MAIDFORD RIVER

Watershed Assessment & BMP Design

JUNE 2015

Prepared by:

FUSS & O'NEILL

Table of Contents

Funding for this project is provided by the Hurricane Sandy Coastal Resiliency Grant Program through the U.S. Department of Interior and administered by the National Fish and Wildlife Foundation (NFWF).

1 What Is the Purpose of this Project?

Background

The Maidford River and Paradise Brook watersheds drain the southeastern corner of Middletown to the Sakonnet River just north of Sachuest Point. The Maidford River is also the principal source of water to Nelson Pond and Gardiner Pond, which are part of the surface water reservoirs for the City of Newport Water Division (NWD). These ponds, along with seven others owned by NWD, supply raw water for treatment before being distributed as drinking water to Newport, Middletown and a small section of Portsmouth, as well as the Portsmouth Water & Fire District and Naval Station Newport.

Water quality in a stream reflects current and former activities in its watershed. The Maidford River and Paradise Brook have elevated concentrations of fecal indicator bacteria and nutrients. The elevated concentrations of fecal coliform exceed the Rhode Island water quality standards for bacteria and pose a risk to human health for recreational users of the streams. Excess nutrients, like phosphorus and nitrogen, can fuel the growth of algae and aquatic plants and negatively impact water quality in the receiving waters, which include the freshwater Nelson and Gardiner Ponds and Narragansett Bay. Water quality in the Maidford River and Paradise Brook is significant because of the importance of Nelson and Gardiner Ponds which are a public drinking water supply, habitat for diverse populations of fish and shellfish in Narragansett Bay, and recreational activities in these waters such as swimming, boating, and fishing.

Flooding is also a major problem in these watersheds. Public roads crossing both streams routinely flood several times a year. This flooding impacts public safety by limiting access on public roads and causes property damage.

Previous and Ongoing Studies

Water quality in the Maidford River and Paradise Brook has been studied for over a decade. Investigations that have been completed or are on-going to better understand the relationship between watershed sources and water quality include the following:

- RIDEM Ambient Water Quality Monitoring - Rhode Island Department of Environmental Management (RIDEM) has been monitoring water quality in these streams for several years as part of their statewide ambient water quality monitoring program.

Maidford River Watershed

Roadway flooding is an ongoing problem in portions of the Maidford River watershed.

- Newport Water Division Source Water Monitoring Program of Public Drinking Water Supplies - NWD conducted a two year study to assess water quality in the Maidford River and Nelson and Gardiner Ponds.
- National Water Quality Initiative (NWQI) -This on-going project being led by the USDA Natural Resources Conservation Service (NRCS) in conjunction with RIDEM is intended to better understand the impacts of agricultural activities in this watershed and provide financial and technical support to farms to manage those impacts.
- North East Water Resources Network (NEWRnet) Study - University of Rhode Island and Salve Regina College have deployed two water quality sensors in the

Maidford to collect data on dissolved oxygen, suspended sediments, nutrients and other factors.

About This Project

The goal of this project is to provide a holistic assessment of the Maidford River watershed, including Paradise Brook, to determine the primary causes of the water quality and flooding impacts and recommend feasible, effective solutions to those problems. This project does not include any new water quality or streamflow data collection and instead relies on existing reliable data to draw conclusions. This project is also intended to complement the on-going National Water Quality Initiative which will recommend specific agricultural improvements in the watershed to be implemented by RIDEM and NRCS, but will not be completed until after this report is published.

Turbid Water in Maidford River Adjacent to Newport Water Diversion

2 The Maidford River Watershed

> **What is a Watershed?**
>
> A watershed is a basin that catches rain and snow and drains into a central waterbody – here that waterbody is the Maidford River. All of the land within the watershed is part of it, and watersheds often contain smaller "subwatersheds." Paradise Brook is a subwatershed within the larger Maidford River watershed. The land, waterbodies, aquifers, people, habitat, and infrastructure are interrelated within a watershed system. Changes in one part of the watershed can affect other parts.

The Maidford River watershed is located on Aquidneck Island in the Town of Middletown, Rhode Island, and includes both the Maidford River and Paradise Brook. Paradise Brook was originally a tributary that discharged to the Maidford River in the southeastern part of the watershed, but currently discharges to Nelson Pond. The watershed area is 3.68 square miles and is generally bounded by Route 138 to the north, topographic high points on either side of Mitchell's Lane and Third Beach Road to the east, Second Beach to the south, and Route 138A to the west.. Notable topographic high points occur within the Norman Bird Sanctuary in the south central portion of the watershed. Topographic low points exist along the Rhode Island Sound coastline and Sakonnet River.

The headwaters of the Maidford River begin in a small pond east of East Main Road (Route 138) and just south of a recent residential development, in the northwestern portion of the watershed. The Maidford River discharges to the Sakonnet River at Third Beach. Paradise Brook's headwater is characterized by marshy, agricultural land and is located east of Mitchell's Lane in the northeastern portion of the watershed.

As shown in Table 2-1 – Watershed Quick Facts, agriculture represents over one-third of the land use in each of the subwatersheds, with other residential areas and forest being other significant land uses in both subwatersheds. Agricultural areas tend to be located in the northern portions of the watershed, with residential development located in the southern half of the watershed. The Maidford River subwatershed, which is approximately three times the size of the Paradise Brook subwatershed, contains a just slightly higher percentage of residential development but roughly five times the population. . Figure 2-2 presents more detailed land use mapping, and also shows land currently identified as conservation land, which are lands protected from future development by the State of Rhode Island or recognized land protection organizations.

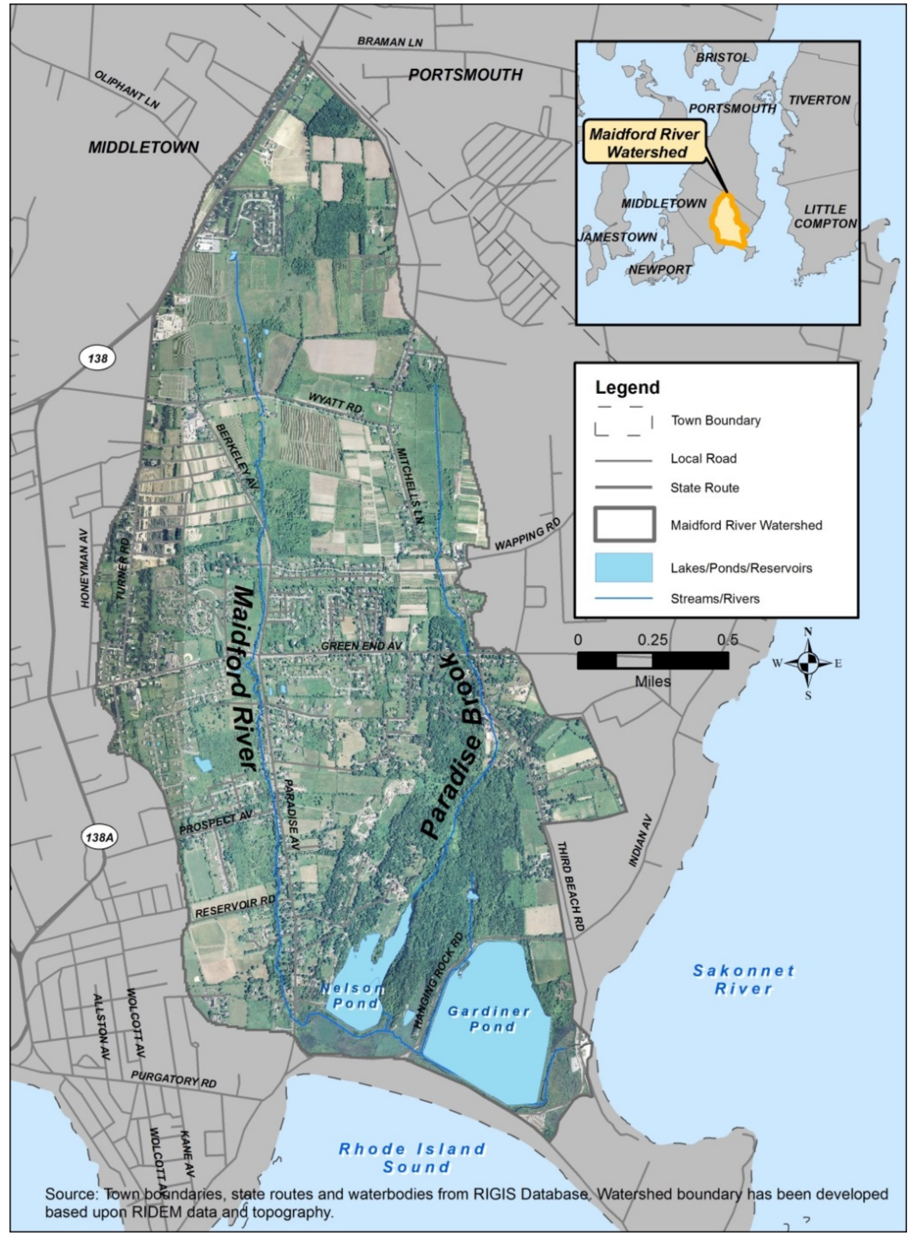


Figure 2-1. Maidford River Watershed

Nelson and Gardiner Ponds are two of Newport Water Division's nine drinking water reservoirs. Water can be diverted from the lower portion of the Maidford River to either Nelson Pond or Gardiner Pond. Nelson and Gardiner Ponds are connected by pipeline and transfers between the two bodies of water occur via gravity. Typically the diversion structure is operated between June and November, with periodic short term closures. Diversion of water from the Maidford River to the two drinking water reservoirs is based upon the elevations of the reservoirs, with the target elevation being one foot below full capacity at ±14 feet above mean sea level.

Impervious Cover

Conversion of undeveloped land to impervious surfaces prevents precipitation from naturally soaking into the ground and introduces new pollutant sources, resulting in a variety of hydrologic and water quality changes in a watershed. Impervious cover is a measure of the amount of impervious surfaces covering the landscape and can be used to assess the ecological condition of a watershed.

Table 2-1. Watershed Quick Facts

	Maidford River	Paradise Brook
Area	1821 acres; 2.85 mi^2	532 acres; 0.83 mi^2
Length	4.6 miles	1.8 miles
Elevation	Highest: 262 ft Lowest: 2 ft	Highest: 206 ft Lowest: 4 ft
Impervious Cover	10.7%	7.2%
Major Land Uses	Agriculture: 40% Residential: 27% Forest: 16% Other: 17%	Agriculture: 34% Residential: 23% Forest: 31% Other: 12%
Population	1,787 persons	340 persons

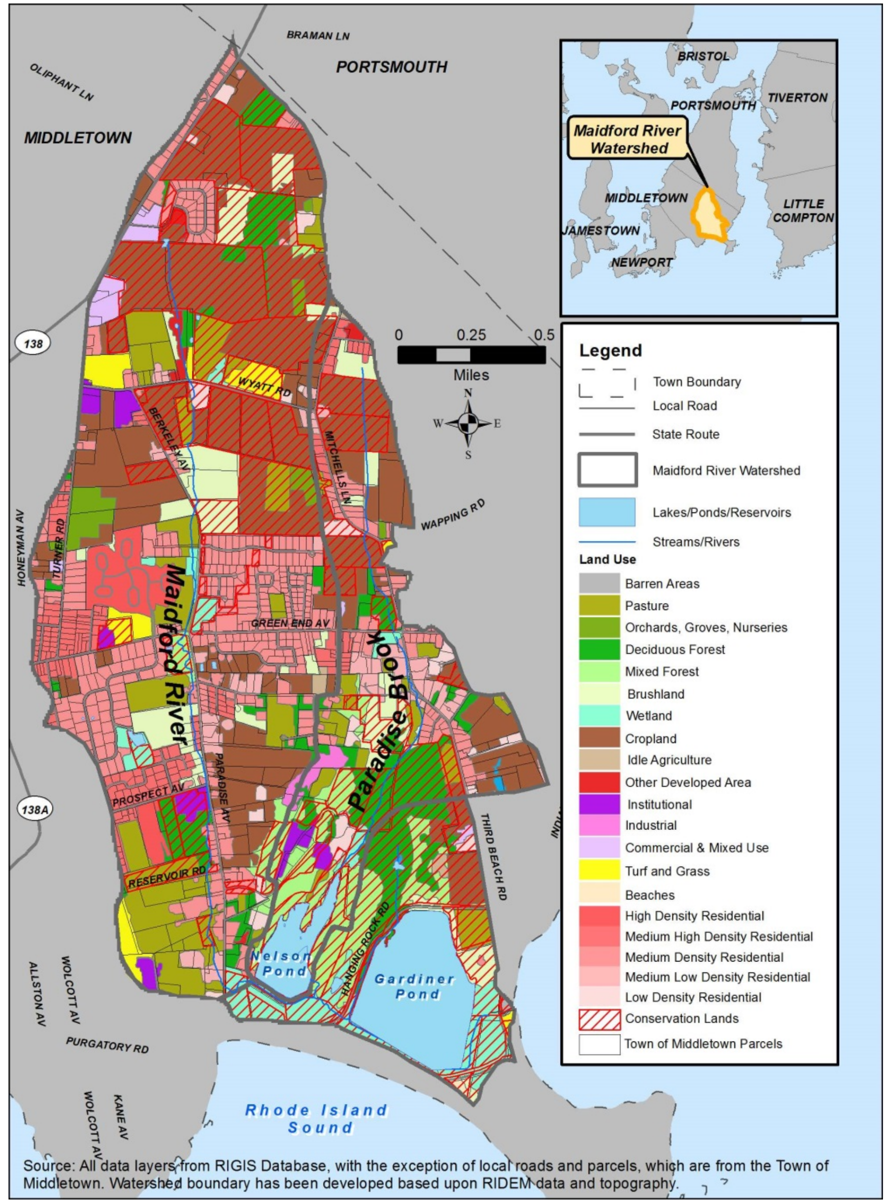


Figure 2-2. Watershed Land Use

3 What are the Water Quality Problems in the Watershed?

Water Quality

Water quality is driven by conditions in the watershed .Human activity on the land and characteristics of the landscape impacts water quality. In the Maidford River watershed, bacteria and nutrients are primary water quality concerns. Bacteria is typically associated with human, domestic animal/livestock, and wildlife waste – failing onsite wastewater treatment systems (OWTS), leaking sewer lines, poor livestock manure management, and pet waste can introduce fecal indicator bacteria such as Enterococcus and fecal coliform, along with other enteric bacteria and viruses, some of them potentially disease-causing pathogens, into the watershed. Nutrients, especially phosphorus and nitrogen, are likewise associated with human and animal waste, but can also come from fertilizer application on lawns and crops, and even atmospheric deposition.

Water quality in freshwater streams is evaluated relative to state standards that provide a benchmark against which to assess the condition of the water for its intended uses, which may include drinking water supply, primary and secondary contact recreation, fish and wildlife habitat, and industrial and agricultural uses. Waters which do not meet the criteria listed on in the water quality standards are placed on the state's list of impaired waters and total maximum daily loads (TMDLs) are developed to identify sources as set targets for water quality improvement.

RIDEM classifies both the Maidford River and Paradise Brook as Class AA waters since they are tributaries within a drinking water supply, and utilizes the criteria for primary and secondary contact recreation to assess water quality. Water quality standards for Class AA freshwaters for nutrients and bacteria are listed in Table 3-1. The RIDEM List of Impaired Waters lists both Maidford River and Paradise Brook as impaired due to fecal coliform concentrations. The 2015 draft List of Impaired Waters also lists the upper segment of Maidford River as impaired due to lead[1]. In addition to being Class AA waters, the Maidford River and Paradise Brook have also been designated as Special Resource Protection Waters (SRPWs) which provides additional protection under Rhode Island's anti-degradation provisions for water. In particular, the regulations prohibit any new or increased activity or discharge subject to permitting by RIDEM resulting in a measurable degradation of existing water quality.

Visible turbidity in Maidford River at Reservoir Road (RIDEM, 2014)

Lack of Riparian Buffer near Wyatt Road

[1] A firing range is located in the upper portion of the Maidford River watershed and is a potential source of lead.

Water quality concerns related to bacteria are well documented in the 2011 Statewide Bacteria TMDL (RIDEM, 2011). Both the upper and the lower segments of the Maidford River and all of Paradise Brook are identified as not meeting water quality standards for bacteria (see Table 3-1) in a Class AA freshwater stream. The RIDEM Total Maximum Daily Load (TMDL) reports the Maidford River is often considered in two segments. The first segment, Segment 2A, extends south from the River's headwaters, crossing perpendicular to Wyatt Avenue through agricultural fields, running parallel to Paradise Avenue and terminating just after the road crossing at Paradise Avenue. Segment 2B of the Maidford River begins at the termination point of Segment 2A, runs along the southern border of Nelson and Gardiner Ponds and discharges at Third Beach. Based on data collected throughout the watersheds in 2000-2005, RIDEM determined that both the geometric mean and 90th percentile maximum criteria were exceeded in both the Maidford River and Paradise Brook watershed. Although the water quality standards for fecal coliform were exceeded at most locations monitored, the data included in the TMDL (RIDEM, 2011) show that some of the highest geometric mean fecal coliform values were located at:

- Wyatt Road in the northern half of the Maidford River watershed
- Hanging Rocks Road near the mouth of the Maidford River
- Mitchell's Lane in the northern half of the Paradise Brook watershed
- Downstream of the Newport Equestrian Center in the southern portion of the Paradise Brook watershed.

Table 3-1. Relevant Water Quality Standards

	Class AA Freshwaters Tributary to Drinking Water Supply
Total Phosphorus	25 µ/L
Fecal Coliform	
Geometric Mean	<200 MPN/100 ml
90th Percentile	400 MPN/100 ml
Enterococci	
Single Sample Maximum	61 colonies/100 ml

*MPN, CFU, and colonies per 100 ml are equivalent expressions of bacteria concentration.

With the exception of the Hanging Rocks Road site, these locations are also included in RIDEM's ongoing National Water Quality Initiative (NWQI) study (Figure 3-1). To date, both dry weather and wet weather samples have been collected at these monitoring locations and a variety of water quality parameters collected, including turbidity, total suspended solids (TSS), total phosphorus (TP), different forms of nitrogen, and the indicator bacteria fecal coliform (FC) and Enterococci. The results provide an excellent picture of current water quality in the watersheds.

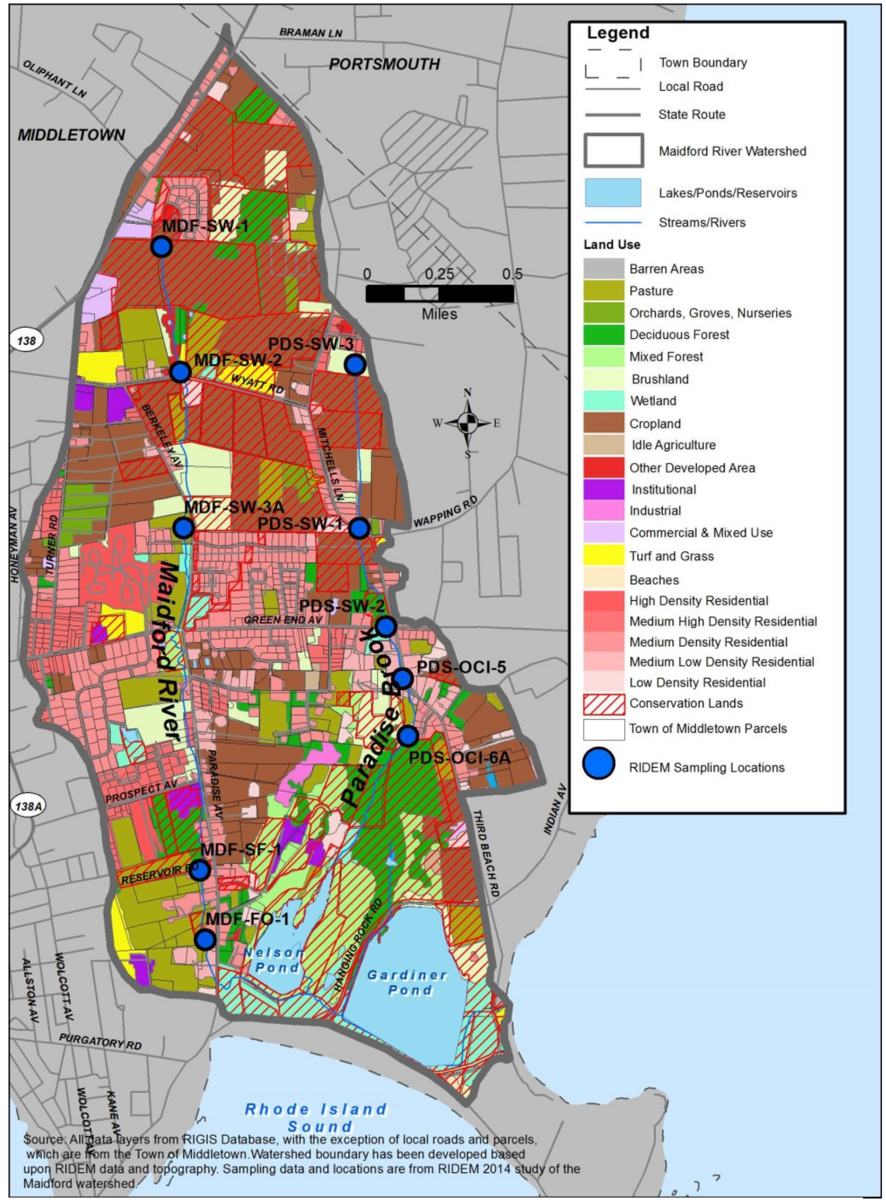


Figure 3-1. RIDEM NQWI Monitoring Locations

Figures 3-2 and 3-3 provides a visual comparison of the spatial differences in water quality in the watersheds under recent wet weather (December 9, 2014) and dry weather (April 15, 2015) conditions. Fecal coliform has been selected as the bacteria of interest due to its use in the development of the 2011 TMDL. Several observations are immediately apparent:

1) Wet weather concentrations of FC are higher than dry weather concentrations,
2) Wet weather FC concentrations are higher in Paradise Brook than the Maidford River
3) Maidford River concentrations of FC increase downstream in wet weather, but are relatively consistent and low in dry weather
4) High FC concentrations at the headwaters of Paradise Brook at Fayal Lane (PDS-SW-3A), which exceed the water quality standard in both dry and wet weather

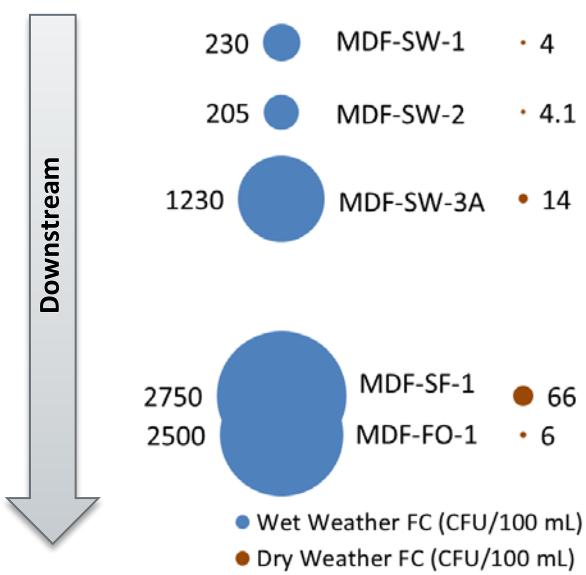


Figure 3-2. Fecal Coliform Concentrations in the Maidford River (RIDEM, 2015)

The high concentrations at Fayal Lane (PDS-SW-3A) are unexpected since the location is upstream of active agricultural areas and this may represent an isolated source in area of the sampling location. These observations, considered in conjunction with the TMDL, point to the influence of several factors on bacteria concentrations in the watersheds:

- Higher wet weather concentrations indicate the influence of stormwater runoff in delivering bacteria loads to the streams.
- Higher wet weather concentrations in Paradise Brook may reflect the more consistent distribution of agricultural land use along the stream corridor (Figure 3-1) compared with Maidford River, which is characterized by more agricultural land use in upstream areas and residential use in downstream areas of the
- watershed. It may also reflect the influence of onsite wastewater treatment systems (OWTS); however, these are not thought to be a significant contribution because of the points below.
- Low dry weather FC concentrations at most locations discount failing OWTS, leaking sewers, or illicit connections, all of which would provide FC sources in dry weather.
- Increasing FC concentration downstream in the Maidford River point away from OWTS (the southern half of the watershed is sewered (Figure 3-4)) and suggest the influence of livestock, wildlife, and residential land use for FC generation and attachment to sediment as a mode of FC transport due to high TSS loads. These observations are consistent with the TMDL and RIDEM's field observations from the NWQI study.

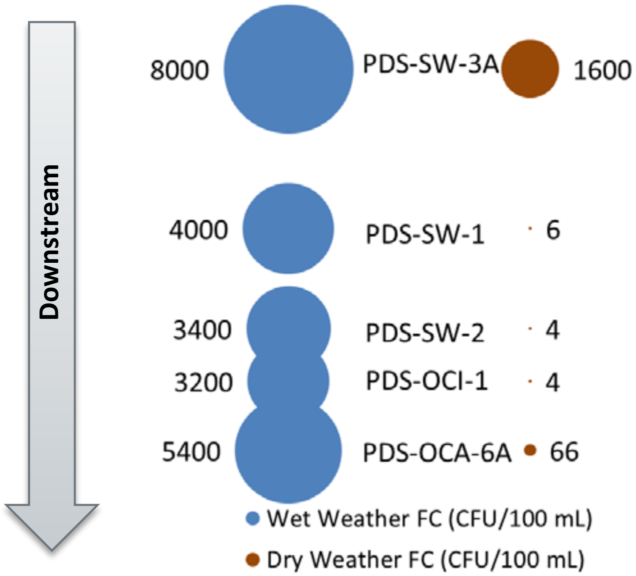


Figure 3-3. Fecal Coliform Concentrations in Paradise Brook (RIDEM, 2015)

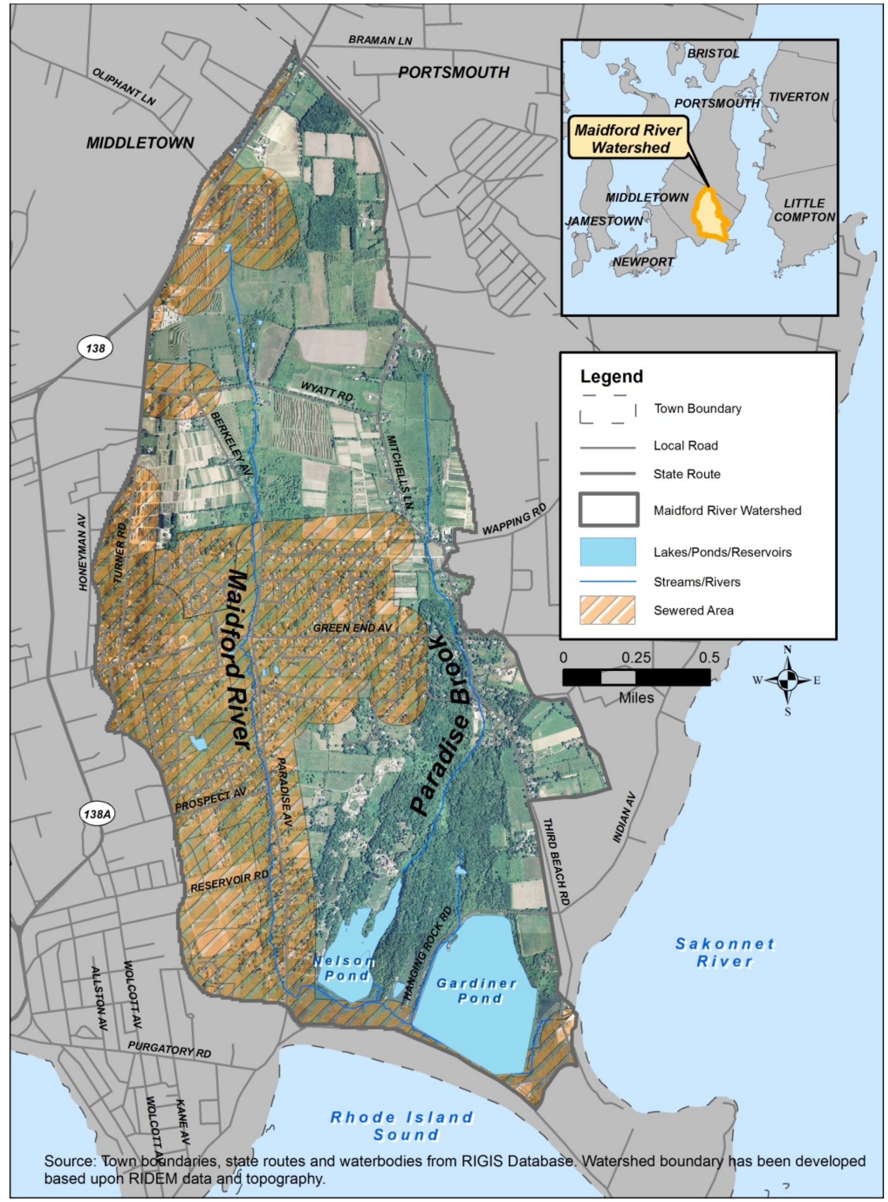
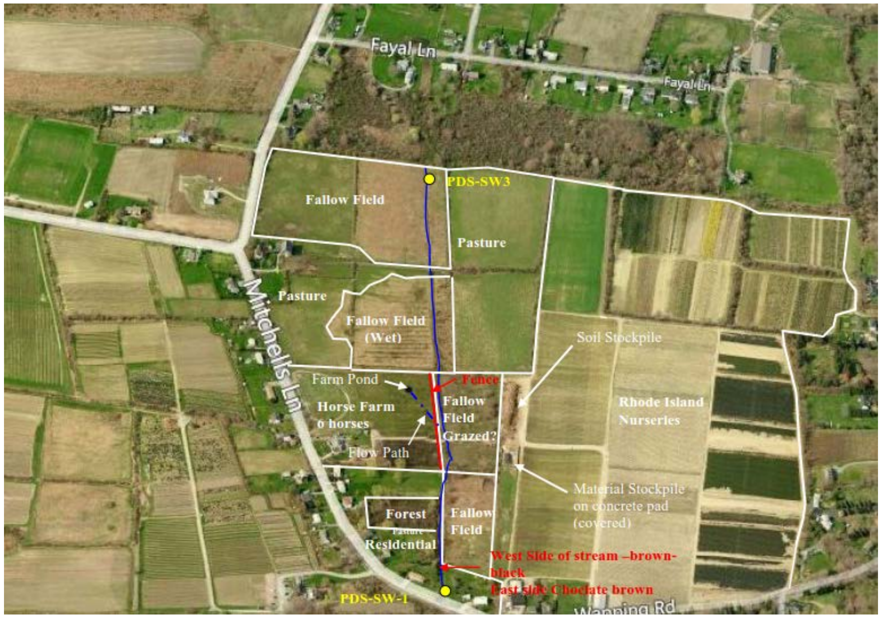


Figure 3-4. Sewered Areas in the Watershed



RIDEM Field Observations of Headwaters of Paradise Brook Note the area of fallow fields directly adjacent to stream.

Elevated total phosphorus (TP) concentrations in the watershed have manifested themselves in algal blooms in the downstream receiving waters – Nelson and Gardner Ponds. Both ponds are included in the 2015 draft List of Impaired Waters for both total phosphorus and total organic carbon (TOC). TOC describes any organic (i.e., carbon-containing) compounds dissolved in water. TOC is released from naturally-occurring and human-made sources. Aquatic life – phytoplankton, algae, plants – release TOC through metabolism and decomposition. Soils can leach TOC into water bodies and inputs from human sources include sewage and runoff containing organic material such as animal waste. Since TP fuels the growth of cyanobacteria, algae and aquatic plants, which eventually decompose adding organic matter to the water column, TP has an influence on TOC concentrations.

TP is widely used as an indicator of water quality. The RIDEM water quality standard of 25 µg/L is generally acceptable for freshwater surface waters, with TP values of 50 µg/L recommended for streams discharging to lakes and reservoirs, and 100 µg/L recommended by the U.S. EPA as a water quality criteria for streams that do not directly empty into reservoirs.

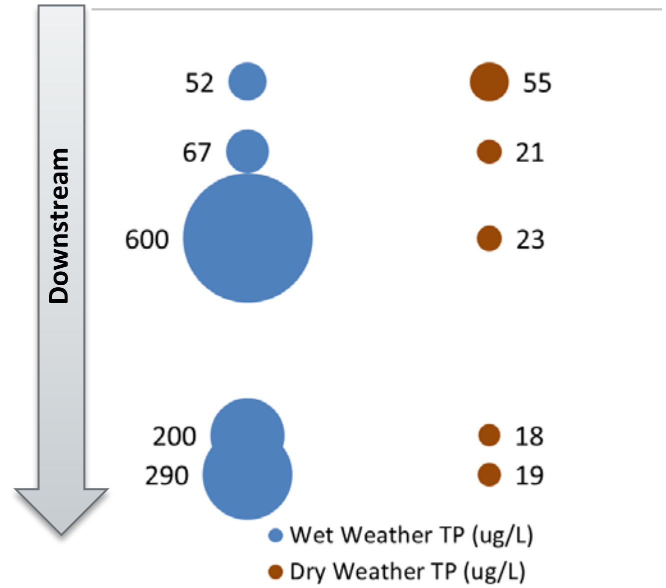


Figure 3-5. Total Phosphorus Concentrations in the Maidford River (RIDEM, 2015)

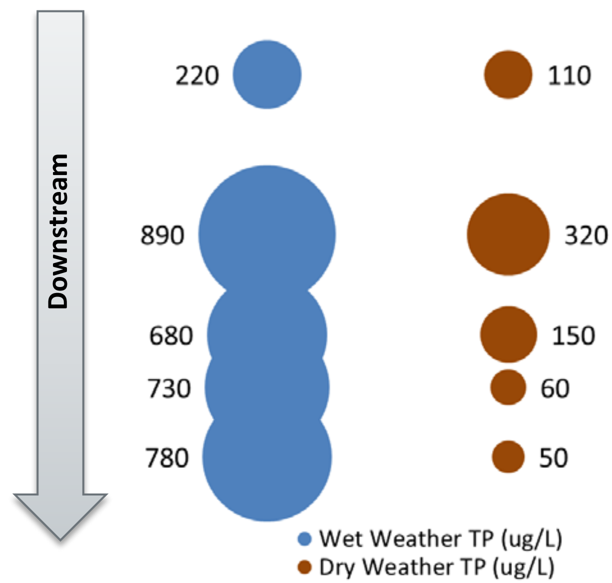


Figure 3-6. Total Phosphorus Concentrations in Paradise Brook (RIDEM, 2015)

RIDEM's recent sampling of the water quality in the Maidford River and Paradise Brook shows that even under dry weather conditions, TP concentrations in Paradise Brook always exceed the standard for Class AA waters (Figure 3-6). In the Maidford River, wet weather concentrations exceed 25 µg/L and notably increase downstream of Wyatt Road, but are relatively consistent and close to the water quality standard in dry weather (Figure 3-5). As with the bacteria data, the recently collected TP data offers several observations:

- Low dry weather TP concentrations, coupled with low ammonia concentrations, in both wet and dry weather, do not point to OWTS as a significant nutrient (or bacteria) source in either watershed compared to other potential sources.
- Significant wet weather increases in TP concentrations suggest the influence of stormwater runoff as an important source of TP in both watersheds.
- Order of magnitude increases in TP concentrations downstream of Wyatt Road in the Maidford River watershed point to a combination of intensive agricultural land use (see photo at right) and increased imperviousness associated with development impacting TP concentrations.
- Because TP is often transported by being attached to sediment, observations of heavy sediment loads by RIDEM and high TSS concentrations in wet weather highlight the importance of erosion control to improve water quality relative to nutrient concentrations.

RIDEM Field Observations at Mouth of Maidford River Notation of heavy sediment load near Station MDF-SF-1.

In summary, both historic and ongoing water quality data indicate issues with bacteria and nutrients in the Maidford River and Paradise Brook watersheds, which not only impact water quality in the streams, but also influence the water quality in Nelson Pond and Gardiner Pond. Both agricultural and residential land use and imperviousness in residential areas contribute to the water quality issues, with stormwater runoff implicated as a major source of both pollutants.

Pollutant Loading Modeling

A pollutant loading model is a tool to estimate the contribution of land use and other activities in a watershed to observed pollutants – bacteria, nutrients, sediment – to waterbodies in a watershed. The "loading" is the mass of the pollutant that is estimated to be generated in a watershed. The Watershed Treatment Model (WTM), developed by the Center for Watershed Protection, was used to estimate pollutant loads for the watershed. The basis of the WTM is a pollutant loading calculation developed by Schueler (1987) called the Simple Method. Based on user specified input describing characteristics of the watershed, the WTM estimates total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS), and fecal coliform bacteria (FC) loads from various land uses. Information on the quality of stormwater runoff, described by parameters called event mean concentrations (EMCs), which are values of the mean concentration of a pollutant in stormwater runoff, and the average impervious cover for each land use type in the watershed are used in the model. Land uses modeled for the Maidford River watershed include high density residential, medium density residential, low density residential, agriculture, open space/recreational turf, commercial, industrial, institutional, forest, water, wetland, and beach parking/campground (see *Appendix A* for more detail).

In addition to pollutants generated from land uses, the WTM also estimates pollutant loads from other sources that may be present, but are not necessarily associated with a particular land use. These additional sources include livestock, onsite wastewater treatment systems (OWTS), winter time road sanding, and stream channel erosion. The model also estimates reductions in pollutant loads based on management activities that are occurring in the watershed. For example, street sweeping and catch basin cleaning are management activities which tend to reduce the amount of pollutants that reach receiving waters. When reviewing modeling results it is important to remember that the loads are what is estimated to be generated from the land surface and do not incorporate any attenuation from sedimentation or biological processes as runoff and streamflow move through the watershed.

Model results show that annual loadings of all pollutants modeled are greater for the Maidford River subwatershed than the Paradise Brook subwatershed (Figure 3-7). This result is expected since the area of Maidford River subwatershed is 3.4 times larger. However, the Maidford subwatershed pollutant yields are 17-28% more than the Paradise subwatershed. Annual runoff depth, which is the depth of rainfall that would be

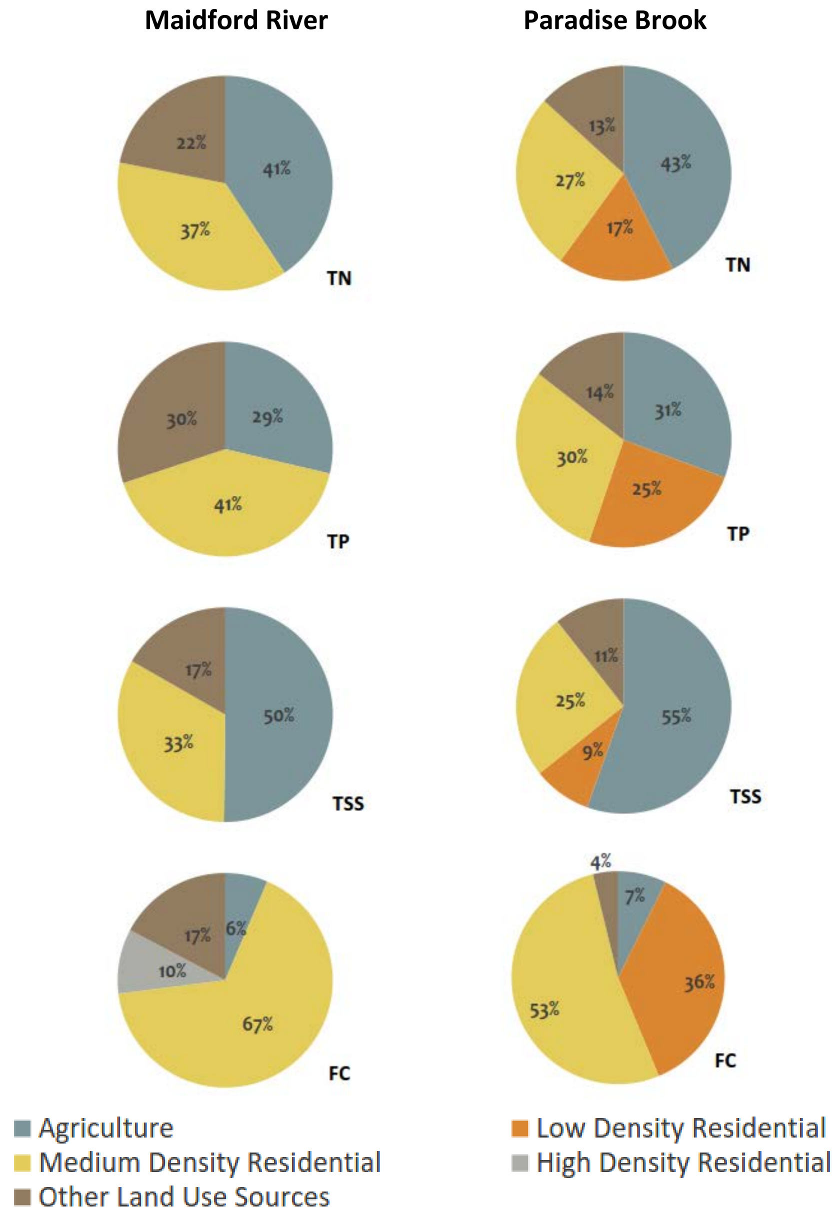


Figure 3-7. Modeled Sources of Pollutant Loadings in the Watersheds

expected to leave the watershed as runoff, rather than infiltrate into the ground or be captured by vegetation, is approximately 67% larger in the Maidford River subwatershed. This is because of the greater proportion of developed land uses in the Maidford River subwatershed, such as residential and commercial areas, which tend to have a greater amount of impervious cover (Figure 3-8). Since precipitation cannot infiltrate into impervious surfaces, a greater proportion of the rainfall becomes runoff.

Overall, model results indicate that the actions associated with the underlying land uses in the watersheds, rather than specific activities that occur in the watersheds, are responsible for the majority of loading for all the pollutants considered (91% TN, 77% TP, 93% FC, and 41% TSS for the Paradise and Maidford subwatersheds combined). The exception to this is TSS loading, which is dominated by road sanding (19%) and stream channel erosion (41%). The WTM estimates that street sweeping and catch basin clean outs, which are known management practices in the watershed, can lower annual TSS loads by approximately 8%. Throughout the entire watershed, and within the individual subwatersheds (Figure 3-7), agriculture and medium density residential areas generate the most nutrients (TN and TP), as well as TSS, a result which is also consistent with RIDEM's recent observation of higher instream turbidity concentrations near agricultural areas within the watershed (RIDEM, 2015). Residential areas are main source of FC, with medium density residential generating 68% of the modeled annual load. Agricultural land use is estimated to generate approximately 7% of the annual FC loading, however, estimated FC generation from livestock nearly doubles the overall FC loading from agricultural-related sources.

The results of the WTM, which identify agriculture and residential land use as primary sources of bacteria loads, are generally consistent with TMDLs for bacteria developed for the Maidford River and Paradise Brook. The Maidford River bacteria TMDL (RIDEM, 2011) identified agricultural activities, stormwater runoff, wildlife and domestic pets as potential bacteria sources. Microbial source tracking methods identified livestock as a possible source in the northern portion of the watershed, with wildlife, including waterfowl, being recognized as a bacteria source in the southern portion. In Paradise Brook, agricultural activities, domestic pets/livestock, and OWTS were all acknowledged as potential bacteria sources in the TMDL, along with stormwater runoff (RIDEM, 2011).

However, pollutant loading is only part of the story – transport of pollutants from their source to the waterbody, along with pollutant generation, determined the water quality of steams and ponds. Impervious areas and soils with limited infiltration capacity (Figure 3-8), which do not allow for infiltration and storage of rainfall, lead to greater runoff generation and potentially greater runoff velocities, which increase the erosive power of runoff as it travels over the land surface. Vegetative cover on the land surface both slows and absorbs runoff, and vegetative buffers near streams can both trap sediment and pollutants and help to maintain stable stream banks.

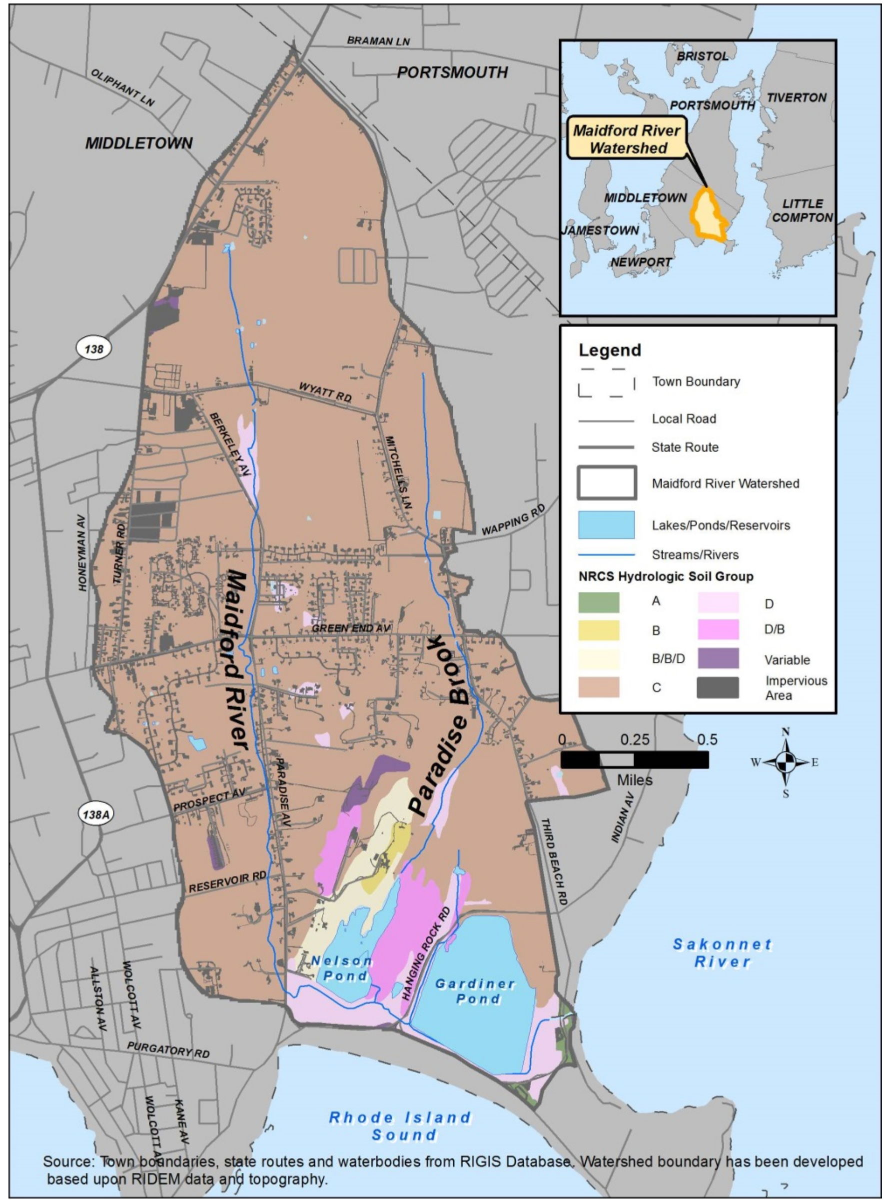


Figure 3-8. Impervious Areas and Hydrologic Soil Groups

4 What are the Flooding Problems in the Watershed?

Flooding in the Maidford River watershed is a long-standing problem, with several road crossings flooding numerous times per year (Figure 4-1). Flooding not only damages private property, but also creates a public safety problem, limiting access for first responders and making travel unsafe for vehicles and also damages private property. Anticipated changes in precipitation frequency and intensity are expected to exacerbate flooding in Rhode Island (RI Sea Grant, 2014).

Table 4-1. Flooding Quick Facts

	Maidford River	Paradise Brook
100-year Peak Flows from FEMA Flood Insurance Story (cubic feet per second)	1,119 cfs	395 cfs
Number of Public Road Crossings below 100-year Floodplain	9	1
Impervious Cover	10.7%	2%

The most recent Flood Insurance Study (FIS) for this watershed prepared by the Federal Emergency Management Agency (FEMA) identifies several existing public and private road crossings that are below the 1% annual recurrence interval storm (100-year) floodplain elevations and often below the 10% annual recurrence interval storm (10-year) floodplain elevation (FEMA, 2013).

What is a 100-year Floodplain?

The 100-year floodplain is the land that is predicted to flood during a 100-year storm, which has a 1% chance of occurring in any given year. The 100-year floodplain is sometime referred to as the 1% annual chance floodplain or base flood. However, areas within the 100-year floodplain may flood in much smaller storms as well.

The severity of the flooding in this watershed is likely under-reported in the FEMA FIS for several reasons. These include the fact that the FEMA model is based on older

Figure 4.1. Flooding on Paradise Avenue

precipitation values and does not reflect current rainfall data for the more intense and frequent storms that now occur in the Northeast United States (RI Sea Grant, 2014). The storm flows reported in the FIS appear to be based on a smaller watershed area (3.33 mi^2) than the actual watershed size (3.68 mi^2).

"In the Northeast, the amount of rainfall during extreme precipitation events (defined as the heaviest 1 percent of precipitation events) has increased by 67 percent over the last 50 years, causing increased flooding and damages." - Rhode Island Sea Grant (2014)

More frequent flooding is also consistent with the Town's observations. Crossings reported to routinely flood a couple of times each year include Third Beach Road, Hanging Rocks Road, Paradise Avenue, Wyndham Hill Road and Berkeley Avenue along the Maidford River

Figure 4-1 shows the location of the mapped floodplain in the watershed and the FIS reported frequency of flooding for public road crossings along the Maidford River and Paradise Brook.

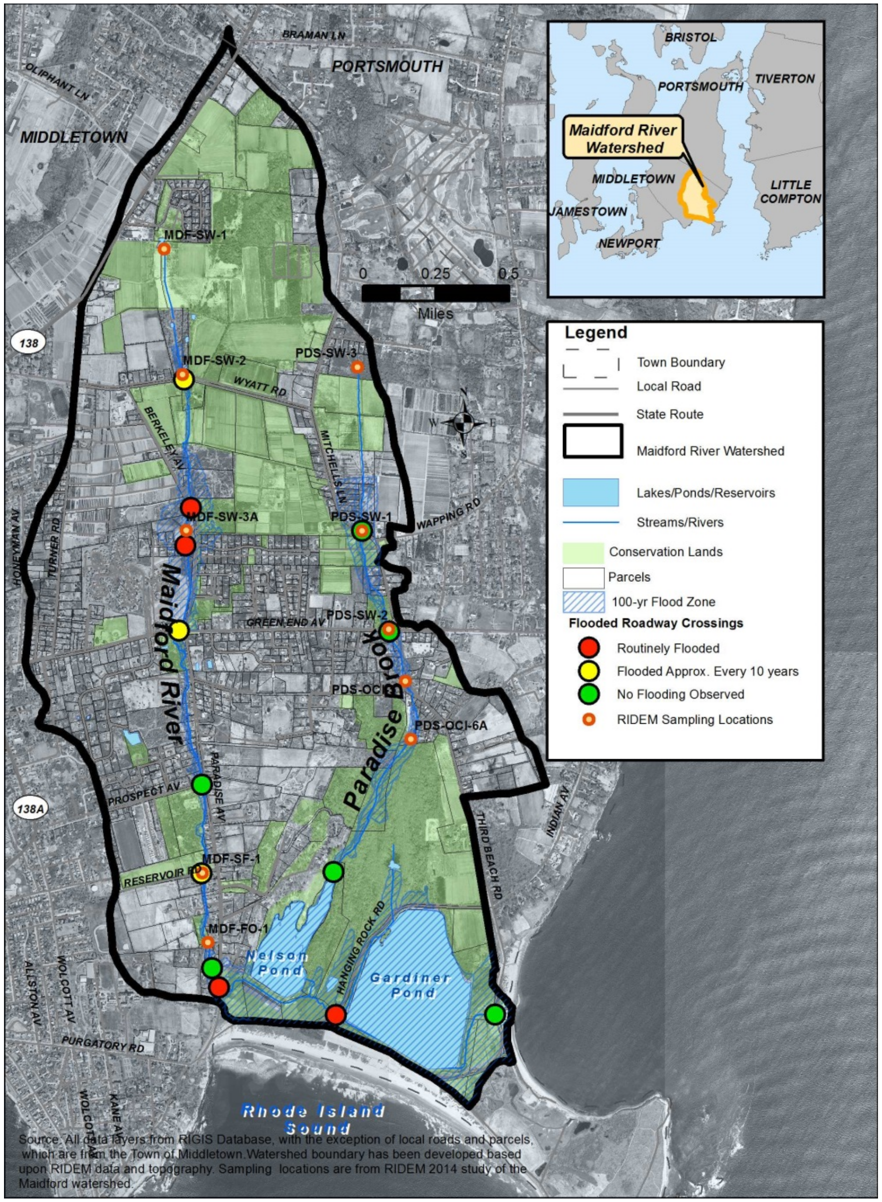


Figure 4-1. Floodplains and Flooded Road Crossings

As part of their National Water Quality Initiative project, RIDEM has measured flows at several sampling stations along the Maidford River and Paradise Brook. Table 4-2 summarizes these measured flows along the Maidford River. One of the anecdotal observations made about this watershed is that it is very "flashy," that is the stream responds quickly to rainfall events and shows a sharp increase in flow after the onset of precipitation and a rapid return to pre-rain conditions shortly after the end of the precipitation. This type of response in a watershed happens because precipitation makes its way quickly from the land into the stream and moves downstream rapidly. For example, during the storm on December 9, 2014 with only 1.8 inches of rain, measured flows in the Maidford River increased by more than 30 times than measured dry weather flows in April. In addition, the magnitude of flow increases noticeably from upstream to downstream. While dry and wet weather flows are similar at the headwaters (MDW-SW-1), they differ by orders of magnitude at the downstream locations, reflecting the effects of impervious cover and land use in the watershed.

Table 4-2 Streamflow (cfs) Measured at RIDEM Sampling Stations

Date Measured	**Upstream >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> Downstream**				
	MDW-SW-1	MDW-SW-2	MDW-SW-3A	MDW-SF-1	MDW-FO-1
12/9/14 Wet Weather (1.81 inches)	0.16	2.24	17.05	87.92	98.42
4/2/15 Dry Weather	0.27	0.83	1.83	3.26	2.64
4/15/15 Dry Weather	0.07	0.63	1.00	Not Measured	1.82

From our review of the FEMA FIS and existing conditions in the watershed, there are factors that contribute to the flooding include:

- There is little open space left in the southern half of the watershed Land use are dominated by single-family residential and agricultural uses. While these may appear to be relatively low impact uses, even with the inclusion of detention basins in residential developments in the watershed, this level of development substantially increases the volume of runoff. For example, compared to undeveloped conditions for a storm with 3 inches of rainfall, this developed watershed would generate about an additional 0.9 inches of runoff over the land area of the watershed, which is approximately 648 million gallons of runoff.
- The natural soils in this watershed have poor infiltration capacity, leading to greater runoff generation. The agricultural activities in this watershed have mostly been in operation for many decades. Long-term agricultural operations can reduce organic content in soil which impacts the ability of that soil to retain water. For every 1% of organic matter in soil, an acre of land can retain 40,000 gallons of water. The flashiness of these streams is the product of water runoff from agricultural fields and developed impervious areas.
- Public road crossings which routinely flood have physical limitations that limit their capacity. Culvert openings are typically built to match the width of the existing streams, substantially expanding the culvert width beyond the width of the rivers would not be practical. The roads above most of these culverts are also very low. As a result, there is little capacity for these crossings to temporarily detain water behind the crossing before overtopping the road.
- Both the Maidford River and Paradise Brook are very channelized with little natural floodplain to store water during flood events.
- Flooding at the Third Beach Road and Hanging Rocks Road crossings is influenced by tides and/or shoaling at the mouth of the Maidford River which reduce its capacity to discharge to the Sakonnet River. This causes flood waters to back up into the lower part of this watershed and flood these structures.

5 **Solutions**

Addressing the water quality and flooding challenges in this watershed requires a holistic approach that implements a range of controls. This section summarizes and prioritizes potential management practices that could significantly improve water quality and flooding problems. Some of these controls have the benefit of addressing several of these issues.

A major challenge in this watershed is the fact that the soils are mostly classified as Hydrologic Soil Group C, which is characterized by limited infiltration capacity. As a result, there is limited potential for management practices in this watershed to recharge groundwater and use that as a tool to either reduce flooding or filter stormwater through natural soils for treatment. Both retrofits of existing infrastructure and construction of new stormwater management structures will need to incorporate subsurface drainage to account for lack of infiltration capacity.

Stormwater Best Management Practices

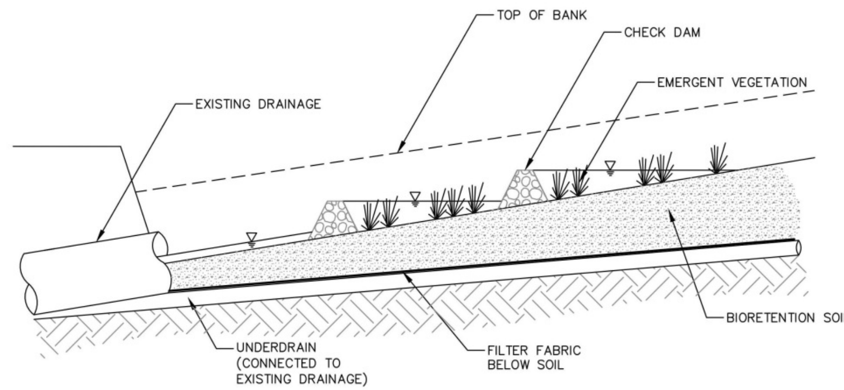
Stormwater best management practices (BMPs) consist of structural and non-structural controls that improve water quality or better manage stormwater runoff volume from private property and town-owned land, such as roads. BMPs include retrofitting existing controls as well as constructing new controls:

- **Retrofit Existing Detention Basins:** Several private developments and agricultural operations in the watershed have existing detention basins. These basins only serve to attenuate peak flows and have no measurable impact on reducing water volumes and improving water quality. Modifications to these basins are proposed in order to maximize their ability to improve water quality, including modifying outlet structures or making other structural changes in the basins to improve their ability to settle out of the water column sediments that typically also carry bacteria and nutrients. More significant modifications include retrofitting the basins with pre- or post-treatment bioretention or wet vegetated treatment systems.

What are Best Management Practices?

A best management practice is an engineered system or intentional action which by its design is intended to alter (i.e., control) the generation and transport of stormwater runoff. These controls can be structural, which involve the use of a specific device or physical element, or non-structural, which involve changes in human behaviors that influence the volume, timing or quality of runoff.

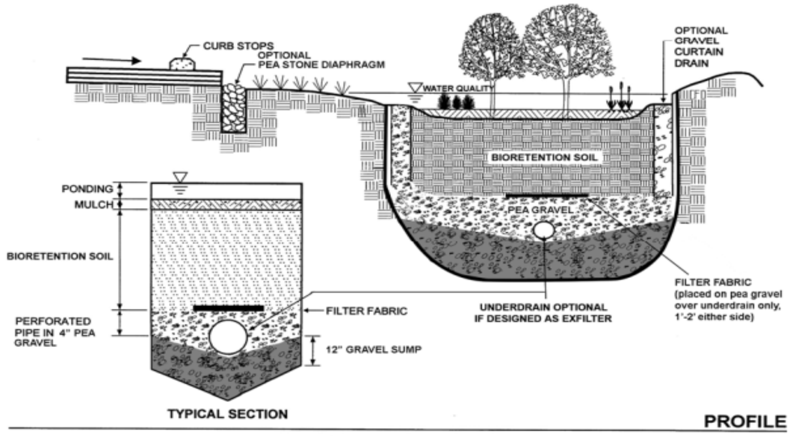
- **Retrofit Existing Roadside Swales:** This watershed is somewhat unique as many of the town roads have roadside swales in place to collect and convey runoff. These swales are currently designed so runoff flows down the road shoulder and over grass cover to control erosion. Retrofitting would consist of installing check dams and underdrains in the swales in order to have the swales provide some water quality benefits by detaining runoff behind the check dams and allowing for filtration through a vegetated filter media.



Example Profile of a Roadside Swale with Check Dams and Underdrain

- **New Stormwater BMPs:** Runoff from much of the watershed is not managed by existing stormwater controls. This class of BMPs consists of installing new controls that are designed to provide some treatment of stormwater for target pollutants (i.e., phosphorous, nitrogen, bacteria). Because of the low infiltration capacity of soils in the watershed, the ability to recharge stormwater into the groundwater and thereby reduce volumes of stormwater draining to flooded rivers is very limited.

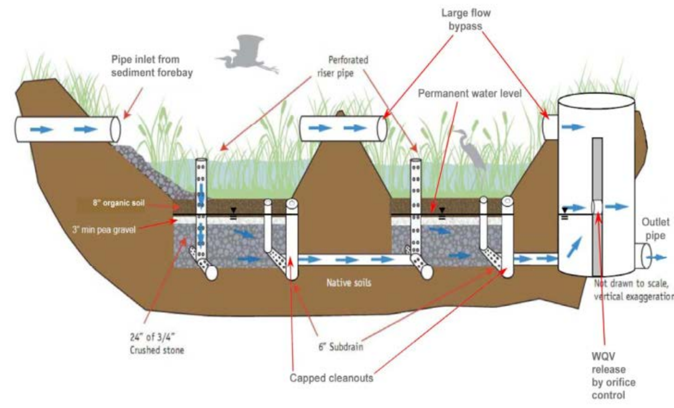
These new structures would have some limited benefit of temporarily detaining these flows. Proposed new stormwater BMPs were selected based on their ability to reduce loadings of the phosphorous, nitrogen and bacteria and include the following:



MDE, 2000

Example Profile of a Bioretention System

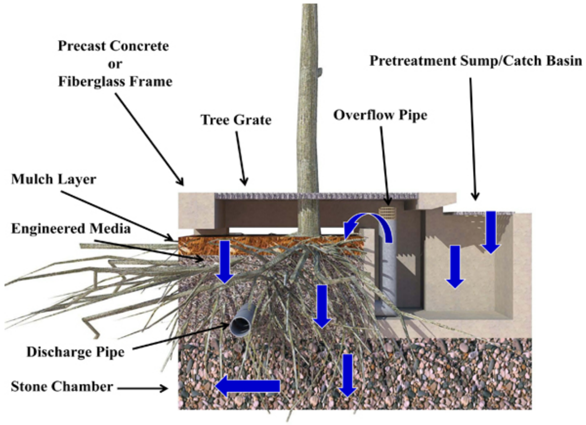
- Bioretention Systems: These systems consist of a planted depression which includes engineered soils to promote water infiltration through the soils, taking advantage of the resulting filtration, as well as vegetative uptake, to remove pollutants. Because of the soils in this watershed, an underdrain would be placed below the bioretention system in order to prevent flooding and standing water in the basin. The layer beneath the engineered soil consists of a sand bed that further filters pollutants. The sand layer is underlain by pea gravel and a subdrain to allow for treatment and discharge of treated effluent.
- Wet Vegetated Treatment Systems: These systems consist of one or more cells where collected stormwater infiltrates into and flows through a gravel bed where wetland roots and rhizomes extend into. Water quality treatment is provided by the filtration process through the soils and gravel and vegetative uptake.. Underdrains are used to convey water into and out of cells in order to promote flow through the gravel bed.



Adapted from UNHSC, 2009

Example Profile of a Wet Vegetated Treatment System

- Tree Filters: These types of controls consist essentially as subsurface bioretention systems that rely on tree roots and an engineered media to provide similar treatment mechanisms as conventional bioretention systems. Tree filters can readily be incorporated in urban environments and neighborhoods by taking advantage of street trees and converting them into small BMPs. They can either be placed roadside in a subdivision or between the curbline and existing sidewalks.



Example Profile of a Tree Filter (from StormTree™)

Flood Control Best Management Practices

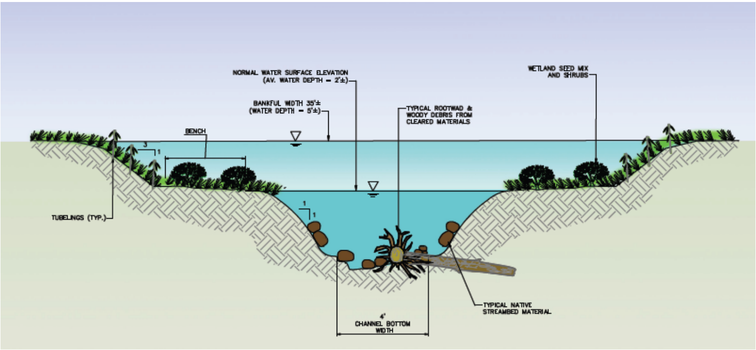
Selection of effective flood control BMPs requires consideration of the particular characteristics of a watershed. Several types of flood control BMPs were evaluated given the existing drainage system, the capacity for infiltration in the watershed, and the watershed infrastructure.

Which BMPs will be effective?

For the Maidford River and Paradise Brook recommended flood control BMPs focus restoration of the floodplains to improve the ability of the Maidford River or Paradise Brook to convey floodwaters. The existing streams in this watershed have limited capacity to store water outside of their channels. When floodwaters exceed the carry capacity of the stream channel, the waters over top the banks flooding adjacent lands and roads.

Floodplain restoration projects are recommended as the most effective type of flood control BMP for this watershed. This type of restoration project consists of creating a floodplain "bench" adjacent to the stream channel. This bench creates additional volume to temporarily store water below the downstream road crossing. Bioengineering techniques are used to stabilize the streambank thereby improving habitat value and providing some natural filtration and vegetative uptake of runoff that drains across these areas. As a result, floodplain restoration can improve water quality from agricultural lands that drain directly to a restoration site.

Restoring floodplains on private property are projects that the USDA Natural Resources Conservation Service (NRCS) can fund. NRCS would purchase an easement from the property owner in order to prevent future development. NRCS would then provide funding for the design, permitting and construction of the floodplain restoration. Floodplain restoration projects funded by NRCS in Rhode Island over the last 5 years include the Pocasset River (Blackamore Pond) in Cranston and Janet Drive in West Warwick.



Example Floodplain Restoration Cross-Section, West Warwick, RI

Completed Pocasset River Floodplain Restoration Project, Cranston, RI

Which BMPs are not likely to be effective?

Selection of flood control BMPs is not a "one size fits all" process. Common BMPs which can be very effective in come watersheds, are not necessarily the best choice for flood control in the Maidford River and Paradise Brook watersheds. BMPs considered, but not recommended include:

Green infrastructure (GI): Green infrastructure is often recommended since GI techniques can often provide multiple benefits including water quality and flood control. GI consists of stormwater BMPs that are constructed to recharge the collected stormwater runoff to groundwater. Given the soils in the watershed with low infiltration capacity and the need to underdrain the new stormwater BMPs proposed, this is not a feasible alternative.

Increasing Capacity of Existing Culverts: This approach is also not recommended for this watershed. Simply increasing the capacity of existing culverts could just transition flooding problems downstream, overwhelming the next culvert or causing more flooding on adjacent properties. Also, existing infrastructure works against this option, since a major challenge is the fact that most of the culvert crossings have very low roads. Significantly increasing the capacity of the culverts would require raising the roads, which in most cases will not be feasible. Simply widening the culverts will not solve the flooding problems because the existing stream widths would still force the floodwaters above the existing channels.

Berkeley Avenue Maidford River Crossing

Paradise Avenue Maidford River Crossing

Channelization: Improving the carrying capacity of the stream by straightening or channelizing the stream is not a feasible alternative and would not result in substantial improvements in flooding. Since this approach would require modifying a natural stream system along with its existing natural habitat resources, it would be difficult if not impossible to permit through state (e.g. RIDEM) and federal (Army Corps of Engineers) regulatory agencies. These improvements would also not be anticipated to result in dramatic improvements to flooding, since these existing natural features have little impact on the large volumes of water conveyed during flood events.

Agricultural Best Management Practices

Agricultural operations in the watershed can be a source of nutrients and bacteria. However, these operations are privately-owned. While most farmers are sensitive to the environment, implementing improvements on farms requires some capital investment that often times is beyond the means of the individual farmer.

As part of the National Water Quality Initiative (NWQI), the USDA Natural Resources Conservation Service (NRCS) is offering financial and technical assistance to farmers and forest landowners interested in improving water quality and aquatic habitats in priority watersheds with impaired streams. In Rhode Island, these priority watersheds include the Sakonnet River, Tomaquag Brook-Pawcatuck River, and Upper East Passage watersheds. The Maidford River and Paradise Brook are part of the Sakonnet River watershed.

The NWQI directs technical assistance to farmers as part of the Environmental Quality Incentives Program (EQIP). This is a voluntary conservation program to assist agricultural producers with implementing structural and management conservation practices to their farms that promote agricultural production and environmental quality as compatible goals.

Through EQIP, agricultural producers receive financial and technical assistance to implement practices on working agricultural land. Table 5-1 lists examples of conservation practices for which NRCS provides assistance.

Table 5-1. Potential Agricultural BMPs

Practice	Benefits
Residue and Tillage Management 	• Prevents soil erosion and protects water quality • Improves soil health and adds organic matter to the soil • Fewer trips and less tillage reduces soil compaction and improves air quality • Time, energy and labor savings are realized with fewer tillage trips *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/sc/home/?cid=nrcs144p2_027126*
Cover Crop 	• Prevents erosion • Improves soil's physical and biological properties • Supplies nutrients • Suppresses weeds • Improves the availability of soil water • Breaks pest cycles *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1077238*
Riparian Forest Buffer 	• Creates shade to lower water temperature • Provides leaves, twigs, stems, and logs for aquatic organisms, fish cover, etc. • Provides habitat for multiple wildlife species • Protects soil from scour erosion • Reduces downstream flooding • Protects water quality by filtering shallow groundwater flow *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/newsroom/factsheets/?cid=nrcs142p2_044362*

Practice	Benefits
Filter Strip 	• Prevents contaminants from entering water bodies to protect water quality • Reduces soil erosion • Provides cover for small birds and animals • Moves agricultural operations farther from a stream *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/technical/?cid=nrcs142p2_044352*
Stream Habitat Improvement and Protection 	• Creates in-stream and riparian habitat • Improve water quality • Provides streambank stability • Provides filtration of contaminants from surface runoff *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/programs/financial/?cid=nrcs144p2_027148*
Streambank and Shoreline Protection 	• Prevents loss of land adjacent to the water • Reduces water and erosion damage • Reduces the offsite effects of sediment resulting from bank erosion • Improves fish and wildlife habitat, aesthetics, and/or recreation *NEH Part 650, Chapter 16, Streambank and Shoreline Protection*

Practice	Benefits
Nutrient Management 	• Applying the correct amount and form of plant nutrients for optimum crop yield and minimum impact on water quality • Protects water quality by preventing over-application • Reduces need for additional applications, reducing input costs and energy *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/technical/?cid=nrcs142p2_044359*
Tree/Shrub Establishment 	• Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration • Improves landscape aesthetics • Improves air quality • Enhances wildlife habitat • Sequesters carbon • Provides long-term erosion control and improvement of water quality • Provides products such as timber, pulpwood, and energy biomass *https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/water/?cid=nrcs144p2_027187*
Water and Sediment Control Basin 	• Basins improve water quality by trapping sediment on uplands and preventing it from reaching water bodies • Structures reduce gully erosion by controlling water flow within a drainage area • Grass cover may provide habitat for wildlife *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nj/technical/cp/?cid=nrcs141p2_018698*

Practice	Benefits
Constructed Wetland 	• For treatment of wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities, or • For improving the quality of storm water runoff or other water flows lacking specific water quality discharge criteria. *https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs144p2_027203*

EQIP is a voluntary program where a farmer must request NRCS's services. When services under EQIP are requested, a NRCS planner will visit the farm and work with the owner to identify potential resource concerns (i.e., soil erosion, soil health and water quality). NRCS then develops a plan that identifies recommended practices to address resource concerns. The farmer may then choose to seek technical and financial support from NRCS to design and implement those practices.

Participants for this program include producers and landowners of agricultural land and non-industrial private forestland who enter into conservation program contracts or easement agreements with NRCS under a partnership agreement.

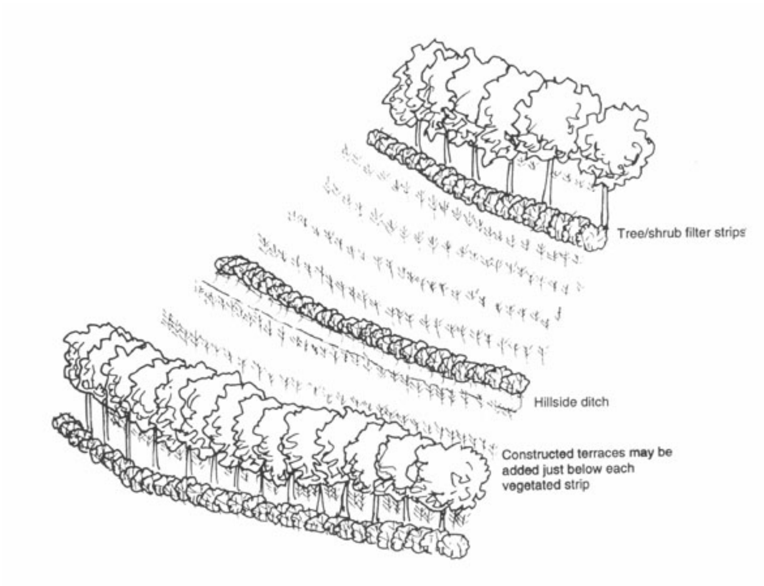
Currently, sources of financial assistance available to farmers in Rhode Island to address water quality issues from their operations are limited. It is therefore recommended that the Town and other conservation partners work with NRCS to educate farmers about the EQIP program and encourage their participation. Currently, NRCS provides some public education about this program, but many farmers are still not aware of this technical and financial resource.

While all farmers in the watershed should be encouraged to take advantage of the EQIP program to improve their operations and the water quality discharged from their farms, the following priority are recommended to improve water quality in this watershed.

- Paradise River subwatershed should be prioritized given the elevated phosphorous concentrations and the significant amount of agricultural land uses in that subwatershed. The following conservation practices should be considered for this subwatershed.
  - Residue and Tillage Management
  - Cover Crops
  - Nutrient Management
  - Tree/Shrub Establishment
  - Water and Sediment Control Basins
  - Constructed Wetland

- Farms where agricultural operations such as fields and pastures that are in proximity to the stream should also be prioritized. Focusing agricultural BMPs to improve buffer areas around streams will improve the attenuation of stormwater volume and quality from the farm before it enters the stream. The following conservation practices should be considered for these farms.
  - Riparian Forest Buffers
  - Filter Strips
  - Stream Habitat Improvement and Protection
  - Streambank and Shoreline Protection

These priority areas for agricultural BMPs are shown in Figure 5-1.



Sketch of a typical filter strip planting (Source: http://www.nrcs.usda.gov)

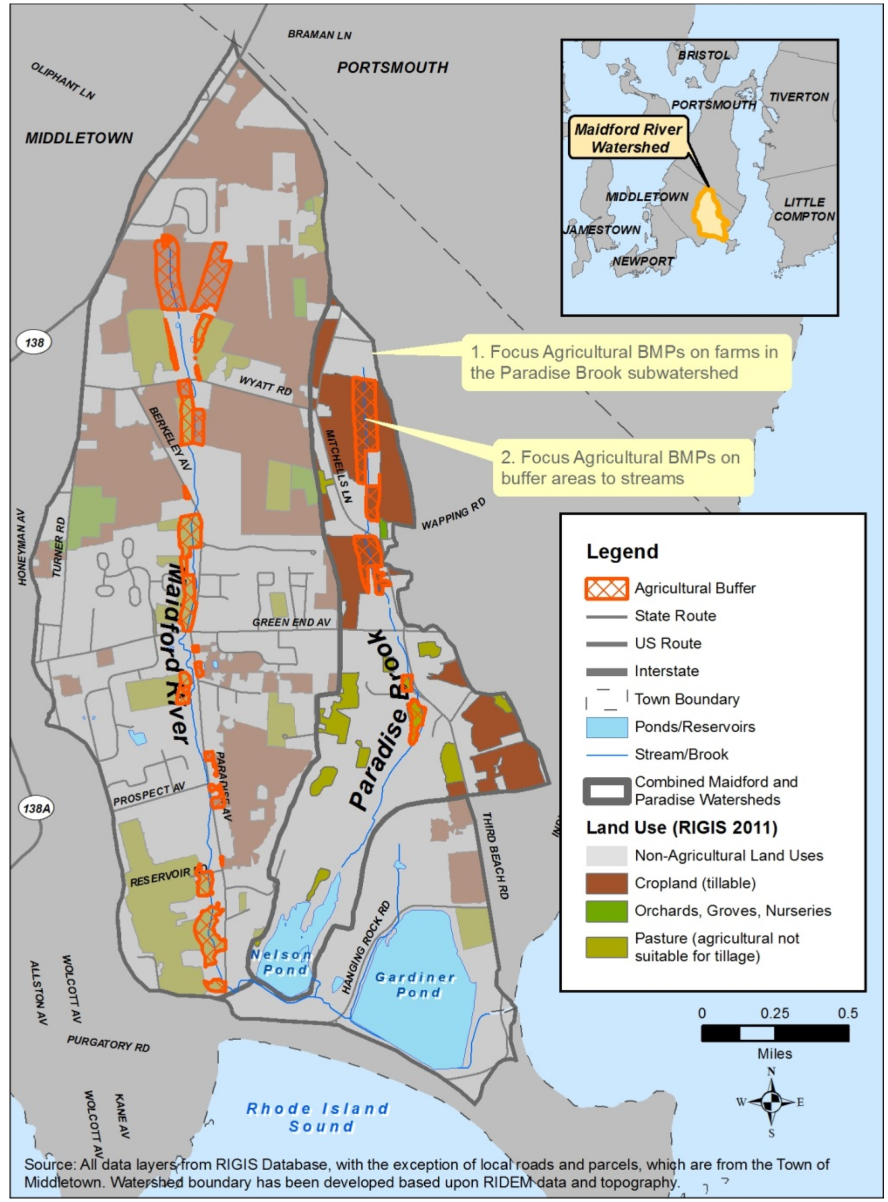


Figure 5-1. Potential Locations for Agricultural BMPs

Other Best Management Practices

There are several other structural and non-structural BMPs that should be considered for this watershed.

- **Repair Stream Bank Erosion**: The streambank just upstream of Berkeley Avenue is eroding. This erosion adds to the sediment load to the stream. Stream bank erosion should also be assessed on private property, especially where flood plain restoration projects are being proposed.

- **Homeowner Lawn Care Education:** Education for local home owners to use soil testing and lawn care management practices to avoid over application of fertilizers, encourage the planting of buffers near streams, and properly dispose of lawn clippings.

- **OWTS Maintenance:** Proper care of onsite wastewater treatment systems, including routine inspection and pump out, is important to keep OWTS properly functioning.

- **Enforce Pet Waste Program:** Better enforce Middletown's existing pet waste program, providing waste bag dispensers where dog walking is allowed and better enforce the no dog walking policy in restricted areas, especially near drinking water bodies such as the frequented path on the top of the embankment at Gardiner Pond.

- **Hobby Farm Fertilizer Use and Manure Management Education:** "Hobby Farms" are often large enough to generate moderate volumes of animal manure or utilize fertilizers, but are not considered traditional agricultural operations and may not be eligible for the types of programs open to larger or commercial agricultural operations. Local-level outreach to hobby farms may be beneficial.

Summary

The purpose of this summary is to compare potential BMPs that can be implemented by the Town to address water quality and flooding issues in this watershed. Figure 5-1 identifies the locations of these BMPs. Table 5-2 summarizes their highlights and describes their expected benefits. These BMPs were selected using the design approaches described earlier and selecting locations for those controls within the watershed that either take advantage of existing infrastructure or are located close to potential sources of pollutant loadings or where they would best influence flooding. Agricultural BMPs have not been included in this summary as they are located on private property and would not be constructed or implemented by the Town.

The specific BMPs identified for this watershed are categorized as follows:

- Group A – Retrofit Existing Detention Basins
- Group B – Retrofit Existing Roadside Swales
- Group C – New Stormwater BMP
- Group D – Flooding BMPs

Table 5-3 provides a matrix that scores each of these potential BMPs based on four criteria: (1) construction costs, (2) maintenance needs, (3) pollutant load reduction, and (4) flood reduction. The factors are weighted, with the greatest weight (a weight value of 3) given to pollutant load reduction and construction cost. The highest scores are assigned to those BMPs that best meet the four criteria. As a result, the highest priority BMPs for the watershed are those with the highest scores. Note that scores in Table 5-3 are assigned based on the type of the BMP implemented and are not based on the overall size of the potential BMP, so the scoring is effectively based on unit capability (e.g. treatment provided by each square foot) basis of the proposed BMP type. This analysis will be refined during the conceptual design phase after we evaluate prioritized BMPs based on impervious area treated and flooding and water quality models for this watershed.

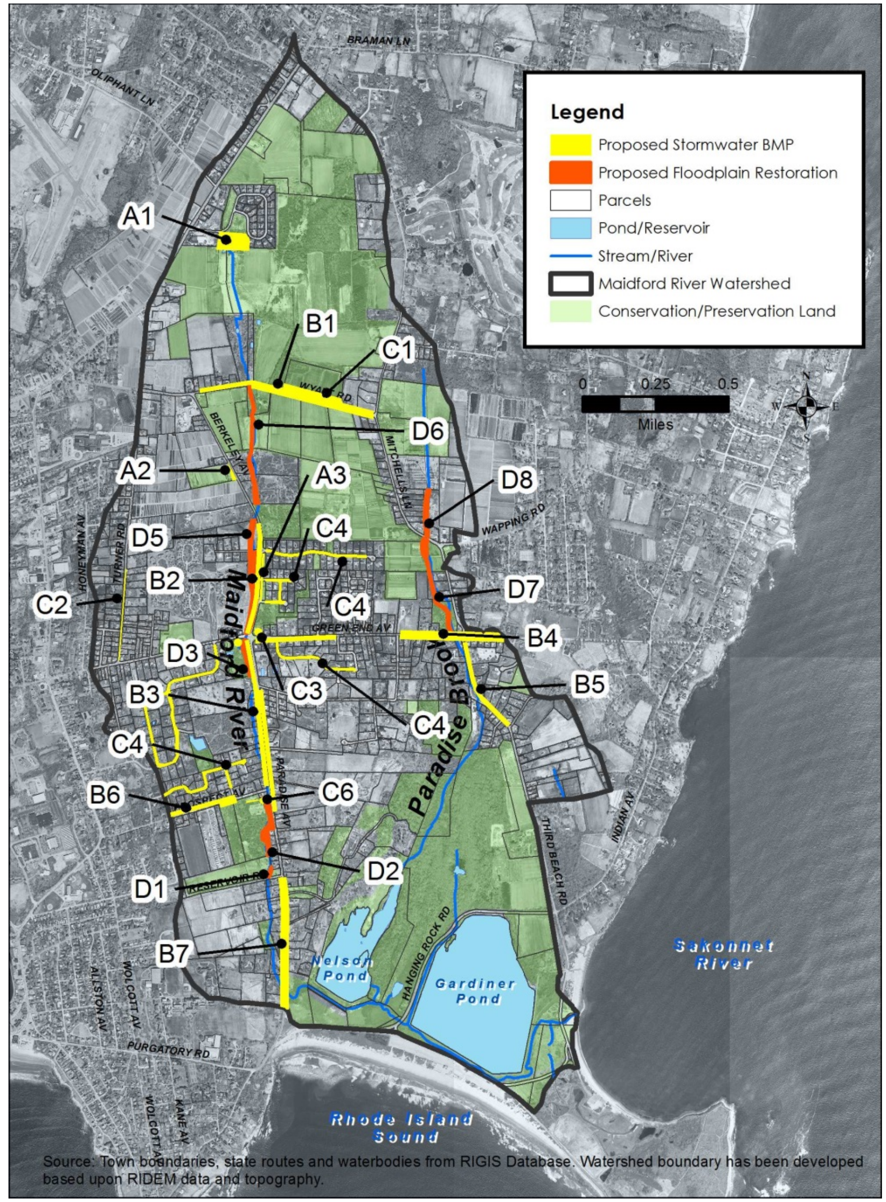


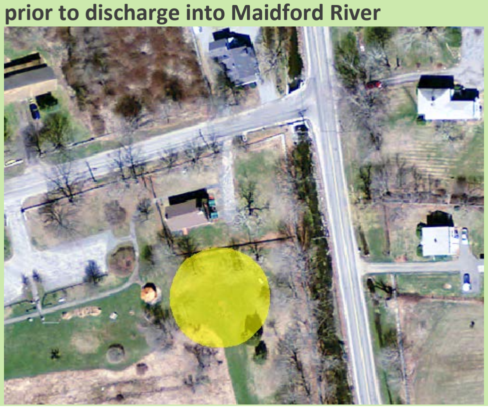
Figure 5-1. Potential BMP Locations

Table 5-2. Potential Stormwater and Flooding BMPs

BMP Name and Description	Highlights	Expected Benefits
Group A - Retrofit Existing Detention Basins		
A1: Bioretention for runoff from East Meadows neighborhood 	• Construct bioretention system in existing field/open space upstream of the existing detention pond where runoff could be diverted to bioretention system before draining into detention basin • Bioretention system would be underdrained because of poor soils • Alternative is to consider a Wet Vegetated Treatment System	• Phosphorous, nitrogen, and bacteria load reduction • Some attenuation of peak flows by providing additional detention in bioretention cells • Maximizes use of existing infrastructure
A2: Retrofit Hoogendoorn Nurseries Detention Basins along Berkeley Avenue 	• Retrofit existing detention basins that serve a large portion of the nursery grounds • The detention basins had evidence of routine overtopping into the Berkeley Avenue System and likely short circuits, providing little existing treatment • Retrofit concept is to connect the 2 existing basins into one large system with a baffle down the middle to lengthen the flow path and maximize sediment removal • May qualify for NRCS EQIP grant funding	• Reduction of peak flows by making the twin detention basins more efficient • More efficient sediment removal by implementing improvements to minimize short circuiting • Maximizes use of existing infrastructure

BMP Name and Description	Highlights	Expected Benefits
A3: Retrofit existing grass channel along Berkeley Avenue near Wyndham Hill Road 	• Retrofit concept is to convert the existing grass channel to a Wet Vegetated Treatment System • Multiple cells in series will maximize treatment in a linear project area • The system will require a liner to prevent groundwater infiltration into the system and maximize capacity to manage stormwater • This retrofit will not reduce the system's existing storage capacity as the new wet vegetated treatment system will be constructed below the existing detention basin.	• Phosphorous, nitrogen, and bacteria load reduction • No loss of existing detention capacity • Improved habitat value • Maximizes use of existing infrastructure
Group B - Retrofit Existing Roadside Swales		
B1: Wyatt Road **B2: Paradise Avenue (north of Green End Avenue)** **B3: Paradise Avenue (south of Green End Avenue)** **B4: Green End Avenue** **B5: Third Beach Road** **B6: Prospect Avenue** **B7: Paradise Avenue near Nelson Pond**  **Example - Wyatt Road Swale**	• Retrofit existing roadside swales to include check dams, emergent plants, and an underdrain system • Bioretention system would be underdrained because of poor soils • Cost is lower compared to new structural BMPs • BMPs can be implemented within the roadway easement • Additional maintenance required since road runoff has high sediment loads	• Phosphorous, nitrogen and bacteria load reduction • Some limited reduction in peak flow for smaller storms that can be retained by check dam system in retrofitted swales • Maximizes use of existing infrastructure

BMP Name and Description	Highlights	Expected Benefits
Group C – New Stormwater BMP		
C1: Bioretention at Middletown Youth Soccer Fields and Parking Lots 	• Construct bioretention areas in between the parking area and the soccer fields upgradient of existing catch basins • Overflow will be directed to existing storm drainage system • Good demonstration value at public soccer fields • Maintenance can be conducted as a part of routine field maintenance	• Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction by providing additional storage in bioretention areas • Public demonstration value
C2: Remove pavement in shoulder on Turner Road and replace with linear bioretention 	• The shoulder of Turner Road between Green End Avenue and Hoogendoorn Nurseries is paved and contains residential mail boxes. • Proposed concept involves pavement removal. This area could either be restored to grass or replaced with linear bioretention, which would treat roadway and driveway runoff. • The homeowners would benefit with an aesthetic improvement to their curb appeal.	• Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction
C3: Bioretention on public land adjacent to the Maidford River along Green End Avenue 	• Divert stormwater collected from upstream areas into bioretention areas (one on the southwest corner and one on the northeast corner) • Opportunity to treat stormwater collected in privately-owned developed areas within public lands prior to discharge to the Maidford River. This includes a condominium complex to the west and a subdivision to the east.	• Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction

BMP Name and Description	Highlights	Expected Benefits
C4: Tree boxes between sidewalk and curb on Windham Avenue, Beagle Drive and Tally Ho Court, Trout Drive, Lighthouse View Drive, River Runs Road/Maidford River Road  **Windham Avenue, Tally Ho court, Beagle Drive Tree Box Locations**	• Proposed for neighborhoods that have a sidewalk on at least on side of the road • Avoids projects on residential "front lawns" by using the tree belt will be more acceptable to homeowners • Provides public shade trees that have additional benefits. • Low cost to install and maintain • Provides similar benefits to bioretention areas • Overflow can connect directly to existing drainage system	• Increase public awareness • Acceptable retrofit within single-family neighborhoods • Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction
C5: Linear bioretention for parking lot runoff at Paradise Valley Park 	• Primarily for demonstration value • Parking lot is close to the Maidford River • Small parking lot so low cost bioretention area	• Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction • Public demonstration value
C6: Divert Prospect Avenue storm drainage into bioretention at corner of Paradise Valley Park prior to discharge into Maidford River 	• Divert stormwater collected from upstream areas into bioretention area • Opportunity to treat stormwater collected in privately-owned areas within public lands prior to discharge to the Maidford River	• Phosphorous, nitrogen and bacteria load reduction • Peak flow reduction

BMP Name and Description	Highlights	Expected Benefits
Group D – Flooding BMPs		
<u>Maidford River</u> **D1: North of Reservoir Road** **D2: Paradise Valley Park** **D3: South of Green End Avenue** **D4: North of Green End Avenue** **D5: South of Berkeley Avenue** **D6: Between Berkeley Avenue and Wyatt Road** **<u>Paradise Brook</u>** **D7: Green End Avenue to Mitchells Lane** **D8: North of Mitchells Lane**  **Example: Green End Avenue to North of Mitchells Lane**	• Restore natural floodplain areas to provide additional floodplain storage • Locations are focused on areas upstream of known flooding issues where additional floodplain storage could improve flooding • Locations are either within existing protected or conservation land or other private land where an easement could be acquired for floodplain restoration	• Peak flow reduction • Habitat restoration • Improved vegetative buffer can reduce pollutant loading from adjacent lands that drain across the buffer

Table 5-3. Prioritization Matrix

BMP Name	Construction Costs	Maintenance Needs	Pollutant Load Reduction	Flood Reduction	Total Score
Weight	*3*	*1*	*3*	*2*	
Score	*1-High* *2-Moderate* *3-Low*	*1-High* *2-Moderate* *3-Low*	*1-Low* *2-Moderate* *3-High*	*1-Low* *2-Moderate* *3-High*	*>20 - Excellent* *16 to 20 - Good* *<16 - Fair*
Group A - Retrofit Existing Detention Basins					
A1: Bioretention for runoff from East Meadows neighborhood	2	2	3	2	21
A2: Retrofit Hoogendoorn Nurseries Detention Basins along Berkeley Avenue	3	3	1	1	17
A3: Retrofit existing grass channel along Berkeley Avenue near Wyndham Hill Road	1	2	3	1	16
Group B - Retrofit Existing Roadside Swales					
B1: Wyatt Road	3	1	1	1	15
B2: Paradise Avenue (north of Green End Avenue)	3	1	1	1	15
B3: Paradise Avenue (south of Green End Avenue)	3	1	1	1	15
B4: Green End Avenue	3	1	1	1	15
B5: Third Beach Road	3	1	1	1	15
B6: Prospect Avenue	3	1	1	1	15
B7: Paradise Avenue near Nelson Pond	3	1	1	1	15
Group C – New Stormwater BMP					
C1: Bioretention at Middletown Youth Soccer Fields and Parking Lots	2	2	2	1	16
C2: Remove pavement in shoulder on Turner Road and replace with linear bioretention	2	1	3	2	20
C3: Bioretention on public land adjacent to the Maidford River on Green End Avenue	1	2	3	2	18
C4: Tree boxes between sidewalk and curb on Windham Avenue, Beagle and Tally Ho, Trout Drive, Lighthouse View Drive, River Runs Road/Maidford River Road	1	2	3	1	16
C5: Linear bioretention for parking lot runoff at Paradise Valley Park	2	2	3	1	19
C6: Divert Prospect Avenue storm drainage into bioretention at corner of Paradise Valley Park prior to discharge into Maidford River	1	2	3	2	18

BMP Name	Construction Costs	Maintenance Needs	Pollutant Load Reduction	Flood Reduction	Total Score
Weight	*3*	*1*	*3*	*2*	
Score	*1-High* *2-Moderate* *3-Low*	*1-High* *2-Moderate* *3-Low*	*1-Low* *2-Moderate* *3-High*	*1-Low* *2-Moderate* *3-High*	*>20 - Excellent* *16 to 20 - Good* *<16 - Fair*
Group D – Flooding BMPs					
Maidford River					
D1: North of Reservoir Road	3	1	1	3	19
D2: Paradise Valley Park	3	1	1	3	19
D3: South of Green End Avenue	3	1	1	3	19
D4: North of Green End Avenue	3	1	1	3	19
D5: South of Berkeley Avenue	3	1	1	3	19
D6: Between Berkeley Avenue and Wyatt Road	3	1	1	3	19
Paradise Brook	3	1			
D7: Green End Avenue to Mitchells Lane	3	1	1	3	19
D8: North of Mitchells Lane	3	1	1	3	19

References

Federal Emergency Management Agency (FEMA) (2013). Flood Insurance Study Number 44005CV000B, Newport County, Rhode Island (All Jurisdictions). Revised September 4, 2013.

Rhode Island Department of Environmental Management (2011). *Rhode Island Statewide Total Maximum Daily Load (TMDL) for Bacteria Impaired Waters*. Available at: http://www.dem.ri.gov/programs/benviron/water/quality/swbpdf/coretmdl.pdf

Rhode Island Department of Environmental Management (2015). *State of Rhode Island 2014 303(d) LIST, List of Impaired Waters, DRAFT March 2015*. Available at: http://www.dem.ri.gov/pubs/303d/303d14d.pdf

Rhode Island Department of Environmental Management (2015). *Maidford River/Paradise Brook National Water Quality Initiative Sampling Study. Satellite Images and Ground Pictures of Study Area and Sampling Stations*.

Rhode Island Sea Grant (2014). *Precipitation and Storms in Rhode Island.* Available at: http://seagrant.gso.uri.edu/wp-content/uploads/2014/05/climate_storm_trends.pdf

Schueler, T. (1987). Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C.

Appendix A

Pollutant Loading Model Results

Sources and Model Assumptions

Parameter	Sources	Model Assumptions & Notes
Stream stability	Photos & notes from field visit, April 22, 2015	WTM calculates TSS load (and subsequently N &P loads) from bank stability. Photos of sites were used to determine bank stability and judge the likelihood of the site adding TSS. Moderate stability chosen for both subwatersheds ("Moderate: 50% of watershed sediment load. Channels show signs of degradation, with some areas of severe channel erosion.")
Land use	RIGIS/RIDEM	RIGIS land uses are grouped to facilitate modelling. Areas quantified through GIS processing
	Photos & notes from field visit, April 22, 2015	Choices validated against photos, aerials, & known information about watershed (see land use table for grouping).
EMCS	Literature values (see EMC table)	EMCs chosen from range of typical literature values
	Aerial photos. Photos & notes from field visit April 22, 2015	Choices validated against photos, aerials, & known information about watershed
Impervious %	Calculated from RIDEM Land Use and Impervious layers	Summed model land use area using RIDEM land use layer. Calculated % impervious per land use using land use summation and impervious raster layer.
Catch basin cleanouts	Middletown SWMPP, 2009	States "as needed". Assumed annual cleaning. Assumed 80% runoff captured from roads with catch basins.
Livestock	Field notes (April 22, 2015), aerial photos, RIDEM agricultural study, 2014.	Agricultural study provided sheep & waterfowl (duck) counts. Field reconnaissance provided llama count and horse location. Horses in equestrian center in Paradise subwatershed estimated by size of building at 80% capacity assuming 12 x 12 stalls.
	Barker, J.C., S. C. Hodges and F. R. Walls. 2002 North Carolina Chemicals manual	Provided nitrogen information for horses, sheep, ducks. Assumed N/P ratio and FC amount for horses & cows similar. Assumed N/P ratio and FC amount for layers/ducks similar. Assumed %44 P2O5 (ratio from WTM documentation, 2013) value for total phosphorus for sheep. Assumed FC for sheep 50% cow. Assumed all livestock exposed to runoff.
	Worksheet adapted from: "Annual Manure Production and Bedding Used Calculation Worksheet," developed by the Rockingham County Conservation District with funding provided by the New Hampshire Department of Agriculture, Markets & Food Agricultural Nutrient . http%3A%2F%2Fnerc.org%2Fdocuments%2Fmanure_management%2Fmanure_generation_calculator.xls	Based on worksheet, assumed 1 llama = 4 sheep in manure production.

Watershed delineation	TMDL watershed delineation.	
Road sanding	Middletown SWMPP, 2009. RIDOT.	States 2000 tons/yr. for Town of Maidford. Calculated for town roads in subwatershed. No sand on state roads.
Street sweeping	Middletown SWMPP, 2009.	States at least annually with mechanical sweeper, some streets more frequently. States no parking restrictions, operator training. Assumed all streets swept annually with mechanical sweeper, no parking restrictions, trained operator.
Septic systems near water	RIDEM sewer service areas	Unsewered residences within 100 ft buffer of streams and lakes
Hydrologic Soils	SURRGO data via RIGIS/RIDEM GIS layer	For purposes of model, D soils include D, B/D, D/B and Variable soil groups.
Length of stream	RIDEM stream layer	Calculated from RIDEM layer
% Roads with/ without storm drains	RIDEM roads layer and outfall locations	
Acres of roads	RIDEM Roads layer. Federal highway information (http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter3/3_lanewidth.cfm). Notes from field visit, April 22, 2015.	Assumed 12 ft lanes. All roads 2 lane except East Main, which is 4.
Population, dwelling units, people per house	RIDEM Census layer	
Total sewered/ unsewered popluation	RIDEM Census layer and sewer service layer	
Nutrient Concentration in Stream channels	Haith et al, 1992. via WTM documentation, 2013.	
Septic Systems	Conversation with Dean Audet. SURRGO data via RIGIS/RIDEM GIS layer.	Assumed 5% failure and highly maintained based on local knowledge. Assumed 3-5 ft groundwater separation. Assumed mixed soils.

All other model inputs provided by WTM, 2013. These include

-Delivery ratios

-Discount factors

-Efficiencies of BMPs

-Cow and layer nutrient and FC input, exposure to runoff.

Model Land Use Grouping

RIDEM Category	Model Category	Notes
Beaches	Beach/ Parking	Paved beach campground lot & parking lot, supported by aerials
Brushland (shrub and brush areas, reforestation)	Forest	
Cemeteries	Open/ Turf	
Commercial (sale of products and services)	Commercial	
Cropland (tillable)	Agriculture	
Deciduous Forest (>80% hardwood)	Forest	
Developed Recreation (all recreation)	Open/ Turf	
High Density Residential (<1/8 acre lots)	High Density Residential	
Idle Agriculture (abandoned fields and orchards)	Agriculture	
Institutional (schools, hospitals, churches, etc.)	Institutional	
Low Density Residential (>2 acre lots)	Low Density Residential	
Medium Density Residential (1 to 1/4 acre lots)	Medium Density Residential	
Medium High Density Residential (1/4 to 1/8 acre lots)	Medium Density Residential	
Medium Low Density Residential (1 to 2 acre lots)	Low Density Residential	
Mines, Quarries and Gravel Pits	Industrial	
Mixed Forest	Forest	
Orchards, Groves, Nurseries	Agriculture	
Pasture (agricultural not suitable for tillage)	Agriculture	
Sandy Areas (not beaches)	Forest	Brush, supported by aerials.
Transitional Areas (urban open)	Open/Turf	
Vacant Land	Open/Turf	
Water	Water	
Water and Sewage Treatment	Industrial	
Wetland	Wetland	

Runoff Event Mean Concentrations

Source	NH Stormwater Manual			PLOAD /CH2M Hill	NY State Stormwater Design Manual				WTM Defaults				Selected			
Pollutant	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC
Units	mg/L	mg/L	mg/L	#/ 100 ml	mg/L	mg/L	mg/L	#/ 100 ml	as noted	as noted	as noted	as noted	mg/L	mg/L	mg/L	MPN/ 100 ml
Low Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	49 mg/L	20000 MPN/100 ml	4.5	0.7	50	8700
Medium Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	50 mg/L	20000 MPN/100 ml	4.8	0.6	100	8700
High Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	51 mg/L	20000 MPN/100 ml	5	0.5	120	8700
Agriculture	5.98	0.37	145	-	-	-	-	-	-	-	-	-	5	0.4	145	800
Commercial	2.97	0.33	77	1400	2.1 -27	0.14 - 0.15	1.9 - 9	11 - 18	2.1 mg/L	0.31 mg/L	43 mg/L	20000 MPN/100 ml	2	0.33	40	1400
Forest	1.78	0.11	51	500	-	-	-	-	2.5 lbs/ acre	0.2 lbs/ acre	100 lbs/ acre	100 billion/ acre	2	0.15	50	500
Industrial	3.97	0.32	149		0	0	124	-	2.2 mg/L	0.25 mg/L	81 mg/L	20000 MPN/100 ml	3	0.3	150	2300
Institutional	2.97	0.33	77	1400	-	-	-	-	-	-	-	-	2.5	0.33	40	1400
Railroad	-	-	-		-	-	-		-	-	-	-				
Recreation/Open Space	1.74	0.11	51	500	0- 9.1*	0 - 2.1*	37-602*	240 - 940*	-	-	-	-	2	1.2	50	500
Roadway	2.65	0.43	141	1400	1.4 - 22	0- 0.55	51-468	120 - 370	2.3 mg/L	0.25 mg/L	81 mg/L	20000 MPN/100 ml	NA	NA	NA	NA

Beachside Parking / Camping**	2.65	0.43	141	1400	1.4 - 22	0- 0.55	51-468	120 - 370	2.3 mg/L	0.25 mg/L	81 mg/L	20000 MPN/100 ml	2.4	0.5	300	500
Water	1.38	0.08	6	500	-	-	-	-	12.8 lbs/ acre	0.5 lbs/ acre	155 mg/L	-	1	0.08	6	500
Wetland	1.38	0.08	6	500	-	-	-	-	-	-	-	-	1	0.2	22	500

*Approximated from "landscaping" and "lawns" categories in NYS Stormwater Management manual
** Estimated from roadway values (shown in table)

Sources:

McCarthy, Jillian, 2008. New Hampshire Stormwater Manual Volume 1: Stormwater and Antidegradation, December 2008.
http://des.nh.gov/organization/divisions/water/stormwater/documents/wd-08-20a_apxd.pdf

New York State Department of Environmental Conservation, 2001. New York State Stormwater Management Manual. Appendix A: The Simple Method to calculate Urban Stormwater Loads.
http://www.dec.ny.gov/docs/water_pdf/simple.pdf

PLOAD version 3.0 An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects User's Manual
http://water.epa.gov/scitech/datait/models/basins/upload/2002_05_10_BASINS_b3docs_PLOAD_v3.pdf

Existing Modeled Land Use

Subwatershed	Existing Modeled Land Use Composition (acres)												
	High Density Residential	Medium Density Residential	Low Density Residential	Agriculture	Commercial	Forest	Industrial	Open Space	Beach Parking/ Camping	Water	Wetland	Institutional	Total
Maidford	51.2	393.1	49.8	727.4	22.6	297.4	2.9	57.8	2.5	105.1	86.7	24.7	1821.1
Paradise	0.0	68.1	53.1	182.6	0.6	167.1	7.0	3.7	0.0	32.5	8.2	9.2	532.1
Total	51.2	461.2	102.9	910.0	23.2	464.5	9.9	61.5	2.5	13.6	94.9	33.9	2,353.2

Modelled Pollutant Loads

Subwatershed	TN lb	TP lb	TSS lb	FC billion	Runoff Volume acre-ft	TN lb/acre	TP lb/ acre	TSS lb/ acre	FC billion/ acre	Runoff Depth feet
Maidford	19,227	2,580	1,000,020	81,600	1,984	10.6	1.4	549	45	1.09
Paradise	5,024	651	224,170	21,512	343	9.4	1.2	421	40	0.65
Total	24,251	3,231	1,224,190	103,112	2,328	10.3	1.4	520	44	0.99

	N lb	P lb	TSS lb	FC billion	Runoff Volume acre-ft	N %	P %	TSS %	FC %	Runoff Depth %
Land Use	22,156	2,503	515,470	95,666	2,328	90.7%	76.6%	40.7%	92.8%	100.0%
Other Sources	2,276	764	751,460	7,446	0	9.3%	23.4%	59.3%	7.2%	0.0%
Septic Systems - Surface	257	43	1,711	1,614	0	1.1%	1.3%	0.1%	1.6%	0.0%
Channel Erosion	1,544	679	514,578	0	0	6.3%	20.8%	40.6%	0.0%	0.0%
Hobby Farms/Livestock	475	42	0	5,832	0	1.9%	1.3%	0.0%	5.7%	0.0%
Road Sanding	0	0	235,171	0	0	0.0%	0.0%	18.6%	0.0%	0.0%
Total before existing load reductions	24,431	3,267	1,266,930	103,112	2,328					
Existing practices load reductions (negative is a reduction)	*-180*	*-36*	*-42,740*	*0*	*0*					
Total minus existing load reductions	24,251	3,231	1,224,190	103,112	2,328					

Land Use Load Contributions

Land Use	N lb	P lb	TSS lb	FC billion	Runoff Volume acre- ft	N % of contribution to total land use load	P % of contribution to total land use load	TSS % of contribution to total land use load	FC % of contribution to total land use load	Runoff Depth % of contribution to total land use load
Low Density Residential	1,459	227	16,214	12,858	120	6.6%	9.1%	3.1%	13.4%	5.1%
Medium Density Residential	7,829	979	163,104	64,671	601	35.3%	39.1%	31.6%	67.6%	25.8%
High Density Residential	1,014	101	24,329	8,039	75	4.6%	4.0%	4.7%	8.4%	3.2%
Agriculture	9,094	728	263,735	6,632	671	41.0%	29.1%	51.2%	6.9%	28.8%
Commercial	276	46	5,519	880	51	1.2%	1.8%	1.1%	0.9%	2.2%
Forest	178	27	8,923	407	66	0.8%	1.1%	1.7%	0.4%	2.8%
Industrial	65	6	3,230	226	8	0.3%	0.3%	0.6%	0.2%	0.3%
Institutional	412	54	6,586	1,051	547	1.9%	2.2%	1.3%	1.1%	23.5%
Recreational	310	186	7,743	353	57	1.4%	7.4%	1.5%	0.4%	2.5%
Beach/ Parking	32	7	3,958	30	58	0.1%	0.3%	0.8%	0.0%	2.5%
Water	1,287	103	7,723	64	0	5.8%	4.1%	1.5%	0.1%	0.0%
Wetland	200	40	4,408	457	74	0.9%	1.6%	0.9%	0.5%	3.2%
Total	22,156	2,503	515,470	95,666	2,328					

Load Reductions from Existing Practices

Load Reduction from Existing Practices (lbs/year)	N lb	P lb	TSS lb	FC billion	N %	P %	TSS %	FC %
Street Sweeping	15	2	374	0	0.1%	0.1%	0.1%	0.0%
Street Sweeping - Sanding	0	0	7834	0	0.0%	0.0%	1.5%	0.0%
Catch Basin Cleanouts	166	35	34533	0	0.7%	1.4%	6.7%	0.0%
Total Reduction	180	36	42741	0	0.8%	1.5%	8.3%	0.0%

Additional Model Inputs

	Maidford		Paradise	
Road Sanding (lbs/yr)	295,400		63,800	
% With storm drains	57.84%		44.11%	
% Without storm drains	42.16%		55.89%	
	Local	State	Local	State
Acres of watershed Road in residential areas	28.21	1.46	5.48	0.00
Acres of watershed Road in other areas	15.70	1.12	4.02	0.00
Total length of streams (miles)	4.57		1.84	
Dwelling units	1,787		340	
Percentage of dwelling units unsewered	6.23%		72.08%	
Number of dwelling units with onsite spetic within 100ft of water	2		7	
Soils (approximate %)				
A	0.58%		0.00%	
B	0.00%		1.81%	
C	89.54%		82.39%	
D	9.88%		15.81%	
Livestock	8 horses, 60 sheep		15 horses, 2 llamas, 30 ducks	
Bank Stability	Moderate		Moderate	






Town of Middletown, RI