	2	3	1	7	7	9	8	8	9	10	5	na	7	6.6
S8	6/24/2005	GC2R006	at bridge on RT. 40	na	3	8	8	4	4	7	6	8	5	7	5	10	5	na	7	6.3
S8	6/24/2005	GC2R006	at bridge under Rt. 40	na	3	8	8	4	4	7	6	8	5	7	5	10	5	na	7	6.3
S8	6/24/2005	GC2R007	between Rt. 40 and Renter Road	na	2	7	8	4	4	5	6	10	7	9	7	10	na	na	na	6.8
S8	6/7/2005	GC3R001	Off of Commissioners Pike (west side of road)	na	7	8	7	7	7	7	8	10	8	9	8	10	na	na	na	8.2
S8	6/13/2005	GC3R001	Bridge at Commissioners Pike (east side of bridge)	na	4	9	8	8	3	6	6	10	9	9	8	10	na	na	na	7.6
S8	6/6/2005	GC3R002	About 225 yards+ below Daretown Lake dam	na	10	8	7	7	8	7	7	10	8	10	8	10	5	na	na	8.2
S8	6/7/2005	GC3R002	Downstream from Commissioners Pike	na	8	8	9	7	7	6	6	10	9	9	8	10	na	na	7	8.0
S8	6/7/2005	GC3R003	Downstream from Commissioners Pike	na	6	9	7	6	7	7	7	10	9	6	8	10	na	na	7	7.7
S8	6/7/2005	GC3R004	At campground picnic area	na	6	8	4	6	2	8	7	10	8	7	9	10	na	na	7	7.5
S8	6/7/2005	GC3R005	At campground picnic area	na	8	7	7	4	2	7	6	10	9	7	9	7	na	na	8	7.4
S8	6/7/2005	GC3R006	downstream from campground	na	9	7	8	4	5	6	6	10	7	7	8	10	na	na	na	7.5
S8	6/7/2005	GC3R007	downstream from campground	na	8	7	8	7	4	7	6	10	10	7	10	10	na	na	6	7.9
S8	6/7/2005	GC3R008	behind a section of campground	na	8	6	3	4	1	5	6	10	7	8	7	10	na	na	na	6.8
S8	6/7/2005	GC3R009	downstream of campground	na	6	8	7	3	4	6	6	10	6	8	7	10	na	na	na	7.0
S8	6/7/2005	GC3R010	downstream of campground, upstream of Slabtown Lak	na	10	6	9	3	7	7	7	10	10	8	10	10	5	na	7	8.0
S8	6/7/2005	GC3R011	upstream of head of Slabtown Lake	na	9	6	8	8	5	6	7	10	7	8	8	10	na	na	na	7.9
S8	6/7/2005	GC3R012	Just Above head of Avis Mill Pond	na	10	8	8	8	8	6	6	10	7	7	7	0	na	na	na	7.7
S8	6/7/2005	GC3R013	at campground	na	3	6	1	3	1	7	7	10	7	7	8	7	na	na	7	6.2
S9	6/28/2005	GA2R001	just below East Lake dam	na	6	4	9	1	6	5	6	10	9	9	9	10	5	na	na	7.2
S9	6/24/2005	GB2R001	behind dairy barns off of Fox Road	na	5	2	1	5	5	7	6	9	7	7	7	1	2	na	8	5.5
S9	6/24/2005	GB2R002	off of Fox Road in pasture	na	5	2	2	1	2	5	7	8	10	9	10	1	3	na	8	5.8
S9	6/24/2005	GB2R003	at western edge of pasture parallel to Fox Road	na	7	4	6	6	5	6	6	10	9	10	9	10	3	na	6	7.2
S9	6/24/2005	GB2R004	above head of East Lake	na	9	9	9	5	6	6	6	10	9	9	9	10	5	na	5	7.7
S9	6/24/2005	GB2R005	East Lake	na	9	9	9	9	9	6	5	10	6	7	6	0	na	na	na	7.4
S10	6/28/2005	GA2R002	about halfway between East Lake and Memorial Lake	na	9	10	9	9	7	6	6	9	10	9	9	10	5	na	na	8.2
S10	6/28/2005	GA2R003	above head of Memorial Lake	na	9	9	9	8	8	5	6	10	9	10	9	10	5	na	na	8.2

Legend
- Good = assessment score > 7
- Fair = assessment score of 5 - 7
- Poor = assessment score < 5

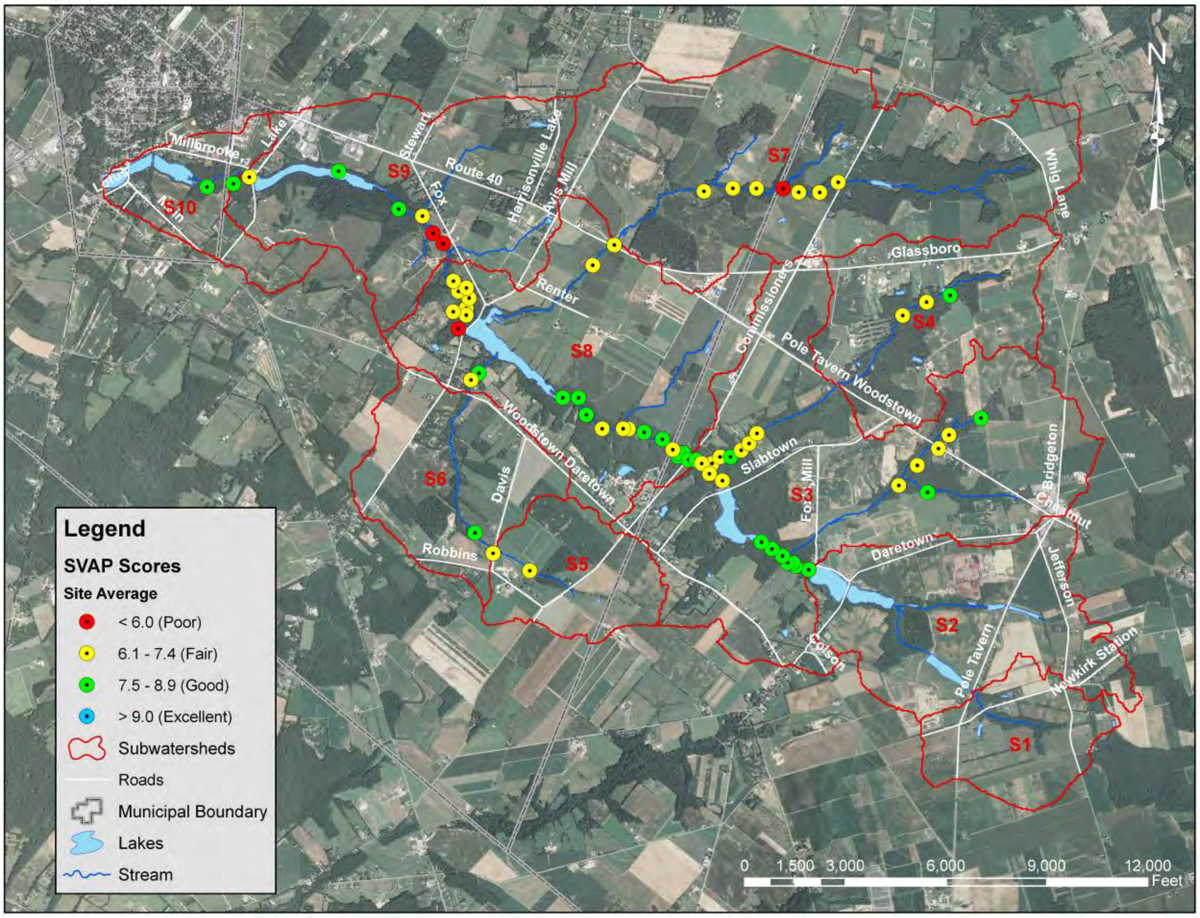


Figure 9: SVAP assessment site averages for the Upper Salem River Watershed.

Subwatersheds S1 and S2

No SVAP assessments were performed within these subwatersheds during this study.

Subwatershed S3

Stream reaches within this subwatershed received overall scores ranging from “fair” to “good” (Figure 9; Table 2).

Subwatersheds S4, S5, S6 and S10

These subwatersheds had few stream reaches assessed (3 or less) (Table 2). Scores in these areas ranged from "fair" to "good" (Figure 9; Table 2). Like many of the other reaches along the Upper Salem River, bank stability received the lowest scores (Figure 9; Figures 10a and 10b; Table 2).

Figure 10a: Fallen trees and exposed roots indicative of unstable banks along the Salem River (Subwatershed S4).
(Photo: RCE Water Resources Program)

Figure 10b: Bare stream banks along a section of the Salem River (Subwatershed S10).
(Photo: RCE Water Resources Program)

Subwatershed S7

Like other portions of the Salem River, subwatershed S7 received low assessment scores for bank stability (Table 2). Overall, reaches along the Upper Salem River in subwatershed S7 were scored as "fair" or "poor" (Figure 9; Table 2).

Subwatershed S8

Two stretches of the Upper Salem River were assessed as "poor" in subwatershed S8 (Table 2). Water appearance was rated as "fair" at many areas assessed (Figure 11a) and bank stability was scored as "poor" in many areas (Figure 11b).

Figure 11a: Route 40 bridge with turbid water (Subwatershed S8).
(Photo: RCE Water Resources Program)

Figure 11b: Bare stream banks and exposed roots indicative of instability (Subwatershed S8).
(Photo: RCE Water Resources Program)

Subwatershed S9

Subwatershed 9 assessments ranged from “poor” to “good” along six stream reaches (Figure 9; Table 2). Three reaches were given low scores for the presence of manure (Table 2) based upon the proximity of cattle operations to the stream (Figures 12a and 12b).

Figure 12a: Cattle crossing and barn areas along the Upper Salem River (Subwatershed S9).
(Photo: RCE Water Resources Program)

Figure 12b: Cattle access to stream indicative of potential manure presence (Subwatershed S8).
(Photo: RCE Water Resources Program)

Benthic Macroinvertebrates

The NJDEP Ambient Biological Monitoring Network (AMNET) maintains two benthic macroinvertebrate stations in the Upper Salem River Watershed (Figure 13). These stations were monitored in 1995, 2000, and 2006 (Table 3). To supplement this data, the RCE Water Resources Program sampled three stations in the summer of 2007 (Figure 13; Table 3). Full details on methods for each can be found in the *Upper Salem River Watershed Restoration and Protection Plan: Data Report* (RCE Water Resources Program, 2011a).

The AMNET macroinvertebrate results show moderate impairments to biological communities within the watershed (Table 3). This is also seen in the RCE collected macroinvertebrate data (Table 3). The types of organisms found, or the lack thereof, indicate that possible chemical perturbations are occurring within the system, and/or the benthic community may be subject to physical or habitat constraints. The habitat assessment revealed suboptimal habitat conditions, which may explain the observed impaired benthic macroinvertebrate community (Table 3). Habitat quality may be low due to physical alterations as observed during SVAP assessments conducted throughout the watershed (Figure 9; Table 2). The overall quality of the streams was assessed as “fair” and individual SVAP element scores ranged from “poor” to “good” (Figure 9; Table 2). The bank stability scores obtained during SVAP assessments may signal increased erosion rates in the Upper Salem River Watershed which may cause filling in of habitat necessary for macroinvertebrates.

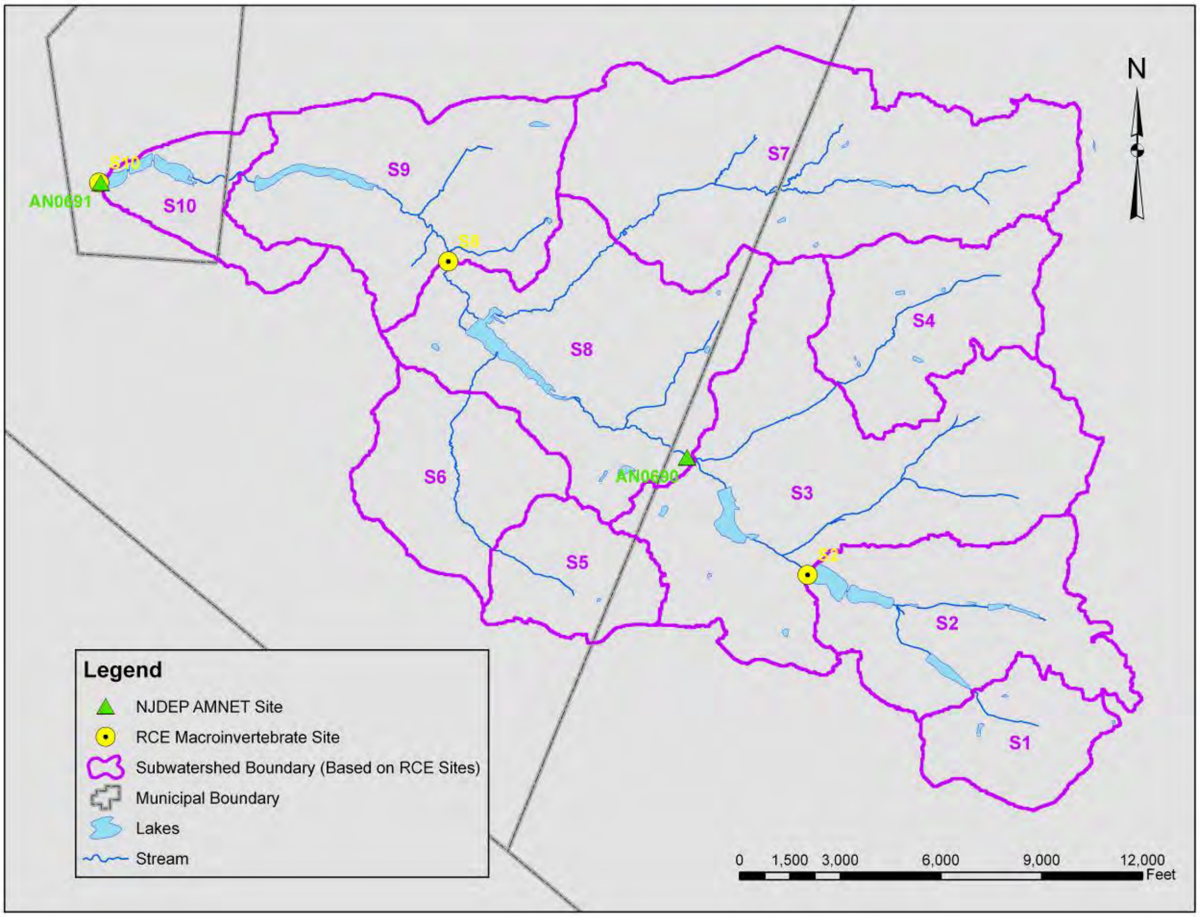


Figure 13: Benthic macroinvertebrate stations in Upper Salem River Watershed.

Table 3: Benthic macroinvertebrate results for Upper Salem River Watershed.

Agency	Station	Date Sampled	Impairment Status	Index	Habitat Analysis
NJDEP	AN0690	8/24/1995	Moderately Impaired	NJIS	N/A
NJDEP	AN0690	8/2/2000	Moderately Impaired	NJIS	Optimal
NJDEP	AN0690	10/19/2006	Poor	CPMI	Suboptimal
NJDEP	AN0691	8/22/1995	Severely Impaired	NJIS	N/A
NJDEP	AN0691	8/2/2000	Moderately Impaired	NJIS	Suboptimal
NJDEP	AN0691	10/19/2006	Poor	CPMI	Suboptimal
RCE Water Resources	S2	8/28/2007	Moderately Impaired	NJIS	Suboptimal
RCE Water Resources	S8	8/28/2007	Moderately Impaired	NJIS	Suboptimal
RCE Water Resources	S10	8/28/2007	Moderately Impaired	NJIS	Suboptimal

Water Quality Parameters

To identify the cause(s) of impairment observed through both the SVAP assessment results and biological sampling, water quality monitoring began in June 2007. As per the NJDEP-approved Quality Assurance Project Plan (QAPP), *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured across stream transects at each sampling station. Using this information, flow (Q) was calculated for each event where access to the stream was deemed safe. Water samples were collected and analyzed by QC Laboratories in Vineland, New Jersey (NJDEP Certified Laboratory #PA166) for TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, total Kjeldahl nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), fecal coliform and *E. coli*.

Ten water quality stations (Figure 4) were monitored for three different types of sampling events. Ambient monitoring, which included analysis for all parameters, occurred from June 8, 2006 through June 17, 2009. These events were monitored for all *in situ* parameters, velocity and depth, and TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, TSS, and fecal coliform. Bacteria-only monitoring was conducted in the summer months of June through August 2007. This entailed collecting additional samples per month for fecal coliform analysis, as well as *in situ* parameters, and velocity and depth to calculate flow. In addition, water samples from three storm events were collected from September through November 2006. Four samples were collected over the course of each storm event for all parameters at all ten monitoring locations.

The NJDEP's Integrated Water Quality Monitoring and Assessment Methods advises that if water quality results exceed the water quality criteria (Table 4) twice within a five-year period, then the waterway's quality may be compromised (NJDEP, 2009c). NJDEP has further stated that a minimum of eight samples need to be collected to confirm water quality, with quarterly samples over a two-year period being ideal (NJDEP, 2005; NJDEP, 2009c). Therefore, if a waterbody has a minimum of eight samples collected and two samples exceed applicable water quality criteria, the waterbody is considered "impaired" for that parameter. By applying this rule to the Upper Salem River Watershed data, it is possible to identify which stations are impaired for each parameter identified as a concern for this project (i.e., pH, TP, TSS, fecal coliform, and *E. coli*). The number of samples exceeding state water quality standards is given in Table 5.

Table 4: Water quality standards for Upper Salem River Watershed (NJDEP, 2009b).

Substance	Surface Water Classification	Criteria
pH (SU)	FW2	4.5 – 7.5
TP (mg/L)	FW2 Streams	Except as necessary to satisfy the more stringent criteria in accordance with "Lakes" or where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.
TSS (mg/L)	FW2-NT	Non-filterable residue/suspended solids shall not exceed 40.
Bacterial counts (col/100 mL): Fecal Coliform	FW2	Shall not exceed geometric average of 200/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 400/100 mL.
Bacterial counts (col/100 mL): *E. coli*	FW2	Shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL.

Table 5: Number of samples (June 8, 2007 – June 17, 2009) that exceed New Jersey water quality standards.

	Select Monitoring Parameters				
Station	**pH**	**TP**	**TSS**	**Fecal coliform***	**E. coli****
S1	0	2	0	13	12
S2	22	15	0	10	12
S3	8	19	0	21	29
S4	2	6	0	23	22
S5	0	26	11	43	39
S6	1	8	1	40	34
S7	3	6	3	46	37
S8	4	39	4	37	33
S9	6	52	10	44	43
S10	18	52	4	25	23

**For fecal coliform, the number of samples higher than the 400 col/100ml standard was calculated.*
*** For E. coli, the number of samples higher than the 235 col/100ml standard was calculated.*

Nitrate

While the focus of water quality issues in this plan is on bacteria (fecal coliform and *E. coli*) and phosphorus impacts due to the currently established TMDLs, other parameters were monitored as part of this study. Nitrate concentrations at the ten monitoring stations were below the water quality standard (10 mg/L) except for stations S5, S7, and S10. Eight samples analyzed at S7 were above the water quality standard while S5 had two samples and S10 had one sample above the water quality standard. Potential sources of nitrate include fertilizers, animal feedlots, septic systems, and animal waste. Many of the implementation projects recommended for the Upper Salem River Watershed (Appendix A) are targeted to reduce bacteria, phosphorus, and TSS, but may also have the ancillary benefit of reducing some levels of nitrate in surface waters.

The primary impacts of concern due to nitrate are on groundwater and drinking water supplies. No groundwater monitoring wells are located within the Upper Salem River Watershed, but one maintained by NJDEP (Well #330680) is located east of the watershed

(Figure 14). Nitrate in this well was 9.36 mg/L, but is from only one sampling event in 1999. This concentration may be indicative of potential problems due to groundwater discharge to surface waters, or if groundwater is used for crop irrigation. These situations may partly explain the nitrate levels detected during this study if groundwater from this region is used. Additional studies on nitrate occurrences in groundwater and drinking waters in the Upper Salem River Watershed are in order, but are beyond the original scope of this study. Future work could also include implementation practices specifically designed to reduce nitrate levels within subwatersheds S5, S7, and S10.

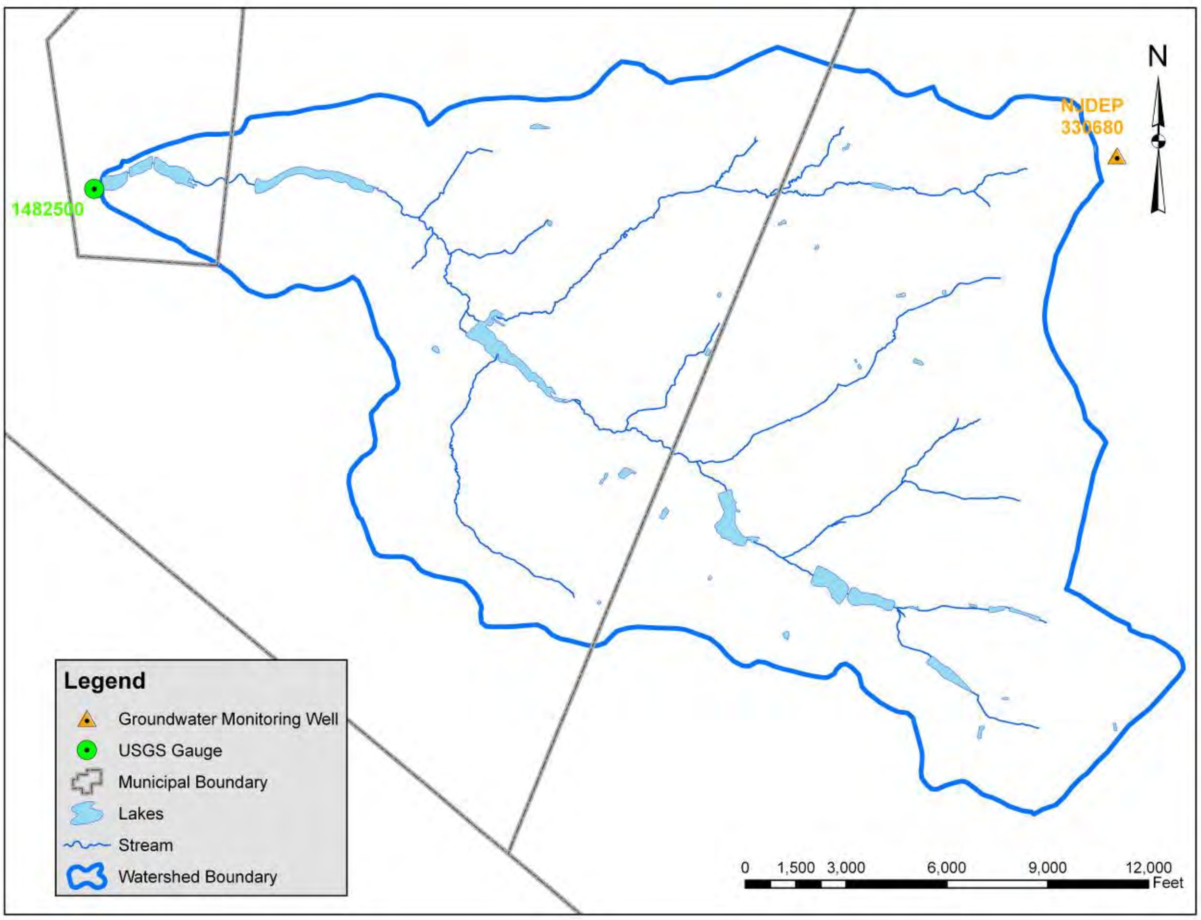


Figure 14: Location of groundwater monitoring wells in the Upper Salem River Watershed region.

pH

Mean pH levels for all stations were within the state's water quality standard (Figure 15). However, many sites had two (2) or more exceedances during the sampling period (Table 5) with violations due to elevated pH levels. Only stations S1, S5 and S6 did not exceed the water quality standard two (2) or more times. Sampling station S2 had 22 exceedances and S10 had 18 (Table 5). Elevated levels of pH can be caused by the loss of carbon dioxide (CO_2) from surface waters due to heightened photosynthesis. The large amounts of nutrients entering the Upper Salem River from the watershed could be stimulating plant growth and causing the loss of CO_2 in waterways (Figure 16).

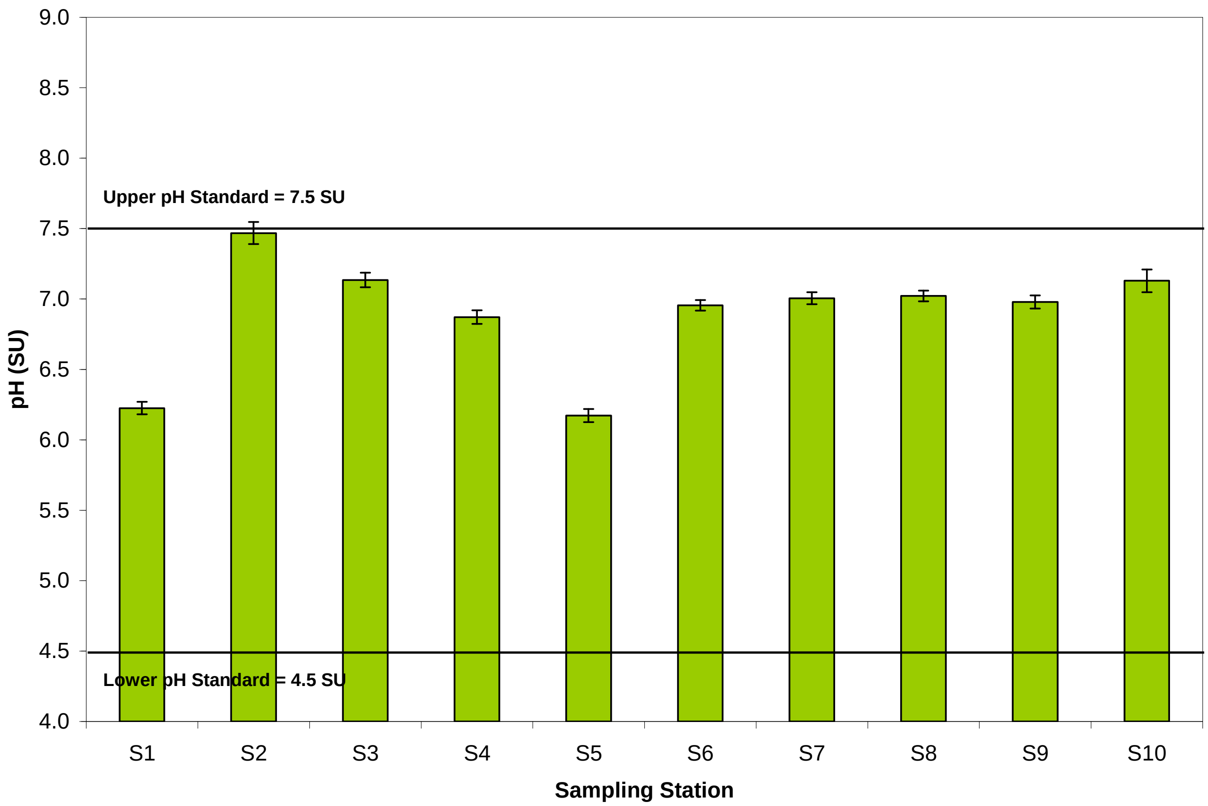


Figure 15: Mean pH levels for RCE monitored stations in Upper Salem River Watershed. Note that levels greater than 7.5 SU or below 4.5 SU are in violation of the state water quality standard. (Error bars indicate standard error of the mean.)

Figure 16: An impoundment along the Upper Salem River showing heightened plant growth.

The standard error of the mean is indicated on data graphs by error bars (Figure 15; Figure 17; Figure 19). The standard error of the mean is an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean. The general rule of thumb is that the smaller the error of a sample set, the less spread out the data is from the mean sample size. Also, the larger the error, the more spread out the samples are distributed from the mean. The standard error on pH levels (Figure 15) was small and ranged from 0.04 to 0.08.

Total Phosphorus (TP)

All water quality monitoring stations exceeded the 0.1 mg/L standard two (2) or more times during the sampling period (Table 5). This indicates elevated TP levels are causing impairments throughout the watershed. Stations S9 and S10, the most downstream sites, exceeded the 0.1 mg/L standard most frequently (on 52 occasions, each) (Table 5). This may be from cumulative impacts from throughout the Upper Salem River Watershed. Stations S5, S7, and S10 (Figure 4) had the highest single concentrations of TP over the course of the monitoring period (0.97 mg/L, 0.88 mg/L, and 0.87 mg/L, respectively). Standard error of the mean for TP had a narrow range of 0.01 to 0.02 (Figure 17).

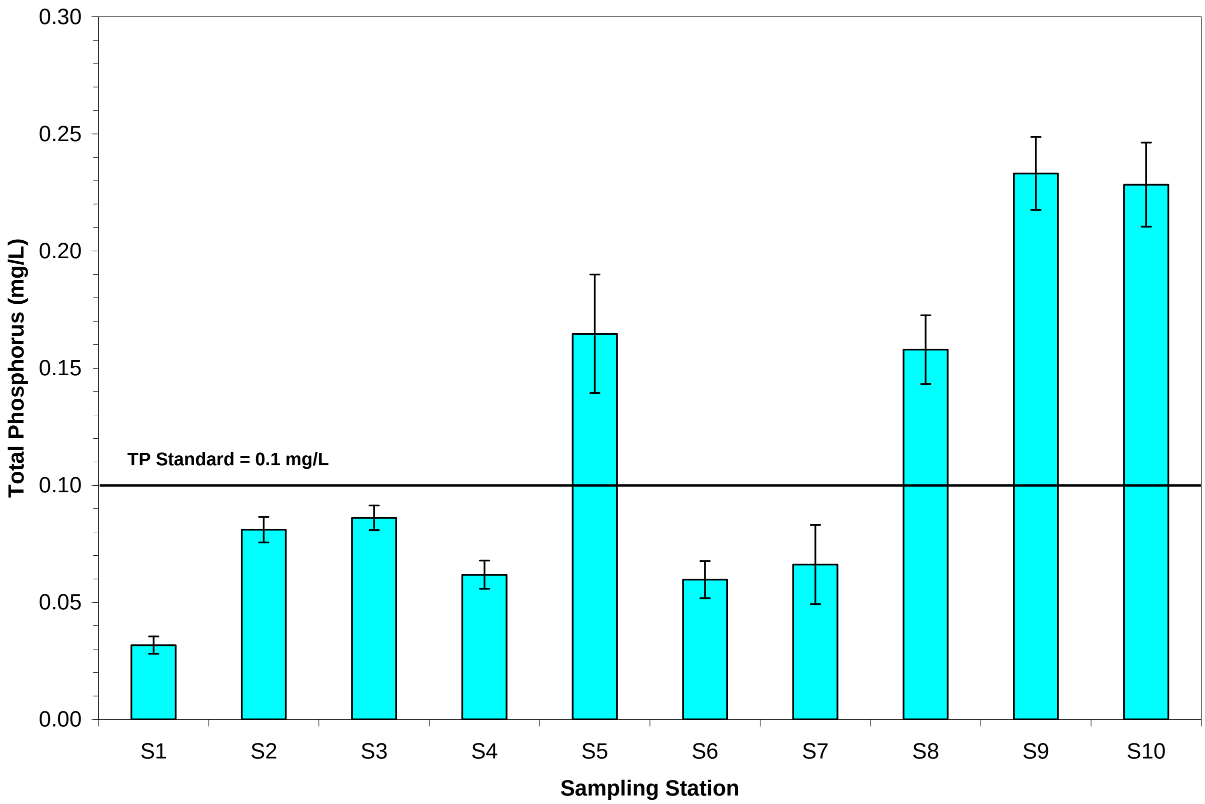


Figure 17: Mean total phosphorus (TP) concentrations for RCE monitored stations in Upper Salem River Watershed. (Error bars indicate standard error of the mean.)

For the analysis of TP data, wet and dry weather loads were compared. TP loads were calculated for both dry weather and wet weather events by multiplying concentrations by the flow measured at each station. Wet and dry dates were distinguished from each other by utilizing the USGS hydrograph separation model (HYSEP). HYSEP estimates the groundwater, or base flow, component of stream flow through one of three methods: fixed interval, sliding interval, or local minimum (Sloto and Crouse, 1996). The local minimum method was used in the Upper Salem River Watershed. Baseflow is calculated in this method and any flows measured during the course of this project that are above the calculated baseflow are considered "wet" events, while those below are considered "dry" events (Sloto and Crouse, 1996). In addition, downstream stations had upstream station loads subtracted from their total load to determine the contribution of individual subwatersheds. In some cases, this can lead to negative loads at a station (e.g., S10) due to there being a larger load upstream of that station (e.g., S9). By using these methods, subwatersheds S8 and S9 were found to have the largest mean TP loads in the Upper Salem River Watershed for both dry and wet weather events (Figure 18). These subwatersheds have the greatest impact in regards to TP results at the most downstream monitoring point for the project area (station S10; Figure 4) and may be contributing to the high concentrations measured during monitoring (Figure 17). High nutrient loading from subwatersheds S8 and S9 are priorities for water quality management.

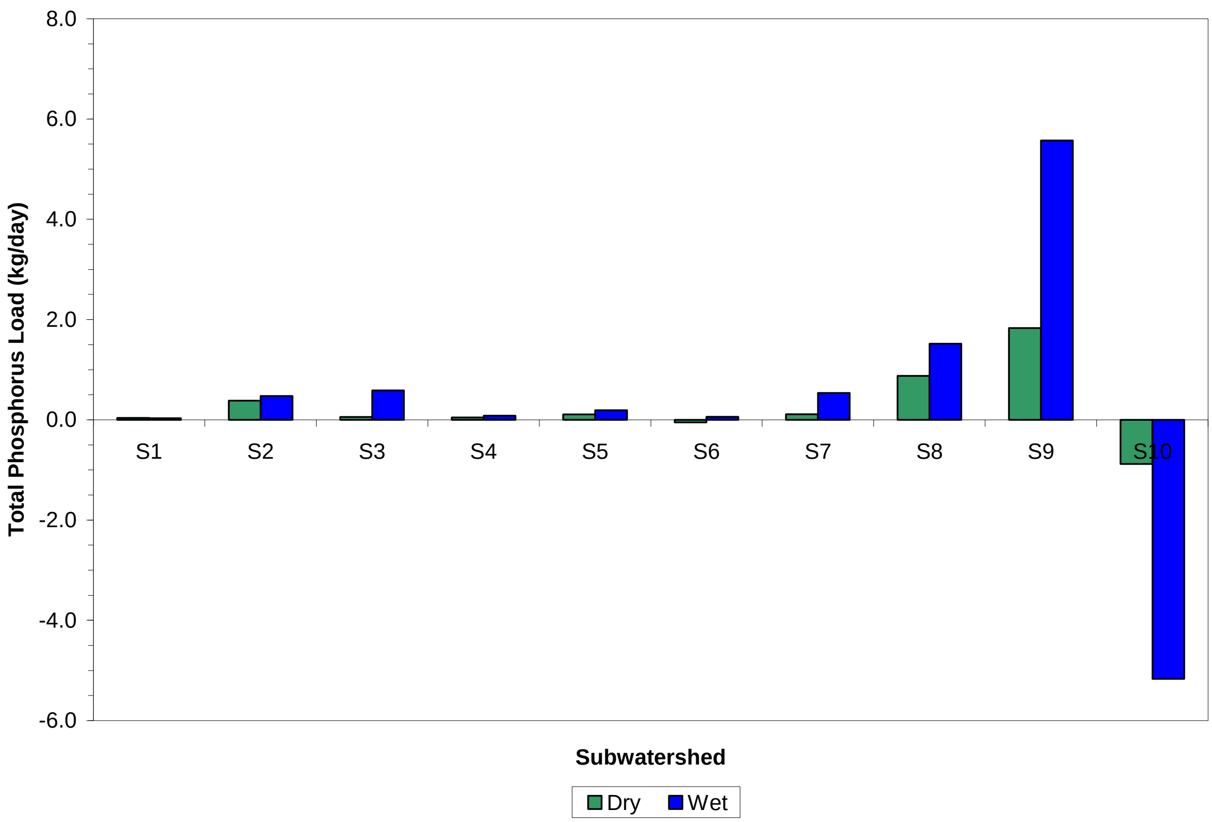


Figure 18: Comparison of daily total phosphorus (TP) loads per subwatershed under dry and wet conditions.

TP loads were also estimated using the Soil and Water Assessment Tool (SWAT) to model nutrient dynamics in the Upper Salem River Watershed (RCE Water Resources Program, 2011b). TP loads were calculated from subwatersheds on an annual basis for 2007-2008 and 2008-2009, and then normalized by subwatershed drainage area to determine loading rates (Table 6). These rates were compared to areal loading coefficients used by the NJDEP for TP. Areal loading coefficients for agricultural land uses, low density residential, and natural lands are 0.60, 0.30, and 0.05 kg/acre/year, respectively (NJDEP, 2004). The normalized total annual TP loading rate estimated using the SWAT model (at the watershed outlet at station S10) for 2007-2008 (0.27 kg/acre) is lower than the NJDEP coefficient (0.60 kg/acre/year), while the rate for 2008-2009 (0.76 kg/acre) is higher than the NJDEP coefficient for agriculture (Table 6). This may be due to higher soil erodibility, high watershed slopes, and different agricultural practices used in the Upper Salem River Watershed, as opposed to those watersheds used to develop the NJDEP coefficients. If the higher value is representative of conditions in the Upper Salem River Watershed, the need for water quality improvement becomes essential.

Under existing conditions, the subwatersheds that produced the largest TP loads were S10, S8, and S3 in both 2007-2008 and 2008-2009 (Table 6). When normalized by area, the largest loading rates were also in subwatersheds S10, S8, and S3 in 2007-2008 and S10, S8, and S4 in 2008-2009 (Table 6).

Table 6: Estimated subwatershed total phosphorus (TP) loadings from Upper Salem River SWAT model.

Subwatershed	TP Load (kg)		TP Load Rate (kg/acre)	
	2007-2008	2008-2009	2007-2008	2008-2009
S3	493	421	0.13	0.11
S4	31	158	0.05	0.24
S5	14	37	0.04	0.10
S7	66	90	0.04	0.05
S8	767	2,150	0.10	0.28
S10	2,420	6,790	0.27	0.76

Note that the loading rates for TP, as well as for fecal coliform and *E. coli*, were calculated based upon the total acreage of the watershed that drains to the sampling point (i.e., subwatershed S3 is comprised of the drainage areas of S1, S2, and S3, since these areas drain collectively to sampling point S3).

Fecal coliform

The former surface water quality standard for bacterial quality of FW2 surface waters was that the geometric means of fecal coliform samples not exceed 200 counts of organisms (colonies) per 100mL (col/100mL). Since initiation of this project, the indicator organism of bacterial quality has changed for freshwaters in New Jersey to the use of *Escherichia coli* (*E. coli*). For this report, however, both the former standard for fecal coliform and *E. coil* will be applied to data collected in the Upper Salem River Watershed since it is a fecal coliform TMDL that is the driver of restoration efforts (Table 4). In the Upper Salem River Watershed, eight of the ten monitoring stations exceeded the geometric mean of 200 col/100 mL over the course of the data collection period with maximum fecal coliform concentrations exceeding 400 col/100 mL at least once at all stations throughout sampling (Figure 19; Table 5). The geometric mean of fecal coliform concentrations was above the standard at stations S3 through S10 (Figure 19). Only stations S1 and S2, in the headwaters of the Upper Salem River, were below the state water quality standard (Figure 19). In addition, all stations exceeded the 400 col/100 mL standard on ten or more occasions during the sampling season (Table 5). Stations S4 and S10 had the highest fecal coliform counts across all stations over all events (60,000 col/100 mL). Standard error of the mean was large, and ranged from 115.49 to 1,439.99 (Figure 19), indicating large variability in fecal coliform levels measured in the Upper Salem River Watershed.

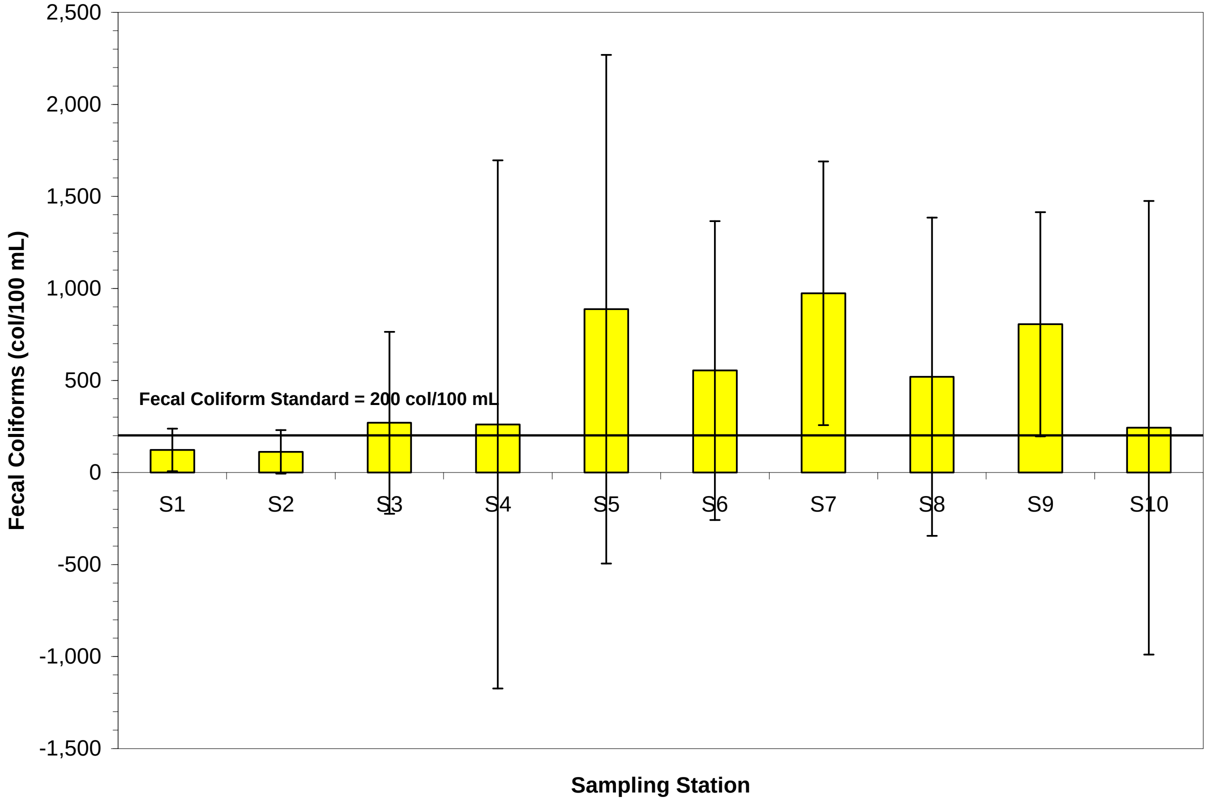


Figure 19: Geometric mean fecal coliform (FC) concentrations for RCE monitored stations in Upper Salem River Watershed. (Error bars indicate standard error of the mean.)

As stated in the TMDL, occurrences of high fecal bacteria in surface waters are largely due to storm events (NJDEP, 2003a). Fecal coliform (FC) loads were calculated in the same manner as TP loads and were also compared between wet and dry events. Fecal coliform loads were greater in almost every subwatershed during sampling events when stream volume was greater than baseflow (wet weather events; Figure 20). Only subwatersheds S8 and S10 had lower loadings during wet events (Figure 20). Assimilation, predation, or some other loss of FC may be occurring upstream of these locations. The S9 subwatershed was found to have the greatest influence on water quality at S10, where USGS gauge 01482500 is located (Figure 1). The S9 subwatershed is a priority for controlling pathogens in the Upper Salem River, as is subwatershed S3, which have the largest fecal coliform loads during wet weather events (Figure 20).

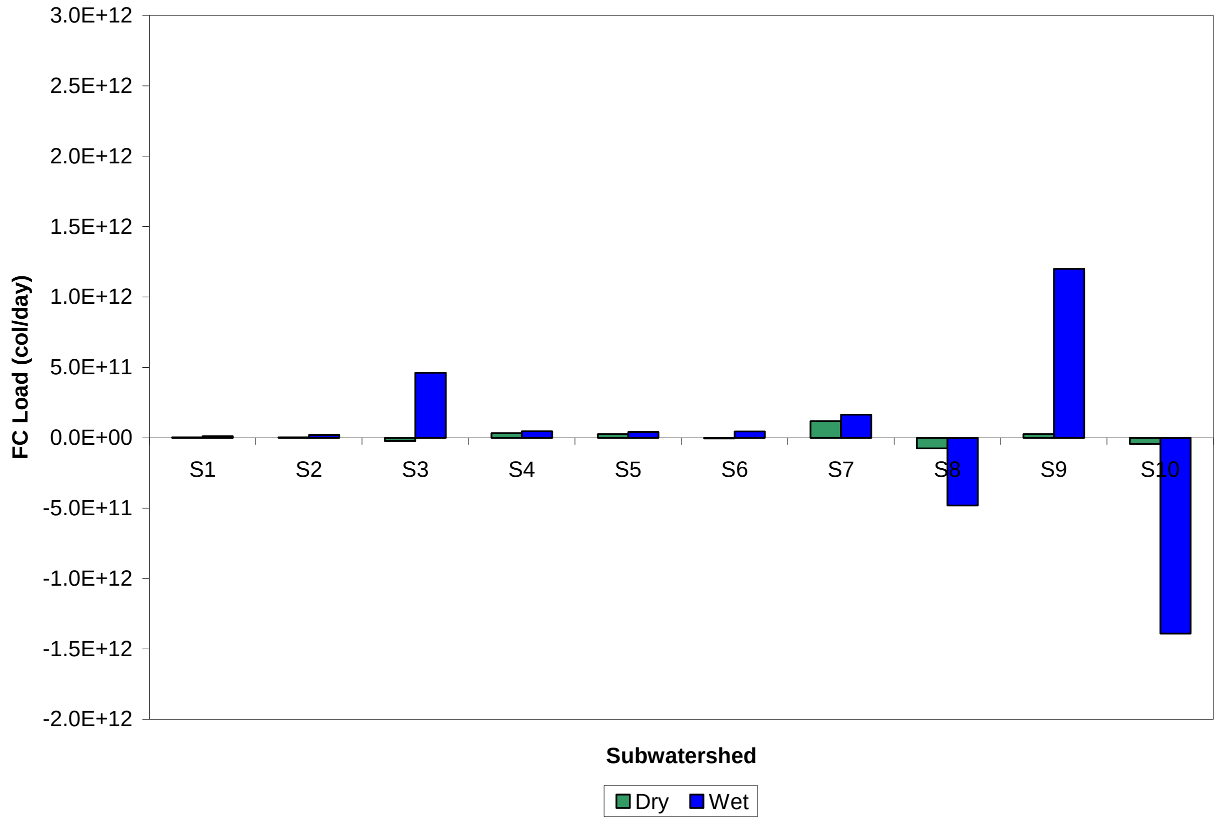


Figure 20: Comparison of daily fecal coliform (FC) load by subwatershed under dry and wet conditions.

Like TP loads, FC loads were also estimated using the Soil and Water Assessment Tool (SWAT) to model nutrient dynamics in the Upper Salem River Watershed (RCE Water Resources Program, 2011b). FC loads were calculated from each subwatershed on an annual basis for 2007-2008 and 2008-2009 and then normalized by subwatershed drainage area to calculate subwatershed loading rates (Table 7). Unlike TP, there are no areal loading coefficients used by the NJDEP for FC. Normalized total annual FC loading rates estimated using the SWAT model (at the watershed outlet at station S10) were 7.37 billion (7.37E+09) colony forming units per acre per month (cfu/ac/mo) for 2007-2008 and 12.5 billion (1.25E+10) cfu/ac/mo for 2008-2009 (Table 7). These are lower than estimated loads from agricultural lands (39 billion per acre) used to develop TMDLs for shellfish-impaired waters in WMA 17 (NJDEP, 2006).

Using these modeled conditions, the subwatersheds that produced the largest FC loads were S3, S8, and S10 in both 2007-2008 and 2008-2009 (Table 7). When normalized by area, the largest FC loading occurred in subwatersheds S5 and S7 in 2007-2008 and S10 in 2008-2009 (Table 7).

Table 7: Estimated subwatershed fecal coliform (FC) loadings from Upper Salem River SWAT model.

Subwatershed	FC Load (cfu/mo)		FC Load Rate (cfu/acre/mo)	
	2007-2008	2008-2009	2007-2008	2008-2009
S3	2.89E+13	1.49E+13	7.84E+09	4.04E+09
S4	1.71E+12	3.81E+12	2.55E+09	5.68E+09
S5	6.83E+12	2.56E+12	1.81E+10	6.79E+09
S7	1.92E+13	7.13E+12	1.16E+10	4.31E+09
S8	3.46E+13	2.75E+13	4.57E+09	3.63E+09
S10	6.60E+13	1.12E+14	7.37E+09	1.25E+10

Escherichia coli (E. coli)

E. coli is one species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends *E. coli* as the best indicator of health risk from water contact in recreational waters, and New Jersey changed their water quality standards accordingly (NJDEP, 2009b). The newly adopted *E. coli* surface water quality standard for FW2-designated waters is that the geometric mean not exceeds 126 col/100mL (Table 4; NJDEP, 2009b). In the Upper Salem River Watershed, *E. coli* results followed the same pattern as fecal coliform with eight of the ten monitoring stations exceeding the water quality standard over the course of the data collection period with maximum *E. coli* concentrations exceeding 235 col/100 mL at least once at all stations during sampling (Figure 21; Table 5). Like fecal coliform, the geometric mean of *E. coli* concentrations was above the standard at stations S3 through S10. Only stations S1 and S2, in the headwaters of the Upper Salem River, were below the state water quality standard (Figure 21). Station S4 had the highest single *E. coli* measurement across all stations over all events (200,000 col/100 mL). The standard error of the mean was large and ranged from 50.82 to 5,860.55 (Figure 21), indicating large variability in *E. coli* levels measured in the Upper Salem River Watershed.

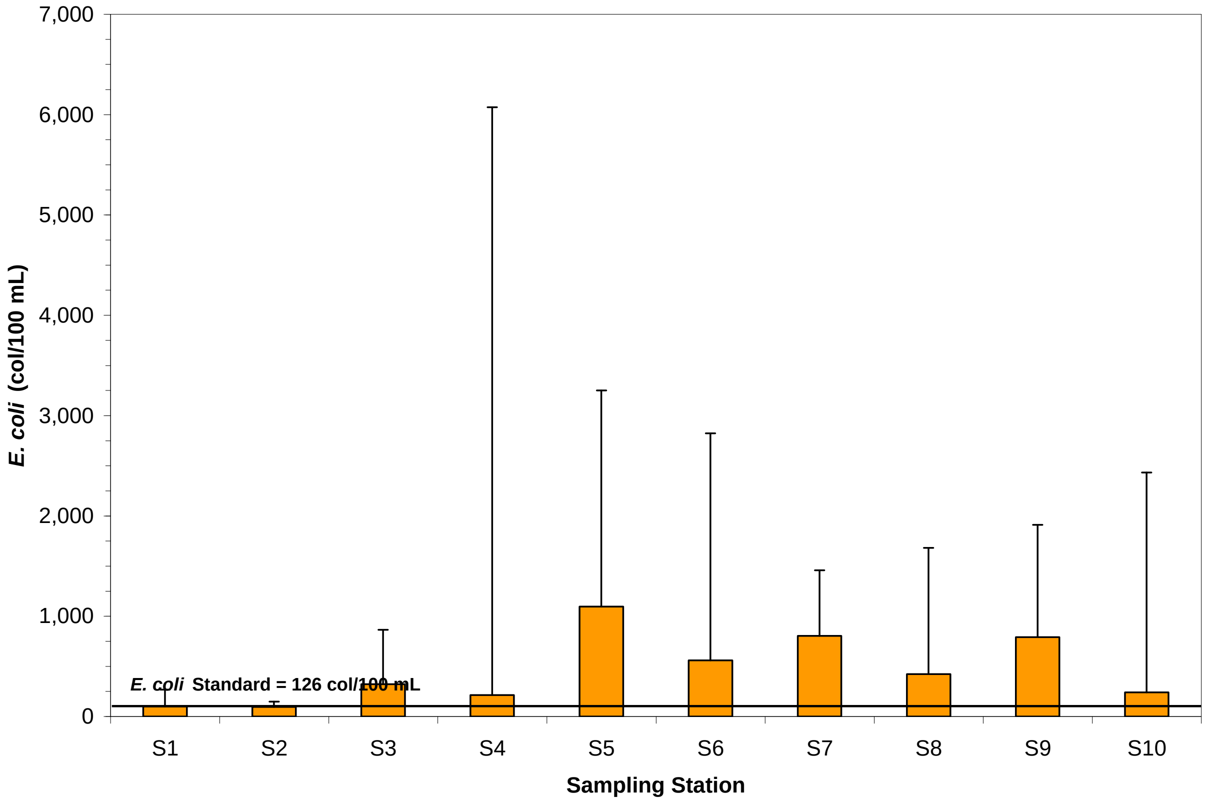


Figure 21: Geometric mean *E. coli* concentrations for RCE monitored stations in Upper Salem River Watershed. (Error bars indicate standard error of the mean.)

E. coli loads were calculated in the same manner as TP and fecal coliform loads and were also compared between wet and dry events. *E. coli* loads were greater in many of the subwatersheds during wet sampling events (Figure 22). Only subwatersheds S4 and S10 had lower loadings during wet events (Figure 22). The suspected loss mechanisms for fecal coliform (e.g., assimilation, predation) would also reduce *E. coli* levels upstream of these locations. The S9 subwatershed, which has the highest loads of *E. coli* during wet weather, is a priority for controlling pathogens in the Upper Salem River (Figure 22).

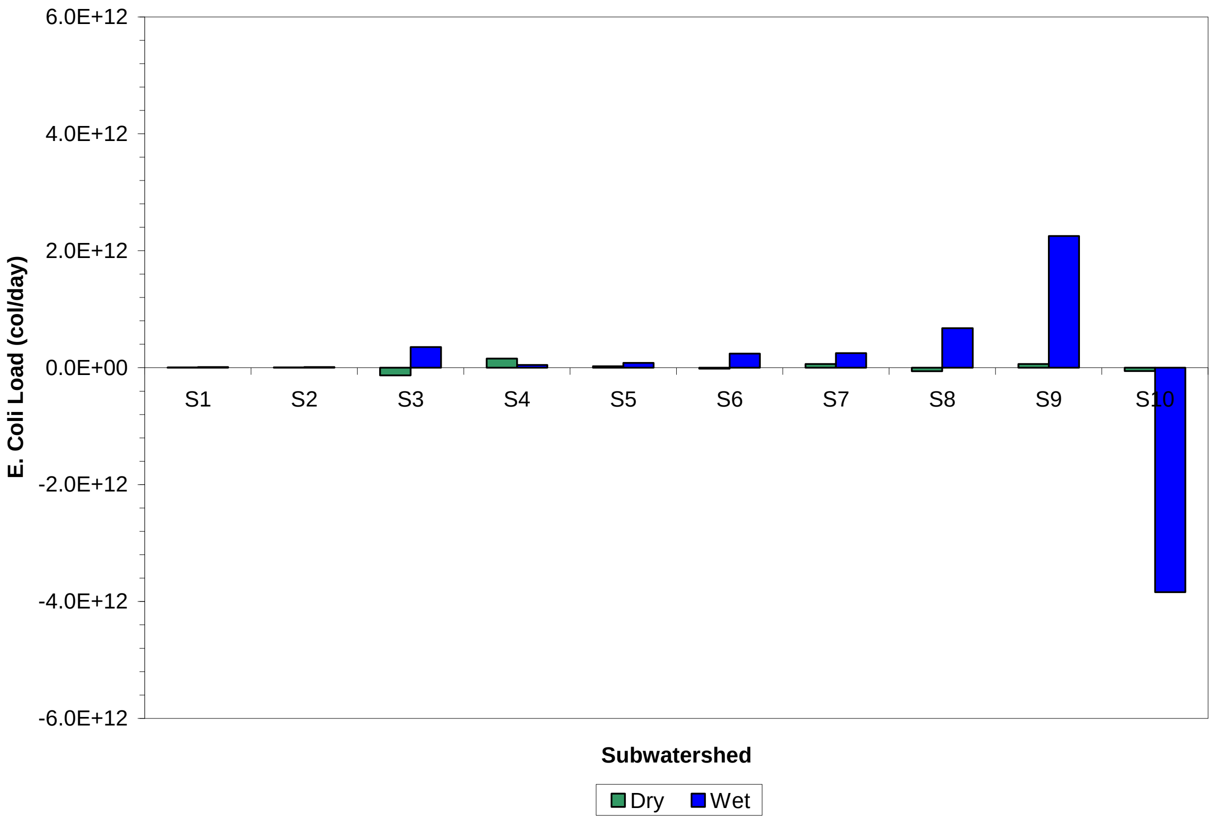


Figure 22: Comparison of daily *E. coli* load by subwatershed under dry and wet conditions.

E. coli loads were also estimated using the Soil and Water Assessment Tool (SWAT) to model nutrient dynamics in the Upper Salem River Watershed (RCE Water Resources Program, 2011b). *E. coli* loads were also calculated from each subwatershed on an annual basis for 2007-2008 and 2008-2009 and then normalized by subwatershed drainage area to estimate subwatershed loading rates (Table 8). Like FC, there are no areal loading coefficients used by the NJDEP for *E. coli*. Normalized total annual *E. coli* loading rates estimated using the SWAT model (at the watershed outlet at station S10) were 8.30 billion (8.30E+09) colony forming units per acre per month (cfu/ac/mo) for 2007-2008 and 26.9 billion (2.69E+10) cfu/ac/mo for 2008-2009 (Table 8).

Using these modeled conditions, the subwatersheds that produced the largest *E. coli* loads were S3, S8, and S10 in both 2007-2008 and 2008-2009 (Table 8). When normalized by area, the largest FC loading occurred in subwatersheds S5 and S7 in 2007-2008 and S10 in 2008-2009 (Table 8).

Table 8: Estimated subwatershed *E. coli* loadings from Upper Salem River SWAT model.

Subwatershed	*E. coli* Load (cfu/mo)		*E. coli* Load Rate (cfu/acre/mo)	
	2007-2008	2008-2009	2007-2008	2008-2009
S3	7.25E+10	2.73E+10	8.12E+09	3.07E+09
S4	2.55E+09	5.12E+09	2.55E+09	5.12E+09
S5	1.58E+10	1.15E+10	1.58E+10	1.15E+10
S7	2.39E+10	8.83E+09	1.17E+10	4.31E+09
S8	2.72E+11	1.94E+11	5.88E+09	4.20E+09
S10	2.24E+11	7.27E+11	8.30E+09	2.69E+10

Source Identification of Pollutants of Concern

Due to the extent and frequency of violation of applicable water quality standards, both TP and pathogenic bacteria (fecal coliform and *E. coli*) pollution are of primary concern in the Upper Salem River Watershed (Table 9). Elevated levels of these parameters were seen at all stations during the course of this study (Figure 17; Figure 19; Figure 21). As stated earlier, TMDLs have been established to reduce TP and fecal coliform levels in the watershed, indicating the importance of addressing these parameters and their impact on water quality. In addition, the elevated pH levels measured during the course of sampling should be noted (Figure 15; Table 5; Table 9). If high pH levels in the Upper Salem River Watershed are due to excessive plant growth, nutrient controls may work to reduce pH. Control and reduction of pollutants, however, are only effective when their sources have been determined and targeted efforts are used.

Table 9: Pollutants of concern (marked with an ✕) for each subwatershed in the Upper Salem River Watershed.

Subwatershed	pH	Total Phosphorus	Fecal coliform	E. coli
S1	-	✕	✕	✕
S2	✕	✕	✕	✕
S3	✕	✕	✕	✕
S4	✕	✕	✕	✕
S5	-	✕	✕	✕
S6	-	✕	✕	✕
S7	✕	✕	✕	✕
S8	✕	✕	✕	✕
S9	✕	✕	✕	✕
S10	✕	✕	✕	✕

Total Phosphorus (TP)

Fertilizers, domestic animal and livestock wastes, failing septic systems, and crop residues are potential agricultural and residential nonpoint sources of phosphorus carried by stormwater runoff and groundwater. Road runoff during storm events may also carry high concentrations of TP to streams and rivers (Flint and Davis, 2007).

Correlations with TSS and TP were conducted at each sampling station to determine the relationship between sediments and nutrients. For all stations, the Pearson correlation coefficient (R^2) was calculated as 0.45, indicating a modest relationship between TSS and TP concentrations for the overall Upper Salem River Watershed (Table 10). At station S5, the correlation between TP and TSS yielded an R^2 value of 0.70 or greater, indicating a strong relationship between these parameters (Table 10). This relationship may indicate that phosphorus is likely attached to suspended sediments as they co-occur (Table 10). Erosion leads to suspended sediments in streams and high phosphorus concentrations in the water column. This relationship is similar under both wet and dry conditions (Figure 23).

Table 10: Correlation coefficients between TP and TSS by monitoring station.

Station	Correlation Coefficient (r)	R^2
S1	0.38	0.14
S2	0.66	0.44
S3	0.60	0.36
S4	0.75	0.56
S5	0.84	0.71
S6	0.78	0.62
S7	0.33	0.11
S8	0.60	0.36
S9	0.64	0.41
S10	0.77	0.56
All Stations	**0.67**	**0.45**

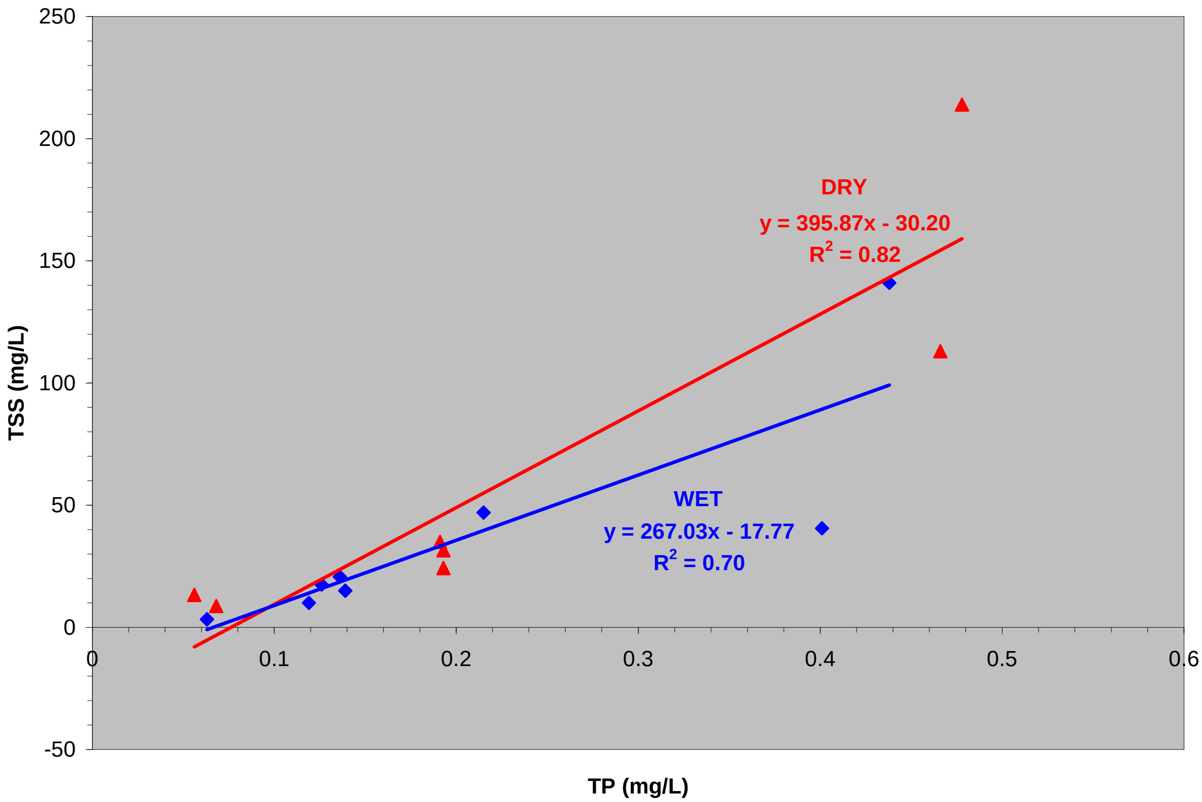


Figure 23: Plot of TP versus TSS concentrations at station S5 for wet and dry events.

At station S7, there is a weak correlation between TSS and TP (Figure 24). TP is relatively unchanging, even when TSS is elevated and when samples were collected under storm conditions. TSS averaged 9.52 mg/L in dry conditions and 22.18 mg/L in precipitation events. In addition, TSS levels only violated the state water quality standard three times throughout sampling at station S7 (Table 5). TP concentrations violated the state water quality standard six times (Table 5). There may be a source of phosphorus within the S7 subwatershed independent of suspended sediments in the Upper Salem River.

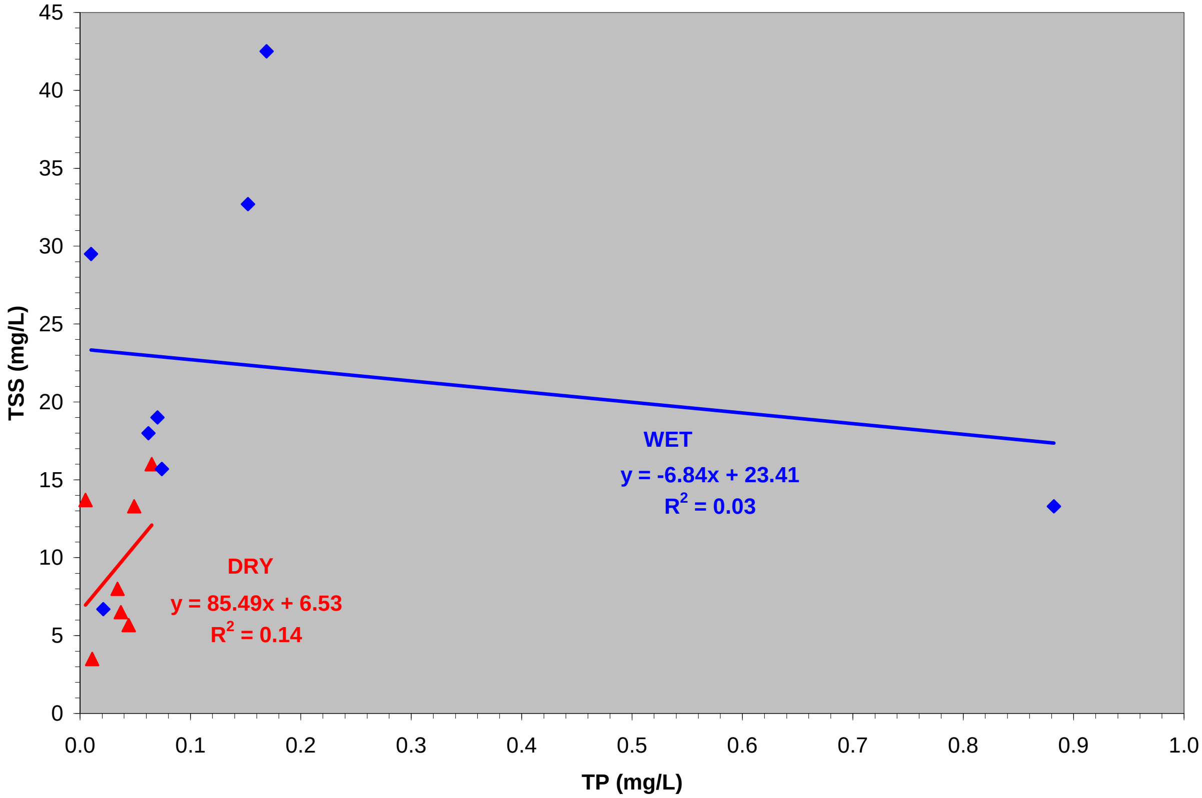


Figure 24: Plot of TP vs. TSS concentrations at station S7 for wet and dry events.

In addition, there are many man-made impoundments and lakes along the Upper Salem River (Figure 1). These areas may be accumulating sediments and sediment-bound phosphorus and harboring potential sinks for these pollutants. If the lakes are functioning as a sink for water quality contaminants, then it is likely that the water quality of the lake and its sediments are impacted. Nutrients that are accumulating in these waterways can create eutrophic conditions represented by algal growth, loss of dissolved oxygen, and lake filling. A study of the lakes and any accumulated sediment and sediment-bound phosphorus is beyond the current scope of this project, but further research would be necessary to determine the impact of these impoundments on water quality within the Upper Salem River Watershed. The water quality of these lakes may ultimately indicate that the expensive option of dredging is necessary to maintain watershed health and improve water quality.

Fecal coliform & E. coli

Using an indicator organism like fecal coliform or *E. coli* to solve pathogen problems in surface waters presents several challenges. First, these bacteria are solely indicators of fecal pollution and not a direct measure of fecal contamination. Second, the measurement of fecal coliform and *E. coli* concentration does not identify sources of fecal pollution as they are found in many different types of mammals. Therefore, it is imperative that prior to any remediation strategies the potential sources of pollution be identified. With more than 97% of the Upper Salem River Watershed without centralized wastewater treatment (Figure 5), failing septic systems are one potential source of fecal contamination. For those areas serviced by a centralized wastewater treatment plant, failing infrastructure could be a hazard that would result in waters impaired by bacteria.

Other sources throughout the Upper Salem River Watershed include wildlife (deer, raccoons, muskrats) and waterfowl (ducks, Canada geese, snow geese). Agricultural practices including the spreading of manure and its use as a fertilizer could potentially lead to runoff of fecal-related pathogens. Nine confined feed operations exist in the watershed, and manure management is important at these facilities to prevent runoff. Livestock access to waterways also leads to direct discharge of fecal matter into the streams, and locations where livestock have access to surface waters have been identified through field visits. Improper disposal of domestic pet wastes are also a potential source of pathogen pollution.

Microbial source tracking (MST) was employed to determine bacterial sources within the Upper Salem River Watershed. MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods to identify the origin of fecal pollution. MST techniques typically report fecal contamination sources as a percentage of targeted bacteria. One of the most promising targets for MST is *Bacteroides,* a genus of obligately anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprise up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Due to large quantities of *Bacteroides* in feces, they are an ideal target organism for identifying fecal contamination (Layton *et al.*, 2006). In addition, *Bacteroides* have been recognized as having broad geographic stability and distribution in target host animals and are a promising microbial species for differentiating fecal sources (USEPA, 2005; Dick *et al.*, 2005; Layton *et al.*, 2006).

Three sets of PCR primers (targets) were used to quantify *Bacteroides* from 1) all sources of *Bacteroides* ("AllBac"), 2) human sources ("HuBac"), and 3) bovine sources of *Bacteroides* ("BoBac"). This assay is based on published results from a study sponsored by the Tennessee Department of Environmental Conservation (Layton *et al*., 2006).

Based on the frequency of bovine-related *Bacteroides* occurrences in water quality samples, some conclusions can be drawn in regards to the sources of pathogen pollution in-stream. The highest frequency of bovine *Bacteroides* (BoBac) was 25% of water quality samples in the S5 subwatershed, followed by subwatersheds S3, S4, S6 and S7 (Figure 25). Bovine *Bacteroides* were less frequently detected (<10% of samples) in the remaining subwatersheds.

Due to limitations on the MST data, the contribution of human *Bacteroides* (HuBac) can not be conclusively determined. However, the majority of residents in the Upper Salem River Watershed are on septic systems (Figure 5). The potential for human fecal matter in streams may be a public health threat and needs to be addressed in some way. All subwatersheds in the Upper Salem River Watershed should be considered for control of bacterial contamination due to the high number of samples that violated the water quality standards for fecal coliform and *E. coli* (Table 5). Surface waters contaminated with human feces may also carry enteric pathogens including the hepatitis A virus, *Salmonella enterica enterica,* serovar Typhi, Norwalk group viruses, and others. Therefore, the control of human sources of pathogens is imperative for both ecological health and human health in the Upper Salem River Watershed.

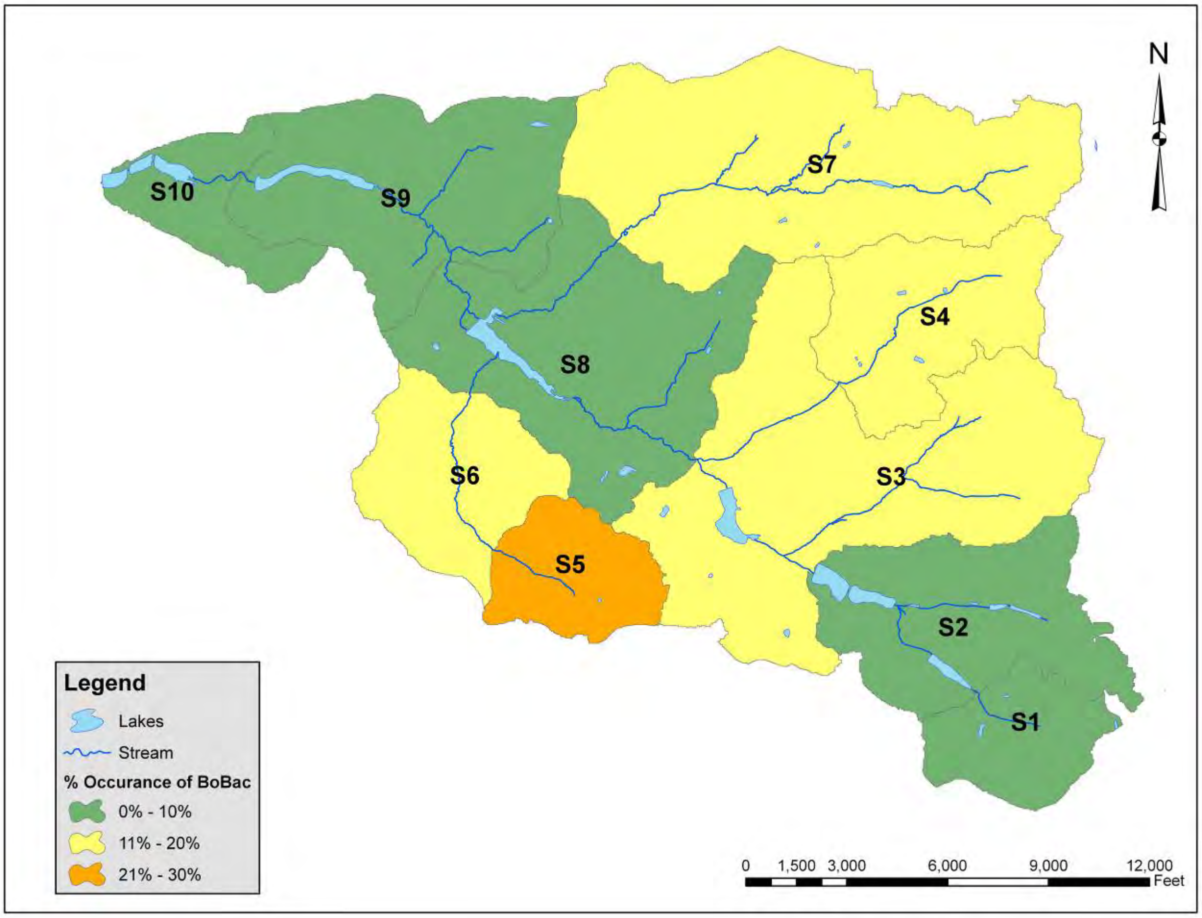


Figure 25: Percent occurrence of bovine *Bacteroides* (BoBac) by subwatershed.

Addressing Pollutants of Concern

The Upper Salem River Watershed Restoration and Protection Plan is dedicated to projects and efforts to control nonpoint source pollution. In the Upper Salem River Watershed, bacterial pollution (fecal coliform and *E. coli*) and TP are of concern. Implementation of the suggested projects will aid in achieving the goals set up in the appropriate TMDLs. Project details include the following information:

- Summary of current conditions at the location or in the watershed
- Descriptions of the implementation efforts
- Anticipated pollutant removal
- An estimate of cost
- Potential funding sources and project partners
- Proposed monitoring

These projects have been prioritized based on percent removal of pollutants, need on a subwatershed basis, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment.

Identification of Priority Implementation Efforts

Phosphorus and bacteria are moved primarily by surface runoff (both storm-driven flows and irrigation) in the Upper Salem River Watershed. Therefore, implementation projects have been identified and prioritized based on the water quality improvement that will result from their implementation and the cost-benefit of proposed solutions in dealing with surface runoff. Identified projects have also been developed based on water quality data collected for this project (Table 5). The urgency of their implementation has been highlighted below for the purposes of attracting funding sources and expediting their implementation schedule.

The following is a list of recommended implementation efforts to improve the water quality within the Upper Salem River Watershed. Details on each of the efforts identified below can be found in Appendix B.

1. Decentralized Wastewater Treatment Outreach and Education
2. Vegetated Buffers
3. Livestock Fencing

4. Rural Road Drainage System Retrofit Designs
5. Detention Basin Retrofit Designs
6. Manure Management
7. Dam Removal
8. Minimum Till Drill Program

Schedule for Implementation of Management Measures

Implementation of projects listed herein obviously requires some level of funding. The RCE Water Resources Program, local environmental commissions, municipalities, and citizen action groups need to work together to begin implementation of this plan. The following is a schedule for implementation provided funding is available (Table 11). In addition, the estimated reductions in the pollutants of concern, if effective improvement projects are enacted, are given in Table 12.

Table 11: Implementation strategy for water quality improvement projects in the Upper Salem River Watershed.

Applicable BMPs	Priority Subwatershed(s)	Target % Removal of TP	Target % Removal of FC/ *E. coli*	Estimated Potential Cost	Implementation Schedule
Decentralized Wastewater Treatment Outreach and Education	All	50% - 100%	50% - 100%	$26,500	December 31, 2016
Vegetated Buffers	All	30%	95%	$0.56/linear foot	December 31, 2016
Livestock Fencing	All	30%	95%	$1 - $2/linear foot	December 31, 2016
Rural Road Drainage System Retrofit Designs	S9	30%	95%	To Be Determined	December 31, 2016
Detention Basin Retrofit Designs	S2, S9, S10	60%	95%	$2 - $4/square foot	December 31, 2016
Manure Management	S5, S6, S7, S8, S9	100%	100%	To Be Determined	December 31, 2016
Dam Removal	S2, S3, S8, S9, S10	To Be Determined	To Be Determined	To Be Determined	December 31, 2016
Minimum Till Drill Program	All	22%	95%	$241,000	December 31, 2016

Table 12: Estimated annual reductions of select pollutants for each recommended water quality improvement project.

Applicable BMPs	Priority Subwatershed(s)	Estimated TP Reduction (kg/year)	Estimated FC Reduction (col/100ml/yr)	Estimated *E. coli* Reduction (col/100ml/yr)
Decentralized Wastewater Treatment Outreach and Education	All	8,873 – 17,746	4.0×10^{14} – 8.0×10^{14}	2.1×10^{14} – 4.2×10^{14}
Vegetated Buffers	All	5,324	7.6×10^{14}	2.0×10^{14}
Livestock Fencing	All	5,324	7.6×10^{14}	2.0×10^{14}
Rural Road Drainage System Retrofit Designs	S9	6,284	5.5×10^{14}	8.7×10^{14}
Detention Basin Retrofit Designs	S2, S9, S10	3,580	To Be Determined	To Be Determined
Manure Management	S5, S6, S7, S8, S9	2,022	2.0×10^{14}	2.0×10^{14}
Dam Removal	S2, S3, S8, S9, S10	To Be Determined	To Be Determined	To Be Determined
Minimum Till Drill Program	All	3,904	7.6×10^{14}	2.0×10^{14}

Information and Education Component

RCE helps the diverse population of New Jersey adapt to a rapidly changing society and improve their lives through an educational process that uses science-based knowledge. RCE focuses on issues and needs relating to agriculture and the environment; management of natural resources; food safety, quality, and health; family stability; economic security; and youth development. RCE is an integral part of the New Jersey Agriculture Experiment Station and Rutgers, The State University of New Jersey and is funded by the United States Department of Agriculture, the State of New Jersey, and County Boards of Chosen Freeholders.

The Water Resources Program is one of many specialty programs under RCE. The goal of the Water Resources Program is to provide solutions for many of the water quality and quantity issues facing New Jersey. This is accomplished through research, project development, assessment and extension. In addition to preparing and distributing fact sheets, we provide educational programming in the form of lectures, seminars, and workshops as part of our outreach to citizens. With New Jersey Agriculture Experiment Station funding and other State and Federal sources, we conduct research that will ultimately be used by stakeholders to improve water resources in New Jersey.

In an effort to recommend educational opportunities that are needed by local stakeholders and projects that will be welcomed by communities in the watershed, project partners held several meetings with members of the local farming community (representing grain, nursery, field crops, sod, and livestock industries), County Health Departments, Salem County governments, municipal governments, and environmental commission representatives. Information gained from these meetings was essential to the development of projects and outreach efforts that lead to action and water quality improvement. The recommended actions referenced in this Watershed Restoration and Protection Plan include the information learned and feedback received from these meetings.

Programs listed below are a small sample of educational opportunities offered by RCE and are available in New Jersey. The RCE Water Resources Program plays an important role, offering programs delivered to municipalities and working with local stakeholders to educate them on specific concerns in their area. Along with the RCE Water Resources Program, the USEPA and NJDEP offer newsletters, brochures and other outreach materials that can be used to supplement programs that educate stakeholders. These materials and the programs described below can be tailored to the specific needs and issues affecting the Upper Salem River Watershed.

For more information on the RCE Water Resources Program and its educational opportunities, please visit http://www.water.rutgers.edu/.

Rain Garden Programs: Schools and Landscapers

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

Stormwater Management in Your Backyard has been adapted by RCE Water Resources Program 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 also 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 also 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 aimed at landscapers and is very similar to the certification program for individuals except it includes much more detail on how landscapers could offer rain garden construction as a service. To learn more about rain gardens, visit http://www.water.rutgers.edu/Rain_Gardens/RGWebsite/raingardens.html.

Stormwater Management in Your Backyard

This program provides in-depth instruction on stormwater management. It introduces the factors that affect stormwater runoff, point and nonpoint source pollution, impacts of development (particularly impervious cover) on stormwater runoff, and pollutants found in stormwater runoff. An overview of New Jersey's stormwater regulations is presented including who must comply and what is required. Additionally, TMDLs are introduced along with various other requirements of the Federal Clean Water Act that have serious implications in New Jersey. Different types of BMPs are presented and how these BMPs can be used to achieve the quality, quantity and groundwater recharge requirements of New Jersey regulations are illustrated. BMPs discussed include bioretention systems (rain gardens), sand filters, stormwater wetlands, extended detention basins, infiltration basins, manufactured treatment devices, vegetated filters, and wet ponds.

The program also discusses various management practices that homeowners can install including dry wells, rain gardens, rain barrels, and alternative landscaping. Protocols for designing these systems are reviewed in detail with real world examples provided. A step by step guide is provided for designing a rain garden so that homeowners can actually construct one on their property. Students have an opportunity to bring in sketches of their property for review and discussion of various BMP options for each site. The course also provides a discussion of BMP maintenance focusing on homeowner BMPs. The course concludes with a discussion of larger watershed restoration projects and how students can lead these restoration efforts in their communities. The course is very interactive, and ample time is set aside for question and answer sessions. For more information about *Stormwater Management in Your Backyard*, visit http://www.water.rutgers.edu/Stormwater_Management/SWMIYB.html.

Environmental Stewards Program

RCE partnered with Duke Farms in Hillsborough, NJ to create a statewide Environmental Stewardship certification program. Participants learn land and water stewardship, BMPs, environmental public advocacy, and leadership. Each group meets twenty times for classroom and field study. They are taught by experts from Rutgers University and its partners. Students are certified as Rutgers Environmental Stewards when they have completed sixty hours of classroom instruction and sixty hours of a volunteer internship. Classes have been held at the Essex County Environmental Center in Roseland, Duke Farms, and the Rutgers EcoComplex in

Bordentown. Partners ask students to provide volunteer assistance to satisfy their internship requirements.

Graduates of this program become knowledgeable about the basic processes of earth, air, water and biological systems. They gain an increased awareness of techniques and tools used to monitor and assess the health of the environment. They gain an understanding of research and regulatory infrastructure of state and federal agencies operating in New Jersey that relate to environmental issues. Unlike some programs, they are also given an introduction to group dynamics and community leadership. Participants are taught to recognize elements of sound science and public policy while acquiring a sense of the limits of our current understanding of the environment. The goal of the Rutgers Environmental Stewards program is to give graduates knowledge to expand public awareness of scientifically based information related to environmental issues and facilitate positive change in their community. For more information on the Rutgers Environmental Stewards Program, visit http://envirostewards.rutgers.edu/.

New Jersey Watershed Stewards Program

The statewide program New Jersey Watershed Stewards (NJWS) was developed by the RCE Water Resources Program in 2009. The idea of the NJWS program was developed as a result of the Water Resources Program faculty and staff attending the National Water Conference in St. Louis in February 2009. The Water Resources Program faculty and staff learned about the successful Watershed Stewards programs of other states, such as in Maine and Texas. The success of these programs inspired the Water Resources Program faculty and staff to develop a Watershed Stewards program for New Jersey.

The NJWS program was designed to raise awareness and empower stakeholders to solve problems of nonpoint source pollution in watersheds throughout New Jersey. As part of the NJWS program, stakeholders complete in-class training, as well as participate in a watershed-scale apprenticeship to obtain the title of a "New Jersey Watershed Steward." Inducted stewards become instrumental in continuing participation in watershed projects in New Jersey and improve the water quality of New Jersey watersheds.

The first NJWS program was offered in spring 2010 at the Rutgers EcoComplex located in Bordentown, NJ. The program included four modules: one on the NJWS program, the second on watershed definition and classification, one on watershed impairments, and a final one on watershed approaches and solutions to watershed impairments. In addition to these modules, class activities were implemented to engage trainees in the program. Upon completion of a one day training program, trainees were required to participate in a NJWS apprenticeship project where they would participate in a watershed-scale project (e.g., installing rain gardens, visually assessing streams, assembling rain barrels, etc.).

The goals of the NJWS program are to increase stakeholder involvement in Watershed Protection Plan and/or TMDL development processes by educating and organizing local citizens; promote healthy watersheds by increasing citizen awareness, understanding, and knowledge about the nature and function of watersheds, potential impairments, and watershed protection strategies to minimize nonpoint source pollution; enhance interactive learning opportunities for watershed education across the state and establish a larger, more well-informed citizen base; empower individuals to take leadership roles involving community and watershed level water resource issues; integrate watershed assessment research, education, and extension; and, deliver local solutions to community and watershed level water resource issues. To learn more about NJWS, visit http://www.water.rutgers.edu/Watershed_Stewards/Watershed_Stewards.html.

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 leaders on the path toward sustainability and in the process become "certified" communities. Sustainable Jersey™ 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, by state government, and by experts and civic organizations in New Jersey to be among municipalities leading the way toward environmental sustainability.

Of the three towns within the Upper Salem River Watershed, only Pilesgrove Township is registered with Sustainable Jersey™ (Sustainable Jersey™, 2011). Both Upper Pittsgrove Township and Woodstown Borough should be encouraged to enter the Sustainable Jersey™ certification process. Several of the actions that are required under the certification process also will help improve the water quality of the Upper Salem River and achieve the goals of this plan. There are three Sustainable Jersey™ Actions that fall into this category: 1) Community Education and Outreach, 2) Water Conservation Education Program, and 3) Innovative Demonstration Projects - Rain Gardens. As the towns strive to achieve their Sustainable Jersey™ certification, they should focus on tailoring these three actions to help improve the water quality within the Upper Salem River Watershed. For more information, visit http://www.sustainablejersey.com/ or email Sustainable Jersey™ at info@sustainablejersey.com.

Nonpoint Education for Municipal Officials (NEMO)

NEMO is a program created in the early 1990's to provide information, education and assistance to local land use boards and commissions on how they can accommodate growth while protecting their natural resources and community character. The program was built upon the basic belief that the future of our communities and environment depend on land use. Since land use is decided primarily at the local level, education of local officials is the most effective, and most cost-effective, way to bring about positive environmental changes and practices. This program is designed to provide educational programs for municipal officials, engineers, and department of public works employees. The goals of this program are to educate these groups on water quality issues associated with nonpoint source pollution, to provide possible solutions to mitigate nonpoint source pollution, and to inform on how land use decisions impact stream and river health. The NEMO program also includes low impact development training. Although there currently is not an official NEMO program in New Jersey, a program could be developed and implemented for municipalities in the Upper Salem River Watershed, if funding were available. For more information, please contact Christopher C. Obropta, Associate Extension Specialist with the RCE Water Resources Program at obropta@envsci.rutgers.edu.

Additional Education Programs

The educational programs described above are on-going opportunities for residents, landscape professionals, and other concerned stakeholders and are applicable to the Upper Salem River Watershed. In addition to these opportunities, an education program specific for the needs addressed in this Watershed Restoration and Protection Plan is Decentralized Wastewater

Treatment Outreach and Education. Additional information regarding this educational opportunity for the Upper Salem River Watershed is given in Appendix A.

Decentralized Wastewater Treatment Outreach and Education

During this study, it became apparent that many areas within the Upper Salem River Watershed service their wastewater onsite with septic systems. These systems themselves are not the primary concern; older systems that are failing may still be in place and may not have been detected. Failing onsite wastewater treatment systems have the ability to emit not only bacteria and associated viruses, but may also contribute to the excess nutrient pollution within this watershed. Education and outreach would be conducted with homeowners to describe proper maintenance and operation of their septic systems.

Interim Measurable Milestones

Development of this Watershed Restoration and Protection Plan is the result of analyzing previously collected data, collecting over 500 water quality samples and several biological samples, gathering input from local stakeholders, and modeling the watershed. This multi-year and multi-step process is based on data collected in the spring, summer, and fall of 2006 and follow-up field work completed in 2007, 2008 and 2009. It is expected that since the time of data collection, some conditions in the watershed may have changed, either benefiting water quality or worsening conditions.

With this in mind, projects that have been identified are expected to have the most effective impact on water quality in the Upper Salem River Watershed. This Watershed Restoration and Protection Plan was developed using a holistic perspective, recommending projects and implementation efforts that will benefit local water quality beyond just what is mandated by TMDLs, including other parameters that may have yet been identified as impairing the watershed.

Projects that involve cessation of human-related pathogens are clearly the top priority, followed by all pathogen management measures, erosion and sedimentation concerns, and low cost-high benefit projects. It should be noted that many of these projects will entail several years of implementation before a project fully achieves its goals. Therefore, it is important that this

Watershed Restoration and Protection Plan remain dynamic and its implementation an evolving process. Regular meetings with municipalities, counties, and stakeholder groups should be held to solicit information on the ever-changing needs of the watershed so additional projects can be added to this plan and targeted to those expressed needs. This document should be consulted during the decision-making process for municipal and county governments as they proceed to plan for growth, keeping watershed protection and water resource protection an utmost priority.

Monitoring Component

Implementation of management measures will result in water quality improvements while minimizing flooding, promoting groundwater recharge or reuse, and other benefits. Both modeling and monitoring can be conducted to quantify these improvements.

Monitoring can be conducted to also quantify the improvements to the Upper Salem River and its watershed that result from the implementation of this plan. The NJDEP does maintain two benthic macroinvertebrate stations on the Upper Salem River (Figure 13). These stations can provide continued information on the improvement of water quality and its effects on aquatic biota. Moreover, water quality samples can be collected at established stations throughout the system and analyzed for various pollutants that are a concern within the watershed, such as nutrients and bacteria. These stations include the USGS gauge located at the outlet of the Upper Salem River Watershed (Figure 1) and the RCE sampling locations (Figure 4). Suggestions for monitoring can be found in the descriptions of individual BMPs described in Appendix A.

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APPENDIX A: IMPLEMENTATION PROJECTS TO ADDRESS KNOWN WATER QUALITY IMPAIRMENTS IN THE UPPER SALEM RIVER

Decentralized Wastewater Treatment Outreach and Education

Current Conditions

Outdated systems, lack of maintenance, and improper usage have been identified as reasons for failure of onsite wastewater treatment systems (Figure A-1). Education is needed on how to maintain and care for decentralized treatment systems. Through a partnership with the county health department, an effort will be undertaken to educate homeowners through targeted education materials. The distribution of educational materials may be administered with the help of pumping/inspecting companies that operate in the watershed, tax mailers, and newspaper articles. Working with septic-related businesses in the watershed will help to correct misconceptions and misuse that may currently be in practice at some residences.

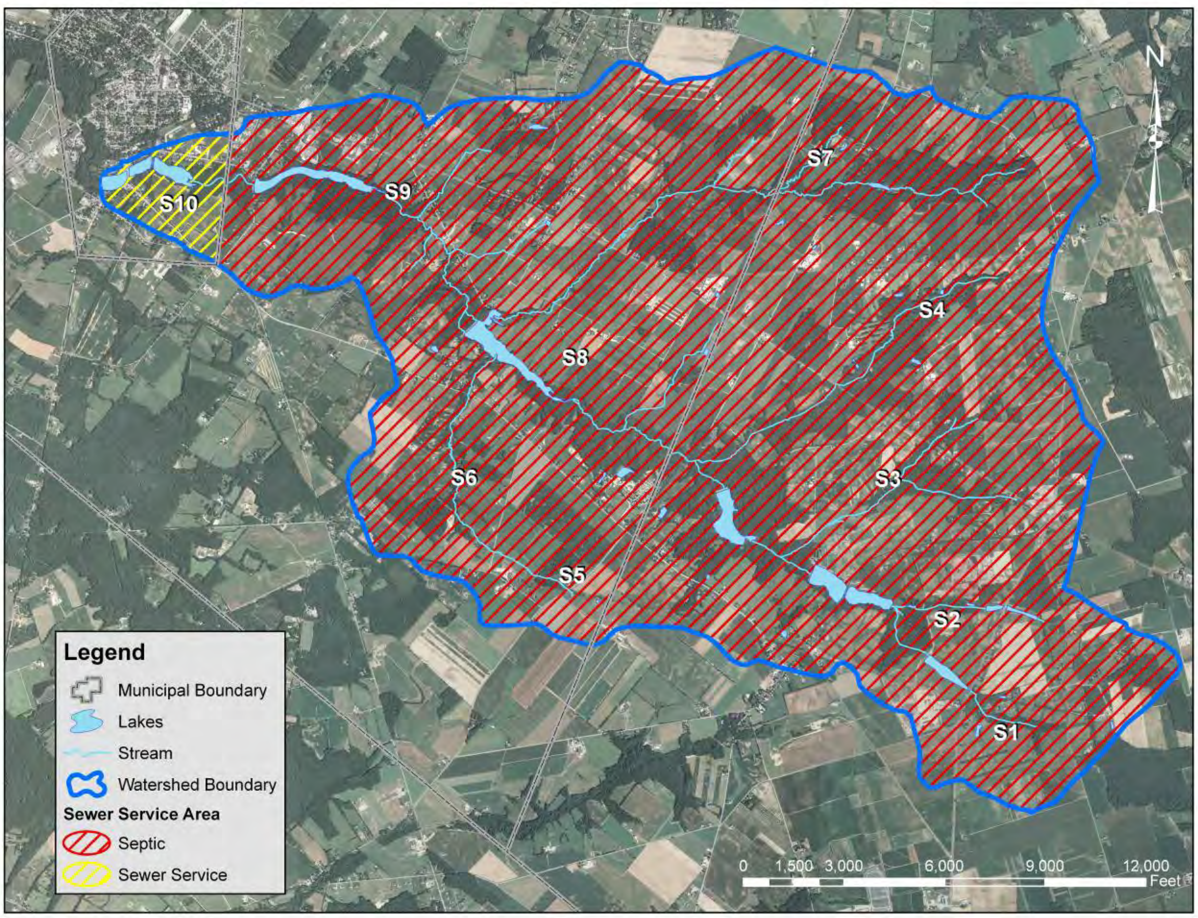

Figure A-1: Areas served by sewer service and septic systems in the Upper Salem River Watershed.

Overall, the majority of the Upper Salem River Watershed's homeowners rely on septic for wastewater treatment (Figure A-1). The USEPA reports that septic system failure rates typically range from 10-20%, where failure has been defined by the USEPA as wastewater ponding on the surface or backing up into the home (USEPA, 2002). In neighboring states such as New York, the reported failure rate is 4% (Nelson, Dix, and Shepard, 1999). With appropriate targeted education and availability of resources, this 4% failure rate could be achieved in the Upper Salem River Watershed, resulting in a significant reduction in pathogens and nutrients impacting surface waters. Currently, the pathogen load in the Upper Salem River ranges from 10^9 – 10^{11} col/day during dry weather and 10^{10} – 10^{12} col/day during wet weather for fecal coliform and 10^9 – 10^{11} col/day during dry weather and 10^9 – 10^{12} col/day during wet weather for *E. coli* (Table A-1).

Table A-1: Bacterial loads (fecal coliform (FC) and *E. coli*) per subwatershed based on RCE water quality monitoring.

Subwatershed	Dry Weather Mean FC Load	Wet Weather Mean FC Load	Dry Weather Mean *E. coli* Load	Wet Weather Mean *E. coli* Load
	col/day	*col/day*	*col/day*	*col/day*
S1	2.86E+09	1.09E+10	1.30E+09	9.16E+09
S2	3.25E+09	2.00E+10	5.45E+09	8.55E+09
S3	-2.44E+10	4.61E+11	-1.31E+11	3.54E+11
S4	3.27E+10	4.54E+10	1.56E+11	4.72E+10
S5	2.58E+10	4.02E+10	2.34E+10	7.95E+10
S6	-5.99E+09	4.39E+10	-1.56E+10	2.40E+11
S7	1.18E+11	1.65E+11	6.03E+10	2.47E+11
S8	-7.53E+10	-4.81E+11	-6.26E+10	6.75E+11
S9	2.62E+10	1.20E+12	6.26E+10	2.25E+12
S10	-4.47E+10	-1.39E+12	-5.96E+10	-3.84E+12

Septic systems from typical residential units will discharge 10^6 – 10^8 most probable number (MPN) of fecal coliforms per 100 mL (Bauer *et al.*, 1979; Bennett and Linstedt, 1975; Laak, 1975; Sedlak, 1991; Tchobanoglous and Burton, 1991), and a reported volume of wastewater from a toilet is 70 liters per person per day (Mayer *et al.*, 1999). Even with a failing septic system, unless the wastewater is being illegally trenched directly to the stream, the effluent will undergo some die-off naturally through soil infiltration and biological degradation. A worst-case scenario for water quality is pooled wastewater from a failing system mobilized by rainfall, entering the stream. This would result in effluent high in nutrients, pathogens and metals impacting local water quality.

In addition to water quality protection yielded from improved septic education and use, this project should engage municipalities in investigating management goals and opportunities. NJDEP's Water Quality Management Planning rules mandate septic management through each County as the Designated Planning Agencies, including septic system inventory, home-owner education and septic system maintenance by municipality. The counties have already begun this work, assisted by Clean Water Act (CWA) Section 604(b) grants and American Recovery and

Reinvestment Act (ARRA) grants given for the express purpose of septic management. This project should build upon these efforts. Management programs should be tailored to a municipality's capabilities, as well as their needs. Management programs typically are more stringent with increasing risks to public health and the environment. Management programs should include specific program goals, public education tasks, record management, technical guidelines for site evaluation, construction, and operation/maintenance, system inspections and maintenance monitoring, and may also include licensing and certification of inspectors, installers, and pumpers (USEPA, 2002). Consultation will be given to municipalities to identify their goals for decentralized management and approaches to reach those goals. Management, though initially difficult to discuss, is a long-term solution to decentralized wastewater problems.

Implementation

This outreach campaign will begin with a homeowner survey to better understand the homeowners' understanding of how a septic system works and the care and maintenance required. Feedback from this survey will direct educational materials that are adapted and/or developed and methods used to effectively reach homeowners. Educational materials will be re-tooled or developed to fit the population's needs. If educational programs are highlighted through the needs survey, then an evening program will be developed to target the residents of Salem County.

Following this initial educational campaign, a web-based follow-up survey will be launched to identify the effectiveness of this outreach program. Results of this survey will be compared to original survey results. Newspaper articles will be written to announce the program's effectiveness, and a final implementation report will summarize the results of this work.

Estimated Project Costs

Completing the Homeowner Needs Survey:	$6,000
Adaptation and Development of Educational Programs:	$8,000
Consultation with Municipalities:	$5,000
Survey of Program Effectiveness:	$6,000
Development of Implementation Report:	$1,500

The total direct cost of implementation is estimated at **$26,500**, which includes production and distribution of educational materials tailored to meet the area's needs. Utilization of work already accomplished under the 604(b) and ARRA septic management funds should lessen this cost.

Post Implementation Monitoring

As indicated above, post-implementation monitoring will be conducted as part of this implementation project. Success will be measured in terms of improved understanding of working septic systems and number of homeowners educated. Success will also be measured by long-term correspondence with the septic inspectors and pumpers working in these communities.

This can be related to water quality using the USGS monitoring station 01482500, Salem River at Woodstown Borough. It is expected that improvement will be demonstrated at this monitoring station, which requires no additional cost.

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Vegetated Buffers

Current Conditions

Considering the amount of agricultural lands within the Upper Salem River Watershed, there are many opportunities for implementation of an agricultural buffer program. An ideal location for a vegetative buffer has been identified along Route 40 in the northern part of the watershed (Figure A-2). The land use draining to this area contains pastureland for livestock which contains a fence to limit the livestock from accessing the stream. The site is located in the subwatershed S7 which is classified as a priority for TP and bacteria management and buffer implementation.

Figure A-2: Potential location of vegetated buffer in subwatershed S7.

Description

A vegetative buffer is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. The vegetation planted in a filter strip typically can be turf grasses, native grasses, herbaceous vegetation and woody vegetation, or some combination of these (Figure A-3). It is important to note that all runoff to a vegetated filter strip must enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's ability to remove pollutants.

Vegetated filter strips can be effective in reducing sediment and other total suspended solids (TSS), as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients. The TSS removal rates for vegetative filters depend upon the vegetation planted in the filter strip, but are estimated to range from 60 to 80% (NJDEP, 2004). The pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake, and microbial activity. Vegetated filter strips have a removal rate of 30% for phosphorus and nitrogen (NJDEP, 2004). Vegetated filter strips with planted or indigenous woods may also create shade along water bodies that decrease aquatic temperatures, provide a source of detritus and large woody debris for fish and other aquatic organisms, and provide habitat and protective corridors for wildlife (Figure A-3).

In addition, buffers act to exclude Canada geese from adjacent waterways. The non-migratory Canada goose has been identified as contributing nutrient and bacteria pollution to lands and waterways throughout New Jersey, including the Upper Salem River Watershed. Many areas have had success with deterrents, such as ‘Geese Police,’ but vegetated buffers offer a permanent solution to goose management. Ideally, the buffer should only be mowed once a year during the winter so that the buffer is kept to a minimum height of 6 inches at all times. The geese will not feel safe walking through the buffer to access the water as the buffer will obstruct the geese’s view making them wary of predators potentially lurking in the buffer. The buffer will also dramatically reduce the amount of turf grass the geese will be able to eat at each site.

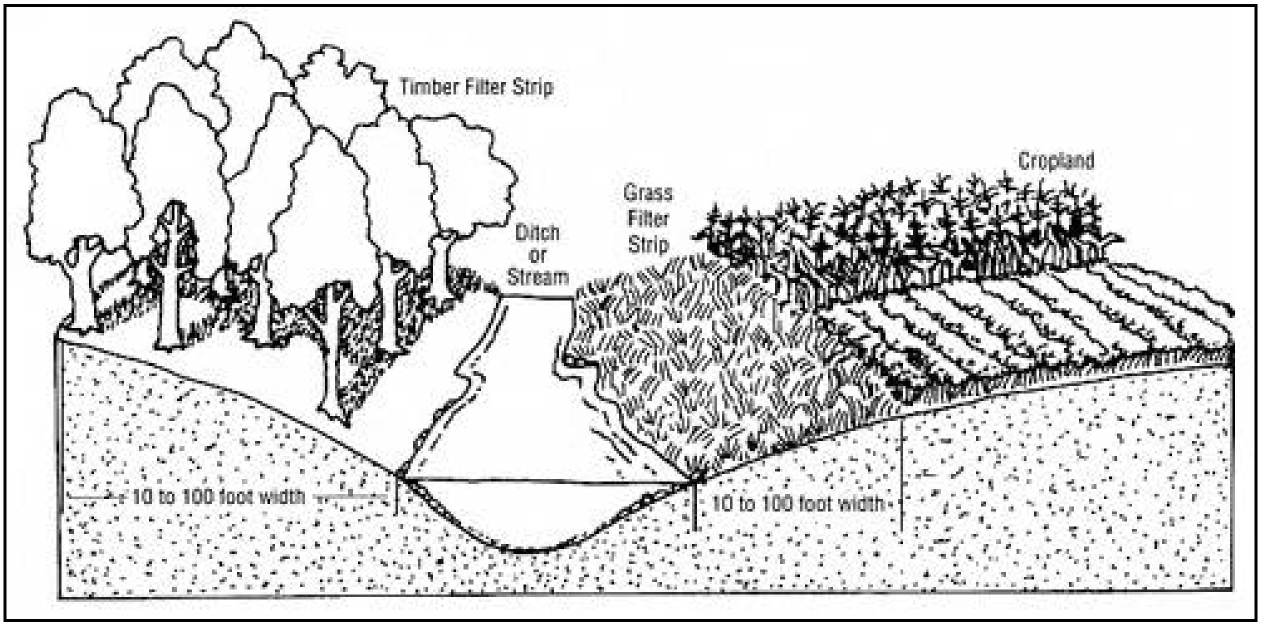

Figure A-3: Typical profile of a vegetated buffer in agricultural areas (FISRWG, 1998).

Location

Potential locations for vegetated stream buffers are found throughout the Upper Salem River Watershed (Figure A-4). The criteria used to determine buffer locations was to locate any agricultural land from the 2007 NJDEP land use data that was within 50 feet of streams and rivers (NJDEP, 2010). Any sites that met this criterion were chosen as potential sites for this BMP. This results in approximately 102,900 feet (19.5 miles) of potential vegetated buffer.

Implementation

The Cumberland-Salem Conservation District (CSCD) developed and implemented an agricultural buffer program, which installed 35 acres of vegetated buffers along agricultural lands in the Upper Cohansey River Watershed. The program was very attractive to farmers for several reasons – the application and paperwork were not cumbersome, money was paid directly to the farmer in a timely manner, and seeds were provided for the buffer planting. The feedback from the farmer advisory committee about this program was always positive. Based upon its success in the Upper Cohansey River Watershed, this program should be replicated in the Upper Salem River Watershed as soon as possible.

The agricultural buffer program developed by the CSCD paid landowners per acre to plant and maintain 30 foot wide agricultural buffers along fields to trap sediment and nutrients for an agreed upon number of years. The design of the CSCD program supplied the landowner with the seed mix for the vegetative filter strip and maintained communication with the landowners to ensure the success of the buffer.

Landowners involved in the program appreciated the minimum amount of paperwork and waiting time for implementation and payment. Vegetative buffers are excellent management practices for agricultural areas because they require little space and are successful at controlling impacts of runoff.

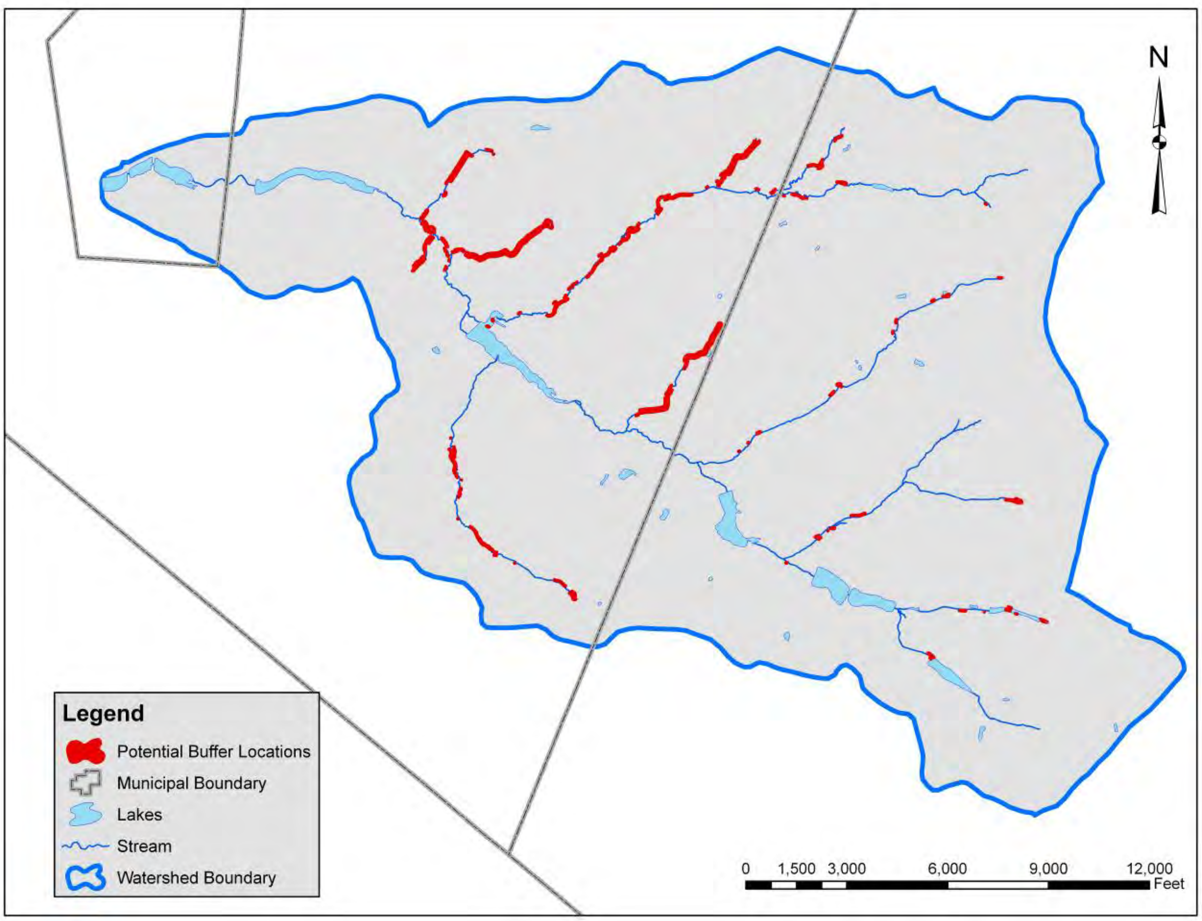

Figure A-4: Potential locations for vegetated buffers within the Upper Salem River Watershed.

A farmer interested in the program would apply to enter the program. The application would include identifying where the buffer will be, the existing slope of the land, and a proposed width of the buffer. After the application is approved the farmer should be supplied with the appropriate amount of seed to create the buffer. The farmer will use the same practices that he or she uses for planting his or her crops to install the buffer; clear the land of existing vegetation, plant the seed and allow time to grow. The agency that manages the program should stay in contact with the farmer while he or she participates in the program, and the status of the buffer should be checked from time to time to ensure the farmer is maintaining the buffer to allow it to function properly.

In addition, it should be noted that where a buffer with wooded or shrub vegetation is called for, NRCS provides cost-sharing for "Riparian Forest Buffer", Practice 391 (defined by NRCS as: planting trees and a grass buffer along waterbodies to act as a filter) and "Riparian Herbaceous Cover", Practice 390 (defined by NRCS as: planting grasses and shrubs along water bodies to act as a buffer and filter). Utilization of this cost-sharing could provide technical service and help defray costs to the landowner.

Maintenance

Vegetated filter strips are expected to trap debris and sediment therefore, they must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding one (1) inch of rainfall. Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations (NJDEP, 2004).

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

Cost

The cost of this program and project in particular is from the filter strip program that was conducted in the Upper Cohansey River Watershed. It will cost $600 for seed, and administrative fees or about $0.42 per linear foot of a 30 foot wide strip. The farmers will be paid $200 a year to maintain each acre of filter strip or $0.14 per linear foot of a 30 foot wide strip.

Utilization of the NRCS cost-sharing for the Riparian Forest Buffer and Riparian Herbaceous Cover practices where needed could provide technical service and help defray costs to the landowner.

Prioritization

This program as envisioned in this plan is on a volunteer basis by the land owner. Priority sites have not been specifically designated within the Upper Salem River Watershed, but those areas that undergo installation of livestock fencing are considered priority sites to also include vegetated buffers (see Livestock Fencing in Appendix A for more information on sites and additional costs). Future work will involve choosing sites in cooperation with the CSCD.

Expected Results

Following the design standards outlined in this document, the vegetative buffers installed should remove 70% of the TSS in the runoff that it filters throughout the year and 30% of the nitrogen and phosphorus in the runoff. There is no removal rate of bacteria for vegetative filter strips, but it is fair to assume that the bacteria act as particles and the removal rate should be similar because the same mechanism expected to reduce TSS will reduce bacteria.

References

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Livestock Fencing

Current Conditions

Livestock-related runoff and direct discharge of animal waste can be major pathways for pathogen and nutrient contamination. Livestock fencing around lakes and streams can prevent livestock from having direct access to these waterbodies and reduce the potential for pathogens and nutrients to enter surface waters. Fencing also provides a physical space between livestock and the waterway where vegetated filter strips could be installed to filter and further treat runoff. This will also improve ecological diversity and stream stability. There are not many situations that call for animal fencing in the Upper Salem River Watershed but they are suspected to be large sources of pathogens.

By restricting livestock access to the surface waters with fencing, landowners can quickly eliminate direct discharges of pathogens and nutrients to surface waters. With fencing setbacks there will be ample room for a vegetated filter strip to remediate contaminants entering the stream from overland flow. Stream stability at the location where livestock are currently entering the river can be increased and the potential for erosion of stream banks lessened if this combination is used. Vegetative filter strips have a removal efficiency of 30% for phosphorus and nitrogen and 80% removal efficiency for TSS (NJDEP, 2004). The major concern of installing this fencing for the landowner is finding an alternative water supply for the animals. It should be noted that NRCS provides cost-sharing for the "Watering Facility," Practice 614 (defined by NRCS as: Livestock watering tanks or hydrants. These limit the animals need to be in or around surface water bodies). Utilization of this cost-sharing could provide technical service and help defray costs to the landowner. Ideally, water and feed should be provided for the livestock at the opposite corner of the property at the highest elevation so that runoff can be minimized.

Location

The locations of potential livestock fencing projects are shown in Figure A-5. The criteria for site selection were any confined animal feeding operations (CAFOs) in the watershed or pastureland (both as defined by NJDEP) crossing a stream or other water body (Figure A-5). This is projected to result in approximately 4,445 feet of livestock fencing around pastureland and approximately 18,800 feet surrounding CAFOs in the Upper Salem River Watershed (Figure A-5). Field verification of these sites to determine if fencing already exists has not been performed, which would affect both the scale and costs for fencing these areas.

Prioritization

There are nine CAFOs located in the entire Upper Salem River Watershed and several locations where pasturelands include streams and lakes. Priority should be given to those locations closest to streams or lakes (Figure A-5), especially the most downstream CAFO which was seen to have cattle in direct contact with the Salem River during SVAP assessments (Figure A-6). This project would serve as a great demonstration project due its high visibility.

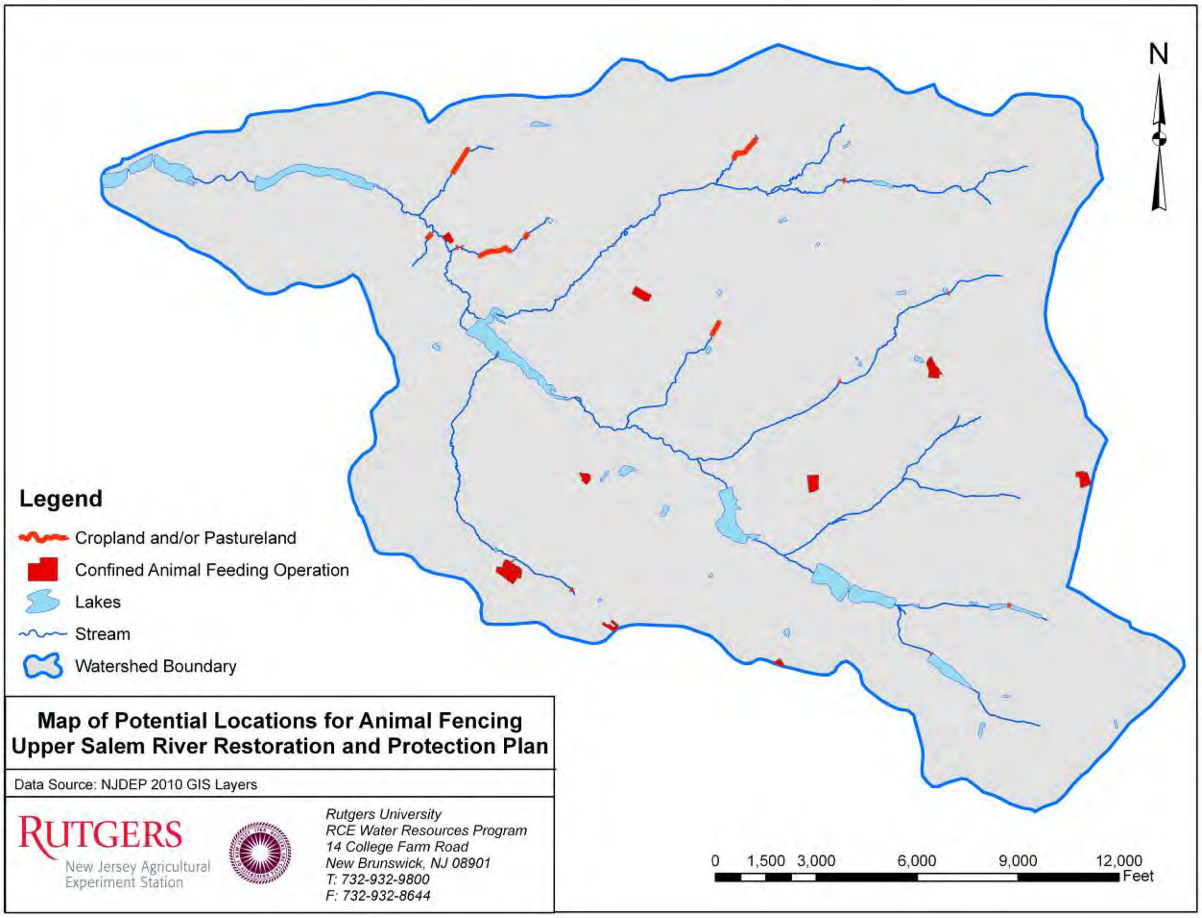

Figure A-5: Potential locations for livestock fencing in the Upper Salem River Watershed.

Figure A-6: Cattle with direct access to the Salem River.

Cost

There are several different types of fencing that can be used (electrified polywire, high tensile electrified wire, high tensile non-electrified wire, barbed wire or woven wire) and each have similar costs. The cost for installing a fence can range from $1.00 to $2.00 per linear foot (Meyer and Olsen, 2005). With an estimated 4,445 linear feet of lands needing fencing, a total of $4,445.00 to $8,890.00 would be needed to fence all estimated pasturelands and from $18,800 to $37,600 for CAFOs within the Upper Salem River Watershed. These costs do not include additional costs from inclusion of vegetated buffers to provide additional improvements to water quality (see Vegetated Buffers in Appendix A for more information on additional costs). It should be noted that NRCS provides cost-sharing for "Use Exclusion", Practice 472 (defined by NRCS as: Using a fence or other barriers to exclude livestock from sensitive areas such as streams, ponds, etc.) and this could help defray costs to the landowner.

Expected Results

If livestock fencing alone is installed, water quality benefits would be expected and some research has quantified those benefits. Stream cattle fencing was found to reduce annual flow weighted average sediment concentrations by 57% and a 40% reduction was observed in average annual soil loss (Owens *et al.*, 1996). Providing an alternate watering source for livestock, in addition to fencing, has been estimated to reduce TSS by 90%, total nitrogen by 54%, and TP by 81% (Agouridis *et al.*, 2005). Following New Jersey design standards, vegetative buffers installed in areas between the fencing and the waterway should remove 70% of the TSS in the runoff that it filters throughout the year and 30% of the nitrogen and phosphorus in the runoff (NJDEP, 2004). There is no removal rate of bacteria (fecal coliform or *E. coli*) for vegetative filter strips, but it is fair to assume that the bacteria act as particles and the removal rate should be similar to TSS because the same mechanism expected to reduce TSS will reduce bacterial concentrations. Livestock fencing in North Carolina in conjunction with tree plantings reduced TSS by 82.3% and TP by 78.5% (Agouridis *et al.*, 2005).

References

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Rural Road Drainage System Retrofit Designs

Current Conditions

Water quality data collected in the Upper Salem River Watershed show total suspended solids (TSS) above the Surface Water Quality Standards (SWQS) in a few sampling locations. To address this concern for TSS and other pollutants (total phosphorus (TP) and bacteria) in the watershed, site visits were conducted. It was noted during these visits that TSS could originate from drainage systems along roadways in the watershed (Figure A-7). This appears to be a common problem in rural areas throughout the watershed.

Figure A-7: Existing rural road drainage system in the Upper Salem River Watershed.

The purpose of rural road drainage systems is to transport runoff from a drainage area to the nearby waterway while improving the water quality of the runoff. Currently, rural road drainage systems are degraded due to the loss of vegetation lining the drainage system. There are several factors that negatively affect the water quality of runoff discharged from the drainage system. Fertilizer used on agricultural land can be a source of TP and nitrogen, and, if manure is used as a fertilizer, it can also be a source of bacterial contamination (fecal coliform and/or *E. coli*). These accumulated pollutants can be carried to local waterways via stormwater runoff. Rural road drainage systems carry runoff from these potential sources directly to the stream or one of its tributaries.

Rural road drainage systems do not have design standards unlike more conventional stormwater systems. Rural road drainage systems are ad hoc creations not necessarily designed for water quality or flood control, but primarily for convenience to the landowner. This approach to design can exacerbate water quality issues due to the lack of specified requirements. In addition, typical rural road drainage systems are not well maintained and usually consist of bare soil, a source of TSS (Figure A-7). Without proper design, drainage systems will continue to contribute to water quality problems. Simple designs that take advantage of nature’s mechanism for treating stormwater can have positive effects on water quality and quantity issues in stormwater runoff that is transported by rural road drainage systems.

Rural Road Drainage System Design Alternatives

The recommended management strategy is meant to protect existing drainage systems from erosion and improve water quality of runoff traveling through them. The State of New Jersey Department of Transportation (NJDOT) Drainage Design Manual requires outlet protection of conduits for runoff velocity generated during the 25-year storm (at a minimum) to prevent erosion (NJDOT, 2006). Therefore, it is recommended that this design guideline be followed to prevent erosion in these systems. The other goal of the strategy is to improve water quality of the runoff entering the drainage system. A common method of improving water quality is to reduce the velocity of runoff to allow soil particles (and, therefore, contaminants attached to the particles) to settle out. Designs should work to mimic flow reductions seen in vegetated buffers for water quality improvement (see Vegetated Buffers in Appendix A for more information). An additional benefit of reducing velocity is encouraging infiltration of stormwater by retaining runoff in the drainage system for a longer period of time and increasing the runoff's contact time with vegetation growing in the drainage system.

When recommendations are made to improve rural road drainage systems, typically they are to widen the drainage system and plant it with a diverse mix of vegetation. Vegetation creates friction to reduce flow and encourage infiltration. Many areas have a very narrow right-of-way along the side of the road. There is very little space available to widen the drainage systems or to plant vegetation in these rights-of-way, so it is recommended that rip-rap installed in a French drain, gabion baskets and weirs be used as flow control structures as appropriate. These have the capability of mimicking the flow reduction ability of vegetation. Due to the space constraints in the Upper Salem River Watershed, this is seen as the easiest way to transform the rural road drainage systems from a potential pollution source to a potential treatment device for stormwater.

Alternative A: Gabion Baskets

Stone-filled gabion baskets are inexpensive and easy to install. The gabion basket is an empty cube made of wire mesh that is filled with large stone. The stone provides structural support and the mesh holds the stone in place. Gabion baskets have been used in the past as check dams for swales and other drainage channels and also for steep slope stabilization. While the baskets are porous, they restrict flow as runoff meanders through the stones found within them. Gabion baskets can be installed temporarily in drainage systems to serve as a physical obstruction to reduce velocities in the channel and improve water quality. The reduction in velocity will require the drainage systems to have a larger storage capacity, however. While there is little room to widen the drainage system, it can be deepened to meet the additional storage capacity requirements. Gabions can also be used on steep slopes within the rural road drainage systems for erosion control.

Alternative B: French Drain

A French drain is an underground trench filled with stone (rip-rap) with the stones exposed to the surface. The size of the channels filled with stone and portions of the drainage system upstream of the exposed French drain need to be designed to account for the additional storage capacity required in the drainage system. The ends of the French drain need to have structural support to prevent stone from dispersing upstream and downstream over time. A gabion basket check dam placed at the front and back of each exposed French drain would provide sufficient support. One of the advantages of this design is that it is useful for locations that require vehicles to cross the drainage system on a routine basis. Farmers often require this for their equipment, and it could also be used for driveways.

Alternative C: Weir
Gabion baskets provide a basic form of velocity control. They do not have the flexibility of flow control that other devices have such as weirs. A weir is simply a wall with a notch cut out of it. The flow is controlled by the shape, elevation and size of the notch and the height of the water behind the notch. The higher the water behind the weir and the larger the shape and size, the higher the flow rate. They can easily be constructed with a concrete footing and cinder blocks. This strategy is interchangeable with Alternative A unless flow control is also needed. They accomplish the same goals and have the same requirements for additional storage capacity. The weir's advantage over the gabion check dam is that there is greater control over the flow, but it costs more to design and implement than gabion baskets.

Figure A-8: Location of potential drainage improvement project.

Location

An ideal location for rural road drainage system retrofitting is along East Lake Road in the western portion of subwatershed S9 (Figure A-8). The red line indicates the location of the degraded drainage systems. One of the strategies listed above should be evaluated for feasibility and implemented as dictated by funding and permission from the landowner(s). If properly retrofitted with one of the recommended strategies, roadway pollutants could be minimized from entering local waterways.

Implementation

After identification of a roadside to implement one of the recommended strategies, several existing parameters would need to be measured to ensure a successful design. The existing infiltration rate of the soils for the drainage system should be tested. The test should be conducted for every 500 feet of drainage system length or noticeable change in soil type. An elevation survey should be conducted or existing topography data should be collected to determine the drainage area for the drainage system. This should include the slope of the drainage system. The two design-limiting parameters for the strategies outlined above are the width of the right-of-way and the depth to groundwater. The designed system cannot exceed the width of the right-of-way and the system should always be located above the seasonal high groundwater elevation by a minimum of two feet.

The alternatives provided herein involve relatively minor work for implementation. The steps involved in installation included re-shaping the drainage system (excavation), installing the flow constriction device (gabion basket check dams, weirs, and/or French drain), reseeding any bare soil and following the soil erosion and sediment control protocol to protect bare soil from erosion. If during the construction of the design over 5,000 square feet of land is disturbed, then the project requires a Soil Erosion and Sediment Control Plan certified by the local Soil Conservation District. The municipality should have a discussion with the NJDOT about its plan to retrofit drainage systems prior to installation. The NJDOT has criteria for drainage of the roads in New Jersey, but they are flexible in the approach as long as it meets its standards.

The drainage system will require inspection every three (3) months; a visual inspection while driving along the system will suffice. The rural road drainage system should be inspected for standing water, debris, excess sediment, and health of vegetation. While vegetation is not part of the recommended strategies, there should be no bare soil in the drainage system; the drainage system should retain grass for additional erosion protection and infiltration. The grass in the drainage systems should be allowed to grow, with debris and excess sediment removed on a routine basis. Excess sediment can be removed by hand with a flat bottomed shovel and dead vegetation should be immediately removed and replaced. Vegetation should appear healthy with no visible bare earth in the system. Clean edges should be maintained between the road and the system with no signs of erosion or litter. Any noted evidence of vehicle compaction should be addressed, and standing water remaining after 24 hours is evidence that additional maintenance is needed.

The spaces between the flow-control mechanisms (gabion baskets, weirs, or French drains) can be transformed into rain gardens. Rain gardens can make drainage systems more aesthetically pleasing and can be used as a tool to convince stakeholders to embrace the proposed changes to drainage systems as many of these changes may not be as aesthetically pleasing.

Expected Results

The strategies shall be designed to reduce the velocity of runoff to a rate equal to or less than what it would be in a grassed channel. The removal rate for vegetative filters is 60 to 80% for TSS and 30% for TP and nitrogen (NJDEP, 2004). While there is no established removal rate for fecal coliform and *E. coli*, it is anticipated that settling of solid materials in the runoff will provide fecal coliform and *E. coli* reductions similar to TSS.

References

New Jersey Department of Environmental Protection (NJDEP), 2004, New Jersey Stormwater Best Management Practices Manual. Division of Watershed Management. Trenton, NJ.

New Jersey Department of Transportation (NJDOT), 2006, State of New Jersey Department of Transportation Drainage Design Manual (August 2006), http://www.state.nj.us/transportation/eng/documents/drainage/drainage.shtm, Last updated November 6, 2006, Downloaded on February 1, 2011.

Detention Basin Retrofit Designs

Current Conditions

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

Many detention basins can be altered or retrofitted to improve their ability to remove TSS and TP loads from stormwater runoff and achieve water quality improvements. If these improvements are made correctly, they could improve water quality, as well as reduce maintenance costs. There are only a few detention basins in the Upper Salem River watershed but they are found in subwatersheds identified as significant sources of pollution for the watershed. This document reviews several recommendations to improve the water quality of a detention basin's effluent. These recommendations can be incorporated into future designs of proposed detention basins because there is still development occurring in the Upper Salem River Watershed.

Detention Basin Retrofit Design Alternatives

The rainfall event used to analyze and design stormwater best management practices (BMPs) for water quality improvements is the "water quality design storm" of 1.25 inches of rain over two hours (NJDEP, 2004). This storm can be used to compute runoff volumes and peak rates to ensure that stormwater quality BMPs, whether they are based on total runoff volume or peak runoff rate, will provide a standard level of stormwater pollution control. Since approximately 90% of storms in New Jersey are typically smaller than this water quality design storm, BMP designs and retrofits that treat these small storms will have a significant impact on improving water quality in the watershed.

Alternative A: Low Flow Vegetated Channel

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

Low flow concrete channels act as an impediment to improving water quality in a detention basin. Removal of the concrete channel and replacement with a vegetated swale is recommended (see Appendix B for detailed engineering information). The swale should have a 0.1% side slope to ensure easy maintenance and slopes should not exceed 3.0%. The swale should be seeded with native grasses to minimize maintenance. Where needed and where possible, replacement soils should be installed with the top 1.5 feet of soil composed of a bioretention soil mix to encourage infiltration. Below this infiltration media, a 6 inch layer of ¾ inch 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 water flow which allows sediment to settle out. In addition, water will be held in the detention basin longer, increasing infiltration and allowing vegetation to take up nutrients carried in stormwater runoff. Finally, native vegetation that is allowed to grow taller will develop a deeper root structure allowing greater infiltration than soil with short turf grass. The channel should be designed to infiltrate and pass water through the basin within 48 hours after a storm to prevent mosquito breeding.

Alternative B: Low Flow Rip-Rap Channel

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

When this retrofit is installed, the low flow concrete channel should be completely removed.

Alternative C: ¾ Inch Stone Filled Sock

Many municipalities are hesitant to remove the low flow concrete channel in detention basins. There is an alternative method that will yield similar results that requires alterations be completed for only a small section of the low flow concrete channel to work; the section is approximately 8 inches wide. Contractors can fill an 8 inch diameter fabric sock with ¾ inch clean stone that is then set in the detention basin and surrounds the outlet of the detention basin (see Appendix B for detailed engineering information). Any runoff must pass through the sock before it enters the outlet. Since the v-shape of the low flow concrete channel will not allow the sock to rest on the bottom of the channel, water will be able to pass underneath the sock. Therefore, only a section as wide as the sock should be removed from the low flow concrete channel. This will ensure that all the runoff entering the basin passes through the sock before it exits the basin.

The purpose of the sock is to act as a check dam in the basin (see Appendix B for detailed engineering information). The stone-filled sock will reduce the speed of the runoff in the basin and promote more ponding of stormwater. This will provide the stormwater a larger contact area with the bottom of the basin promoting more infiltration and treatment. The stone-filled sock will act as a rough filter removing sediment and nutrients attached to the sediment from the water column and allow the ponded water to slowly drain to the outlet structure. Higher flows will overtop the sock and make its way to the outlet structure, maintaining the flow control capacity of the basin.

Alternative D: Native and Low Maintenance Grasses and Vegetation

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

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

Location

Four stormwater detention basins are located within the Upper Salem River Watershed (Figure A-9; Figure A-10).

Prioritization

Figure A-9: Detention basin adjacent to the Pilesgrove Township Municipal Building.

After field inspection of potential sites in the Upper Salem River Watershed, the detention basin at the Pilesgrove Township Municipal Building was determined to be a priority location for retrofitting (Figure A-9). Due to the lack of vegetation in parts of the basin and high visibility of this project, the best option for improving water quality is to implement *Alternative D: Native and Low Maintenance Grasses and Vegetation* at this site.

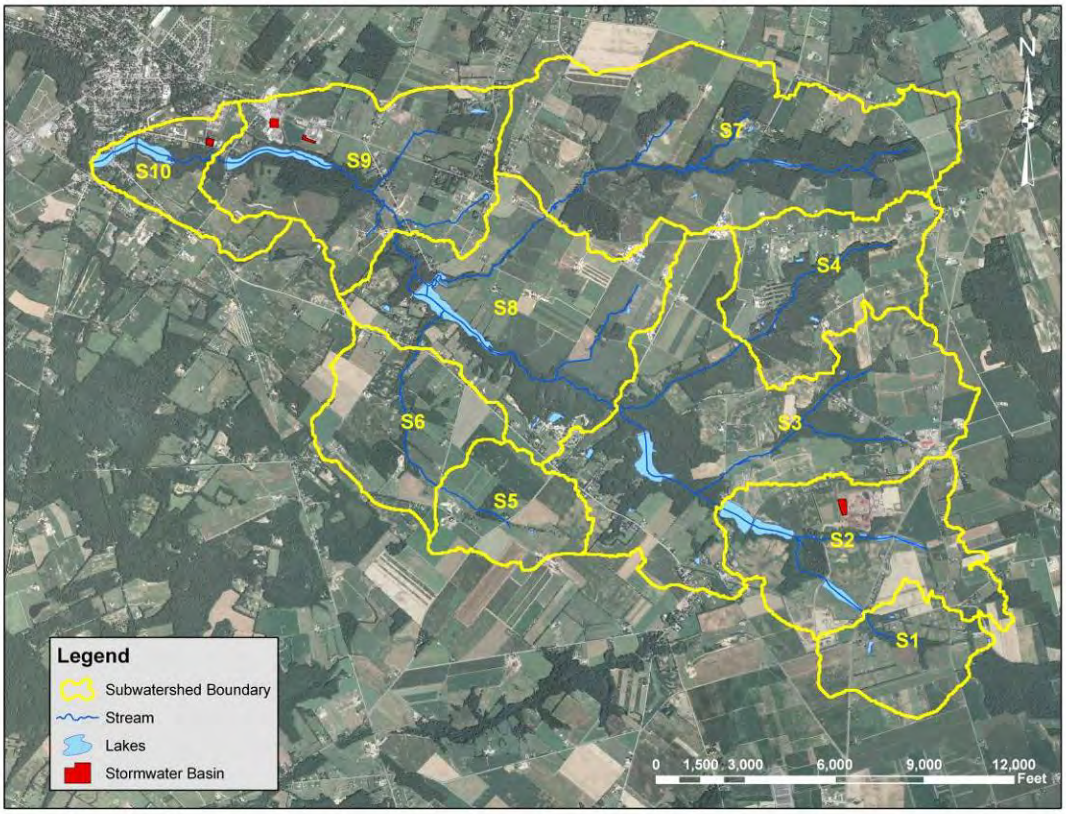


Figure A-10: Location of detention basins in the Upper Salem River Watershed.

Implementation

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

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

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

Cost

The cost of the detention basin retrofit 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 would be approximately \$2 to \$4 per square foot 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 square foot. The cost estimates vary because the designs to improve the detention basins have so much flexibility to them. The cost to remove a low flow concrete channel is approximately \$100 per linear foot of low flow channel.

Expected Results

Retrofit designs should target infiltration of runoff generated from the water quality design storm. Since approximately 90% of all storms in each year in New Jersey come in storms smaller than the water quality design storm, this will have a dramatic effect on water quality in the watershed. While it is hard to measure the exact effect, the basins will have many of the same characteristics as a vegetated filter strip (see Vegetated Buffers in Appendix A for more information). It is difficult to estimate the reductions for each pollutant because many of the functions of the basin will be enhanced by the proposed changes. Targeted reductions in TSS, total nitrogen and total phosphorus are expected to be 90%, 60% and 30%, respectively (NJDEP, 2004). Depending on the final design of the detention basin, it will function like a bioretention basin or a wetland. The removal rates for bioretention basins and wetlands are at or above 90% for fecal coliform (Karathanasis 2003; Rusciano and Obropta, 2007). 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 Upper Salem River Watershed.

References

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.

New Jersey Department of Environmental Protection (NJDEP), 2004, New Jersey Stormwater Best Management Practices Manual. Division of Watershed Management. Trenton, NJ.

Rusciano, G.M. and C.C. Obropta, 2007, Bioretention Column Study: Fecal Coliform and Total Suspended Solids Reductions. *Trans. of the ASABE,* 50(4) 1261-1269.

Manure Management

Current Conditions

Animal waste from livestock operations, manure storage facilities, and field application can pollute groundwater and surface waters when not contained or applied properly. Manure contains pathogens and nutrients which have the potential to degrade water quality and stream conditions. In the Upper Salem River Watershed, nutrient and bacterial (fecal coliform and *E. coli*) contamination is occurring in many areas. Mean bacterial levels were highest in subwatersheds S5 through S9 (Figure A-11). Human health can also be impacted due to groundwater contamination or exposure to surface waters containing manure. Many of the microorganisms that cause infectious diseases in humans, such as Salmonella and Cryptosporidium, in addition to *E. coli*, are found in livestock manure.

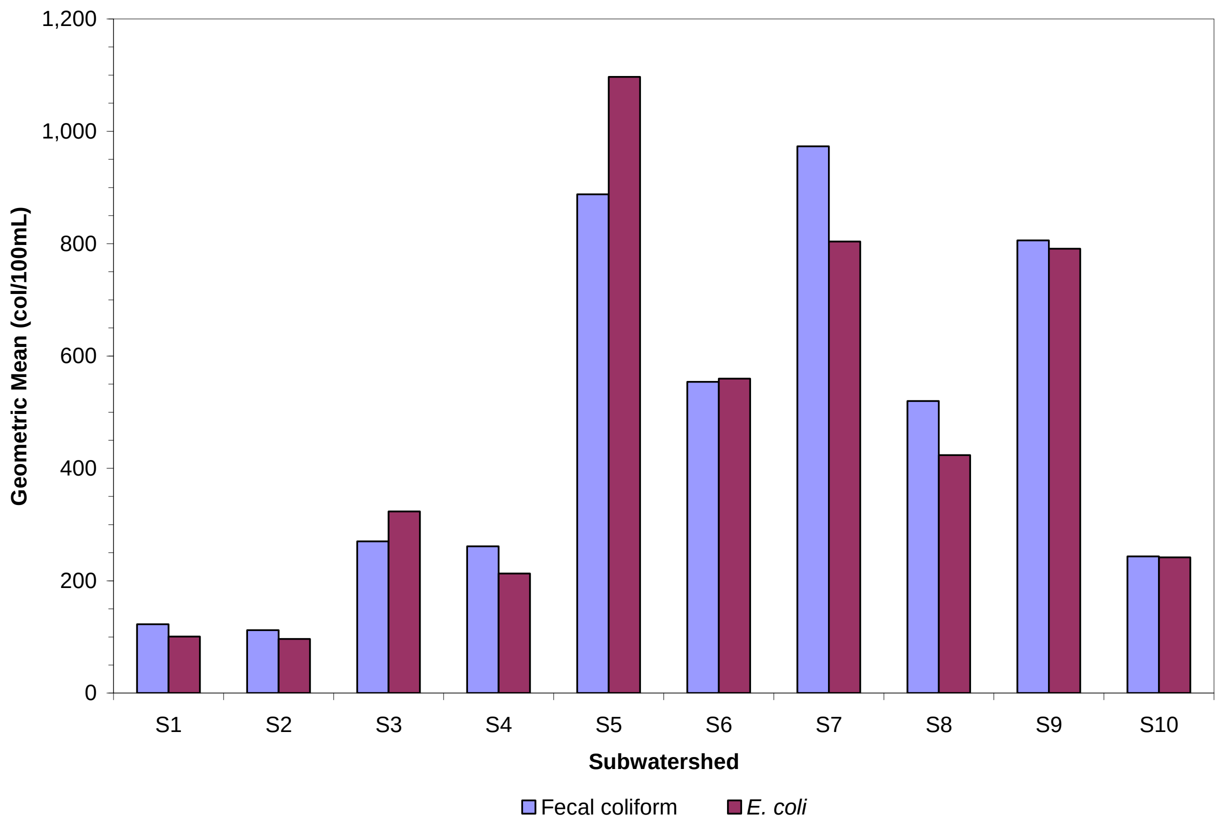


Figure A-11: Geometric mean concentrations of fecal coliform and *E. coli* in the Upper Salem River Watershed.

The State of New Jersey requires that all livestock farms proactively address and manage nonpoint source pollution that may originate from livestock operations, especially confined animal feeding operations (CAFOs) (RCE of Salem County, 2003). RCE provides educational meetings to livestock operations to assist them in preparing animal waste management plans (http://njaes.rutgers.edu/animal-waste-management/meetings.asp). Because the New Jersey

Department of Agriculture requires the development and implementation of Animal Waste Management Plans (N.J.A.C. 2:91), manure management in the Upper Salem River Watershed will focus on providing assistance on best management practices (BMPs) that will help farming operations to supplement, rather than achieve, compliance with these regulations and their animal waste management plans (New Jersey Association of Conservation Districts, ND).

Description

The goal of animal waste management is to make the best use of manure while protecting natural resources. When managed properly, manure can be a valuable resource on a farm. It can be a source of nutrients for crop production and can improve soil quality. However, if there is insufficient land to use the amount of manure that is produced or if manure is mismanaged, then risks to water supplies and the environment could result.

Manure management involves a plan of strategies and practices designed to control and/or mitigate manure generated from animal operations. Manure management plans draw together a wide range of techniques focused on manure production, storage, treatment and application on farmland and can help to demonstrate that applications are in line with good agricultural practices. An animal waste management plan highlights the volume of material produced and compares this with the amount of on-farm storage capacity.

Specific strategies recommended to manage manure for the Upper Salem River Watershed are vegetated buffers, livestock fencing, construction of stream crossings, and proper manure storage.

A. Vegetated Buffers

A vegetative buffer is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. Vegetated buffers are fully described in Appendix A (see Vegetated Buffers in Appendix A for more information on additional costs).

B. Livestock Fencing

By restricting livestock access to surface waters with fencing, landowners can quickly eliminate direct discharges of pathogens and nutrients to surface waters. With fencing setbacks, there also can be room for placement of a vegetated filter strip to remediate contaminants entering the stream from overland flow. Livestock fencing is fully described in Appendix A (see Livestock Fencing in Appendix A for more information on additional costs).

C. Construction of Stream Crossings

Trampled stream banks erode easily, allowing manure and sediments in surface waters. Limiting the amount of access livestock have to the stream can be accomplished by providing a crossing that directs them over the stream to prevent this situation. This crossing is either a stabilized area or structure constructed across a stream. Stream crossings may require the appropriate permits, depending on its location, the type of crossing, and size.

D. Manure Storage

To temporarily store animal waste, an impoundment created by an embankment, excavating a pit, or some other structure, ideally covered, should be provided on site to prevent manure releases to local waterways. The type of structure can vary depending upon the type of waste to store, the size of the livestock operation, length of storage needed, and use of manure after storage. Storage facilities should be located as close to the source(s) of waste regardless of type.

A survey of the nine CAFOs located in the Upper Salem River Watershed and verification of cropland and pastureland impacted by manure (as either a fertilizer or due to livestock) (Figure A-12) needs to be conducted to determine the status of their animal waste management plans, if applicable, and to evaluate which BMPs have been installed or are recommended for the operation. After completion of the survey, appropriate recommendations and designs can be made.

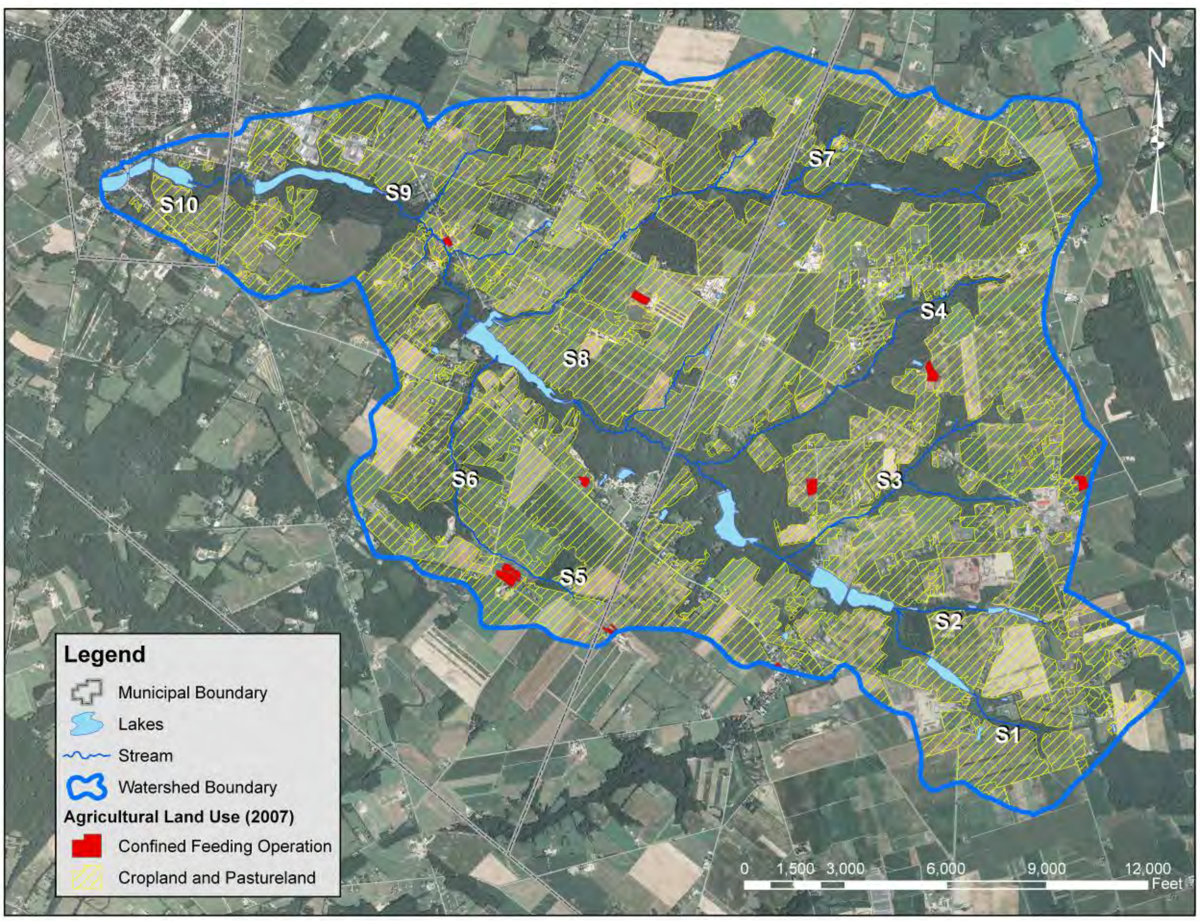


Figure A-12: Potential locations for manure management sites in the Upper Salem River Watershed.

Location

The locations of potential manure management projects within the Upper Salem River Watershed include the nine CAFOs and any pastureland utilized by livestock (Figure A-12). Cropland, pastureland, and CAFOs make up approximately 95% of all agricultural lands in the watershed. Field verification of these sites to determine whether or not manure management is necessary has not been performed, which would affect both the scale and costs for projects in these areas.

Prioritization

Priority should be given to CAFOs and pastureland with livestock in subwatersheds S5 through S9 since the highest levels of bacteria were measured at those locations (Figure A-11; Figure A-12).

Cost

Costs have not been estimated for all manure management recommendations due to the variety of recommended strategies and the lack of specificity on sites to employ these strategies. For example, livestock fencing is estimated to cost from $1.00 to $2.00 per linear foot (Meyer and Olsen, 2005) (see Livestock Fencing in Appendix A for more information on additional costs), and vegetated filters cost $600 for seed and administrative fees or about $0.42 per linear foot of a 30 foot wide strip (see Vegetated Buffers in Appendix A for more information on additional costs).

Expected Results

If manure management measures are enacted, the resulting water quality benefits will vary depending on the type of measure installed. Recommended strategies not currently in place will, at a minimum, have some benefit if properly designed and installed to reduce the opportunities for manure to have direct access to local surface waters.

References

Meyer, R. and T. Olsen, 2005, Estimated Costs for Livestock Fencing. File B1-75 Fact Sheet. Iowa State University Extension. Ames, IA.

New Jersey Association of Conservation Districts, No Date, On-Farm Strategies to Protect Water Quality: An Assessment and Planning Tool for Best Management Practices on New jersey Farms.

Rutgers Cooperative Extension (RCE) of Salem County, 2003, Water Quality Protection on New Jersey Farms, CAFO Requirements, October 2003. Fact Sheet RCE of Salem County.

Dam Removal

Current Conditions

There are many man-made impoundments and lakes along the Upper Salem River (Figure A-13). Many of these impoundments were originally created for flood control and possible irrigation for adjacent farmland. Today, these waterbodies are used primarily for recreation. These areas may be accumulating sediments and sediment-bound phosphorus and may be harboring potential sinks for these pollutants. If these impoundments are functioning as a sink for water quality contaminants, then it is likely that the water quality of the lake and its sediments are impacted. Nutrients that are accumulating in these waterways can create eutrophic conditions represented by algal growth and excessive vegetation (Figure A-14), loss of dissolved oxygen, and lake filling. Nutrient problems were noted at many dams located along the Upper Salem River during SVAP surveys conducted in 2005.

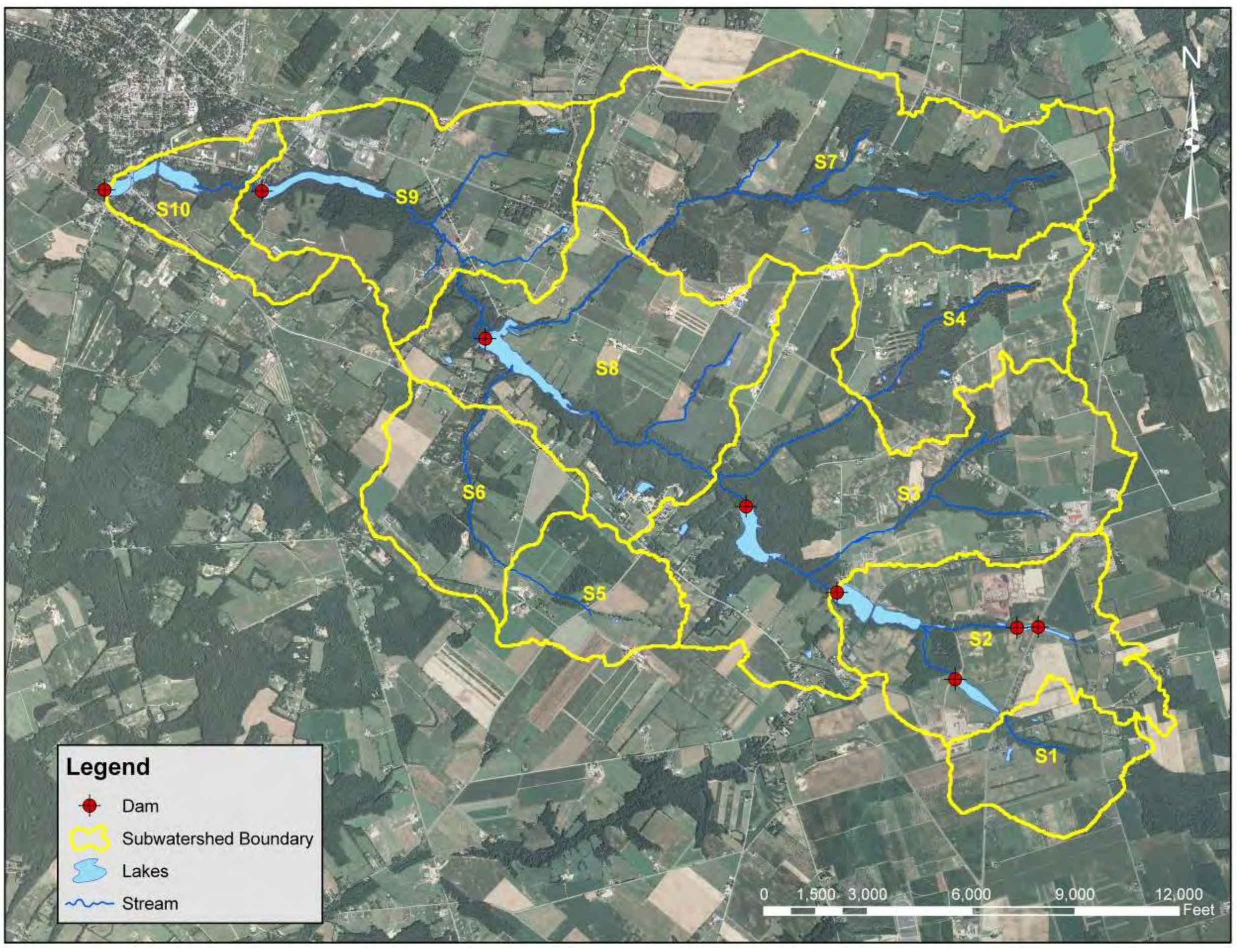


Figure A-13: Location of dams within the Upper Salem River Watershed.

A study of the lakes and any accumulated sediment and sediment-bound phosphorus is beyond the current scope of this project, but further research would be necessary to determine the impact of these impoundments on water quality within the Upper Salem River Watershed. The water quality of these lakes may ultimately indicate that the expensive option of dredging is necessary to maintain watershed health and improve water quality.

Figure A-14: An impoundment along the Upper Salem River showing heightened plant growth in the waterbody behind it.

Location

The locations of potential dam removal projects are shown in Figure A-13. Since there are only eight dams located within the Upper Salem River Watershed, all eight dams should be investigated as potential projects for dam removal.

Implementation

This proposed project will start with a review of the structural integrity of each of the dams within the Upper Salem River Watershed based upon records with NJDEP's Bureau of Dam Safety and Flood Control and other available data. Visual inspection of each dam, where appropriate, will be conducted to verify the status of each dam in the watershed. The results of the safety review of the dams in this watershed will be used in conjunction with water quality data collected as part of the restoration planning process to determine which dams will be selected for removal. Additional water quality data may need to be collected as part of this decision-making process. Funding for both the additional monitoring data and actual dam removal will be sought from appropriate agencies, and in cooperation with any and all landowners.

In addition to removing select dams from the Upper Salem River, vegetated buffers should be planted along the newly created waterway to reduce erosion and increase native habitat (see Vegetated Buffers information sheet in Appendix A for more information).

Maintenance

After dam removal, there is expected to be maintenance only if vegetated buffers are installed as part of the project. Vegetated filter strips are expected to trap debris and sediment. Therefore, they must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding one (1) inch of rainfall. Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations (NJDEP, 2004).

Mowing of filter strips must be performed on a regular schedule based on specific site conditions (typically once every six months at a minimum). Turf grass should be mowed at least once a month during the growing season. If the buffer contains shrubs and/or trees, then mowing should not occur. Vegetated stream buffers must be inspected at least annually for erosion and scour. When establishing or restoring vegetation in the stream buffer, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible. All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs (NJDEP, 2004).

Cost

Project costs need to be calculated on an individual basis for each dam to be removed as costs will vary depending on size of the dam, material(s) used to construct the dam, permit costs, sediment testing and possible dredging, and other factors. Other dam removal projects throughout the country have ranged from tens of thousands of dollars to millions of dollars. These costs do not include additional costs from inclusion of vegetated buffers to provide addition improvements to water quality after dam removal (see Vegetated Buffers information sheet in Appendix A for more information on additional costs).

The U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) Farm Bill Programs offer funding to farmers to implement various projects, and these programs often require the farmer to pay a cost-share. Many farmers do not have the financial capacity to pay this cost-share. Additional financial and technical assistance is available through New Jersey Department of Agriculture (NJDA) Soil and Water Conservation Cost-Share Program and New Jersey Conservation Reserve Enhancement Program (NJCREP) (http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=cep). These funds can be combined with NJDEP 319(h) implementation funds to help offset costs (http://www.state.nj.us/dep/watershedmgt/319grant.htm).

Prioritization

There are eight dams located in the entire Upper Salem River Watershed (Figure A-13). Priority should be given to those waterbodies that are experiencing nutrient problems as noted during the SVAP surveys conducted in 2005, and to help reduce phosphorus as part of the existing TMDL for phosphorus on the Salem River. These areas include the dam at Avis Mill Pond in subwatershed S8 and the Slabtown Lake dam in subwatershed S3 (Figure A-13).

Expected Results

Removal of dams has shown both long- and short-term benefits to stream ecology (Bednarek, 2001). Restoration of natural flow regimes has resulted in increased biodiversity through the enhancement of spawning grounds or other habitat suitable for fish, amphibians, aquatic insects, and other organisms (Bednarek, 2001). By returning riverine conditions and sediment transport to formerly impounded areas, riffles and pools, gravel, and cobble have reappeared, adding structural components that were previously missing as habitat for aquatic organisms. Fish passage has been another benefit of dam removal, but the disappearance of the lake or pond may also decrease certain publicly desirable fisheries (Bednarek, 2001).

Short-term ecological impacts of dam removal include an increased sediment load that may cause losses of both biota and habitats. However, several dam removal projects suggest that the increased sediment load caused by dam removal should be a short-term effect (Bednarek, 2001). Dam removal is an important alternative for river restoration.

References

Bednarek, A.T., 2001, *Undamming Rivers: A Review of the Ecological Impacts of Dam Removal*. Environmental Management. 27(6): 803-814.

New Jersey Department of Environmental Protection (NJDEP), 2004, New Jersey Stormwater Best Management Practices Manual. Division of Watershed Management. Trenton, NJ.

Minimum Till Drill Program

Current Conditions

Based on water quality monitoring data, suspended sediments are a targeted pollutant for control and remediation. Erosion has been highlighted as a major concern in all but one of the ten subwatersheds in the Upper Salem River Watershed. Due to the agricultural nature of the watershed (65% agricultural land use), low till, no till, and other till methods have been investigated as management options to reduce sediment loss on agricultural lands which causes sediment retention in local ponds (Figure A-15). A minimum till drill used in bi-annual rotation is an effective tool to conserve valuable top soils, decrease erosion and transport of nutrients, and still produce a crop undiminished by a change in till methods. This is a realistic implementation opportunity that will be successful, according to the feedback received from the agricultural community in and around the watershed. Also, due to the large areas of the watershed covered by cropland and pastureland, this agricultural management practice has great potential to improve water quality and soil protection (Figure A-16).

Figure A-15: Turbid discharge from Avis Mill Pond in the Upper Salem River Watershed.

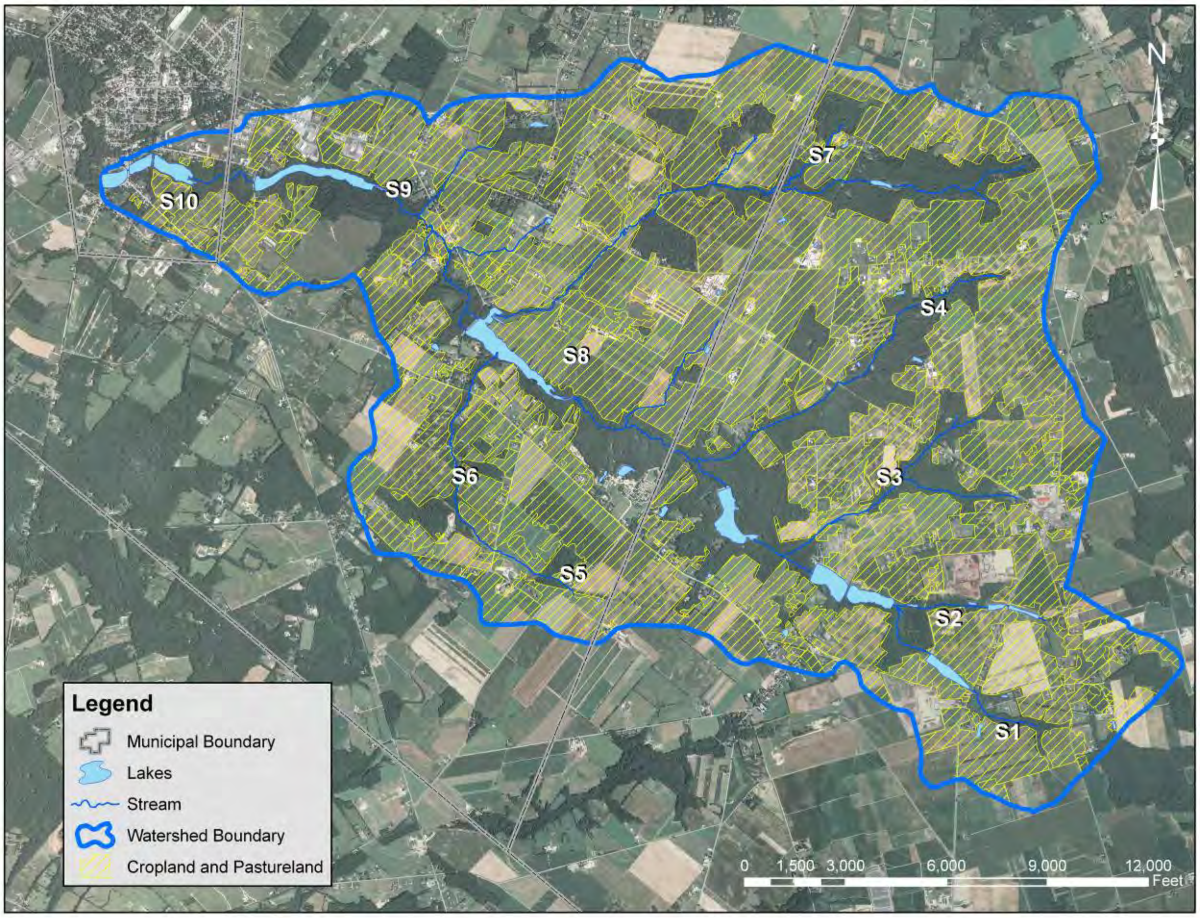


Figure A-16: Cropland and pastureland within the Upper Salem River Watershed.

Implementation

The project team proposes that two minimum till drills be purchased and housed at the Salem County RCE office. Farmers will be paid $15 per acre to utilize this equipment and participate as a partner in this minimum till effort. Farmers will have the option of using this equipment on an annual or biannual basis. The Salem County RCE office and Cumberland-Salem Conservation District (CSCD) will be responsible for providing advice and consultations with farmers to encourage this program's success and make this a positive, stronger relationship with landowners. Farmers' participation and feedback during this project will result in a document and final report that includes the following information:

- comparison of crop yields from regular till to minimum till
- cost comparison of regular versus minimum till for fertilizers, pesticides, hours in the field, and equipment
- comments on equipment use, erosion control, and lessons learned

The final report will also include a photo log of regular till versus minimum till. An outreach campaign will also be developed and implemented that will include feedback from the agricultural community and feedback from those working in the minimum till program. The feedback and open discussions will lead to shared advice and increased production at a lower cost to farmers.

It is the goal of project partners that farmers will initially be paid for their participation in the data gathering process. After five years, equipment will be leased and maintained at the Salem County RCE office for those interested in utilizing minimum till on their properties.

Estimated Project Costs

Purchase of Two Minimum Till Drills:	$70,000 ($35,000 per unit for two units)
Equipment Maintenance Costs:	$10,000
Oversight of Operations/Feedback Surveys:	$75,000 ($15,000 per year for five years)
Payment for Farmer Participation:	$36,000
Water Quality Monitoring Costs:	$35,000
Outreach Program Materials:	$5,000
Final Report and Documentation:	$10,000

Total direct cost of this implementation project is **$241,000**. Some of these costs may be reduced by utilizing NRCS information on no-till practices and cost-sharing. Financial and technical assistance is available through NJDA Soil and Water Conservation Cost-Share Program and NRCS's Farm Bill Programs. Leveraging of funds is also possible to further incentivize this practice to the farmer. This can be done by combining NRCS financial and technical assistance programs with NJDEP 319(h) NPS Pollution Control implementation funds.

Expected Results

Minimum tillage of croplands can substantially reduce soil erosion. The reductions in sediment losses from fields undergoing minimum till in the United States range from 40% to 90% and can be up to 98%, if conservation tilling is implemented across a subwatershed (Holland, 2004). There is no removal rate of bacteria for minimum till practices, but if bacteria act as particles their reduction should be similar because the same mechanisms expected to reduce TSS will work to reduce bacteria.

Post Implementation Monitoring

Sampling stations used in this project will be monitored as farmers join the program in that particular subwatershed. Water quality monitoring should be conducted bi-weekly and during storm events and should include TSS and nutrients and should be initiated when the farmer agrees to participate and before fields are planted. Monitoring should continue for six months after planting. Monitoring will also include an analysis of buffer widths surrounding the till and minimum till fields, and water quality data's correlation to buffer width and health.

References

Holland, J.M., 2004, *The Environmental Consequences of Adopting Conservation Tillage in Europe: Reviewing the Evidence*. Agricultural Ecosystems & Environment. 103: 1-25.

APPENDIX B: CONCEPT DESIGNS FOR IMPLEMENTATION PROJECTS TO ADDRESS KNOWN WATER QUALITY IMPAIRMENTS IN THE UPPER SALEM RIVER

UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

On-Farm Strategies to Protect Water Quality

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Located in Salem County, the Upper Salem River Watershed is roughly 15 square miles in area and has over 20 miles of river.

Primary land use within the watershed is agriculture (65.3%), while remaining land uses include forest (12.7%), wetland (10.1%), urban areas (9.8%) and open water (1.6%).

To protect water quality, On-Farm Strategies can be implemented within the watershed's agricultural land. Shown on the map to the right, agricultural land use is broken down into two segments, Confined Animal Feeding Operations (red hatch) and Cropland and Pastureland (yellow hatch). The following strategies, if implemented in these areas properly, can ensure water quality protection for the Salem River.

WATER ACCESS AND EXCLUSION

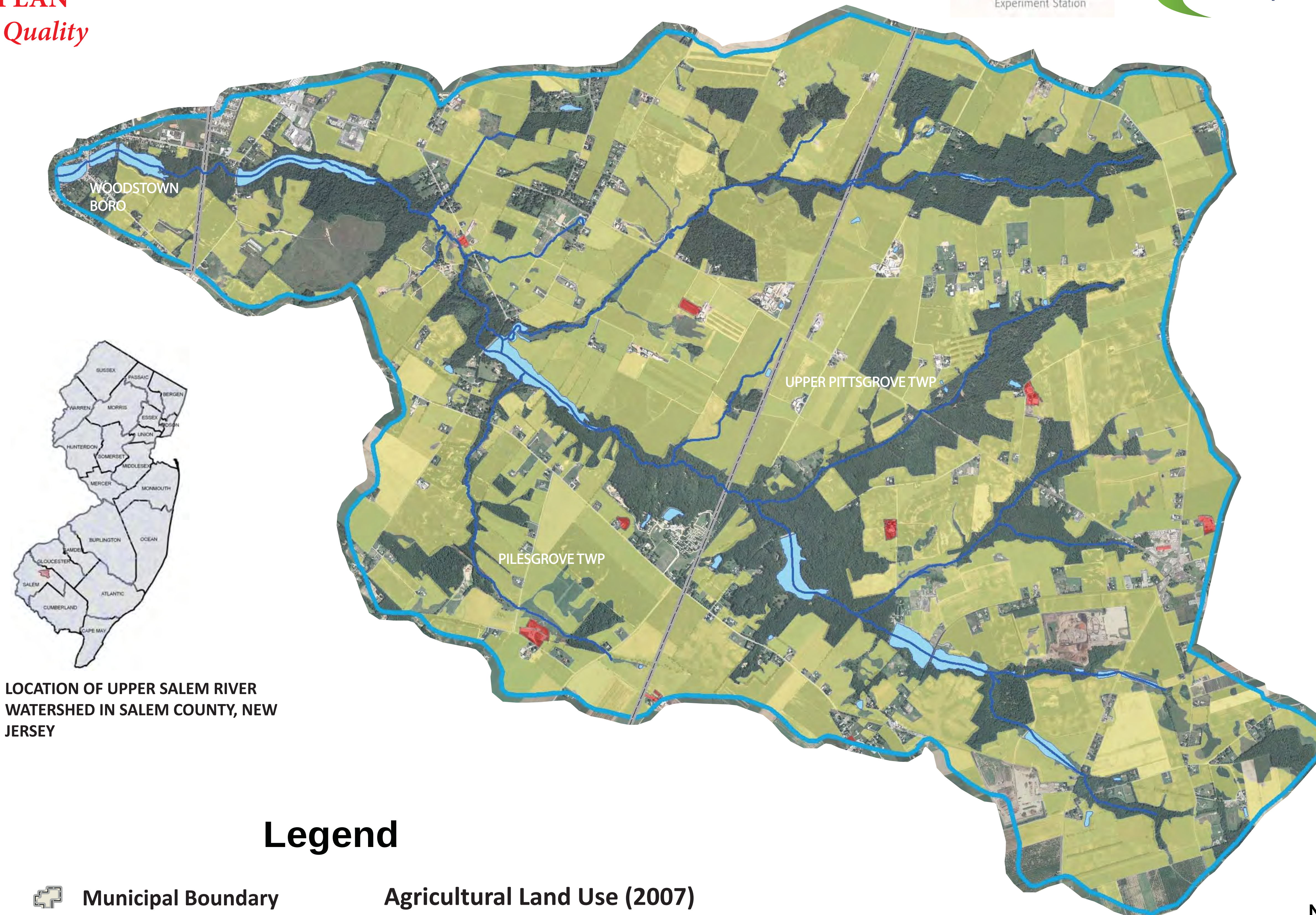
- Water Access Ramp
- Exclusion Fencing

MANURE MANAGEMENT

- Concrete Manure Compost Bin
- Wood Post and Plank Storage Pad
- Concrete Storage Tank

WATER CROSSING

- Bridgemat Crossing
- Pipe Culvert Crossing
- Modified Streambank Crossing



LOCATION OF UPPER SALEM RIVER WATERSHED IN SALEM COUNTY, NEW JERSEY

Legend

- Municipal Boundary
- Watershed Boundary
- Lakes
- Streams

Agricultural Land Use (2007)

- Confined Animal Feeding Operations
- Cropland and Pastureland

0 1,500 3,000 6,000 9,000 12,000 Feet

N

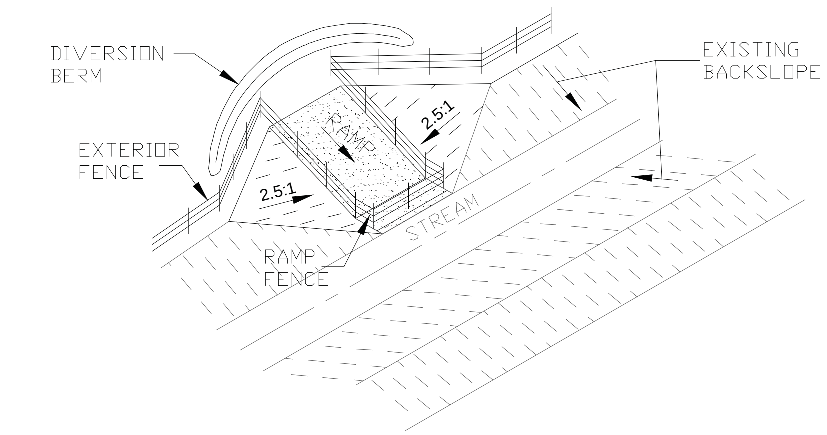
UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

Water Access and Exclusion

Rutgers New Jersey Agricultural Experiment Station

Water Resources Program

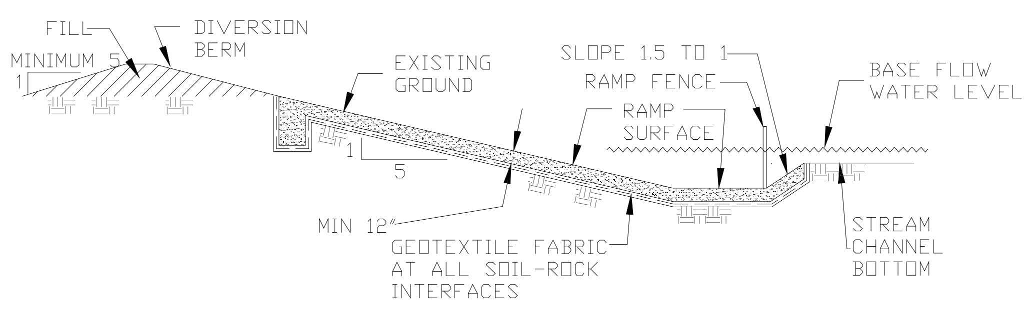
WATER ACCESS RAMP



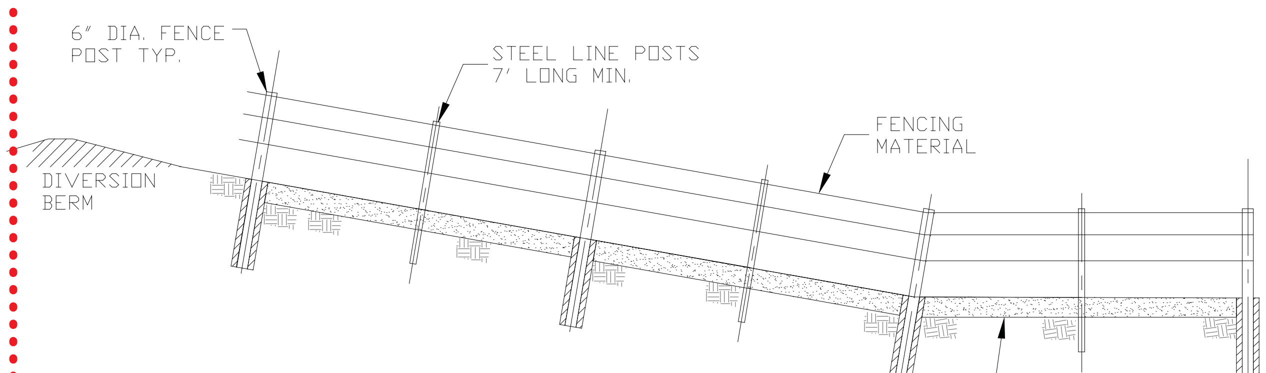
PERSPECTIVE

Example of Access Ramp with Wooden Board Fencing

The access ramp allows livestock vital access to water while keeping animals from accessing the whole body of water. The ramp design and fencing creates boundaries to livestock access to water and can help ensure protection of water quality.

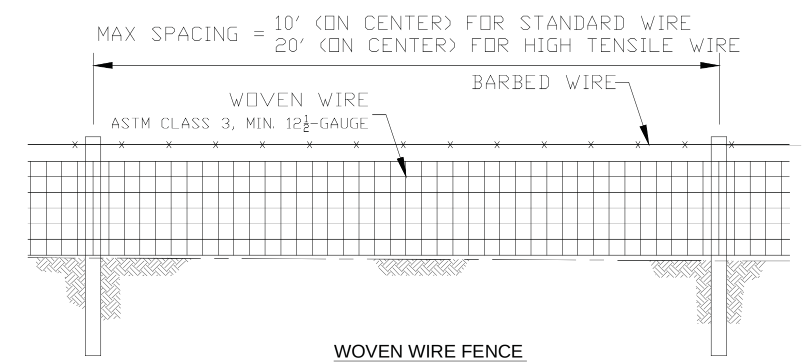


CROSS SECTION



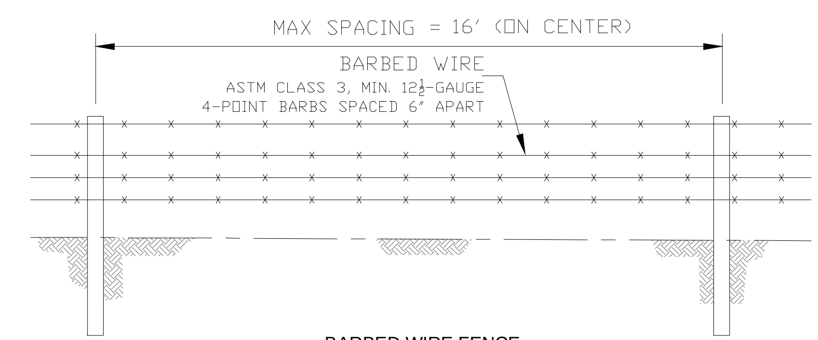
CROSS SECTION

EXCLUSION FENCING



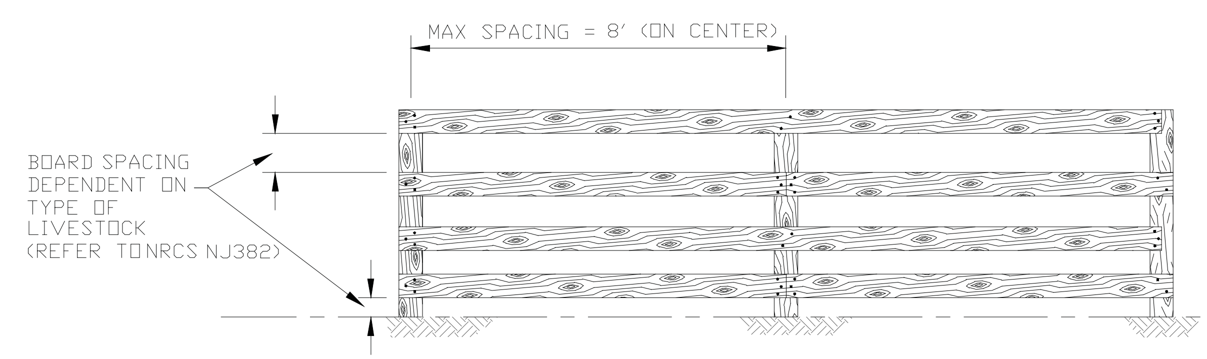
WOVEN WIRE FENCE

Woven Wire Fence



BARBED WIRE FENCE

Barbed Wire Fence



WOODEN BOARD FENCE

NOTES:

1. REFER TO NRCS STANDARD NJ614 FOR OTHER WATERING FACILITY OPTIONS.
2. REFER TO NRCS STANDARD NJ382 FOR COMPLETE FENCING DESIGN STANDARDS.
3. THE DETAILS PROVIDED ON THIS SHEET MAY NOT SERVE AS FINALIZED ENGINEERING PLANS FOR ANY DEMONSTRATION PROJECT.

NOT TO SCALE

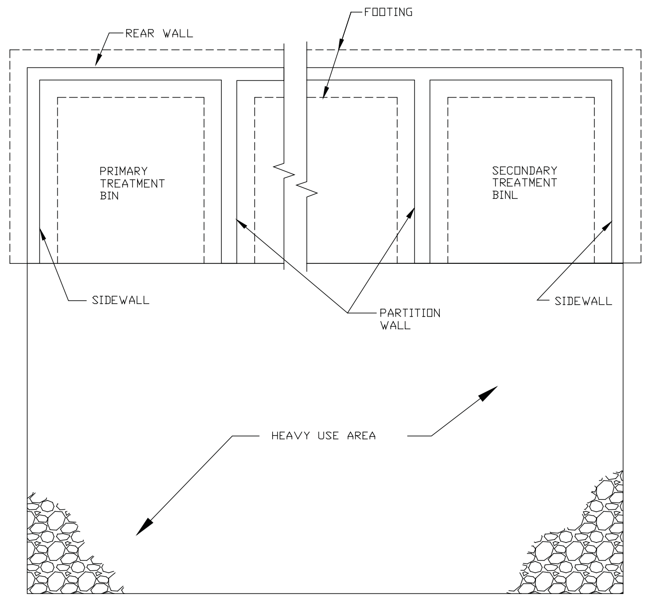
PHOTOS FROM USDA-NRCS

STANDARD STREAM ACCESS AND FENCING DETAILS MODIFIED FROM NRCS, ILLINOIS

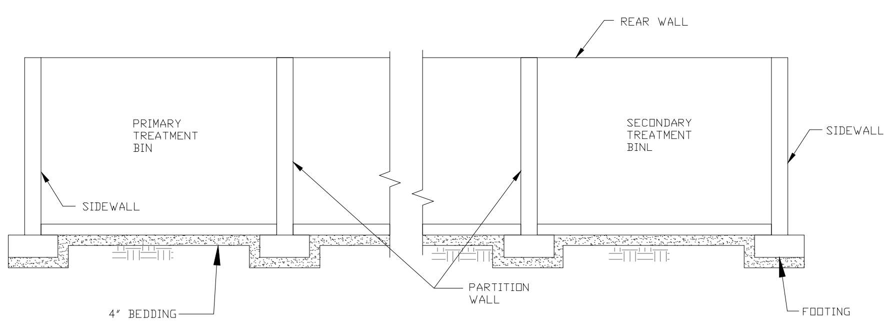
UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

Manure Storage

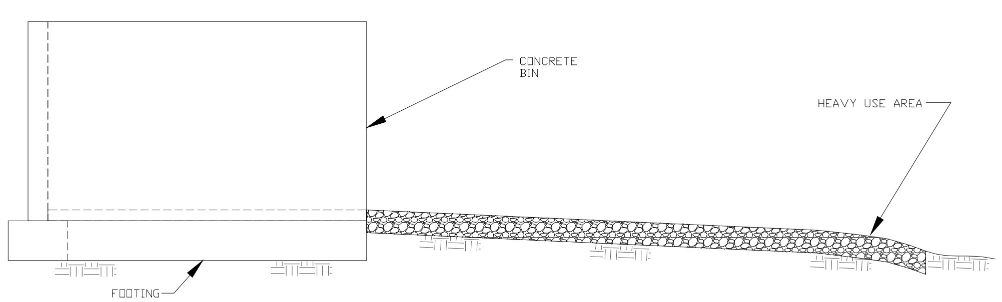
CONCRETE MANURE COMPOST BIN



PLAN



PROFILE



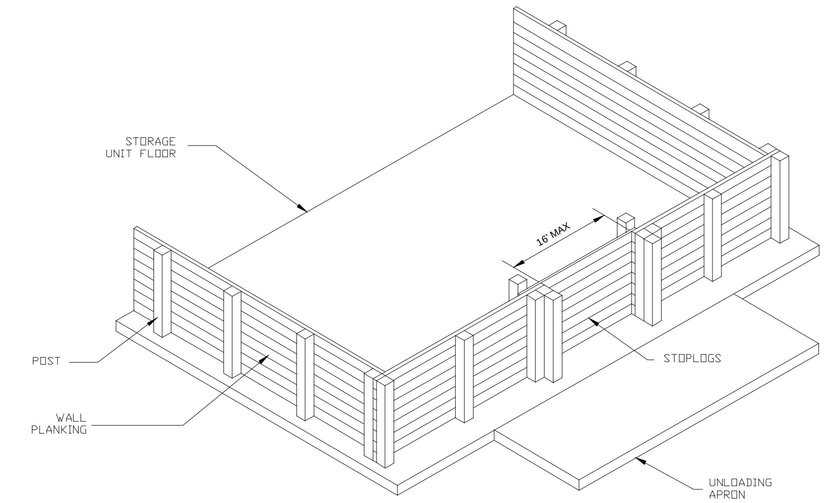
CROSS SECTION

Concrete Manure Compost Bin

Wood Post and Plank Storage Unit

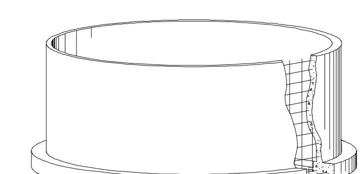
Concrete Storage Tank

WOOD POST AND PLANK STORAGE UNIT

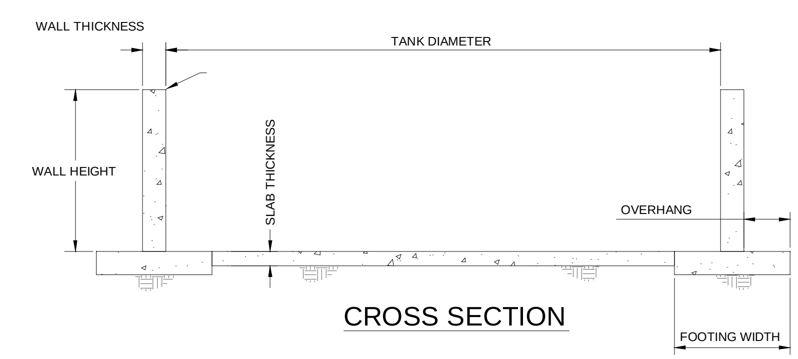


PERSPECTIVE

CONCRETE STORAGE TANK



PERSPECTIVE



CROSS SECTION

NOTES:

1. REFER TO "ON-FARM STRATEGIES TO PROTECT WATER QUALITY" BY NEW JERSEY ASSOCIATION OF CONSERVATION DISTRICTS FOR MORE INFORMATION.
2. ALL ANIMAL WASTE BMPS SHOULD BE ACCOMPANIED BY A WASTE MANAGEMENT AND NUTRIENT MANAGEMENT PLAN.
3. TOPOGRAPHIC AND SOIL SURVEYS MUST BE COMPLETED FOR FINAL DESIGNS.
4. THE DETAILS PROVIDED ON THIS SHEET MAY NOT SERVE AS FINALIZED ENGINEERING PLANS FOR ANY DEMONSTRATION PROJECT.

NOT TO SCALE

STANDARD WASTE MANAGEMENT DETAILS MODIFIED FROM NRCS, ILLINOIS

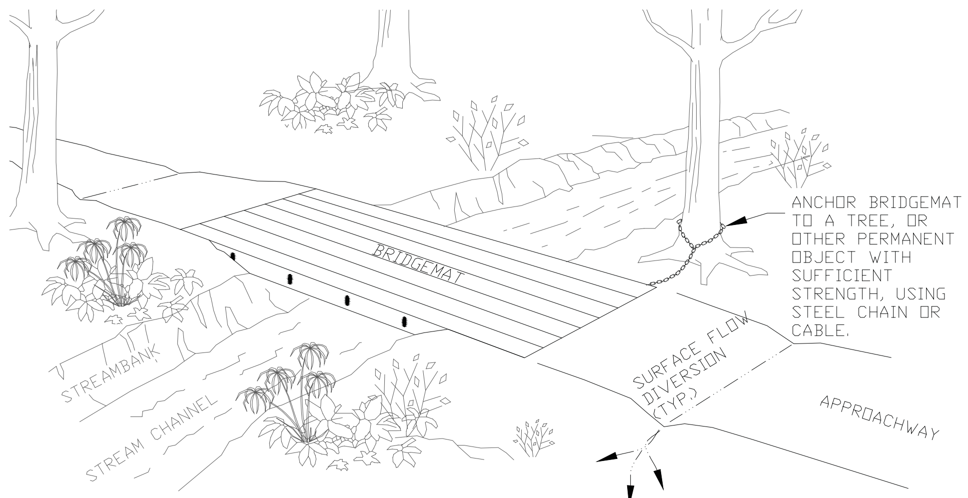
RUTGERS New Jersey Agricultural Experiment Station
Water Resources Program

UPPER SALEM RIVER WATERSHED
RESTORATION & PROTECTION PLAN
Water Crossing

RUTGERS
New Jersey Agricultural Experiment Station

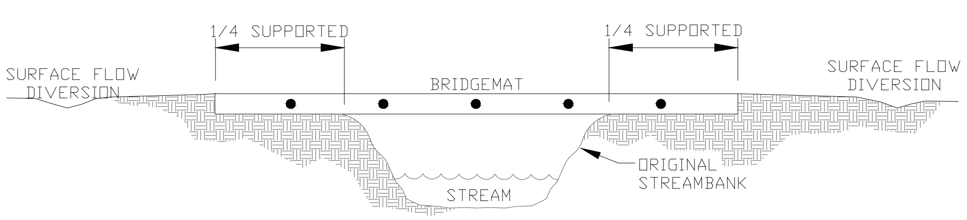
Water Resources Program

BRIDGEMAT CROSSING



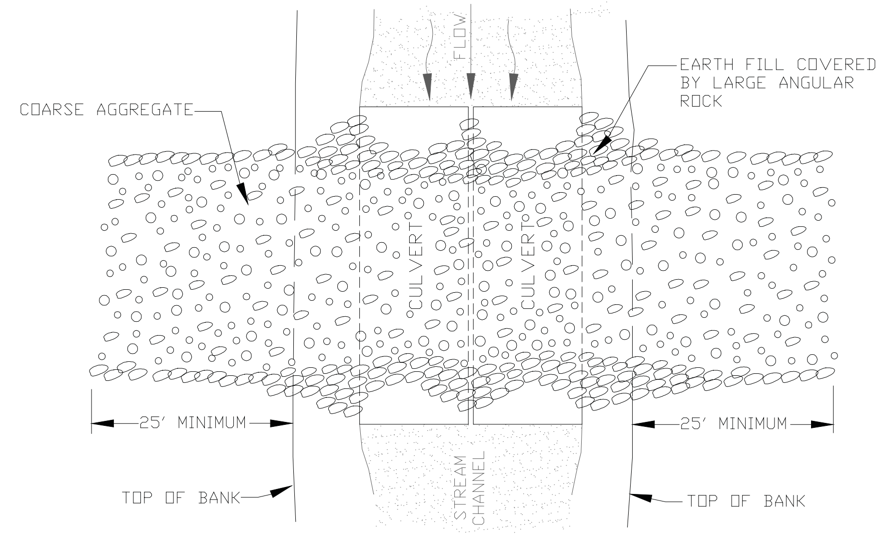
PERSPECTIVE

Bridgemat Stream Crossing



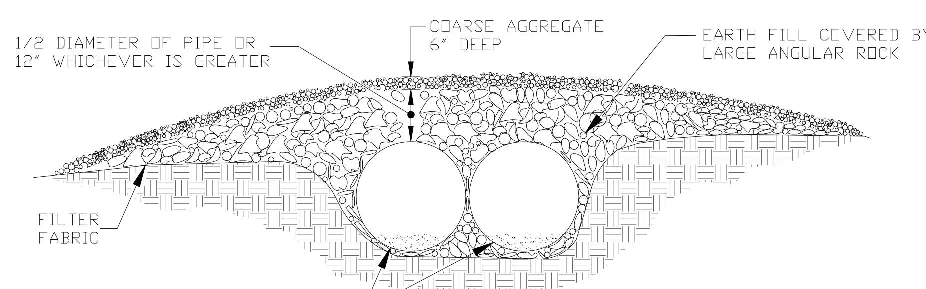
CROSS SECTION

PIPE CULVERT CROSSING



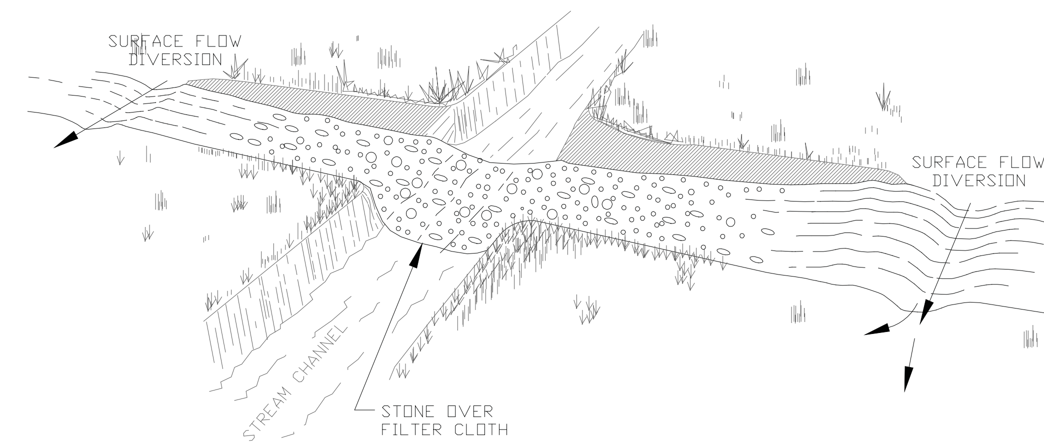
PLAN VIEW

Single Pipe Stream Crossing



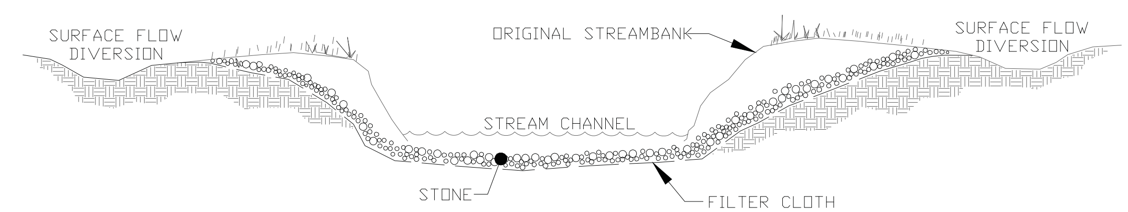
CROSS SECTION

MODIFIED STREAM BANK CROSSING



PERSPECTIVE

Construction of Stone Stream Crossing



CROSS SECTION

NOTES:
1. ALL STREAM-CROSSING DETAIL OPTIONS MUST INCLUDE TRAVEL-WAYS OF 6-FOOT MINIMUM WIDTH AND AN APPROACH NOT STEEPER THAN 4 HORIZONTAL TO 1 VERTICAL.
2. ALL STREAM CROSSING SHOULD BE DESIGNED ACCORDING TO NRCS STANDARDS (NJ578). THE DETAILS PROVIDED ON THIS SHEET MAY NOT SERVE AS FINALIZED ENGINEERING PLANS FOR ANY DEMONSTRATION PROJECT.
3. TOPOGRAPHIC AND SOIL SURVEYS MUST BE COMPLETED FOR FINAL DESIGNS OF STREAM CROSSING APPLICATIONS.

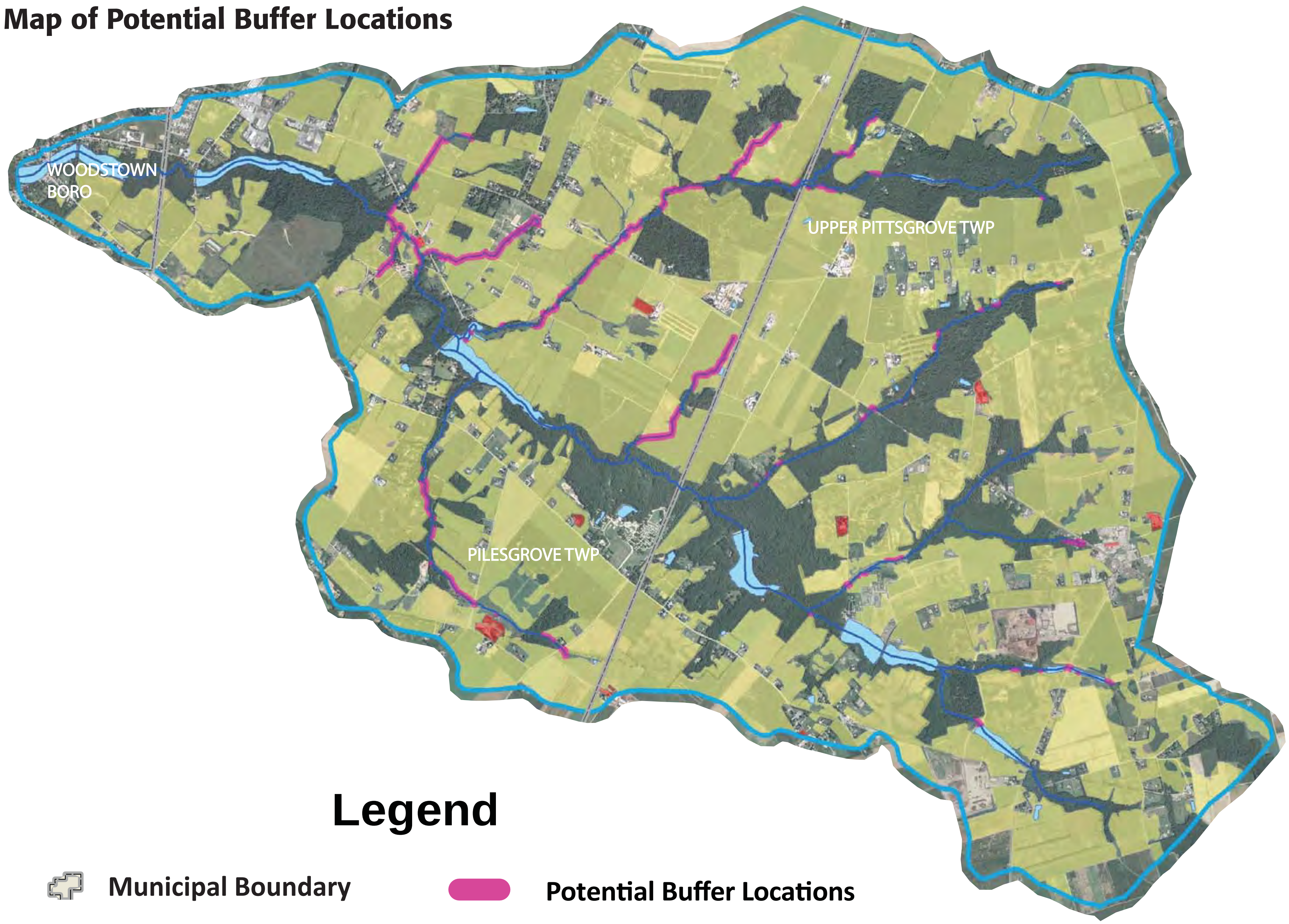
NOT TO SCALE
STANDARD STREAM CROSSING DETAILS ADAPTED FROM TOWN OF CARY, NORTH CAROLINA

UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

Vegetated Filter Strips as Stream Buffers

Rutgers New Jersey Agricultural Experiment Station — Water Resources Program

Map of Potential Buffer Locations



Legend

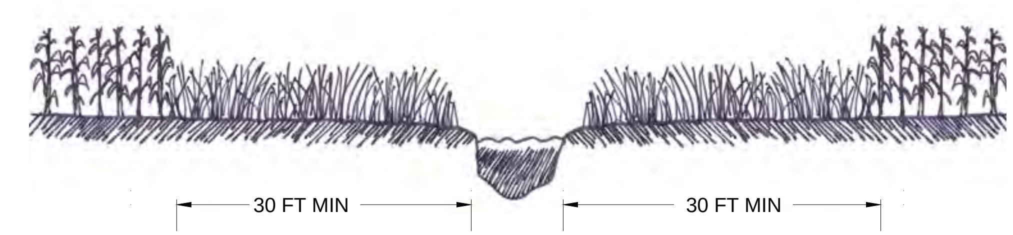
- Municipal Boundary
- Watershed Boundary
- Lakes
- Streams
- Potential Buffer Locations

Agricultural Land Use (2007)

- Confined Feeding Operation
- Cropland and Pastureland

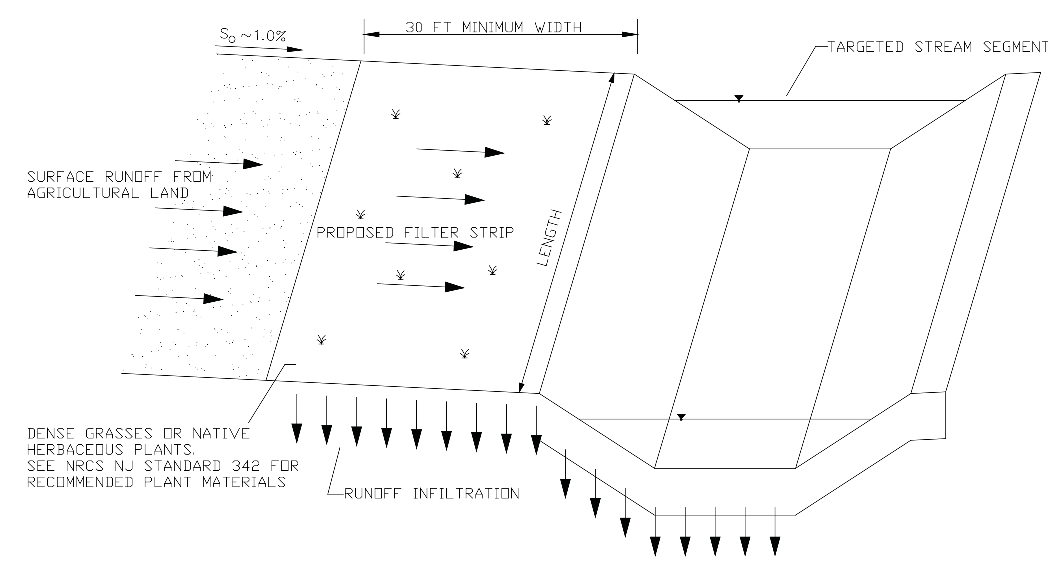
N

0 1,500 3,000 6,000 9,000 12,000 Feet



CROSS SECTION VIEW

Grassed Filter Strip



PERSPECTIVE VIEW

NOTES:

1. ALL VEGETATED FILTER STRIPS SHOULD BE DESIGNED, INSTALLED, AND MAINTAINED ACCORDING TO NRCS STANDARDS (NJ STANDARD 393).
2. TOPOGRAPHIC AND SOIL SURVEYS MUST BE COMPLETED FOR FINAL DESIGNS.
3. THE DETAILS PROVIDED ON THIS SHEET MAY NOT SERVE AS FINALIZED ENGINEERING PLANS FOR ANY DEMONSTRATION PROJECT.

PHOTO FROM NRCS
PERSPECTIVE VEGETATED FILTER STRIP DETAILS MODIFIED FROM GREENE COUNTY, MO
CROSS SECTION VIEW VEGETATED FILTER STRIP DETAILS MODIFIED FROM NRCS

UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

Road Side Drainage

Throughout the Watershed, rural road drainage systems are commmon alongside roadways and farm fields. These systems fill with sediment and must be maintained. Current maintenance practice is to scrape the drainage systems, leaving soil vulnerable to erosion and the lakes at risk. Vegetation and proper construction will slow runoff down to non-erosive velocities and allow infiltration.

The drainage systems along East Lake Road convey runoff directly to East Lake.

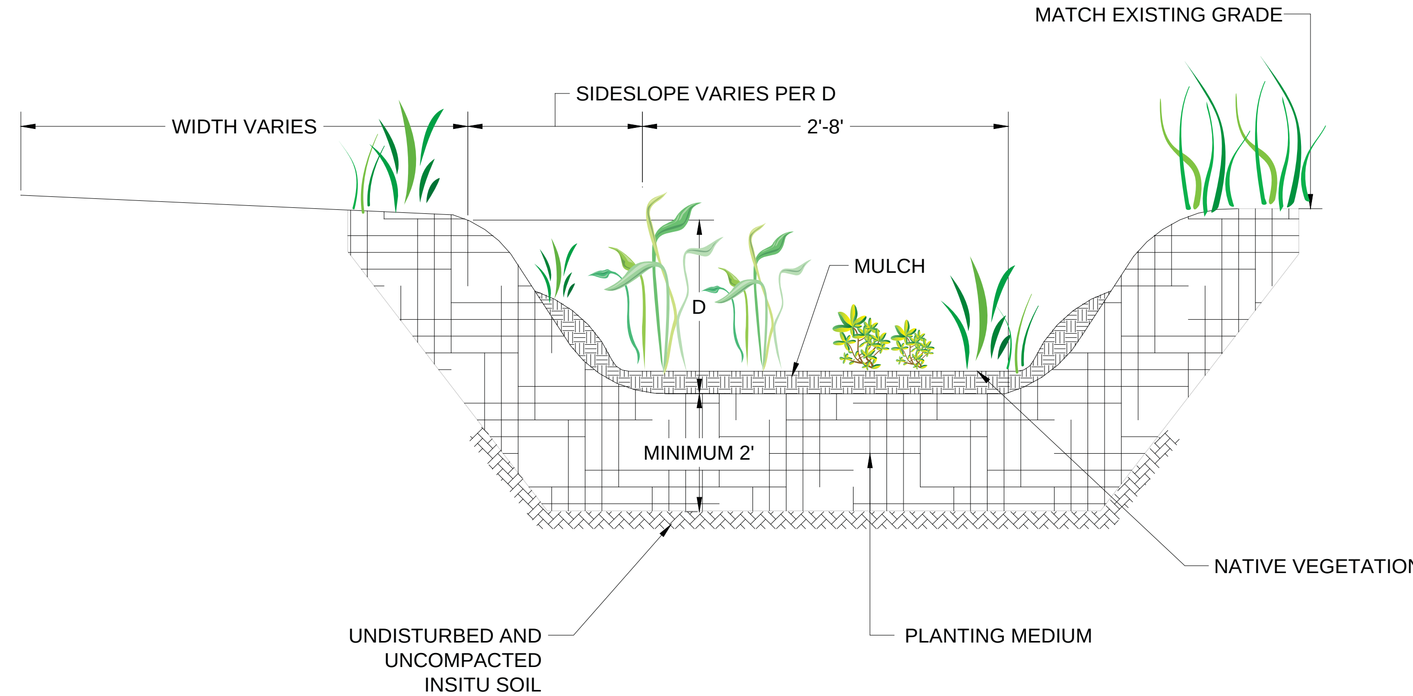
East Lake Road
Between South Main Street
and East Millbrooke Avenue

Rural Road Drainage System
Approximately 400'

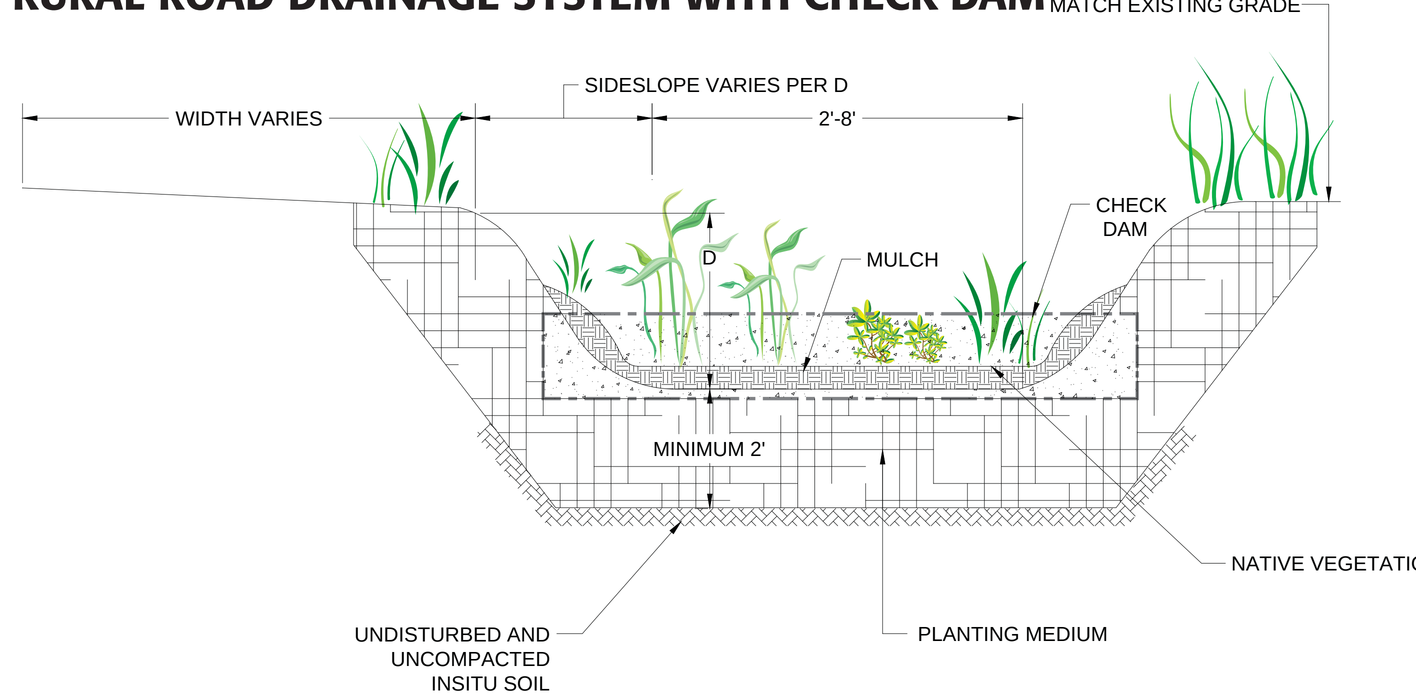
Scraped Drain

NOT TO SCALE

RURAL ROAD DRAINAGE SYSTEM



RURAL ROAD DRAINAGE SYSTEM WITH CHECK DAM



NOTES:

1. ALL RURAL ROAD DRAINAGE SYSTEMS MUST MEET STANDARD LISTED BELOW.
2. PLEASE REFER TO NRCS FIELD OFFICE TECHNICAL GUIDE FOR CHECK DAM DESIGN CRITERIA.
2. TOPOGRAPHIC AND SOIL SURVEYS MUST BE COMPLETED FOR FINAL DESIGNS.
3. THE DETAILS PROVIDED ON THIS SHEET MAY NOT SERVE AS FINALIZED ENGINEERING PLANS.

1. Standards for Soil Erosion and Sedimentation Control in New Jersey (Revised 1999):
   a. Standard for Grassed Waterways
   b. Standard for Permanent Vegetative Cover for Soil Stabilization
   c. Standard for Permanent Stabilization with Sod
2. USDA - NRCS Field Office Technical Guide
   a. Standard 412 Grass Waterway
   b. Standard 342 Critical Site Plantings

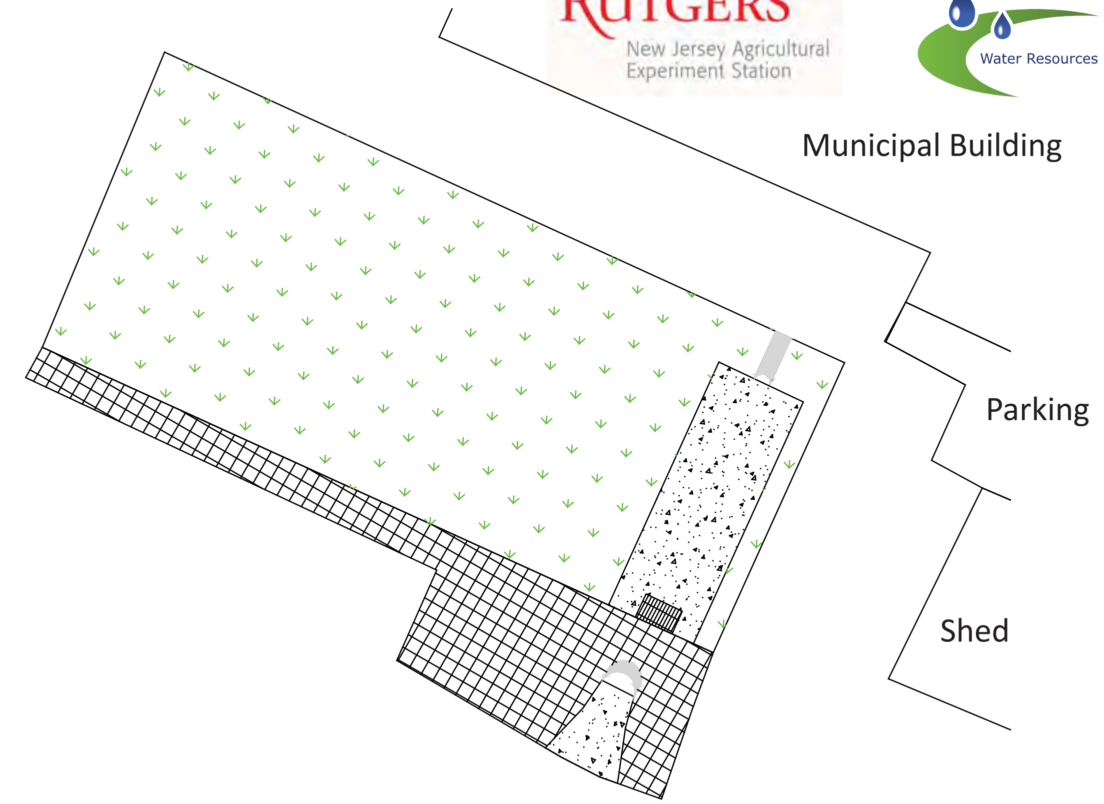
UPPER SALEM RIVER WATERSHED RESTORATION & PROTECTION PLAN

Detention Basin Retrofit

Pilesgrove Township Municipal Building
1180 Route 40
Pilesgrove, New Jersey

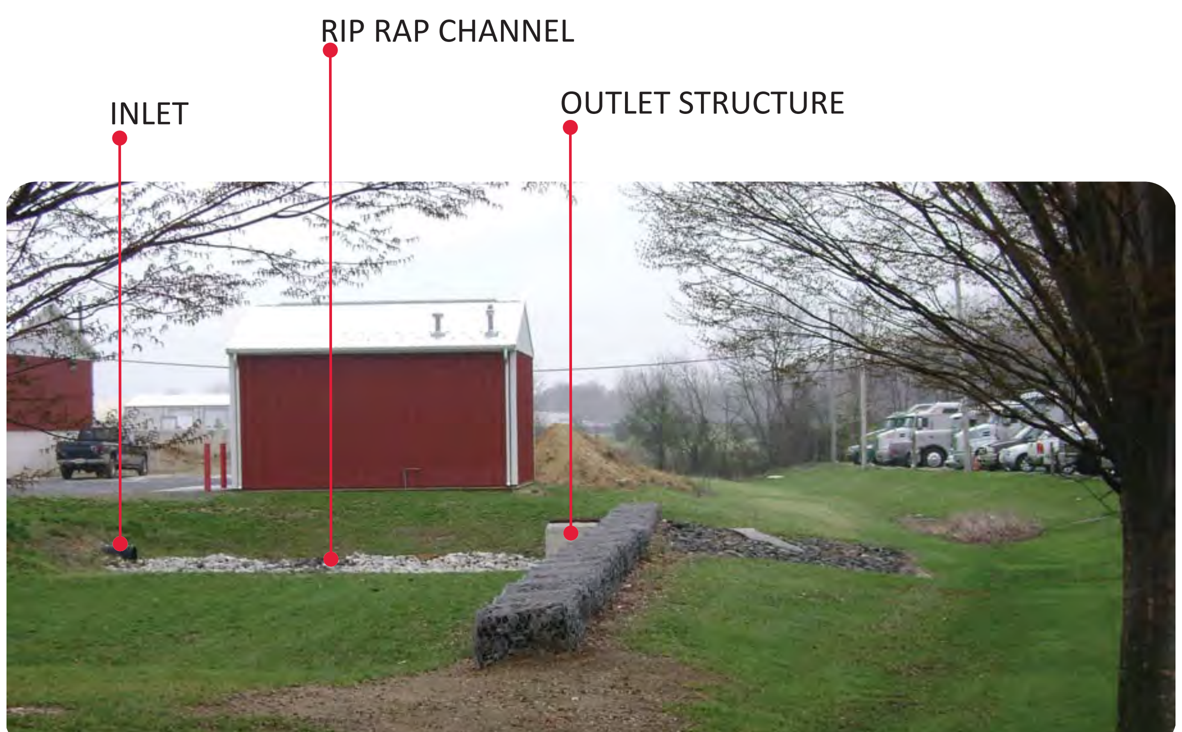
Currently at the Municipal building, a small detention basin with rip rap low flow channel manages stormwater runoff flows from the buildings roof and also the parking lot.

The basin is currently planted with turf grass that is mowed monthly.



To improve the function of the detention basin, native vegetation should be established and the outlet modified to allow water to infiltrate into the basin. A stone sock will be placed infront of the outlet structure to allow small storms to infiltrate while larger storms will bypass over the sock.

The native plants will not need monthly mowing and will create a naturalized basin wtih a variety of grasses and blooming perennials.

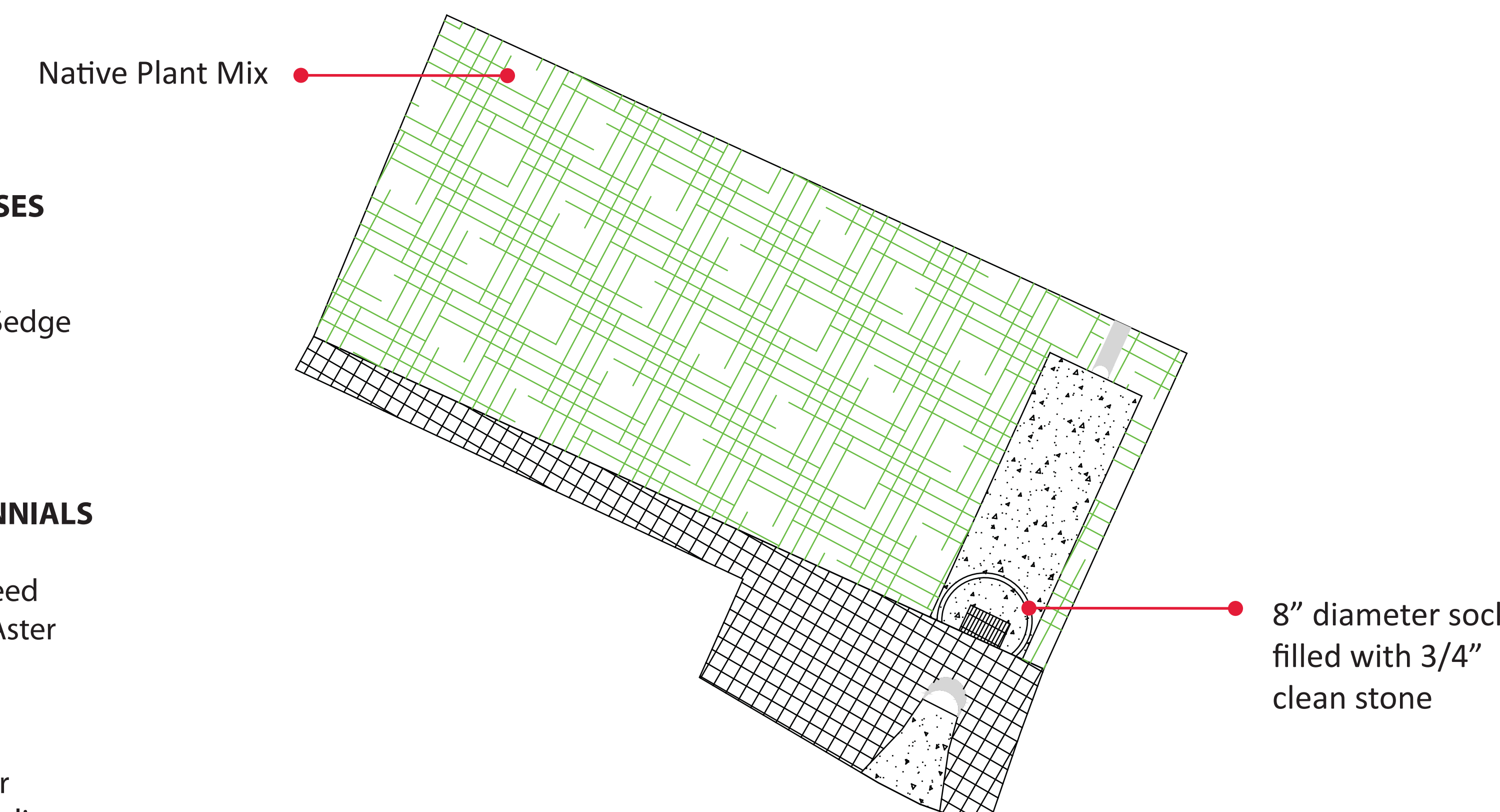


NATIVE GRASSES

Big Bluestem
Common Fox Sedge
Switch Grass
Indian Grass
Soft Rush

NATIVE PERENNIALS

Swamp Milkweed
New England Aster
Joe Pye Weed
Boneset
Rose Mallow
Cardinal Flower
Great Blue Lobelia



NOT TO SCALE