Fecal Coliform TMDL
for the
Pettaquamscutt (Narrow) River Watershed, Rhode Island

Including:

Narrow River Estuary
Gilbert Stuart Stream
Mumford Brook

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December 2001

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EXECUTIVE SUMMARY

This report addresses the phased Total Maximum Daily Load (TMDL) for pathogen impairments of three waterbodies within the Pettaquamscutt River Estuary (Narrow River) watershed. The watershed, shown in Figure 1, includes slightly more than 36 square kilometers within the towns of North Kingstown, Narragansett and South Kingstown in southern Rhode Island. The Narrow River has been listed in Rhode Island's 1998 and draft 2000 303(d) lists of impaired waters for violating state fecal coliform standards. As a result of monitoring conducted in support of this TMDL, Gilbert Stuart Stream was also included in the draft 2000 303(d) list. Mumford Brook, though not currently listed, has also been found through recent monitoring efforts to have a fecal coliform impairment. This report will specify TMDLs and recommend mitigation measures for Narrow River (waterbody identification number RI0010044E-01), Gilbert Stuart Stream (waterbody identification number RI0010044R-01), and Mumford Brook (no waterbody identification number assigned). Crooked Brook, also located within the Narrow River watershed, has been included on the 1998 and draft 2000 303(d) lists of impaired waters as well. Because there is insufficient monitoring data to completely characterize impairments to Crooked Brook, it will be addressed in a separate TMDL scheduled for completion in 2002.

Sections 303(d) of the Clean Water Act and EPA's implementing regulations in 40 CFR § 130 describe the statutory and regulatory requirements for approval of TMDLs. This executive summary contains all of the information required by EPA to fulfill the legal requirements under Section 303(d) and EPA regulations.

Description of Waterbodies, Priority Rankings, Pollutant of Concern and Pollutant Sources

Narrow River

The Narrow River is just over 9.5 kilometers long and runs parallel to the West Passage of Narragansett Bay in the southern portion of its watershed. The "river" is more appropriately described as a composite of a tidal inlet and back bay, an estuary, and two fjord-like ponds. The waterbody and the surrounding watershed are widely utilized as a wildlife habitat and recreational resource.

Three perennial and seven intermittent streams discharge to Narrow River. The principal tributaries to the river are Gilbert Stuart Stream, which discharges to Upper Pond at the northern extremity of the river, and Mumford and Crooked brooks that discharge to Pettaquamscutt Cove, near the southern extremity. The remaining regions of the river receive a majority of baseline freshwater inflow as groundwater seepage from the coastal margin. Land use within the watershed is predominantly residential with approximately 35 percent of the land area developed.

Water quality in the Narrow River has been a concern for more than 40 years, since water quality sampling has consistently revealed elevated bacteria levels. A review of historical analytical data confirmed that, with the possible exception of Lower Pond, the Narrow River has consistently violated fecal coliform standards. The following fecal coliform trends also emerged: the highest concentrations have consistently been found in the southern portion of Pettaquamscutt Cove, concentrations in the middle section of the river between Lacey Bridge and Middlebridge Bridge have consistently exceeded allowable limits, concentrations peaked in

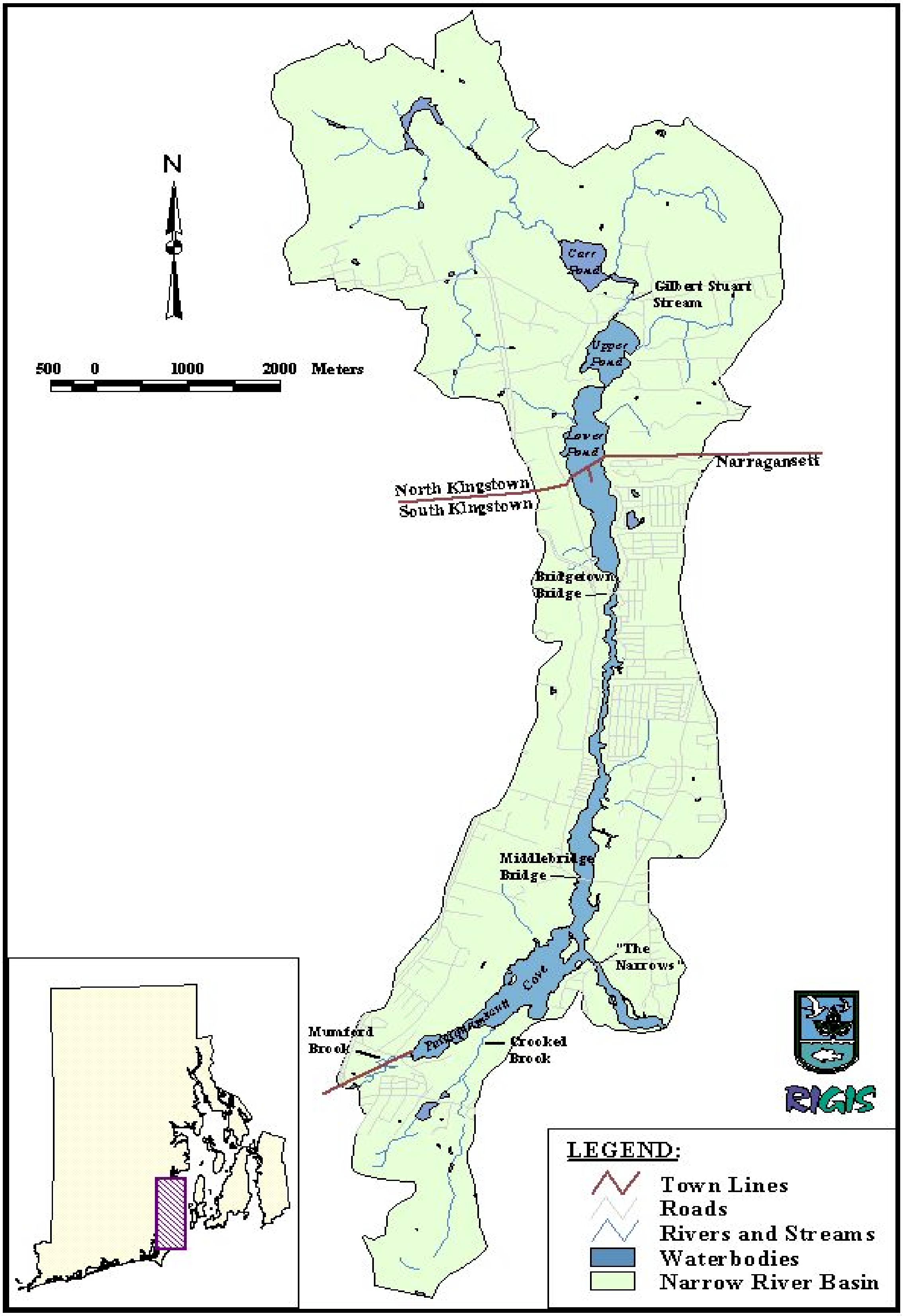


Figure 1: Narrow River Basin

the warmest summer months (usually August or September) and were highest immediately following a significant rainfall event. Narrow River water quality was evaluated by river segment (Figure 2). A summary is presented in Table 1.

Table 1: Narrow River water quality summary.

Segment	Dry weather geometric mean (fc/100mL)	Wet weather geometric mean (fc/100mL)	Segment weighted geometric mean (fc/100mL)	90^{th} percentile (fc/100mL)
1 – Upper Pond*	5*	30*	15.4*	45*
2 – Lower Pond	4	10	6.5	23
3 – Upper River	19	*39*	27.3	70
4 – Lower River	20	44	29.9	88
5 – Pettaquamscutt Cove	26	255	120.8	454
6 – The Narrows	9	36	20.2	70

* - Values was obtained from 1992-99 Watershed Watch data

Gilbert Stuart Stream

Gilbert Stuart Stream is the largest freshwater tributary to Narrow River. It originates at the discharge spillway of Carr Pond at the Gilbert Stuart Museum historical site, travels approximately 0.3 km through hardwood wetlands and terminates at the northern end of Upper Pond. The stream and surrounding watershed are utilized by the public and local organizations for hiking, camping and canoeing. Recent conservation efforts in the stream have also restored an anadromous fish run. The surrounding watershed is predominantly sparsely settled with several camps and low-density residential development. Concentrations in the stream have sporadically been very elevated and consistently violate state bacteria standards.

Mumford Brook

Mumford Brook is the second largest tributary to Narrow River. It originates at the outfall of a predominantly groundwater fed pond near Tower Hill Road in South Kingstown. The brook traverses approximately 0.4 km through a fairly remote hardwood wetland, and then another 0.4 km through a *Phragmites* dominated swamp before discharging to the Southern end of Pettaquamscutt Cove. Land-use in the watershed surrounding the wetland areas is predominantly medium-density residential. A nature trail and bike path that follows the course of an abandoned railbed through the wetland is currently under construction. Concentrations in the brook have consistently been very elevated and are consistently at least two orders of magnitude greater than other sampled tributaries. A summary of the water quality sampling statistics for Gilbert Stuart Stream and Mumford Brook is provided in Table 2.

Table 2: Gilbert Stuart Stream and Mumford Brook water quality summary

Location	Existing dry weather geometric mean (fc/100 ml)	Existing wet weather event mean (fc/100 ml)	Weighted geometric mean (fc/100mL)	90^{th} Percentile (fc/100mL)
Gilbert Stuart Stream (SW-1)	182	573	290	4320
Mumford Brook (SW-25)	4,966	228,519	66,667	74,892

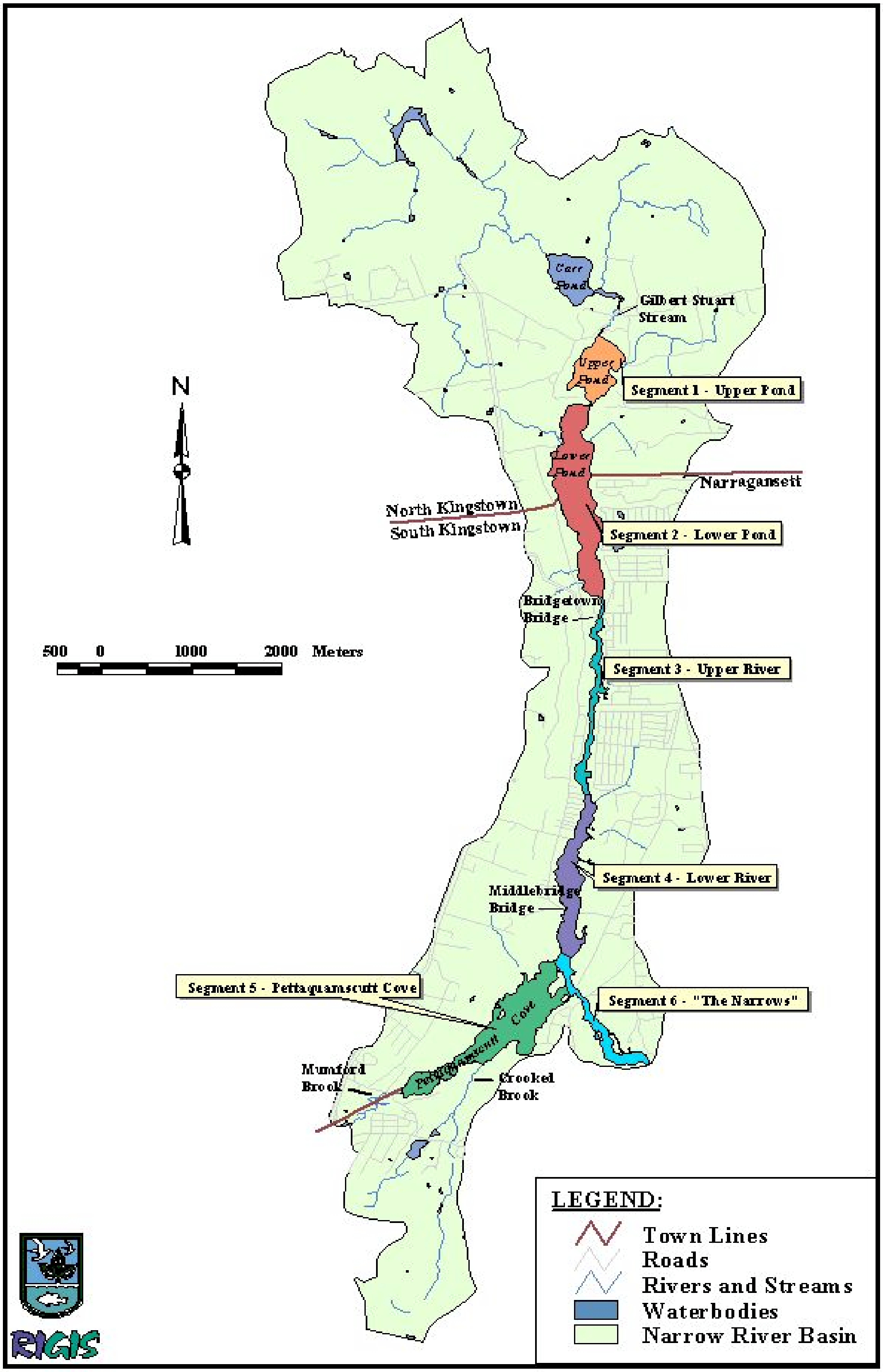


Figure 2 Narrow River Segments

Priority Ranking
The Narrow River is listed as a Group 1 waterbody (highest priority) on the State of Rhode Island's 1998 303(d) list of water quality impaired waterbodies (RIDEM, 1998). Gilbert Stuart Stream is listed on the State of Rhode Island's 2000 303(d) list also as a Group 1 waterbody. Mumford Brook is not currently on the 303(d) list, however, it has been found to be impaired for bacteria based on recent sampling.

Pollutant of Concern
The pollutant of concern is fecal coliform, a parameter used by Rhode Island as an indicator of pathogen contamination.

Pollutant Sources to Narrow River
Narrow River's three largest tributaries, Mumford Brook, Gilbert Stuart Stream and Crooked Brook act as the principal pathways by which nonpoint loadings enter the Narrow River during periods of dry and wet weather. Gilbert Stuart Stream is the primary fecal coliform source to Upper Pond while Mumford Brook and Crooked Brook are the principal sources to southern Pettaquamscutt Cove. Birds also contribute significant fecal coliform loadings to the river. They are present throughout the Narrow River watershed, however, the largest waterfowl populations are consistently seen in the heavily developed residential area between Bridgetown Bridge and Middlebridge Bridge, and within the Pettaquamscutt Cove National Wildlife Refuge located in the southern portion of Pettaquamscutt Cove. Predictably, water quality impacts that appear attributable to birds are most evident in these areas. Bird-related fecal coliform loadings to the middle section of the river are estimated through a mass balance approach explained in Chapter 5. Loadings to Pettaquamscutt Cove from wildlife and waterfowl are not estimated because accurate population counts are unavailable, other significant sources are present and tidal action increases the complexity of any calculations.

All dry weather sources continue to contribute during wet weather conditions to a larger or lesser degree. However, wet weather sources of fecal coliform to the Narrow River are dominated by storm water runoff entering the river through tributary channels, storm sewer outfalls, and overland as sheet flow. Storm sewer outfalls discharging to Segments 2, 3 and 4 have a dramatic effect on water quality during runoff events. Fecal matter from domestic animals, wildlife, waterfowl and failing septic systems is deposited on lawns, parking lots, docks, streets and along the shoreline. It accumulates during dry periods and is subsequently washed off and efficiently transported to receiving waters through storm drains during rain events. Estimated loadings from waterfowl and storm sewers are presented in Table 3.

Table 3: Waterfowl and storm sewer loadings

Impacted Segment	Sources	Dry Weather Estimated loading	Wet Weather Estimated loading
2 - Lower Pond	Storm sewers	0	1.05×10^{11} fc/storm *****
3 and 4 – Middle river	Storm sewers	0	3.4×10^{11} fc/storm *****
	Waterfowl	7.3×10^{8} fc/day ± ******	7.3×10^{8} fc/day ± ******

***** - Based on SWMM modeling and sampling accomplished in conjunction with the Tri-Town Study (ASA et al, 1995)
****** - Calculated based on observed receiving water concentrations

Pollutant Sources to Gilbert Stuart Stream
Although wildlife and storm water runoff may contribute significant fecal coliform loadings to the stream, human activity appears to be the dominant source. Since monitoring began in 1992,

fecal coliform concentrations in Gilbert Stuart Stream have consistently been elevated. A failing septic system at the Gilbert Stuart Museum, located at the headwaters of the stream, was replaced around 1997, however concentrations in the stream remained elevated. During the 1999 sampling effort, the primary source of fecal coliform contamination to Gilbert Stuart Stream was localized to the Gilbert Stuart Museum property. A privy in close proximity to Carr Pond was identified as the likely source. With the ready cooperation of the museum curators, John and Deborah Thompson, the use of the privy was eliminated and replaced with a portable toilet. Recent sampling indicates that the water quality in Gilbert Stuart Stream has improved markedly.

Pollutant Sources to Mumford Brook

Fecal coliform concentrations in the brook are consistently the highest of any tributary in the watershed. Although wildlife and storm water runoff may contribute significant fecal coliform loadings to the brook, human activity again appears to be the dominant source. The highest concentrations in Mumford Brook have consistently been measured in close proximity to East Narragansett Avenue in South Kingstown. The consistent nature and extremely high concentrations noted indicate an anthropogenic source. Homes in the immediate vicinity rely on standard on-site disposal systems for wastewater treatment. Soils in the area are comprised of thin mantles of “high risk” well-draining gravel fill and glacial outwash or poorly draining glacial till over bed rock. Based on the monitoring data and the previously described conditions, it appears that one or more septic systems in the area may be discharging inadequately treated effluent to the brook.

Description of Applicable Water Quality Standards and Numeric Water Quality Target

The Narrow River is designated a Class SA water body by the state. The water quality standard for fecal coliform concentrations in Class SA waters are *“not to exceed a geometric mean MPN value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution,”* (RIDEM, 1997) where MPN is the most probable number. The geometric mean standard of 14 fc/100mL minus a 10% margin of safety, or 12.6 fc/100mL, and a 90th percentile value of no greater than 49 fc/100mL are the numeric water quality targets for the Narrow River TMDL.

All of the freshwater tributaries discharging to the Narrow River are designated as Class A waterbodies by the state. The water quality standard for fecal coliform concentrations in Class A waters are *“not to exceed a geometric mean MPN value of 20 (per 100 ml) and not more than 10% of the samples shall exceed an MPN value of 200,”* where MPN is the most probable number (RIDEM, 1997). Additionally, the allowable fecal coliform levels in tributaries must be adequately protective of the receiving water. Pollutant loadings from tributaries must not impact receiving water quality sufficiently to prevent attainment of any designated uses. In the absence of site specific data to guarantee that Narrow River water quality would be maintained if each tributary discharged at the Class A standard, this TMDL requires that each tributary meet the Class SA standard at its point of discharge. A geometric mean of 14 fc/100mL and a 90th percentile value of no greater than 49 must be applied to the most downstream sampling station in each of the tributaries. These values will serve as the numeric water quality targets for the Gilbert Stuart Stream and Mumford Brook TMDLs.

Designated Uses

Class SA waters are *“designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities and fish and wildlife habitat. They shall be* *suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value"* (RIDEM, 1997). The Narrow River is regionally significant as a wildlife habitat and shellfish resource. The area is also widely used for camping, hiking, recreational boating, fishing, and swimming.

Class A freshwaters are *"designated as a source of public drinking water supply, for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value"* (RIDEM, 1997).

Antidegradation Policy
Rhode Island's antidegradation policy requires that, at a minimum, the water quality necessary to support existing uses be maintained. If existing water quality is better than what is necessary to support the protection and propagation of fish, shellfish, wildlife, and recreation in and out of the water, the quality should be maintained and protected unless, through a public process, some lowering of water quality is deemed necessary to allow important economic and social development to occur. In waterbodies identified as having exceptional recreational and ecological significance, water quality should be maintained and protected (RIDEM, 1997). The designated and existing uses for the Narrow River include fishing, shellfishing, swimming, and boating. The goal of the TMDL is to restore all designated uses to the Narrow River that are impacted by elevated levels of fecal coliform.

Natural background
It was not possible to separate natural background from the total nonpoint source load due to a lack of site specific data on fecal coliform contributions from wildlife in the watershed.

TMDL Endpoint – Linking Water Quality and Pollutant Sources
The loading capacity for this TMDL is expressed as a concentration and is set equal to the state geometric mean standard minus a 10% explicit MOS. The loading capacity for the Narrow River is therefore, a geometric mean of 12.6 fc/100mL with a 90^{th} percentile value no greater than 49 fc/100mL. Since Gilbert Stuart Stream and Mumford Brook discharge to a Class-SA waterbody and no site-specific data is available to guarantee that Narrow River water quality would be maintained if each tributary discharges at the Class A standard, both must meet the Class SA standard at their points of discharge. The loading capacity for the Gilbert Stuart Stream and Mumford Brook is therefore, a geometric mean of 14 fc/100mL with a 90^{th} percentile value no greater than 49 fc/100mL.

In the case of bacterial impairments, it has been determined by USEPA, Region 1 that it is appropriate to express a TMDL in terms of concentration for the following reasons:

1) Expressing bacteria TMDLs in terms of concentration provides a direct link between existing water quality, the numeric target, and the water quality standard.
2) Using concentrations in bacteria TMDLs is more relevant and consistent with the water quality standards, which apply for a range of flow and environmental conditions.
3) Bacteria TMDLs expressed in terms of daily loads are typically more confusing and more difficult to interpret, since they are completely dependent on flow conditions, which are often difficult to determine.

4) Follow-up monitoring will compare concentrations, not loads, to water quality standards.

Linking Pollutant Loadings to Numeric Targets

Fecal coliform sources in the watershed and the avenues of pollutant transport to the Narrow River were identified from multiple site surveys during wet and dry weather combined with the review of aerial photos, topographic maps, land use maps, and other GIS resources. The field investigations have identified sources and their magnitudes where possible. Determining loads from sources such as contaminated groundwater, waterfowl or wildlife, was difficult even after considerable effort and expense. No reliable site-specific data pertaining to groundwater loadings or wildlife populations was available.

Water quality in the Narrow River was evaluated by dividing the receiving water into six segments. Each segment was assumed to have relatively homogenous physical properties and an assumed constant volume. The calculated area and volume of each segment were based on RIGIS coverages and values given by Gaines (1975) in his study of the Narrow River. RIDEM has identified and quantified sources to the extent possible from its own investigations and from the results of similar studies. It was assumed that, with the exception of wildlife/waterfowl sources, the primary sources that control the fecal coliform concentration in each segment have been identified. The fecal coliform concentration elevation in each segment was assumed to vary proportionally with loadings.

The reduction goal for each river segment and tributary was determined by comparing current fecal coliform conditions to the applicable water quality target, then calculating the percent reduction required to reach that target. Since the water quality regulations specify both a geometric mean criterion and a 90th percentile criterion, two calculations are made at each location. The three-step process is outlined below.

Comparison of the weighted geometric mean to the geometric mean standard

Current bacterial conditions in the Narrow River, Gilbert Stuart Stream and Mumford Brook were determined as a “weighted geometric mean” value that is the sum of the wet and dry weather geometric means, weighted by their probability of occurrence. This approach is explained further in later sections of this report. This value was then compared to the geometric mean portion of the applicable standard to determine if a violation had occurred.

Comparison of the combined dataset’s 90th percentile value to the percent exceedence standard

The second part of the fecal coliform standard states that, in Class SA waters, “*not more than 10% of the samples shall exceed a value of 49 MPN/100ml*”. To address this second portion of fecal coliform standard, a second calculation was made. The 90th percentile value at each receiving water station and at the most downstream station in each tributary was calculated from the combined set of wet and dry weather sample results using the 90th percentile function in Microsoft Excel. This value was then compared to the applicable target to determine if a violation had occurred.

Calculation of required reductions

The weighted geometric mean and 90th percentile were calculated as described above. These values were then compared to the applicable portion of the standard. Required reductions were specified that ensured each Narrow River segment and tributary met both parts of the standard. It is assumed that fecal coliform loads are directly related to observed fecal coliform concentrations in the receiving water and that required percent reductions in waterbody concentrations will be achieved by an equal percent reduction in source loads. Reductions required of specific sources may be larger than the prescribed overall percent reductions as determined from in-stream concentrations depending on the proportion of the overall load a specific source comprises.

Supporting Documentation for the TMDL Analysis

Recent water quality studies considered significant to this TMDL are presented in Table 4. These references were used to characterize the present water quality conditions or identify water quality trends. References to external documents are cited in the reference section of this document.

Table 4: Supporting documentation.

Study name	Reference
Flushing and Exchange in the Narrow River Estuary	ASA, 1989
Papers on the Geomorphology, Hydrography, and Geochemistry of the Pettaquamscutt River Estuary	Gaines, 1975
RIDEM 1980-1982 Storm water Study	RIDEM, 1982
RIDEM Shellfish Growing Area Water Quality Monitoring Program 1980-1999	DEM/OWR
The Narrow River Special Area Management Plan, December 8,1986	CRMC, 1986
Modeling the Fresh Water Inflow into the Pettaquamscutt River	DeMeneses, 1990
URI Watershed Watch 1992-1999	Watershed Watch
Narrow River Storm water Management Study Problem Assessment and Design Feasibility (Tri-Town Study)	ASA et al, 1995
The Narrow River Special Area Management Plan, April 12, 1999	CRMC, 1999
RIDEM 1999 TMDL Monitoring Study	RIDEM, 1999

Critical Conditions and Seasonal Variations

Critical conditions were determined based on a review of the data compiled by URI's Watershed Watch, collected since 1992, and RIDEM's 1999 TMDL study. The data indicate conclusively that in-stream fecal coliform concentrations are highest during the warmest summer months (July – September) and for a 72-hour period following significant rainfall. The endpoints determined in this TMDL ensure that the Narrow River will meet water quality standards during these critical time periods.

Strengths/Weaknesses in the Overall Analysis Process

Strengths:

- The TMDL is based on an extensive knowledge of land use and potential bacteria sources in the watershed.
- The TMDL incorporates the findings of several studies and utilizes a large amount of data collected over several years.
- The TMDL endpoints for both dry and wet weather as presented in the load allocation section allow water quality standards to be met in critical conditions. Critical conditions were determined based on more than ten years of data.
- The phased approach allows an emphasis on mitigation strategies rather than on modeling and more complex monitoring issues to keep the focus on minimizing or eliminating sources.

Weaknesses:

- The study identified water quality impacts from birds, wildlife, and from residential septic systems by excluding other sources to the maximum extent feasible. The impacts of these categories of sources were therefore identified indirectly.

- RIDEM was unable to collect enough additional storm water runoff flow data during the 1999 monitoring effort to completely verify results obtained by SWMM model runs during the Tri-Town study. However, the flow estimates and event mean concentrations generated by that study were utilized to determine current storm sewer outfall loadings.
- Although twenty-three (23) storm sewer outfalls discharge directly to the river, only four or five of the largest have been consistently monitored during wet-weather conditions.
- Limited flow data and stage-discharge relationships were obtained for tributary streams.
- The majority of dry weather data was collected during the summer of 1999 under severe drought conditions (i.e. low flow conditions).

Required Reductions (Load Allocation/Waste Load Allocation)

Other than storm sewer outfalls, there are no point sources to either the Narrow River or its tributaries. The required fecal coliform reductions for Narrow River, Gilbert Stuart Stream and Mumford Brook are calculated from observed concentrations at in-stream stations. They represent an overall reduction goal that is applicable to the composite of all tributary, point and nonpoint sources contributing to the water quality impairment. As such these reductions serve as both a load allocation and a waste load allocation.

Required Narrow River Reductions

The water quality target, based on the Class SA standard, dictated the allowable fecal coliform concentrations in the Narrow River. In-stream concentrations were determined by river segment, predominantly using RIDEM's 1999 monitoring data. Reductions were specified that ensure attainment of both portions of the fecal coliform standard. A summary of the calculated reductions for each segment is presented in Table 5.

Table 5: Required reductions for Narrow River receiving water.

Subwatershed	Target 90th percentile concentration (fc/100 ml)	Observed 90th percentile concentration (fc/100 ml)	Target geometric mean concentration (fc/100 ml)	Weighted geometric mean concentration (fc/100 ml)	Reduction required to meet water quality standards
Segment 1 – Upper Pond	49	45	12.6	15.4	18 %
Segment 2 – Lower Pond	49	23	12.6	6.5	*
Segment 3 – Upper River	49	70	12.6	27.3	54 %
Segment 4 – Lower River	49	88	12.6	29.9	58 %
Segment 5 – Pett. Cove	49	454	12.6	120.8	90 %
Segment 6 – The Narrows	49	70	12.6	20.2	38 %

* Lower Pond currently meets fecal coliform water quality standards based on the available monitoring data, however, four of the larger storm sewer outfalls currently discharge to this segment. RIDEM recognizes that these storm sewer outfalls release substantial bacteria loads during wet weather conditions that threaten water quality in Lower Pond and contribute to water quality impairments in downstream segments. This TMDL, therefore, targets these outfalls for water quality best management practices (BMPs) to mitigate pollutant loadings to the greatest extent practicable.

Required Gilbert Stuart Stream and Mumford Brook Reductions

The state's water quality regulations specify that freshwater tributaries to Class SA waterbodies are designated Class A. Therefore, the tributaries to the Narrow River are directly subject to Class-A water quality standards. Additionally, the allowable fecal coliform levels in tributaries must be adequately protective of the receiving water. Pollutant loadings from tributaries must not impact receiving water quality sufficiently to prevent attainment of any designated uses. In the absence of site specific data to guarantee that Narrow River water quality would be maintained if each tributary discharges at the Class A standard, this TMDL requires that each tributary meet the Class SA standard at its point of discharge. The fecal coliform concentration reductions required for Gilbert Stuart Stream and Mumford Brook to meet the Class SA standard are specified in Table 6. These reductions ensure the attainment of both parts of the fecal coliform standard. Crooked Brook reductions will be determined through additional monitoring performed in conjunction with the Crooked Brook TMDL scheduled for 2002.

Table 6: Required reductions for tributaries.

Subwatershed	Target 90th Percentile	Current 90th Percentile	Target geometric mean concentration (fc/100 ml)	Weighted geometric mean concentration (fc/100 ml)	Reduction required to meet water quality standards
Gilbert Stuart Stream	49	4,320	14	290	98.9 %
Mumford Brook	49	74,892	14	66,667	99.9 %

Margin of Safety (MOS)

There are two basic methods for incorporating the MOS into the TMDL. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly allocate a portion of the TMDL as the MOS. This TMDL uses a combination of the two approaches to ensure an adequate MOS. The primary sources of fecal coliform in the Narrow River watershed are nonpoint in nature. Because nonpoint source loadings, especially bacteria loadings, are inherently difficult to quantify with any certainty, this TMDL uses the following conservative assumptions:

- Conservative estimates of both the amount of rainfall needed to produce runoff and recovery time were used in the weighted geometric mean calculations.
- No allowances were made for bacterial decay.
- The dilution effects of groundwater infiltration were not considered when calculating receiving water fecal coliform concentrations
- The weighted geometric mean values were developed using annual averages for the number of wet and dry weather days. However, the actual monitoring data used in the calculations were from warm weather when fecal coliform concentrations are typically much higher. As a result, the calculated weighted geometric mean and related reductions are conservative in nature.

Also included in the allocation of this TMDL was an explicitly expressed MOS. The target geometric mean concentration for the Narrow River was set at 12.6 fc/100 ml, providing a 10% MOS below the standard of 14 fc/100 ml. The target geometric mean concentration for each fresh water tributary was set at the Class-SA standard of 14, which provides a 30% MOS below the applicable Class-A freshwater standard of 20 fc/100mL, while adequately protecting the receiving water.

Seasonal Variation

The Narrow River TMDL is protective of all seasons, since a large majority of the fecal coliform data was collected during the summer months when in-stream fecal coliform concentrations are typically the highest.

Proposed Monitoring

This is a phased TMDL. Additional monitoring is required to ensure that water quality objectives are met as remedial actions are accomplished. The ongoing University of Rhode Island's Watershed Watch monitoring program, which now includes multiple receiving water stations and stations in Gilbert Stuart Stream, and Mumford and Mettatuxet Brooks, will be the principal method of obtaining the data necessary to track water quality conditions in the watershed. The sampling, conducted by NRPA volunteers, in tandem with RIDEM's Shellfish Water Quality Monitoring Program, should be sufficient to characterize water quality throughout the watershed. RIDEM and the Watershed Watch/NRPA will conduct additional monitoring in Gilbert Stuart Stream and Mumford Brook to confirm that the desired water quality standards have been achieved as remedial measures are implemented in those areas. In addition, RIDEM will be implementing a TMDL monitoring program in Crooked Brook during 2001 and 2002. Also, as proposed BMPs are installed in the watershed, post-construction influent and effluent sampling will be required to assess the effectiveness of the selected technology.

Implementation Plans

The purpose of this section is to inventory identified sources and to recommend mitigation measures to achieve necessary water quality improvements in the Narrow River. The three largest perennial streams entering the Narrow River act as the principal pathways by which nonpoint loadings enter the Narrow River during periods of dry and wet weather. During wet weather, storm sewer outfalls discharging to Segments 2, 3 and 4 also severely degrade water quality. Significant nonpoint sources to the Narrow River and its tributaries include overland storm water runoff, wildlife, and birds.

Tributaries

Remedial measures are recommended for Gilbert Stuart Stream and Mumford Brook (Table 7), since bacterial loadings to these tributaries appear to originate predominantly from human sources. The proposed remedial actions are described in greater detail later in this report. No remedial action is recommended for Crooked Brook at this time, since preliminary analysis indicates that fecal coliform loadings to the brook may be from nonanthropogenic sources. Additional monitoring will be performed in the brook in conjunction with the Crooked Brook TMDL planned for completion in 2002.

Table 7: Summary of current and proposed work on Narrow River tributaries.

Description of Impacted Area	Jurisdiction	Abatement Measure	Status
Gilbert Stuart Stream	Gilbert Stuart Birthplace Museum / RIDEM	Discontinue use of outhouse near Carr Pond. Replace with portable toilet.	Use discontinued in October 1999. 2000 sampling indicates that water quality has improved
Mumford Brook	RIDEM	Identify/repair failing septic system(s) near Mumford Road	Suspected septic systems are being investigated. Projected repairs in 2001-2

Nonpoint Sources and Storm Sewers

The most significant reductions for nonpoint fecal coliform sources can be achieved through non-structural "good housekeeping" efforts by local residents. Good housekeeping practices include: connecting to the municipal sewers if available, restoring vegetated buffers around the river and tributary streams, discouraging the prolonged residence of waterfowl, regularly inspecting and pumping septic systems, disposing of pet wastes away from the river and storm sewer systems, and minimizing the use of fertilizers.

Storm water runoff is the largest wet weather source of bacteria to the Narrow River and its tributaries. Storm sewers magnify the problem by rapidly collecting, concentrating and directly routing polluted runoff to receiving waters. Storm sewer outfalls discharging to Segments 2, 3 and 4 represent the only point sources of fecal coliform to Narrow River. They supply the majority of the fecal coliform load to the middle portion of the river during wet weather. The twelve largest storm sewer outfalls (shown on Figure 3.4), representing an estimated ninety-three (93) percent of the total fecal coliform load from outfalls to the Narrow River, are listed in Table 5.7. Consistent with the goals of this TMDL, these outfalls are targeted for water quality best management practices to mitigate pollutant loadings to the greatest extent practicable. The largest outfalls should receive priority for BMP implementation, however, special consideration should be given to those outfalls discharging to, or immediately upstream of, Segments 3 and 4. These two segments are shallow and narrow with relatively little dilution volume available to absorb the impact of pollutant loadings. Consequently, significant loading reductions in these reaches would lead to substantive in-stream water quality improvements during wet weather. Ultimately all direct discharge outfalls that contribute to the impairment of the Narrow River should be addressed as necessary to meet water quality goals".

“End-of-pipe” structural BMPs designed to treat current flows and pollutant loadings at the storm sewer outfalls would necessarily be rather expensive and/or require substantial land area. RIDEM suggests that a multi-faceted storm water management strategy be incorporated by the municipalities that utilizes a combination of end-of-pipe structural BMPs, smaller-scale structural retention/infiltration BMPs located up-gradient within the catchment areas and the implementation of nonstructural BMPs throughout the watershed.

As mandated by EPA, RIDEM is required to amend the existing Rhode Island Pollution Discharge Elimination System (RIPDES) regulations to include Phase II Storm Water Regulations. The new regulations will become effective in the Fall of 2001. Automatically designated municipalities must develop a storm water management program plan (SWMPP) that describes the Best Management Practices (BMPs) for each of the following minimum control measures:

1. a public education and outreach program to inform the public about the impacts storm water on surface water bodies,
2. a public involvement/participation program,
3. an illicit discharge detection and elimination program,
4. a construction site storm water runoff control program for sites disturbing more than 1 acre,
5. a post construction storm water runoff control program for new development and redevelopment sites disturbing more than 1 acre and
6. a municipal pollution prevention/good housekeeping operation and maintenance program.

The SWMPP must include the measurable goals for each control measure (narrative or numeric) that will be used to gauge the success of the overall program. It must also contain an implementation schedule that includes interim milestones, frequency of activities and reporting of results. In addition, the Director of RIDEM (Director) can require additional permit requirements based on the recommendations of a TMDL.

Operators of municipal separate storm sewer systems (MS4s) within urbanized areas (UAs) or densely populated areas (DPAs) will be required to develop a SWMPP and obtain a permit (for those portions within the UA or DPA) by March 10, 2003. DPAs include places that have equal to or greater than 1,000 people per square mile and have, or are part of, a block of contiguous census designated places with a total population of at least 10,000 people, as determined by the latest Decennial Census. Operators of MS4s located outside of UAs and DPAs and that discharge to Special Resource Protection Waters (SRPWs), Outstanding National Resource Waters (ONRWs), or impaired waters will also be required to obtain a permit (or expand permit coverage throughout the jurisdiction) by March 10, 2008, unless the operator has demonstrated effective protection of water quality to the satisfaction of the Director. The Director will also require permits for MS4s that contribute to a violation of a water quality standard, are significant contributors of pollutants to waters of the state or that require storm water controls based on waste load allocations (WLAs) determined through a TMDL.

The MS4s that discharge to the Narrow River are owned and operated by the Town of Narragansett, the Town of South Kingstown, or by the Rhode Island Department of Transportation (RIDOT). Based on the latest census data, an area within the Town of Narragansett meets the criteria of a DPA, including the portion of the Narrow River watershed south of Sprague Bridge. Accordingly, the Town of Narragansett will be required to apply for a RIPDES permit for that portion of their MS4 located within the DPA by March 10, 2003. The remaining Narragansett, South Kingstown and RIDOT storm sewer outfalls are part of MS4s that are not located in a DPA or UA. However, because they discharge significant loadings to an impaired waterbody (which is also a SRPW), because these loadings contribute to a violation of a water quality standard, and because it has been determined through this TMDL that storm water controls are necessary to restore water quality, the operators will be required to obtain a RIPDES permit (or expand coverage of an existing permit).

RIDEM will continue to work with the Coastal Resources Management Council (CRMC), Rhode Island Department of Transportation (RIDOT), the Southern Rhode Island Conservation District (SRICD) and the local municipalities to identify funding sources and to evaluate locations and designs for storm water control BMPs throughout the watershed. In accordance with the requirements of this phased TMDL, monitoring of Narrow River water quality will continue so that the effectiveness of ongoing remedial activities can be gauged. A summary of ongoing and proposed mitigation actions is presented in Table 8.

Public Participation

The Narrow River Preservation Association (NRPA) provided valuable data, advice and support during the 1999 TMDL study of the Narrow River and has contributed actively to the content of this TMDL. NRPA has ensured that improvements to the water quality of the Narrow River have remained on the agendas of local, state and federal agencies. RIDEM has worked to keep committee members informed of TMDL progress and ongoing water quality improvement initiatives and actions.

Public meetings and open comment periods are important components of the TMDL process. RIDEM held an initial public meeting in March 1999 prior to TMDL development, which was open to and attended by interested public and government officials and concerned private citizens. The goal of the meeting was to inform the public about the upcoming Narrow River watershed study and to solicit input regarding pollution sources and/or other concerns. A meeting, targeted primarily at state and local officials and local organizations, was held in December 1999 to discuss the results of that summer's monitoring program. A second public meeting, held March 16 2000, was cosponsored with NRPA to further raise public awareness of the project and to discuss RIDEM's proposed water quality improvement measures. A fourth meeting will be scheduled to discuss this draft TMDL. All interested stakeholders will be given thirty days to review the document and submit comments. RIDEM will address all of the comments in a document to be submitted to the EPA with the final draft of the Narrow River TMDL document.

Table 8: Summary of current and proposed mitigation measures

Description of Impacted Area	Jurisdiction	Abatement Measure	Status
Mettatuxet and Rio Vista neighborhoods	Narragansett	Illicit discharge to storm sewer detection and elimination	Scheduled to start in Fall of 2001
Mettatuxet Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Shadbush Trail Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Wampum Road and Conanicus Road Outfalls	Narragansett/CRMC	Structural storm water BMP(s)	Wet detention pond design plans completed. Application for 319 funding conditionally approved
Lakeside Drive and South Ferry Road Outfalls	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Old Pine Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Shagbark Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Woodbridge Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP	Targeted for future BMP
Mettatuxet Beach Outfall	Narragansett/CRMC/Southern Rhode Island Conservation District (SRICD)	Structural/nonstructural storm water BMP(s)	Aquafund grant awarded to SRICD for feasibility study and preliminary BMP design.
Pettaquamscutt Avenue Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Indian Trail Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Narrow River watershed	Narragansett/South Kingstown	Identify any residents not connected to sewers and require that they connect as failing systems are identified	Completed by Narragansett. South Kingstown is in process.
Middle river	Narragansett/RIDEM/ SRICD/NRPA	Deter waterfowl from river and waterfront areas and reduce storm water loadings by educating residents. Reduce pet waste impacts	Aquafund grant awarded to SRICD to launch an education campaign for neighborhood residents to minimize storm water-related loadings

1.0 INTRODUCTION

The Pettaquamscutt River has been listed in Rhode Island's 1998 and draft 2000 303(d) lists of impaired waters for violating Rhode Island's fecal coliform standards. As a result of monitoring conducted in support of this TMDL, Gilbert Stuart Stream was also included in the draft 2000 303(d) list. Mumford Brook, though not currently listed, has also been found through recent monitoring efforts to have a fecal coliform impairment. This report will specify TMDLs and recommend mitigation measures for Narrow River (waterbody identification number RI0010044E-01), Gilbert Stuart Stream (waterbody identification number RI0010044R-01), and Mumford Brook (no waterbody identification number assigned). Crooked Brook, also located within the Narrow River watershed, has been included on the 1998 and draft 2000 303(d) lists of impaired waters as well. Because there is insufficient monitoring data to characterize impairments to Crooked Brook at this time, it will be addressed in a separate TMDL scheduled for completion in 2002.

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting water quality standards. The objective of a TMDL is to establish water-quality-based limits for pollutant loadings that allow the impaired waterbody to meet standards. The TMDL analysis examines point source inputs, such as storm sewer outfall discharges, and nonpoint source inputs, including storm water runoff from agricultural and urbanized areas. Natural background levels and a margin of safety to account for any modeling or monitoring uncertainties are also included in the analysis. The goal of this phased TMDL is to reduce pollutant loadings and to restore water quality in Narrow River, Gilbert Stuart Stream and Mumford Brook to meet the standards set by the state's water quality regulations. Because the degree of uncertainty associated with sources and the effectiveness of remedial measures, this TMDL will be conducted in a phased manner. In a phased TMDL, the achievement of numeric goals, after implementation of remedial measures, is confirmed through continued monitoring

1.1 Background

This phased TMDL will address the fecal coliform impairments of the Narrow River, Gilbert Stuart Stream and Mumford Brook. Specific sources of bacterial contamination and proposed mitigation actions will also be addressed.

The Narrow River is located in southern Rhode Island, west of Narragansett Bay. Its watershed lies within the towns of North Kingstown, Narragansett and South Kingstown. (Figure 1). The river has long been recognized as a valuable environmental resource for the surrounding community and a diverse wildlife population. It is a vast recreational resource that supports swimming, fishing, shellfishing, boating, water-skiing, and windsurfing. The surrounding watershed provides many places to hike, picnic, birdwatch and camp, while many species of wildlife use the estuary and adjacent wetlands as a primary food source, a rest stop along migratory routes, and as breeding, nesting and spawning grounds. Several rare and unusual species have been documented, including several species of marsh grass, osprey, least tern, sea cucumber, moonfish, luminescent moss, and a small stand of very diverse ferns (CRMC, 1986) watershed.

Over the past 30 to 40 years, seasonal cottages and camps have increasingly been converted to year-round residences, while new homes have taken the place of open-space. As a result of these development trends in the watershed, the water quality of the Narrow River has been a growing concern. Numerous reports and studies have concluded that the increased urbanization of the watershed has substantially increased the pollution load to the river from surface water runoff, storm water outfalls, and failing septic systems. As a result, the Narrow River has been impacted by point and nonpoint sources of contamination resulting in the degradation of aquatic habitat and the closure of shellfishing areas.

1.2 Applicable Water Quality Standards

The standards for water quality in the Narrow River are specified in Rhode Island's water quality regulations (RIDEM, 1997). The water quality standards are intended to protect public health, safety, and welfare. They comply with the requirements of the federal Clean Water Act of 1972 and Rhode Island General Laws (Chapter 46-12). The conditions specified in the regulations are water quality goals for each waterbody. When a waterbody does not meet these goals, the standards serve as the regulatory basis for establishing water-quality-based treatments and strategies. The treatment levels established on this basis may exceed the technology-based levels of treatment normally required by the Clean Water Act.

The Narrow River estuary is identified as a Class SA marine waterbody. The fresh water tributaries to the Narrow River are identified as Class A waterbodies. Rhode Island's Water Quality Regulations describe Class SA waters and Class A fresh waters as follows:

Class SA waters are *"designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities, and fish and wildlife habitat. They (Class SA waters) shall be suitable for aquacultural uses, navigation, and industrial cooling. These waters shall have good aesthetic value."*

Class A waters are *"designated as a source of public drinking water supply, for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value."*

Rule 8.D of the Water Quality Regulations establishes physical, chemical, and biological criteria as parameters of minimum water quality necessary to support the water use classifications of Rule 8.B. Therefore, sections of Rule 8.D also are applicable. In particular, Rule 8.D(2) establishes class-specific criterion for fresh and seawaters. For Class SA sea waters, the following conditions, excerpted from Rule 8.D, Table 2 of the Regulations must be met:

Class SA - Fecal coliform concentrations are *"not to exceed a geometric mean (MPN) value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution"* (RIDEM, 1997), where MPN is the most probable number.

For Class A fresh waters of the state, the following conditions, excerpted from Rule 8.D, Table 1 of the Regulations must be met:

Class A- *Fecal coliform not to exceed a geometric mean value of 20 MPN/100ml and not more than 10% of the samples shall exceed a value of 200 MPN/100ml.*

Also applicable is Rhode Island's antidegradation policy, which requires that, at a minimum, the water quality necessary to support existing uses be maintained. If existing water quality is better than what is necessary to support the protection and propagation of fish, shellfish, and wildlife, and recreation in and out of the water, the quality should be maintained and protected unless, through a public process, some lowering of water quality is deemed necessary to allow important economic and social development to occur. In waterbodies identified as having exceptional recreational and ecological significance, water quality should be maintained and protected (RIDEM, 1997). The designated and existing uses for the Narrow River include fishing, shellfishing, swimming, and boating. The goal of the TMDL is to restore all designated uses to the Narrow River that are impacted by elevated levels of fecal coliform.

2.0 DESCRIPTION OF THE NARROW RIVER STUDY AREA

The Narrow River watershed encompasses approximately thirty-six (36) square kilometers within the towns of North Kingstown, Narragansett and South Kingstown. The river lies in the southern portion of the watershed. It is just over 9.5 kilometers long and runs parallel to the West Passage of Narragansett Bay. Although considered a river, it may more accurately be described as the composite of a tidal inlet and backbay, an estuary, and two fjord-like ponds. The estuarine portion of the river runs southerly from Gilbert Stuart Stream to its mouth where it discharges to Rhode Island Sound. The river is regionally significant as a recreational resource, a wildlife habitat and shellfishing resource

2.1 Physical Characteristics

The Narrow River estuary is comprised of three distinct reaches. The relatively sparsely settled upper reach consists of two kettle-hole ponds separated from each other and the lower reaches by shallow sills less than one meter deep. The Upper Pond and the Lower Pond have maximum widths of approximately 500 meters and depths of 13.5 and 19.5 meters, respectively. The ponds are highly stratified and contain permanently anoxic bottom layers. Biogenic hydrogen sulfide accumulates to levels among the highest reported in marine waters (Gaines, 1975). The heavily developed middle reach between Lacey Bridge and Middlebridge Bridge is quite narrow (approximately 10 meters) and shallow (one to two meters) (ASA, 1989). The lower reach consists of a long narrow inlet extending 2 km. from the river mouth to Middlebridge Bridge. Depth in this reach is typically between one and two meters while width varies from approximately 10 meters in “the Narrows” near Sprague Bridge, to 100 meters in the upper portion of Pettaquamscutt Cove.

2.2 Physical Oceanography

The unique geographic features and physical dimensions of the Narrow River system control much of the actual hydrodynamics. Past studies have indicated that up to 90% of the tidal amplitude at the mouth is attenuated over the relatively short length of the river reach. The tidal range at the mouth of the river is approximately 1.07 meters; whereas it is only 0.43 meters at Sprague Bridge, 0.13 meters at Lacey Bridge and 0.10 meters at the head of Upper Pond (Gaines, 1975). Tides at the mouth of the river follow a 12.4-hour, semi-diurnal period, with tides at the head of the river lagging by approximately 4 to 6 hours (ASA, 1989). Currents in the system can reach maximum velocities of over 1 m/s in some of the narrower sections of the river, while in the ponds, the currents are almost nonexistent. Strong currents, especially in The Narrows, contribute to constant changes in bathymetry and coastline, causing modifications to system hydrodynamics over time. The ponds exhibit stratification with a deep stable anoxic layer that mixes only rarely with upper surface waters. The ponds and Pettaquamscutt Cove act as water storage basins because of their large surface areas relative to the surface areas of the river sections. River segment areas and volumes as determined by Gaines are presented in Table 2.1.

The river’s salinity varies substantially along its length. Since the river is relatively shallow and narrow below Lacey Bridge, tidal currents increase significantly, resulting in homogenous salinity with depth. North of Lacey Bridge, the upper and lower ponds are only slightly impacted by tidal energy from Rhode Island Sound. The intrusion of saline water into these ponds occurs only intermittently. This combination of fresh and saline water, limited tidal energy and basin depth results in substantial stratification in both Upper and Lower Ponds. Surface salinity above a depth of 2 meters is typically in the 10 and 12 parts per thousand range; whereas, salinity increases to 21 to 27 parts per thousand below a depth of 3 meters in the Upper and Lower Ponds. The decreasing water temperatures with depth also contribute to enhanced stratification within the Ponds (ASA et al, 1995 and CRMC, 1999).

Table 2.1: Narrow River segments areas and volumes

Segment	**Location**	**Surface Area ($1000\ m^2$)**	**Volume ($1000\ m^3$)**	
1	Upper Pond	280	0-2 meters = 507	2-5 meters = 513
2	Lower Pond	690	0-2 meters = 1230	2-5 meters = 1139
3	Upper River	190	95	
4	Lower River	330	100	
5	Pettaquamscutt Cove	690	347	
6	The Narrows	130	89	

The stratification of the Ponds produces a number of significant consequences. There is a reduction of mixing between the stratified layers of the Ponds, with lower layers becoming anoxic. The slow flushing of the bottom waters of the Ponds causes materials introduced from streams, surface water runoff, or groundwater flow to accumulate for long periods of time. For example, bottom waters in the Upper Pond are thought to have a residence time of 3-5 years. The bottom waters periodically overturn in the Ponds. The displacement of bottom waters to the surface results in the release of gases, such as hydrogen sulfide, and nutrients which have been known to cause eutrophic conditions and fish kills (CRMC, 1999).

A dye study and the application of a computer simulation model during the Tri-Town Study (ASA et al, 1995) determined flushing rates, shown in Table 2.1. The flushing time represents the mean number of days that it takes for anything (i.e. a pollutant) in that section to pass completely through. The integrated flushing time is the sum of the flushing time of that section and all of the sections downstream from it. It represents the total time required for a pollutant in a particular section to be flushed completely out of the Narrow River system to the ocean. Flushing times for the Lower Pond range from 26 to 360 days and average 48 days. These times are nearly twice the flushing times calculated for the Upper Pond, which has a smaller effective volume and receives most of the freshwater that enters the two ponds. Flushing times in the Upper and Lower River segments are much shorter, typically on the order of one to two days. In Pettaquamscutt Cove, flushing times averaged 6.6 days, while the flushing times in "The Narrows" were on the order of a few hours.

Table 2.2: Narrow River flushing times.

Location	Flushing Times (days)				
	16-May-93	26-Jun-93	6-Aug-93	25-Sep-93	***Average***
Upper Pond	15.01	34.66	201.54	31.89	***27.86***
Lower Pond	26.11	60.95	360.09	57.55	***47.73***
Upper River	0.86	1.81	11.00	1.95	***1.52***
Lower River	0.43	0.65	4.75	0.84	***0.65***
Pettaquamscutt Cove	4.91	5.51	16.62	9.69	***6.62***
The Narrows	0.07	0.09	0.51	0.18	***0.11***

Table 2.3: Narrow River integrated flushing times.

Location	Integrated Flushing Times (days)				
	16-May-93	26-Jun-93	6-Aug-93	25-Sep-93	***Average***
Upper Pond	42.47	98.17	577.89	92.40	***77.47***
Lower Pond	27.46	63.51	376.35	60.51	***50.01***
Upper River	1.35	2.56	16.26	2.96	***2.28***
Lower River	0.50	0.75	5.26	1.02	***0.76***
Pettaquamscutt Cove	4.98	5.60	17.14	9.87	***6.72***
The Narrows	0.07	0.09	0.51	0.18	***0.11***

2.3 Groundwater and Surface Water Inflow

Groundwater outflow from the watershed to the river occurs directly as groundwater seepage, or as stream base flow. Approximately 65% of the total contribution of freshwater inflow to the Narrow River is from groundwater. In the densely developed, central part of the watershed, approximately 73% of the freshwater entering the river has moved through the highly permeable sands and gravels of its shoreline as groundwater inflow (Urish, 1991).

There is a strong likelihood that untreated sewage effluent has historically entered the river directly along the shoreline from failing septic systems in the densely developed, central part of the watershed. Septic systems become nonfunctional when inundated with groundwater, resulting in the release of untreated sewage effluent. Groundwater table records show that portions of this area are sometimes saturated with groundwater to the land’s surface (Urish, 1991).

Perennial and intermittent streams and groundwater provide inputs of freshwater into the river. Freshwater inflow to the Narrow River was determined through a combination of direct measurement stream flow measurements and computer modeling during the Tri-Town Storm water Study. The summer of 1993 at the time of the Tri-Town monitoring activity was exceptionally dry. Rainfall amounts during both June and August of that year were less than 0.5 inches. Low precipitation amounts combined with high evapotranspiration had a noticeable impact on stream flow causing five of the eleven sampling stations to run dry at some point during the study.

A summary of the dry weather, freshwater inflow is presented in Table 2.4. Gilbert Stuart Stream, which discharges to Upper Pond, provides the largest single freshwater flow to the Narrow River system. Mumford Brook and Crooked Brook, which flow to Pettaquamscutt Cove, are second and third largest tributaries, respectively. Many of the smaller tributaries such as, Mettatuxet, Walmsley and Crew brooks and Girl Scout and Seven Farms streams stop flowing or run completely dry during the warmest summer months. As the data shows, freshwater flows in the Narrow River watershed diminish rapidly with the start of the growing season in early May because of the increased evapotranspiration. The period of lowest flow typically occurs in late summer to early fall, which coincides with the period of lowest groundwater table. Flows gradually increase through the fall and winter months to peak during the early spring wet season.

2.4 Geology and Topography

The path of the Narrow River was initially carved into bedrock millions of years ago by glaciers. During the most recent glacial period, approximately 18 thousand years ago, additional changes occurred. The glacier deepened much of the river valley by adding material to the east and west sides of the river. In addition to depositing material on the valley walls, the recent glacial action resulted in a layering of outwash material in the valley itself, some of it around massive chunks of ice. This process produced the two fjord-like ponds known as Upper Pond and Lower Pond. Further south in the watershed, glacial outwash resulted in a thinner layer of sand and gravel being deposited over the relatively flat area of the Lower River and cove (CRMC, 1999). Finally, approximately 1,700-years ago, marine inundation of the valley occurred from Rhode Island Sound. This resulted in the formation of a permanent tidal inlet to the river with associated tidal deltas and salt marshes in the Lower River. The event completely changed the river from a closed freshwater system to a tidally influenced, saline system, or estuary (Gaines, 1975).

The river bisects its watershed into two sloping, glacial till hillsides with glacial outwash and ice contact deposits at their bases immediately adjacent to and under the river. Some of the hillside slopes are extreme, ranging from 20-40% on the western sides (CRMC, 1999). More gradual slopes are seen in some outwash and ice contact deposits north and south of, as well as immediately adjacent to the river (USGS, 1961).

2.5 Soils

The Soil Survey of Rhode Island (SCS, 1981) defines a number of developmental constraints for soils found in the Narrow River watershed. It should be noted that some of these limitations apply to areas of the watershed that have been densely developed. In particular, the survey indicates that, due to the highly permeable nature of the soils associated with a Merrimac-Urban Land Complex, which is found throughout a large part of the developed area of the watershed, "onsite septic systems in this complex need careful design and installation to prevent pollution of groundwater". Other soils found in the area, such as Rainbow Silt Loam, 3 to 8 percent slopes, are limited by a seasonally high water table and slow to very slow substratum permeability.

The steep slopes and surficial soils that bound the Narrow River also present a potential source of pollution to the waters resulting from erosion and subsequent sedimentation. When vegetation is removed and the land is cleared for development, the rate and volume of surface water runoff is increased dramatically and soil erosion is accelerated. Soils carried by surface water runoff enter the river causing adverse changes in the quality of the waters and the overall impacts to its ecosystem. The physical constraints mentioned have prevented development in many areas of the watershed. There is, however, concern for the future. As the easily buildable land is developed, pressure to utilize the remaining, marginal land will increase. The availability of sanitary sewers to these marginal areas will exacerbate development pressures.

Table 2.4: 1993 Narrow River watershed fresh water inflows*

Region	Source Name	Sampling Dates					
		4/21/93	5/15/93	6/28/93	8/6/93	9/25/93	10/15/93
Upper Pond – Segment 1	Gilbert Stuart Stream	1387	1243	470	81	348	236
	Girl Scout Stream	80	114	1	*Dry*	*Dry*	*Dry*
	Groundwater	385**	341**	105**	6**	67**	33**
	Subtotal	1852	1698	576	87	415	269
Lower Pond – Segment 2	Seven Farms Stream	34	2	*Dry*	*Dry*	*Dry*	*Dry*
	Lakeside Pipe	10	7	*Dry*	*Dry*	*Dry*	*Dry*
	Walmsley Brook	11	2	1	*Dry*	*Dry*	*Dry*
	Crew Brook	6	1	*Dry*	*Dry*	*Dry*	*Dry*
	Groundwater	275**	245**	*78***	*6***	52**	28**
	Subtotal	336	257	79	6	52	28
Upper River – Segment 3	*No Significant Tributaries*	---	---	---	---	---	---
	Groundwater	257	229	76	13	52	30
	Subtotal	257	229	76	13	52	30
Lower River – Segment 4	Wampum Road Outfall	66**	59**	18**	1**	11**	6**
	Mettatuxet Brook	88**	78**	26**	3**	17**	10**
	Groundwater	157**	139**	45**	2**	30**	16**
	Subtotal	311	276	89	6	58	32
Pettaquamscutt Cove – Segment 5	West Brook	90**	81**	24**	1**	15**	8**
	Canonchet Brook	66**	59**	18**	1**	11**	6**
	Crooked Brook	121	17	16	2	11	19
	Mumford Brook	42	62	47	39	44	39
	Groundwater	279**	247**	75**	4**	48**	23**
	Subtotal	320	219	105	43	81	72
The Narrows – Segment 6	*No Significant Tributaries*	---	---	---	---	---	---
	Groundwater	123**	109**	33**	2**	21**	10**
	Subtotal	123	109	33	2	21	10

* - All flows are given in thousands of cubic feet per day (thousand ft^3/d)
* * - Indicates that values are derived from HIM model estimates; all other flows were determined from direct measurements

2.6 Development and Land Use

The ratio of developed land to undeveloped land in the 36 square kilometer watershed is approximately 35% to 65%, based on 1988 Rhode Island Geographic Information System (RIGIS) land use data. Most of the undeveloped lands are located in the north-northwest section of the watershed within the town of North Kingstown. North Kingstown is 71% undeveloped and comprises 56% of all undeveloped land in the watershed. South Kingstown is 69% undeveloped, containing a total of 18% of all undeveloped land in the watershed. Narragansett is 54% undeveloped and contains 26% of all the undeveloped land in the watershed (CRMC, 1999).

Land use within the watershed varies between the three towns. North Kingstown, the most rural of the three towns contains 64% of the agricultural lands within the watershed. Narragansett contains 55% of the total residential land and 64% of the limited commercial and industrial land within the watershed. Most of the high density, residential development in the watershed is located along the central section of the river within the towns of Narragansett and South Kingstown. In this area, residential lots varying from 1/8 to 1/2-acre directly abut the river. Approximately 14% of the watershed has been designated as open space by state, local or private entities. This includes an addition of 175 acres of land to the Pettaquamscutt Cove National Wildlife Refuge and over 150 acres protected by the Narrow River Land Trust since 1988 (CRMC, 1999).

2.7 Sewering of the Watershed

The Narrow River neighborhoods have been progressively sewered over the past twenty years (Figure 2.1). Sanitary sewers are available to most of the densely developed portions of the watershed in Narragansett and South Kingstown. North Kingstown, the least densely developed portion of the watershed, does not have sanitary sewers available. The densely developed Middlebridge area in South Kingstown has been sewered for more than a decade. The greater Mettatuxet area in Narragansett has been sewered for approximately 20 years. Sewer lines were extended to the Rio Vista, Edgewater and Pettaquamscutt Terrace neighborhoods between 1996 and 1997. The neighborhoods of Pettaquamscutt Lake Shores, Riverdell and Forest Lakes were sewered in 1999. It should be noted that residents of these Narragansett neighborhoods are required to abandon their septic systems and tie-in to the sewer system provided by the Town within one year of the sewer lines being opened (Jeffrey Ceasrine – Town Engineer, personal communication).

While ongoing sewering within the watershed may reduce the pollutant loading to the river from human sewage, it allows for an increase in watershed development. Marginal lots, previously unbuildable because of individual sewage disposal system (ISDS) constraints, will now be developed. This new development will increase the proliferation of nonpoint pollution sources in the watershed, which may actually increase pollutant loadings to the river especially during wet weather.

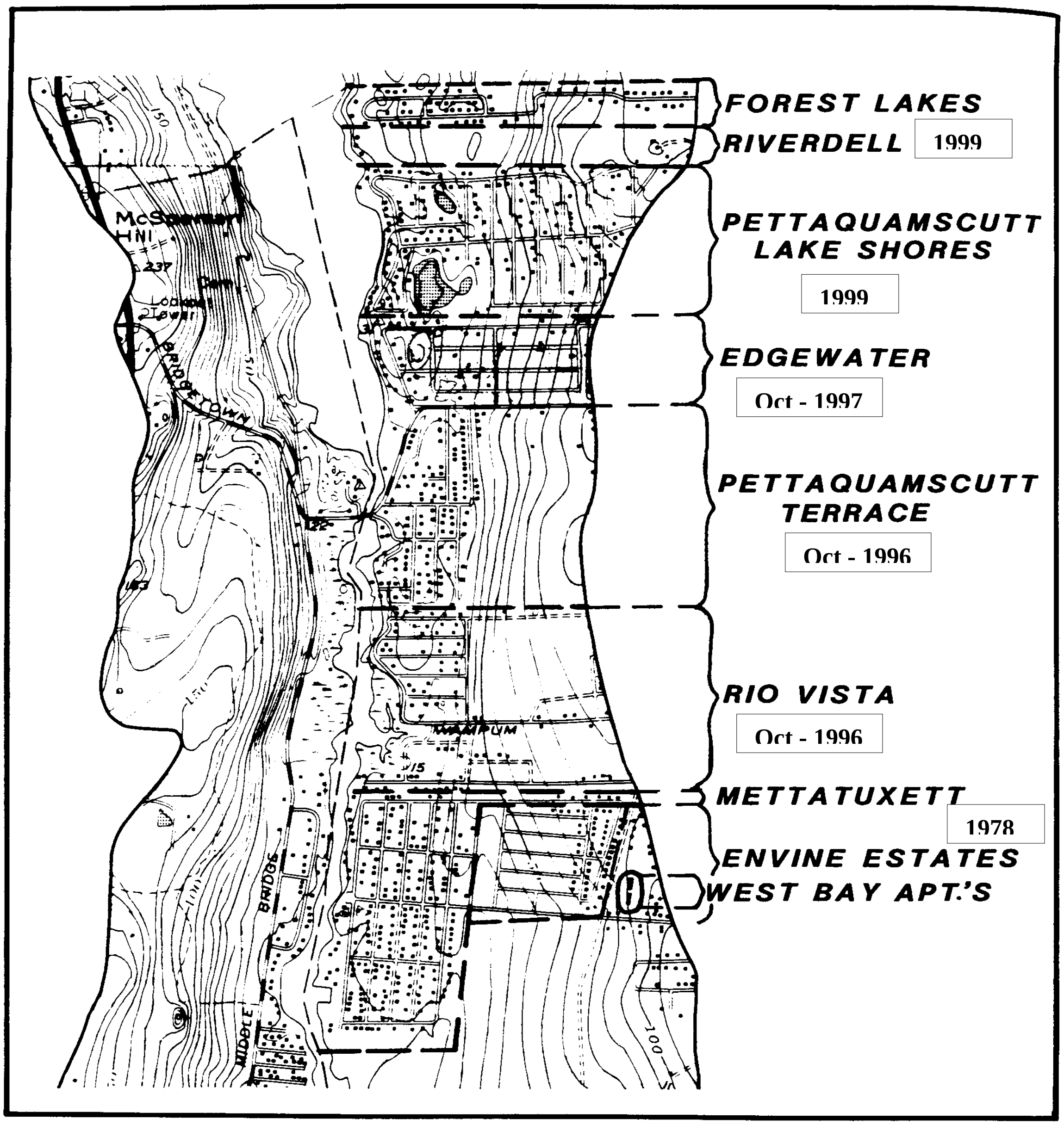


Figure 2.1 Sewering within the Narrow River watershed (ASA, 1995)

2.8 Climate

Temperature and precipitation records are available from the National Weather Service gauge located in Kingston, Rhode Island, a few miles west of the Narrow River drainage basin. Due to the close proximity of the weather station, data from this station are considered representative of the North Kingstown, South Kingstown and Narragansett climate. A United States Geological Survey (USGS) study by Lang (1961) shows a reduction of about 10% in precipitation from the Kingston, Rhode Island Station to the Narrow River area. Temperature and precipitation data from the Kingston weather station are available dating back to 1889. Based on information compiled through 1993 the average annual temperature is 48 degrees F. Precipitation for the area has ranged from a low of 30.7 inches/year in 1965 to a high of 72 inches in 1898, with an annual average of 48 inches.

3.0 DESCRIPTION OF WATER QUALITY MONITORING ACTIVITIES

Many studies have focused on the Narrow River watershed over the past 40 years. Data collected by RIDEM show that total coliform levels in the Narrow River have exceeded state standards since 1959 (CRMC, 1986). Other studies conducted by RIDEM and others in succeeding years (1972, 1974, 1980, 1983, and 1986) have also shown specific locations with consistently high levels of both total and fecal coliform. These locations include Gilbert Stuart Stream, Mumford Brook, Pettaquamscutt Cove, Lacey Bridge, and the Mettatuxet and Middlebridge areas. Past studies have concluded that the primary sources of bacterial contamination within the Narrow River watershed were failed septic systems, and fecal material from both domestic and wild animals (CRMC, 1986). A study by RIDEM, conducted in 1980 and 1982, which involved the sampling of a number of storm drains along the river, also found that these drains were a significant source of bacterial contamination during wet weather.

The readily available information from recent bacterial monitoring of the Narrow River comes from four primary sources. RIDEM's Shellfish Water Quality Monitoring Program has conducted total and fecal coliform monitoring in the river in support of the Shellfish Growing Area Water Quality Monitoring Program since before 1981. The University of Rhode Island's Watershed Watch Program, which has utilized trained volunteers to monitor Narrow River surface water quality several times each year since 1992, provides the second source of fecal coliform data. The third source, one of the most comprehensive studies performed to date, was accomplished as part of the "Narrow River Storm water Management Study Problem Assessment and Design Feasibility" report by Applied Science Associates (ASA), Rhode Island Watershed Watch, SAIC Engineering, Inc., and UWR (Urish, Wright and Runge) completed in 1995. Finally, the most recent watershed information available was obtained through RIDEM's 1999 monitoring program conducted in support of this TMDL.

3.1 Shellfish Growing Area Water Quality Monitoring Program

The Shellfish Growing Area Water Quality Monitoring Program is part of the State of Rhode Island's agreement with the US Food and Drug Administration National Shellfish Sanitation Program (NSSP). NSSP requires Rhode Island to conduct continuous bacteriological monitoring of the state's waters where shellfish is intended for direct human consumption. The Narrow River is designated Growing Area 7-2, shown in Figure 3.1. Based on sampling results, the river was conditionally closed to shellfishing in 1979. Between 1980 and 1985, 24 of 48 samples taken in the river were out of compliance for bacterial contamination. As a result, the river was permanently closed to shellfishing in July of 1986. Permanently closed areas have no NSSP monitoring requirements. Between 1986 and 1997, RIDEM has sampled only four of the original thirteen sample stations, Bridgetown Road Bridge, Mettatuxet Yacht Club dock, Middle Bridge, and Sprague Bridge. Surveys have been timed to follow wet weather events, approximately four times per year between February and November. In 1998 only one warm-weather survey was accomplished and, because of the ongoing TMDL monitoring and the desire to eliminate a repetition of effort, no surveys were accomplished during 1999.

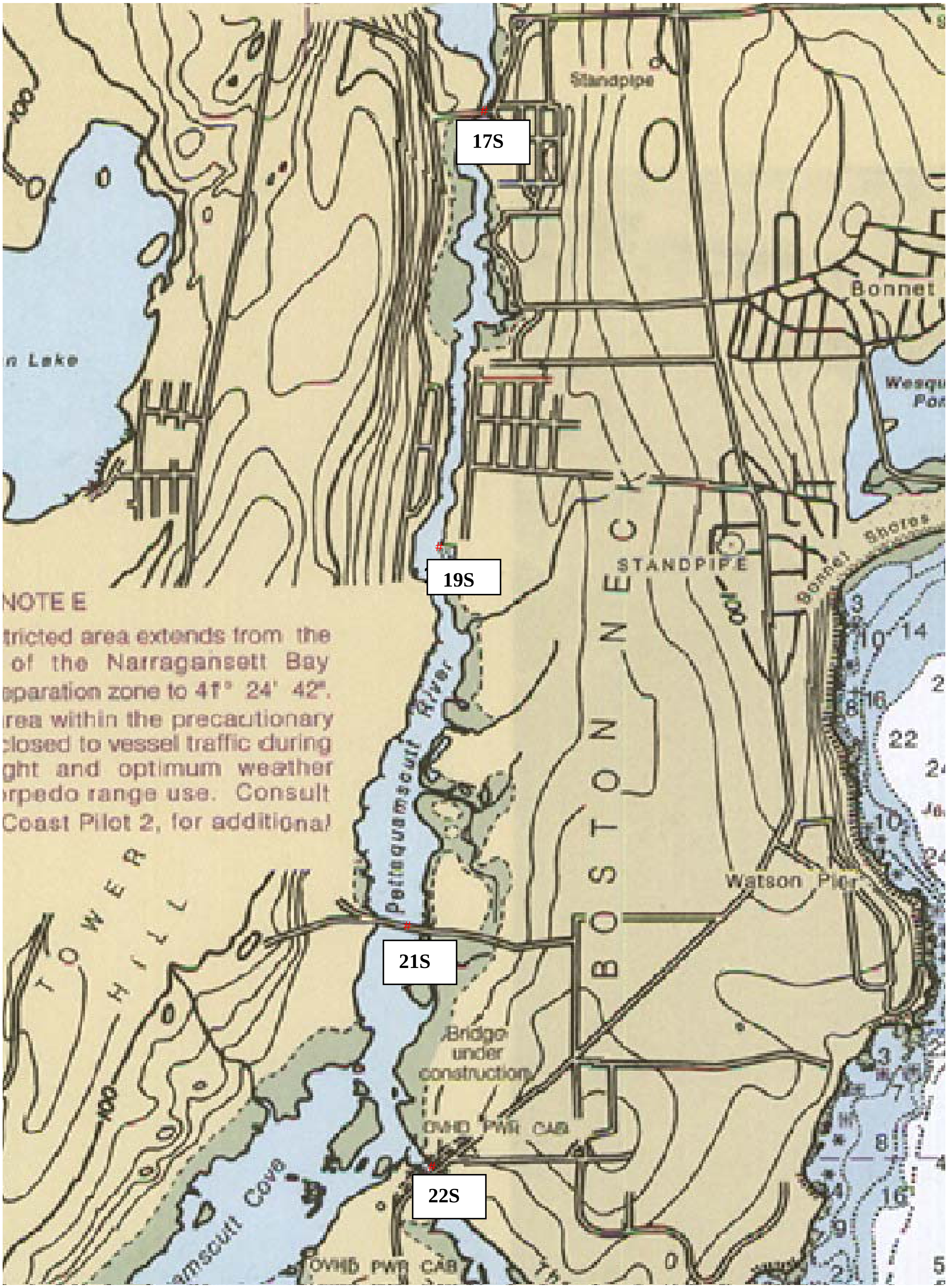


Figure 3-1 Shellfish Growing Area Water Quality Monitoring Stations

3.2 The University of Rhode Island's Watershed Watch Program

The Watershed Watch Program annually trains and organizes volunteers in coordination with the Narrow River Preservation Association (NRPA), to sample the river. Volunteer monitoring began in the watershed in 1992 as an extension of the 1991 Narrow River Storm water Management Project. Initial funding for monitoring was provided through a RIDEM Aqua Fund grant which expired in 1995. Since then, the Narrow River Preservation Association has assumed responsibility for providing volunteers and financial support to continue the monitoring effort.

NRPA sampled ten stations (NR-1 through NR-10) for the 1992 monitoring season. These locations, as shown in Figure 3.2, were selected to supplement or complement locations sampled during the storm water management study. They were also chosen for safety concerns and ease of accessibility. NR-11 in Mettatuxet Brook was added at the start of 1996 sampling season to better characterize pollutant inputs from that source. The monitoring season runs from late April until early November each year.

Water quality monitoring is performed biweekly according to a schedule determined prior to the start of the monitoring season. Monitors make in-situ measurements of dissolved oxygen, salinity, and temperature and collect and filter water samples for subsequent laboratory analysis of chlorophyll at all locations. At several of the deeper stations in Upper and Lower Ponds, water clarity is monitored by making Secchi disk transparency measurements. A suite of water samples is also collected for analysis of fecal coliform and nutrients (total and dissolved phosphorus, nitrate and total nitrogen) on five Saturdays throughout the monitoring season. Collections of these samples are scheduled to be within 1.5 hours after low tide in Narragansett to maximize the detection of pollutant inputs to the river. Since sample timing is predetermined at the start of the monitoring season without regard to weather, a variety of weather conditions are encompassed.

3.3 1995 Narrow River Stormwater Management Study (Tri-Town Study)

Funded by a 1991 grant from RIDEM's Aquafund, the Narrow River Stormwater Management Study was a cooperative effort of the towns of Narragansett, South Kingstown and North Kingstown, the Rhode Island Department of Environmental Management (RIDEM), the Coastal Resource Management council (CRMC), and the Narrow River Preservation Association. The study was initiated in 1992, while the bulk of the fieldwork was performed in 1993. The purpose of this study was to acquire information to accurately assess storm water related water quality problems in the Narrow River and to recommend options and alternatives for the establishment of a comprehensive storm water management plan. The study was comprised of four main tasks: mapping, field data collection/sampling, modeling and engineering. A fifth element of the study included the establishment of a volunteer monitoring program to supplement the dry weather sampling and to provide long-term water quality data.

The monitoring program for the Tri-Town Study consisted of dry weather receiving water sampling, dry weather source sampling and wet weather storm sewer outflow sampling. The dry weather receiving water survey data were used to determine the flushing characteristics and pollutant concentrations in the river. Dry weather source sampling and stream flow data from

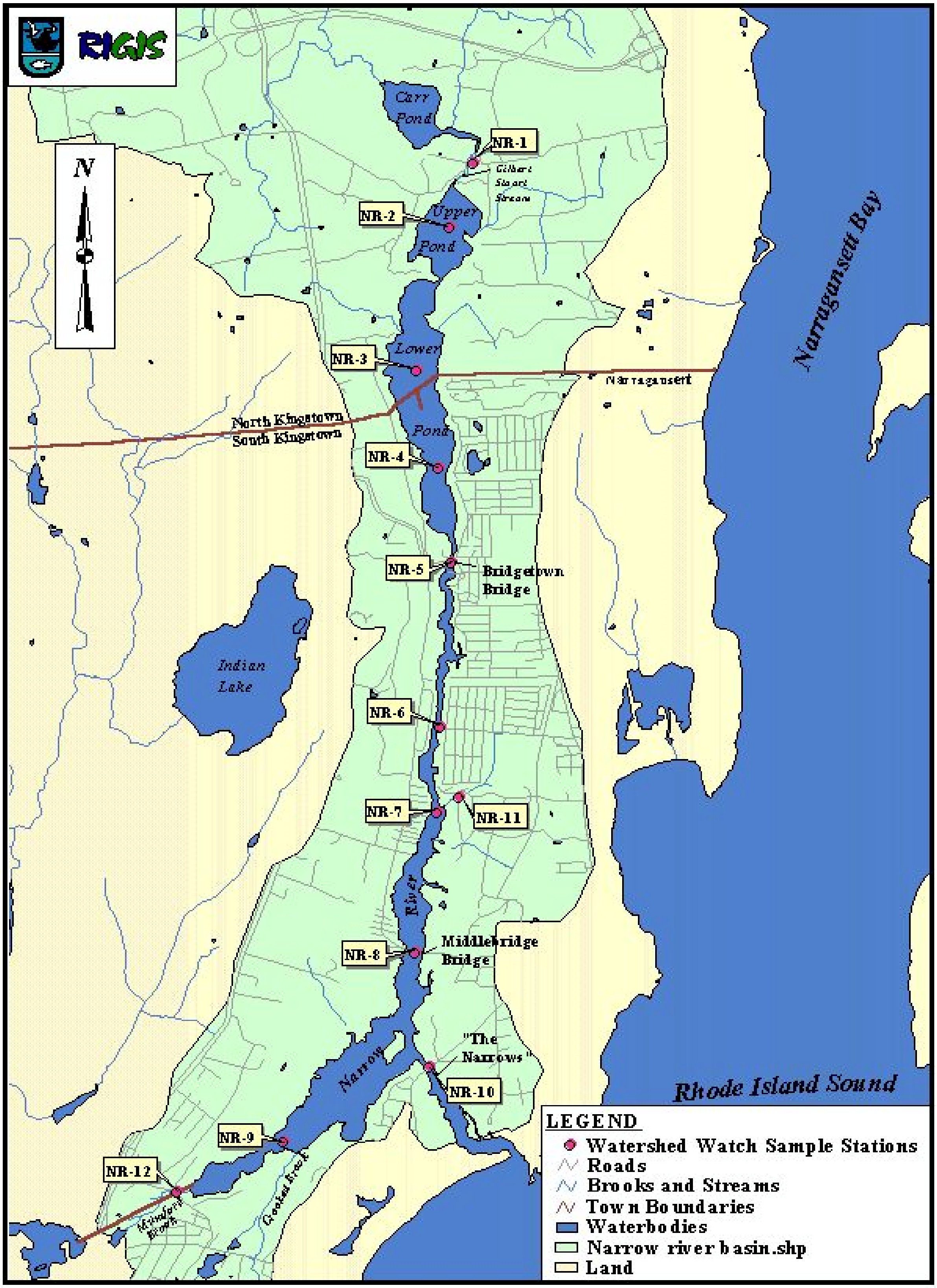


Figure 3.2 Watershed Watch Monitoring Locations

the Citizen's Monitoring Program were used for estimating the quantity and quality of freshwater (ground and surface) inflow to the river. Wet weather sampling data from four selected outfalls were used to estimate the loadings to the river from storm water runoff. The program was designed to provide sufficient data to accommodate watershed modeling efforts to enable an engineering analysis.

3.3.1 Dry weather receiving water monitoring

Receiving water monitoring consisted of water quality sampling and profile measurements at thirteen representative locations along the river and a dye release study. The information obtained from the receiving water surveys was used in combination with the dry weather source data, to determine the flushing characteristics and pollutant concentrations in the river. This information was then input to a computer-simulation model.

Water Quality Monitoring

Four receiving water surveys were accomplished at approximate low tide during the study period. Survey dates were May 16, June 28, August 6, and September 25, 1993 and included 13 sampling stations. At each sampling station, profile measurements were made of salinity, temperature and dissolved oxygen. Unfortunately, bacterial monitoring was restricted to sampling at five locations per survey, so receiving water fecal coliform data obtained through this study was limited.

Dye Study

A dye study was conducted on the reach of the Narrow River between Lacy Bridge and Sprague Bridge on October 11-25, 1993 to determine the flushing characteristics of the region. The study involved injecting a Rhodamine WT tracer dye into the water for a period of two days, then measuring the dilution of the dye with a fluorometer over the course of the following few days.

Prior to the initiation of the dye study, a tide gauge was installed in the river at the intended dye injection site and left in place to monitor water levels throughout the study. The primary sampling transect consisted of eleven stations throughout the study reach. In an effort to understand conditions beyond the study area, a station in Lower Pond was sampled during every survey to evaluate the way in which the pond was acting as a source and sink for the dye.

Dye injection was initiated on slack high water and continued for two days (four full tidal cycles). The first fluorescent dye survey was performed during the first low tide following initiation of dye injection. High and low tide fluorescence surveys were accomplished on the following day and continued for three days following the termination of dye injection. Low tide surveys continued for two additional days. A final low tide survey was conducted four days later.

3.3.2 Dry weather source monitoring

Dry weather loadings were evaluated through a combination of direct measurements and sampling of surface waters and the application of a computer simulation model to predict groundwater contributions. Dry weather sampling efforts were designed to provide adequate data to allow for a determination of surface water loadings and to support validation of the groundwater inflow model.

Groundwater inflow and water quality
The HIM model (DeMeneses, 1990), a surface and groundwater model, was utilized to evaluate freshwater inflows from groundwater to the Narrow River. The model utilizes hydrologic, climatologic, land use and soils data to estimate the quantity and quality of ground and surface water inputs to receiving waterbodies.

Tributary stream flow and water quality
Although the HIM model has the capability to estimate loadings (flows and concentrations) from both surface and groundwater, it was determined that direct measurements of the significant fresh water tributaries would provide more accurate loading data. Ten primary tributary stations, shown in Figure 3.3, were selected for water quality testing and direct stream flow measurements. Five sampling surveys were performed throughout the study to get representative flow for spring, summer and early fall periods.

3.3.3 Wet weather source monitoring

The purpose of the wet weather monitoring program was to obtain sufficient data to calibrate the storm water management model (SWMM) to the watershed. The program was designed to isolate the effects of a discrete event in order to characterize runoff and determine the impact on receiving water quality. The desired rainfall characteristics for monitoring were as follows:

- Minimum rainfall total of 0.5 inches
- Minimum rainfall duration of 6 hours
- Minimum antecedent dry period of 3 days

Wet weather sampling was implemented to determine potential pollutant loadings to the river from storm water discharges. During the Tri-Town Study, Applied Sciences Associates identified a total of 42 municipal storm sewer outfalls in the Narrow River watershed, 23 of which discharge directly to the Narrow River. The 12 largest of these direct discharge outfalls, shown in Figure 3.4, were considered for the sampling program. The remaining 19 outfalls discharge into detention ponds, wetlands or are directed as overland flow with no direct point of discharge to Narrow River.

Due to monetary and personnel constraints, the field sampling program was restricted to the collection of fecal coliform samples and flow measurements at four outfalls, representing some of the largest catchment areas. The outfalls selected were chosen based on accessibility (the ability to access the outfall at all times of the day was required) and flow measurability (stations where flow measurements were difficult and accuracy of the measurement was an issue were not considered). In addition, outfalls with larger drainage areas were given higher ranking while outfalls that were tidally influenced or directly drained wetland areas were not considered. Based on the above criteria, the following stations were selected:

<u>Sampling Station WI - Lakeside Drive</u>
This sampling station, in the northern portion of the river near the southerly end of Lower Pond, is a storm outfall pipe that discharges directly onto the beach on the eastern shore of the river. The outfall services a drainage area of 43.2 acres with 8% covered by impervious surfaces.

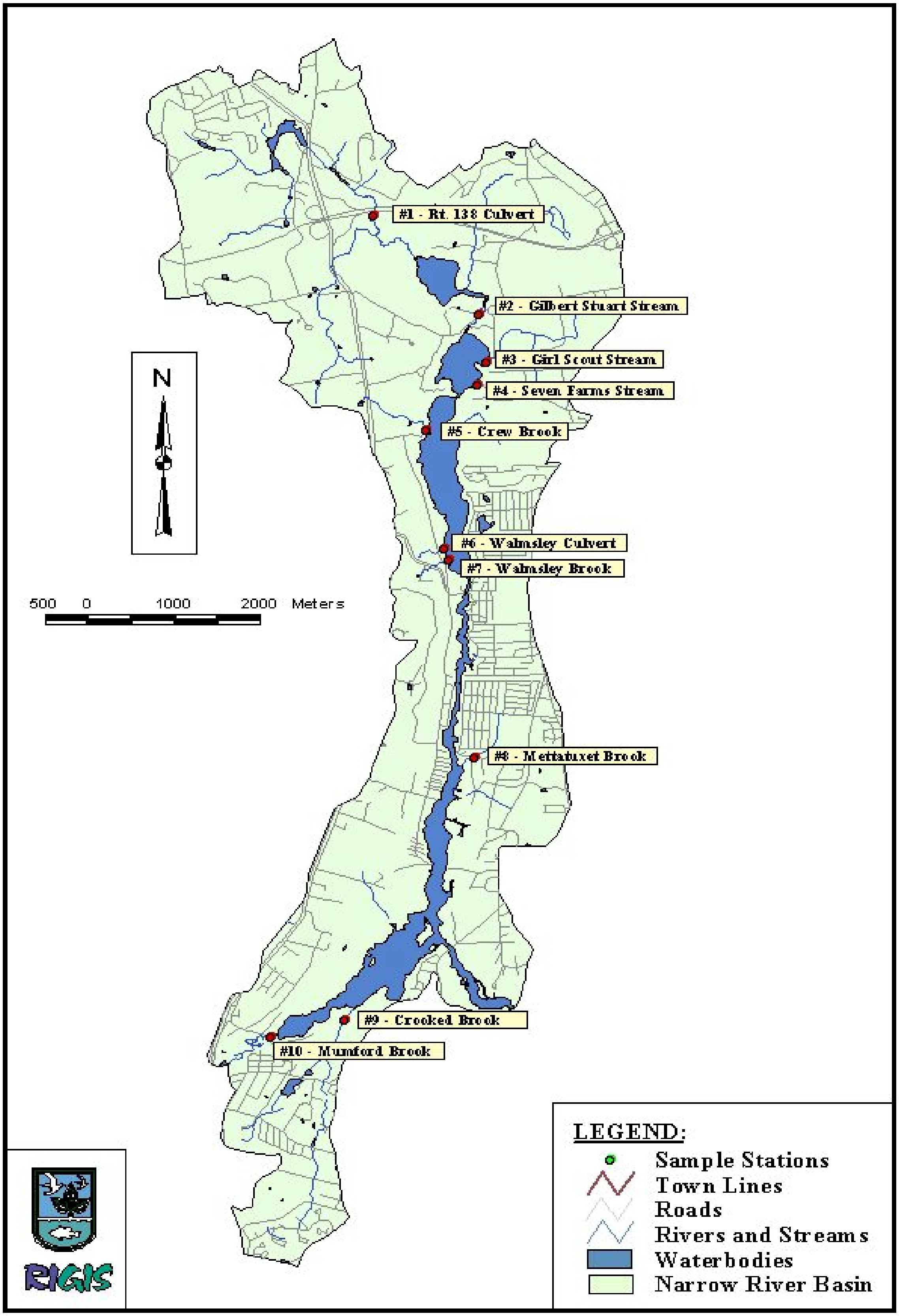


Figure 3.3 Tri-Town Study Tributary Monitoring Locations

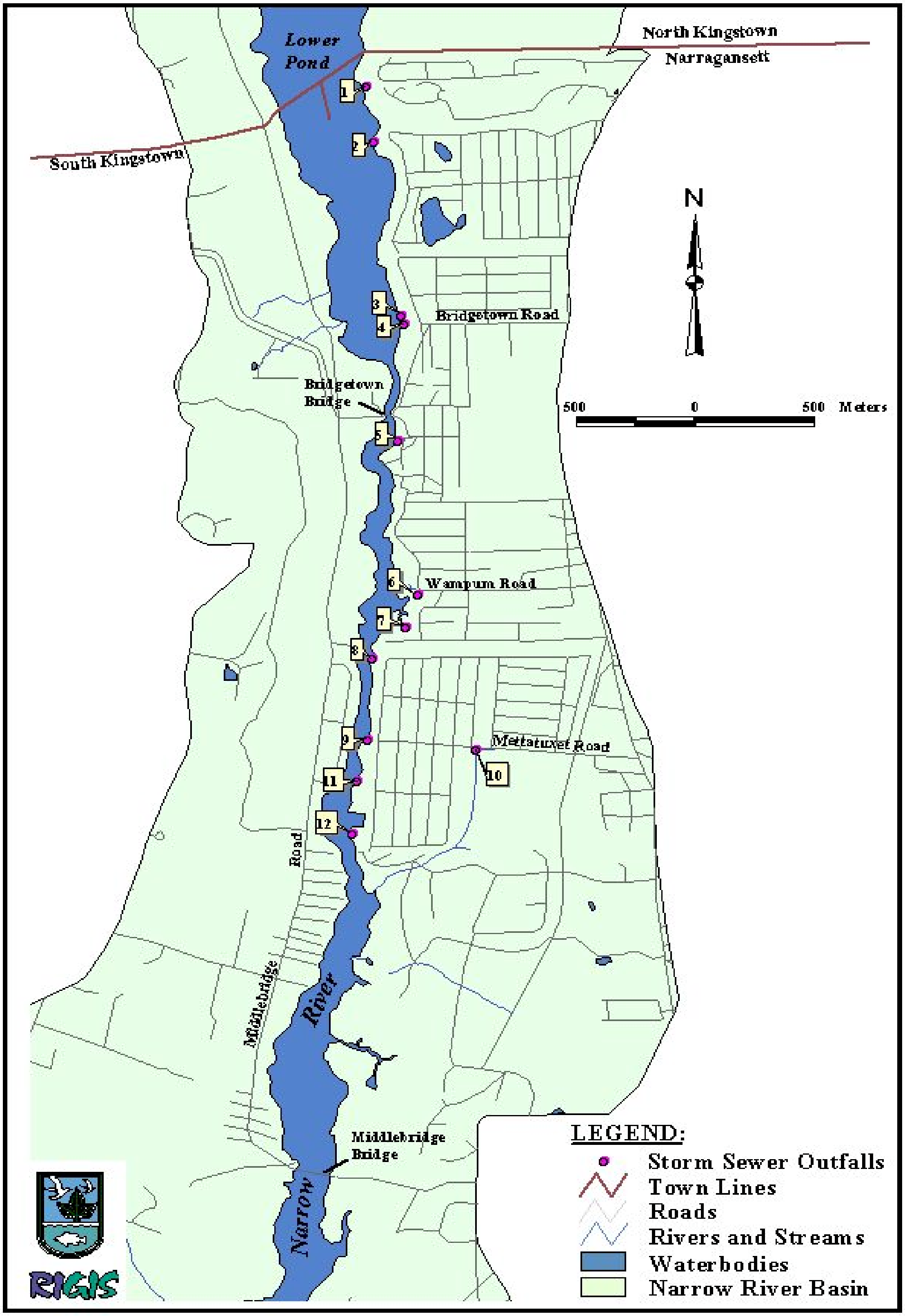


Figure 3.4 Storm Sewer Outfall Locations

Sampling Station W2 - Wampum Road
Sampling Station W2 is a culvert, located near the westerly end of Wampum Road, which discharges to the eastern shore of the river. The drainage area associated with the culvert consists of 81.2 acres, with 5 % covered by impervious surfaces.

Sampling Station W3 - Conanicus Road
This sampling location is located south of Sampling Station W2 near the intersection of Conanicus Road and Circuit Drive. The outfall has a drainage area consisting of 25.7 acres, with 14 % covered by impervious surfaces.

Sampling Station W4 - Mettatuxet Road
Sampling Station W4 is a culvert located at Mettatuxet Road in the heavily developed Mettatuxet residential area of Narragansett. The outfall discharges to Mettatuxet Brook, which flows directly into the river. The drainage area contributing runoff to this culvert is 52.4 acres, with 19 % covered by impervious surfaces.

3.4 RIDEM's 1999 Narrow River TMDL Monitoring Program

The Pettaquamscutt River TMDL monitoring program began June 8, 1999 and continued until November 9, 1999. The program had three goals: (1) to quantify current dry and wet weather bacterial source loadings, (2) to evaluate the impacts of bacterial loadings on receiving water quality, and (3) to provide RIDEM with a means to identify or support remedial initiatives in the Narrow River watershed. Initially four dry weather surveys and two multi-day wet weather surveys were proposed to meet the study goals. Between June and October 1999 seven sampling surveys were accomplished (including three pre-storm wet weather surveys) that met the dry weather criteria and were evaluated as such. Two wet weather surveys were accomplished as proposed, however, because of the unusually dry 1999 summer, suitable storms meeting the desired threshold criteria did not materialize until October. Monitoring locations are shown on Figure 3.5.

3.4.1 Dry weather receiving water monitoring

The dry weather sampling program was designed to provide accurate, current dry weather information regarding bacterial source loadings and corresponding in-stream water quality.
For planning purposes, "dry weather" was defined as:

- Less than 0.03 inches of rainfall during the previous three days (72 hours), and
- Less than 0.5 inches of rainfall during the previous seven days.

The 0.03 inches/3 day criterion is based on the premise that negligible runoff would result from this amount of rainfall. The 0.5 inches/7 day criterion reflects the RIDEM Shellfish Program definition of dry weather conditions.

Seven dry weather surveys of fifteen receiving water stations, listed in Table 3.1 and shown on Figure 3.5, were accomplished over the course of the study. Between Lacey (Bridgetown) Bridge and Middlebridge Bridge, an area of elevated fecal coliform levels, multiple samples were taken across river transects. At six sampling stations: SW-9, SW-11, SW-12, SW-13, SW-

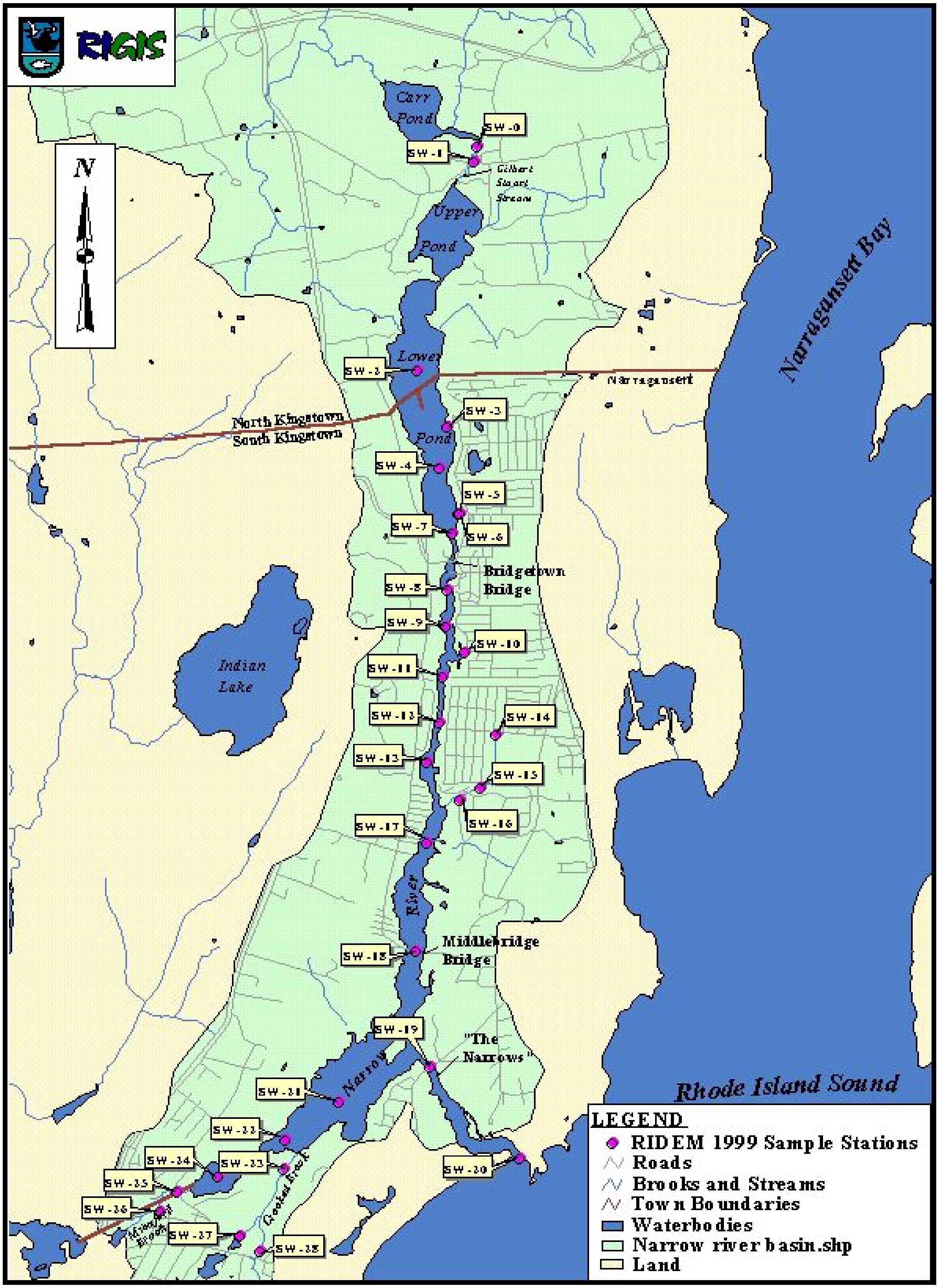


Figure 3.5 RIDEM 1999 Monitoring Locations

17 and SW-18, RIDEM sampled near the east and west river banks in addition to mid-channel in an effort to isolate sources to a particular side of the river. In general, all locations were sampled during ebb tide conditions (within 1.5 hours of low tide) for fecal coliform and monitored for temperature, dissolved oxygen and salinity.

Table 3.1: RIDEM 1999 Narrow River dry weather monitoring stations

Station ID	Location
SW-2	In centerline of Lower Pond just north of Bow Run
SW-4	In centerline of Lower Pond opposite Baneberry Trail
SW-7	In centerline of river at south end of Lower Pond
SW-8	In centerline of river opposite Beach Avenue
SW-9	In centerline of river opposite Iroquois Avenue
SW-11	In centerline of river just upstream of Conanicus Road
SW-12	In centerline of river opposite Checker Berry Road
SW-13	In centerline of river just upstream of Mettatuxet Yacht Club
SW-17	In centerline of river just south of Mettatuxet
SW-18	In centerline of river at Middle Bridge
SW-19	In centerline of river at Sprague Bridge
SW-20	Just outside mouth of Narrow River
SW-21	In centerline of river in northern (widest) portion of Pettaquamscutt Cove
SW-22	In centerline of river in central section of Pettaquamscutt Cove
SW-24	In centerline of river in southern portion of Pettaquamscutt Cove

In Segment 3, between stations SW-9 and SW-12, a small fecal coliform gradient was noted, indicating a possible source from the eastern bank. Five supplemental locations, listed in Table 3.2 and shown in Figure 3.6, were sampled in the immediate vicinity, during a single survey to identify any potential bacteria sources

Table 3.2: RIDEM 1999 Narrow River supplemental dry weather monitoring stations

Station ID	Location
SW-9A	Near east bank south of SW-9
SW-10C	Near east bank in vicinity of Wampum Road
SW-10D	Near east bank in vicinity of Wampum Road
SW-10G	Near east bank in vicinity of Wampum Road
SW-11A	Center of channel midway between SW-11 and SW-12

3.4.2 Wet weather receiving water monitoring

Two multi-day wet weather surveys were accomplished over the course of the study, which included sampling at twelve receiving water stations, listed in Table 3.3 and shown on Figure 3.5. Each survey included sampling before the storm, during the storm and for consecutive days after the storm. It was intended to accomplish post storm sampling for at least three contiguous days following a storm to determine the rate at which the receiving water returns to pre-storm conditions. This was accomplished for Storm #1, but proved impossible for Storm #2 since a second storm passed through the area within 48 hours. In general, all locations were sampled during ebb tide conditions (within 1.5 hours of low tide) for fecal coliform and monitored for temperature, dissolved oxygen and salinity.

The main purpose of the monitoring program was to determine the cause-effect relationship

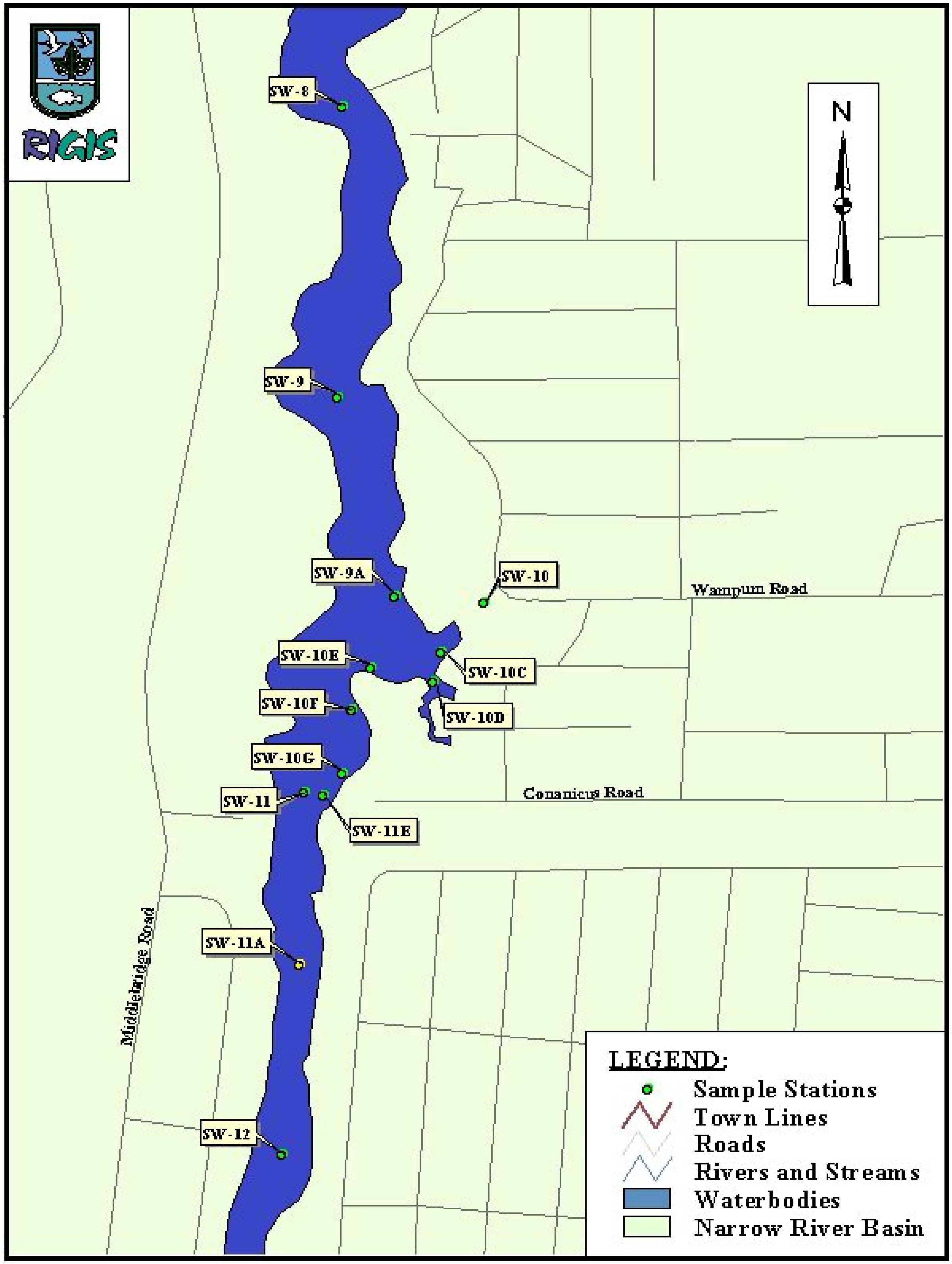


Figure 3.6 Wampum and Conanicus Road Supplemental Sampling Locations

between storm water-related fecal coliform loadings and in-stream water quality and to estimate the recovery rate of the receiving water. For planning purposes, "wet weather" was defined as:

- precipitation of at least 0.5 inches within a 24-hour period and
- an antecedent dry period of at least three days.

The "0.5 inches or greater of rain or snowmelt within a 24-hour period …" definition reflects the RIDEM Shellfish Program criteria for the closing of conditional shellfishing areas. It is based on the premise that sufficient runoff would result from this amount of precipitation to ensure contributions from a majority of the watershed. The antecedent dry period was determined after a review of previous water quality data indicated that three days was sufficient time for in-stream conditions to return to pre-storm conditions.

Table 3.3: RIDEM 1999 Narrow River wet weather monitoring stations

Station ID	Location
SW-2	In centerline of Lower Pond just north of Bow Run
SW-4	In centerline of Lower Pond opposite Baneberry Trail
SW-8	In centerline of river opposite Beach Avenue
SW-12	In centerline of river opposite Checker Berry Road
SW-13	In centerline of river just upstream of Mettatuxet Yacht Club
SW-17	In centerline of river just south of Mettatuxet neighborhood
SW-18	In centerline of river at Middle Bridge
SW-19	In centerline of river at Sprague Bridge
SW-20	Just outside mouth of Narrow River
SW-21	In centerline of river in northern (widest) portion of Pettaquamscutt Cove
SW-22	In centerline of river in central section of Pettaquamscutt Cove
SW-24	In centerline of river in southern portion of Pettaquamscutt Cove

3.4.3 Dry weather source monitoring

Dry weather source monitoring locations were determined after a thorough review of existing water quality data and several watershed reconnaissance visits. The sampling program was designed to provide current estimates of dry weather loadings from all significant sources. To determine bacterial contributions from tributaries, fecal coliform concentrations were measured in the four largest tributaries Gilbert Stuart Stream, Mumford Brook, Crooked Brook and Mettatuxet Brook during each of the seven surveys. The four storm sewer outfalls contributing the largest bacteria loadings during wet weather (as ranked by the Tri-Town Study (ASA et al, 1995)) were also monitored during the study. No dry-weather flow more substantial than a slight trickle was ever noted at any of these outfall locations. Therefore, no dry weather outfall samples were taken during this study.

The dry weather source monitoring stations are listed in Table 3.4 and shown on Figure 3.5. The supplemental monitoring stations were added in Gilbert Stuart Stream and Mumford Brook during the course of the study to further characterize fecal coliform concentrations in known source areas. In general, all locations were sampled for fecal coliform and monitored for temperature, dissolved oxygen, conductivity, and salinity. Discharge was measured at selected, non-supplemental stations as identified in Table 3.4. Since several of the storm sewer outfall and tributary sample locations fell within the tidally influenced zone, sample collection at these locations was conducted during low-tide conditions, or in such a manner that tidal influences were minimized and only fresh source water was obtained.

Table 3.4: RIDEM 1999 dry weather source monitoring stations

Station ID	Location	Description	Fecal coliform measured	Discharge measured
SW-0	Gilbert Stuart Stream – upstream	Tributary	√	
SW-1	Gilbert Stuart Stream – downstream	Tributary	√	√
SW-3	Outfall South of Private Beach on Woodsia Rd	Outfall	No dry wx flow	√
SW-5	Northern Lakeside Pipe Outfall	Outfall	Insuff. dry wx flow	√
SW-6	Southern Lakeside Pipe Outfall	Outfall	No dry wx flow	√
SW-10	Wampum Road Outfall	Outfall	No dry wx flow	√
SW-14	Mettatuxet Brook at Road Outfall– upstream	Outfall/Tributary	√	
SW-15	Middle Mettatuxet Brook	Tributary	√	√
SW-16	Lower Mettatuxet Brook– downstream	Tributary	√	
SW-23	Crooked Brook– downstream	Tributary	√	√
SW-25	Mumford Brook– downstream	Tributary	√	√
SW-26	Mumford Brook– upstream	Tributary	√	
SW-27	Sprague Pond Brook	Tributary	√	
SW-28	Crooked Brook– upstream	Tributary	√	

Supplemental stations in Gilbert Stuart Stream are shown in Figure 3.7, while Mumford Brook stations are shown in Figure 3.8.

Table 3.5: RIDEM 1999 supplemental dry weather source monitoring stations

Station ID	Location	Shown in Figure
F-0	Carr Pond	3.7
F-01	Gilbert Stuart Stream spillway	3.7
F-01A	Groundwater seepage into Gilbert Stuart Stream spillway	3.7
F-02	Gilbert Stuart Stream emergency spillway	3.7
F-15	Middle Mettatuxet Brook just upstream from SW-15 location	not shown
F-25	Mumford Brook at Mumford Road – downstream	3.8
F-25-1	Mumford Brook swamp – downstream west branch	3.8
F-26	Mumford Brook – upstream of swamp	3.8
SW-25A	Mumford Brook swamp	3.8
SW-25B	Mumford Brook swamp	3.8
SW-25C	Mumford Brook swamp	3.8
SW-25D	Mumford Brook swamp	3.8
SW-25E	Mumford Brook swamp	3.8
SW-25-1	Mumford Brook swamp – approximately 50 feet upstream from Mumford Road	3.8
SW-25-2	Mumford Brook swamp – west stream branch	3.8
SW-25-3	Mumford Brook swamp – east stream branch	3.8

3.4.4 Wet weather source monitoring

The wet weather source monitoring conducted during the 1999 RIDEM TMDL study was designed to provide current estimates of wet weather loadings from the largest fresh water tributaries and a representative subset of storm sewer outfalls. The main objectives of the sampling program were to isolate the effects of a discrete rain event for runoff characterization, to validate the previous Tri-Town Study modeling effort and to ensure that current loadings were consistent with those observed during the 1993 sampling program. Sampling locations and intervals listed in Table 3.6 were determined based predominantly on the findings of the Tri-Town Study. To determine bacterial contributions to the Narrow River from tributaries, Gilbert Stuart Stream (SW-1), Mettatuxet Brook (SW-15), Crooked Brook (SW-23) and Mumford Brook (SW-25) were sample during each wet weather survey accomplished. Similar to the Tri-Town Study, storm sewer outfalls at Lakeside Drive (SW-5), Wampum Road (SW-10), and Mettatuxet Road (SW-14) were sampled. The Conanicus Road outfall was not sampled during the RIDEM study because it was not easily accessible and because its catchment area is quite similar to that of the Wampum Road outfall. Because resources were limited, an outfall that discharges to the southern end of Lower Pond in the Pettaquamscutt Lake Shores neighborhood (SW-3) was selected instead. It was felt that this location would to provide better spatial coverage of the watershed.

Table 3.6: RIDEM 1999 wet weather source monitoring stations

Station ID	Location	Sample Type	Time Interval from start of storm (hrs)
SW-1	Gilbert Stuart Stream	Grab	0, 3, 6, 12, 21, 42, 72
SW-3	Pettaquamscutt Shores outfall	Grab	0, 2, 4, 6
SW-5	Lakeside Drive outfall	Grab	0, 1, 2, 3, 4, 6, 12, 21, 30, 42
SW-10	Wampum Road outfall	Grab	0, 1, 2, 3, 4, 6, 12, 21, 30, 42
SW-14	Mettatuxet Road outfall	Grab	0, 2, 6, 21, 42
SW-15	Lower Mettatuxet Brook	Grab	0, 1, 2, 3, 4, 6, 12, 21, 30, 42
SW-23	Crooked Brook	Grab	0, 2, 6, 21, 42, 72
SW-25	Lower Mumford Brook	Grab	0, 1, 2, 3, 4, 6, 12, 21, 30, 42, 72
SW-26	Upper Mumford Brook	Grab	0, 2, 6, 21, 42

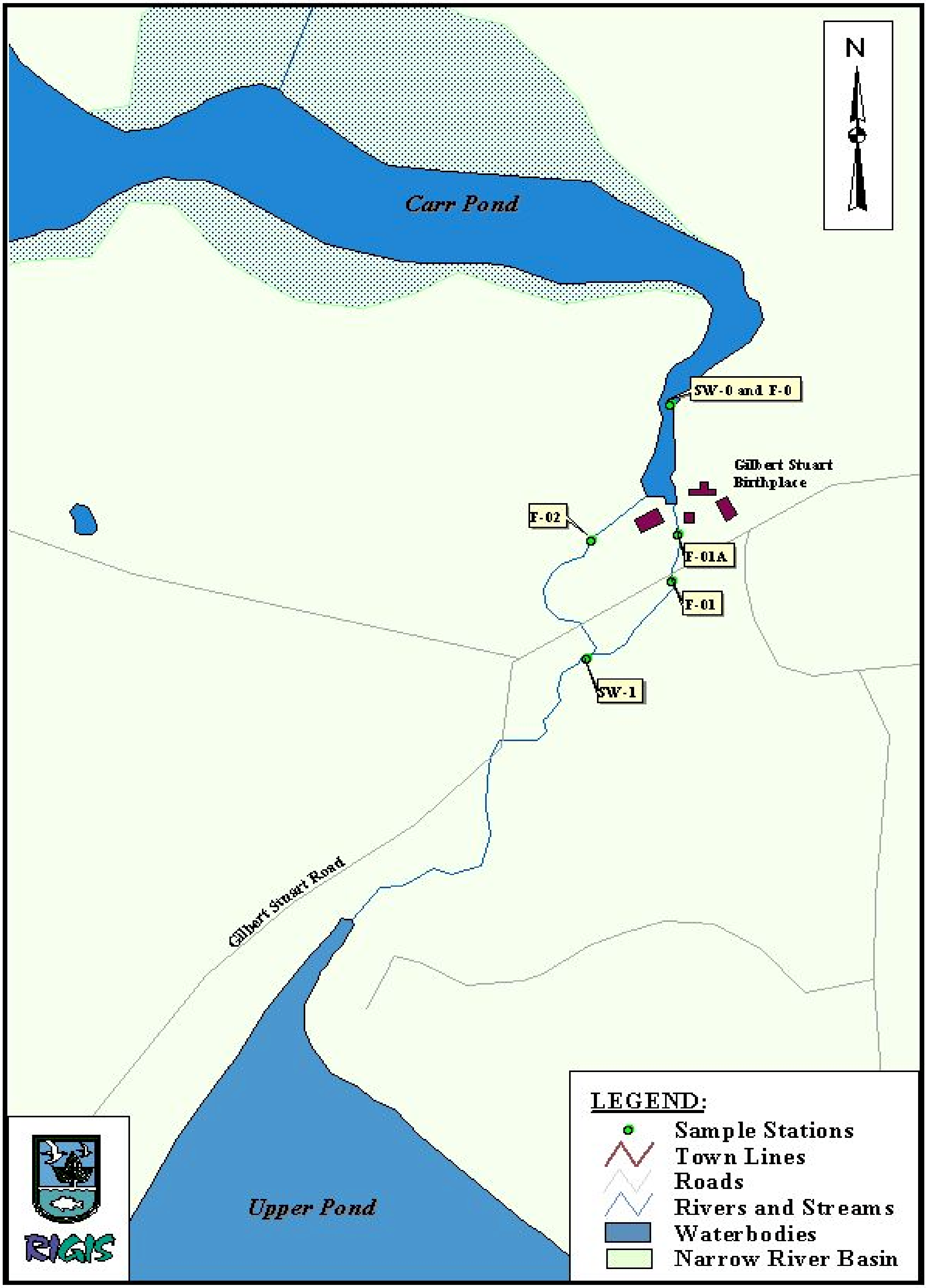


Figure 3.7 Gilbert Stuart Stream Supplemental Sampling Locations

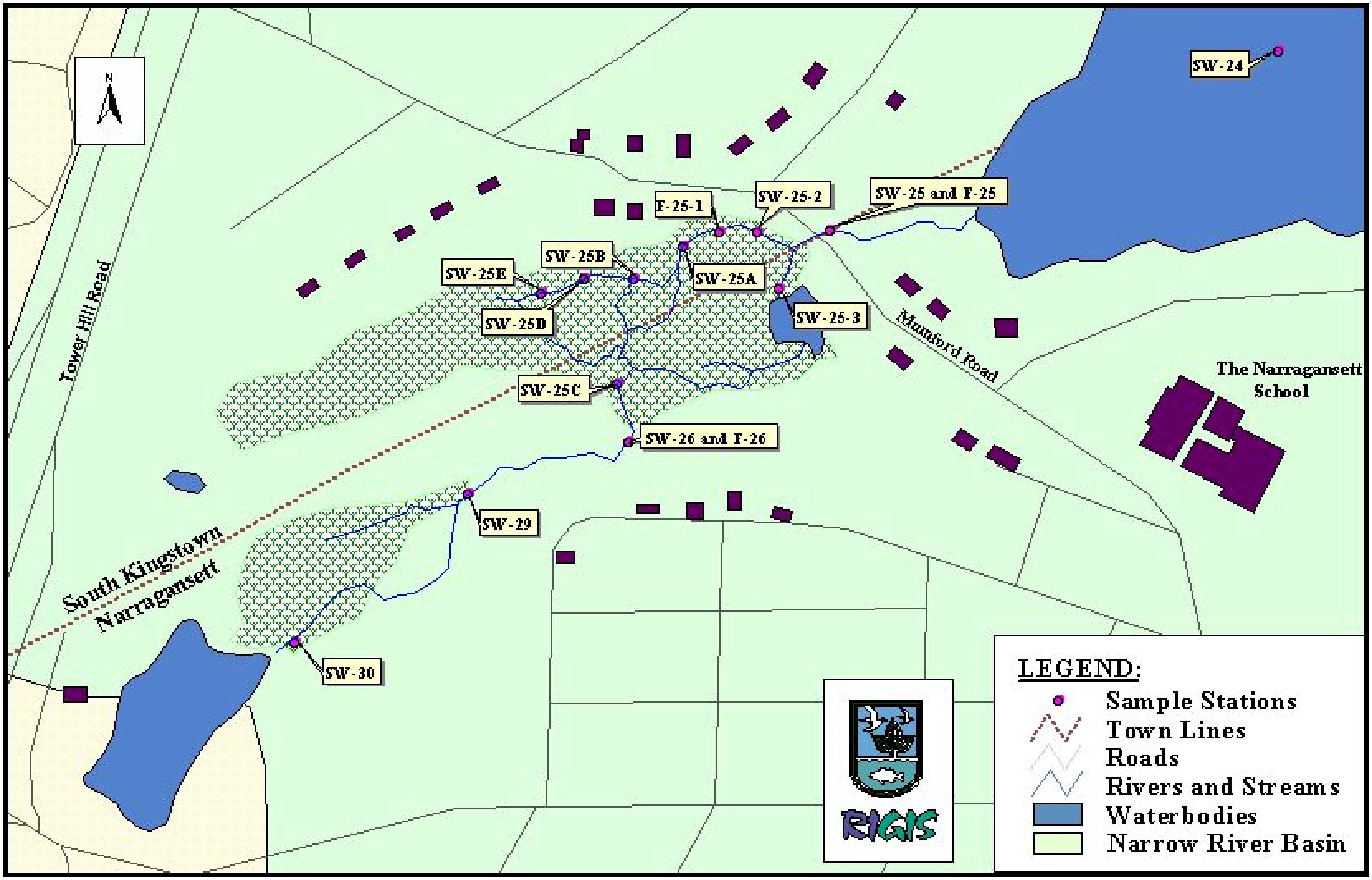


Figure 3.8 Mumford Brook Supplemental Sampling Locations

4.0 NARROW RIVER RECEIVING WATER QUALITY CHARACTERIZATION

4.1 Dry Weather

RIDEM Shellfish Growing Area Water Quality Monitoring Program closed the entire river to shellfishing in 1986 because fecal and total coliform sampling results consistently indicated bacteria levels above state standards. Since 1986, water quality monitoring by the RIDEM Shellfishing Program has typically been timed for wet weather conditions to observe the river during its “worst case” state. As a result no dry weather samples were taken between 1992 and 1997. The dry weather data available from the RIDEM Shellfish Program since 1992 is presented in Table 4.1. Although the data is limited, it appears to support the findings of other studies accomplished in the area. Dry weather concentrations exceed water quality standards for geometric mean concentrations, variability or both at all stations, concentrations peak during the warmest summer months (July through September) and the highest concentrations are found in the middle section of the river near Mettatuxet.

Table 4.1: RIDEM Shellfish Program dry weather water quality data (1992-2000)

Station number	Date	Fecal coliform (MPN)		Station number	Date	Fecal coliform (MPN)
Station 17S at Lacey Bridge				**Station 21S at Middle Bridge**		
17S	07/17/97	230		21S	07/17/97	43
17S	09/16/97	43		21S	09/16/97	43
17S	10/17/97	23		21S	10/17/97	15
17S	04/12/00	4		21S	04/12/00	2
Geometric mean		***31***		***Geometric mean***		***15***
Station 19S at Mettatuxet Yacht Club				**Station 22S at Sprague Bridge**		
19S	07/17/97	430		22S	07/17/97	9
19S	09/16/97	230		22S	09/16/97	93
19S	10/17/97	43		22S	10/17/97	9
19S	04/12/00	9		22S	04/12/00	2
Geometric mean		***79***		***Geometric mean***		***11***

The Watershed Watch data set is more extensive and better suited to analysis. Station geometric means from the dry weather bacteria data from 1992 to 1999 is charted in Figure 4.1. The geometric mean of each station shown in Figure 4.1 is calculated from approximately 14 data points.

Based on this data, violations of the Class SA geometric mean standard for fecal coliform occur only in the river segment near Wampum Road during dry weather. Generally, fecal coliform concentrations are fairly low in Upper and Lower Ponds (geometric mean of 5 fc/100 ml). South of the ponds, concentrations rise gradually to reach a peak slightly above the allowable limit (geometric mean of 17 fc/100mL) in the vicinity of Wampum Road (NR-6). Below Wampum Road, concentrations gradually decrease to a geometric mean of 11 fc/100mL at Middle Bridge (NR-8). Dry weather concentrations in the northern portion of Pettaquamscutt Cove (NR-9) are at the bacteria standard with a geometric mean of 14 fc/100mL then decrease further after encountering the larger dilution volumes and faster flushing rates available in “the Narrows” (NR-10).

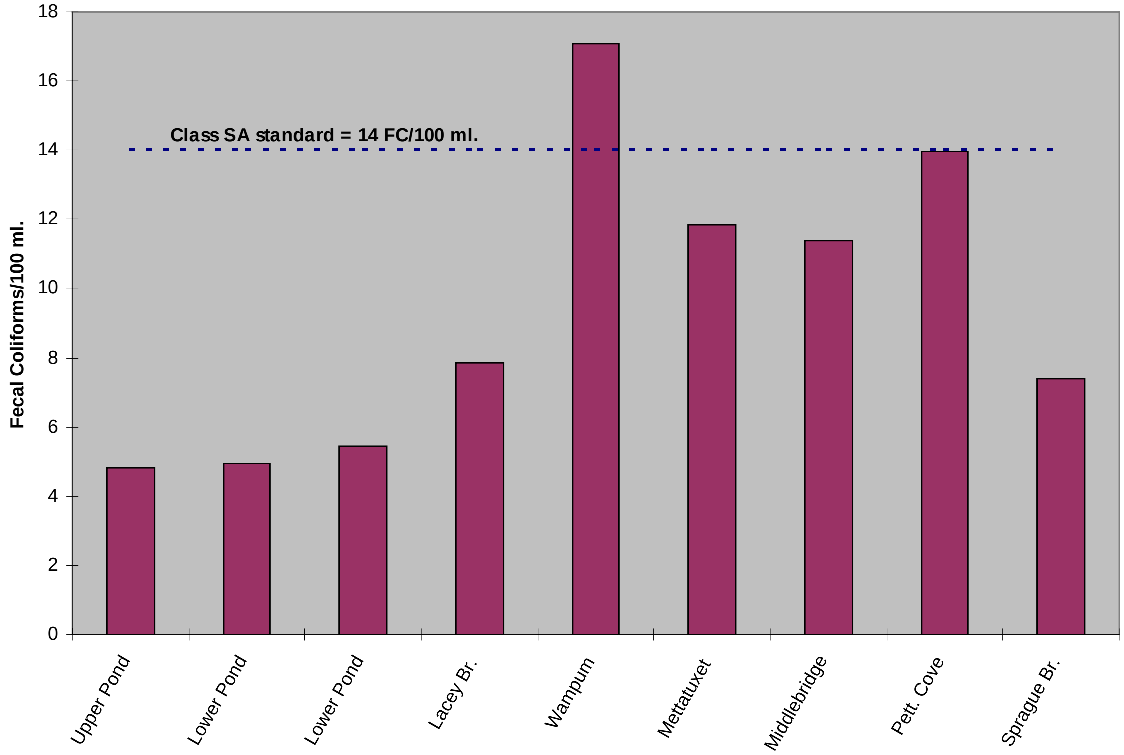


Figure 4.1: Watershed Watch 1992-1999 Dry Weather Results

During the Tri-Town Study, receiving water bacterial monitoring was restricted to sampling at five locations during four surveys accomplished. The limited data is presented in Table 4.2. Because of the limited amount of bacterial data obtained through this study, any substantial conclusions about fecal coliform contamination in the river is prohibited. General observations from the data are that fecal coliform concentrations were consistently highest in Pettaquamscutt Cove and, during the June survey, concentrations at all locations were comparatively elevated. The elevated June concentrations may have been the result of a possible small runoff event triggered by 0.18" of rainfall (recorded by the URI weather station) on June 27th.

Table 4.2: Tri-Town Study receiving water bacterial monitoring data

Station	**Survey Dates**			
	15-May-93	**28-Jun-93**	**6-Aug-93**	**25-Sep-93**
Upper Pond	3	15	< 1	2
Southern Lower Pond	2	15	< 1	< 1
Upper River – Wampum	7	29	< 1	2
Middle Pettaquamscutt Cove	*NS*	*NS*	*NS*	17
Southern Pettaquamscutt Cove	6	110	91	*NS*
Sprague Bridge	4	11	9	4

NS – indicates that the location was not sampled

RIDEM's 1999 dry weather receiving water fecal coliform data are presented in Table 4.3 with station geometric means shown in Figure 4.2. The Narrow River does not meet fecal coliform standards in the heavily developed reach between Conanicus Road southward to Middlebridge Road or in the southern portion of Pettaquamscutt Cove. The data confirm that fecal coliform concentrations are relatively low in the Upper and Lower Ponds (geometric mean of 3 to 4 fc/100 ml) during dry weather. South of the ponds, concentrations begin to rise from a geometric mean of 7 fc/100 ml near Lacey Bridge (SW-8) to a geometric mean of 13 fc/100 ml opposite Conanicus Road (SW-11). Proceeding south from the Conanicus Road area, concentrations gradually increase to exceed the geometric mean portion of the water quality standard, peaking at a geometric mean value of 20 fc/100mL just south of the Mettatuxet neighborhood (SW-17). Below SW-17, concentrations decrease gradually so that concentrations are just above bacteria standards at Middlebridge Bridge (geometric mean value of 15 fc/100mL at SW-18). Below Middlebridge Bridge, concentrations decrease rapidly after encountering the larger mixing volumes and faster flushing rates of the Narrows and upper Pettaquamscutt Cove. The southern portion of Pettaquamscutt Cove is shallow and poorly flushed in comparison to the remainder of the Cove. Concentrations in this area violate the fecal coliform standard with a geometric mean concentration of 26 fc/100mL (SW-24).

Table 4.3: RIDEM dry weather receiving water monitoring data*

Station number	6/23/99	7/9/99	7/22/99	8/20/99	8/25/99	9/15/99	9/29/99
SW-2	4	5	3	2	10	7	1
SW-4	2	4	4	1	2	7	5
SW-7	30	8	7	6	--	--	--
SW-8	4	10	13	2	10	10	11
SW-9	25	8	10	3	--	--	--
SW-9E	--	20	15	2	--	--	--
SW-9W	--	16	10	1	--	--	--
SW-11	33	22	10	4	--	8	18
SW-11E	--	--	17	6	--	13	22
SW-11W	--	--	9	4	--	9	7
SW-12	66	22	21	10	3	15	11
SW-12E	--	36	34	21	--	10	7
SW-12W	--	10	12	6	--	38	14
SW-13	93	21	50	14	10	7	4
SW-13E	--	--	70	17	--	7	6
SW-13W	--	--	60	27	--	8	11
SW-17	110	25	70	15	8	9	6
SW-17E	--	23	--	--	--	--	--
SW-17W	--	35	--	--	--	--	--
SW-18	44	19	24	14	9	8	8
SW-19	14	21	18	12	1	3	10
SW-20	7	10	9	12	7	23	3
SW-21	2	12	1	1	1	7	10
SW-22	5	22	8	6	2	7	6
SW-24	9	52	20	28	1	390	78

* All values are in units of fecal coliforms per 100 milliliters.
-- Indicates that location was not sampled

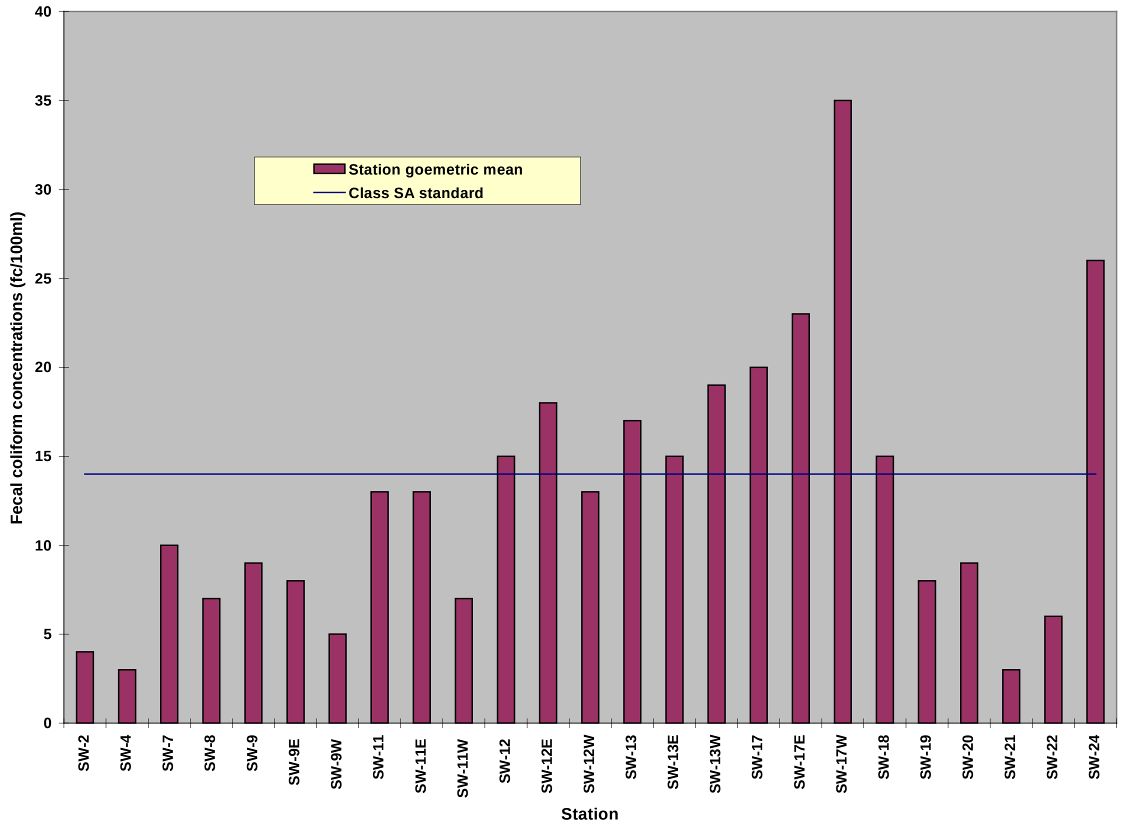


Figure 4.2: RIDEM 1999 Dry Weather Monitoring Results

At several locations between Lacey Bridge and Middle Bridge, a known area of elevated fecal coliform levels, multiple samples were taken across station transects in an effort to isolate sources to a particular side of the river. At selected sample stations in the reach, RIDEM sampled near the east and west banks in addition to mid-channel sampling. In Section 3, between stations SW-9 and SW-12, a small fecal coliform concentration gradient was noted, indicating a possible source from the eastern bank. Supplemental monitoring stations, shown in Figure 3.6, were sampled along the eastern bank in the immediate vicinity to localize any fecal coliform concentration increases. The results of the supplemental monitoring are shown in Table 4.4. No surface water inputs or other likely sources were found in the area. All efforts to identify other potential anthropogenic sources in the reach proved fruitless. Bank-to-bank concentration differences were small, and observed concentrations were sufficiently inconsistent and variable that no identifiable trends emerged.

Table 4.4: RIDEM supplemental dry weather receiving water monitoring data*

Date	SW-9A	SW-10C	SW-10D	SW-10E	SW-10F	SW-10G	SW-11	SW-11E	SW-11A	SW-12
13Oct99	5	4	16	6	11	1	18	6	7	6

* All values are in units of fecal coliforms per 100 milliliters.

4.2 Wet Weather

A wet weather receiving water characterization has been compiled from a number of sources. Monitoring data was considered "wet weather" if at least 0.5 inches of rain had fallen within the previous three days of the sampling date. Wet weather water quality monitoring data available from the RIDEM Shellfish Program since 1992 is presented in Table 4.5. According to this data, the Narrow River violates standards for geometric mean concentrations and variability at all sampling stations during wet weather. Trends observed during wet weather conditions are similar to those observed during dry weather, however, concentrations are consistently much higher. Concentrations peak during the warmest months (July through September) and drop substantially during the colder months between November and April. The highest concentrations are again found in the middle section of the river adjacent to the Mettatuxet neighborhood. To the south of Mettatuxet, concentrations gradually decrease as waters interact with the larger mixing volumes and more rapid flushing rates closer to the river's mouth.

Table 4.5: 1992-98 RIDEM Shellfish Program wet weather monitoring data

Survey date	Fecal Coliforms (MPN/100ml)				Precipitation		Tidal state
	Station 17S	Station 19S	Station 21S	Station 22S	Amount (inches)	Days prior to sampling	
03/09/92	2	2	2	2	0.92	1	Flood
07/16/92	430	930	230	43	0.73	1	High
09/28/92	430	930	43	75	1.35	1	Flood
11/16/92	3	4	15	2	0.92	3	Flood
02/15/93	9	39	9	4	1.94	1	Ebb
07/27/93	230	230	430	93	0.98	.5	Flood
09/22/93	230	9300	230	230	1.00	.5	Ebb
11/01/93	93	43	15	21	0.50	1	Flood
03/29/94	75	43	43	4	1.20	1.5	Ebb
05/25/94	23	43	23	93	1.00	1.5	Ebb
08/22/94	750	430	150	230	1.90	.5	Flood
11/22/94	4	23	93	4	0.70	.5	High
03/01/95	23	9	4	4	1.20	1	Ebb
08/07/95	430	430	150	43	0.93	1	Ebb
10/17/95	23	9	9	9	0.80	3	Ebb
07/15/96	93	230	93	230	3.79	1	High
09/19/96	43	93	150	43	3.05	1	Flood
04/15/97	4	43	2	2	0.95	2	Low
09/10/98	9	9	23	23	0.94	2	Flood
03/24/99	2	4	4	9	0.55	2	Flood
Mean	145	642	86	58			
Geomean	36	61	31	19			

1992 to 1999 wet weather bacteria data available from Watershed Watch, which consists of approximately 10 samples per station, are summarized in Figure 4.3. Based on this data, a violation of the class SA fecal coliform standard occurs in the entire river reach with the exception of the central and upper portions of the Lower Pond. Concentrations in the Upper Pond become elevated above allowable levels with the influence of storm water runoff. In the middle section of Lower Pond, because of the larger dilution volume and longer residence time, concentrations drop to acceptable levels (geometric mean of 10 fc/100 ml). As the river becomes increasingly narrow and shallow south of the ponds, concentrations rise to peak (geometric mean of 54 fc/100mL) in the vicinity of Wampum Road (NR-6), which is well above the allowable limit. Below Wampum Road, concentrations gradually decrease to a geometric mean of 21 fc/100mL at Middle Bridge (NR-8). Wet weather concentrations in Pettaquamscutt Cove (NR-9) are well above the bacteria standard with a geometric mean of 34 fc/100mL. Concentrations remain elevated at Sprague Bridge (NR-10) until encountering the larger dilution volumes and faster flushing rates available in Rhode Island Sound.

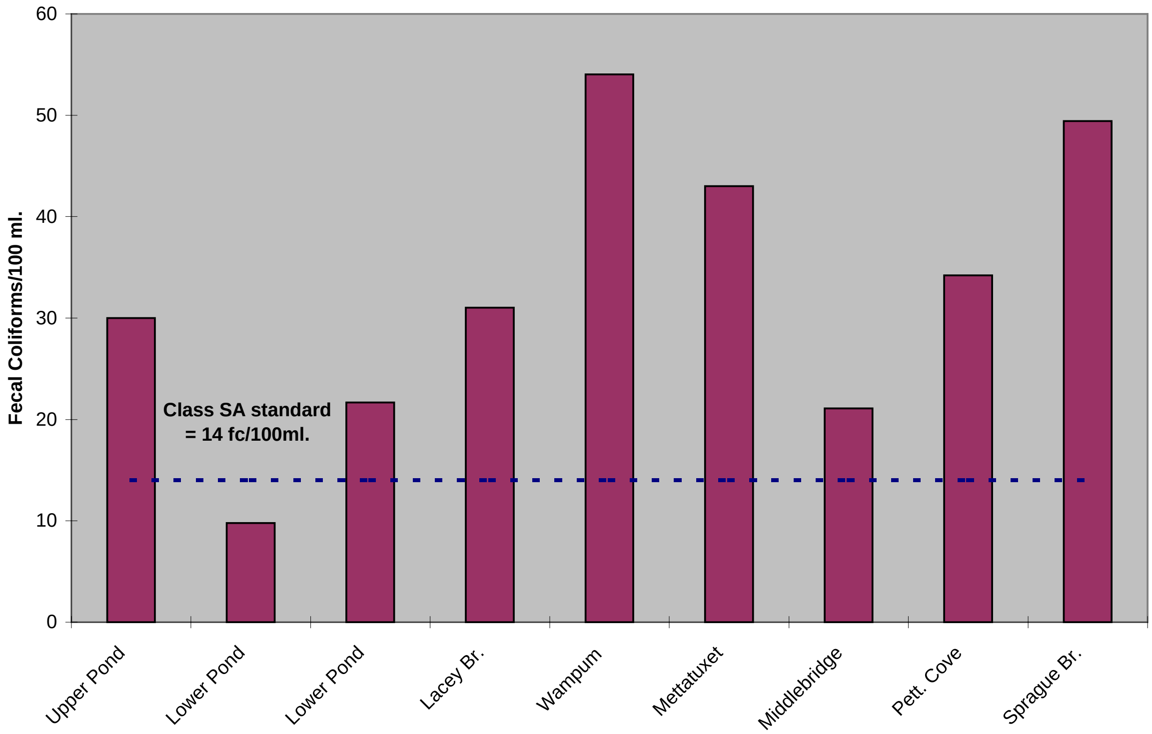


Figure 4.3 Watershed Watch 1992-1999 Wet Weather Monitoring Results

RIDEM's 1999 wet weather receiving water fecal coliform data have been presented in Table 4.6. The results were consistent with the findings of Watershed Watch. According to the data, only the Lower Pond sampling stations met fecal coliform standards during wet weather conditions. Also, dry and wet weather trends were similar with the exception that concentrations were much higher throughout the watershed. Observed fecal coliform concentrations were again fairly low in the Lower Pond (geometric mean of 7-10 fc/100 ml). South of the ponds, concentrations increased rapidly to peak in the vicinity of the Mettatuxet neighborhood (geometric mean of 35-39 fc/100mL). Below the Mettatuxet neighborhood, concentrations decreased gradually to a geometric mean value of 27 fc/100 ml at Middlebridge Bridge. Below the bridge, concentrations remain elevated until reaching Rhode Island Sound. The highest concentrations in the Narrow River during wet weather were consistently found in Pettaquamscutt Cove, especially in the shallow and poorly flushed southern portion. The geometric mean of fecal coliform concentrations in this area was 255 fc/100 ml, which is well above the safe swimming fecal coliform level set at 50 fc/100mL for sea water.

Table 4.6: RIDEM 1999 wet weather receiving water data

Station Number	Fecal Coliforms per 100 ml						
	9/30/99	10/1/99	10/2/99	10/3/99	10/18/99	10/19/99	*Geometric Mean*
SW-2	<1	48	11	3	17	11	*7*
SW-4	5	20	15	1	26	29	*10*
SW-8	520	12	9	9	90	21	*31*
SW-11	1,200	28	4	6	160	28	*39*
SW-12	200	33	9	9	90	39	*35*
SW-13	120	20	8	22	170	40	*38*
SW-18	90	11	16	7	380	10	*27*
SW-19	48	70	7	10	320	31	*36*
SW-20	69	4	15	8	230	17	*22*
SW-21	44	330	18	6	57	47	*40*
SW-22	18	630	18	20	4,300	410	*139*
SW-24	85	1,000	68	62	380	2000	*255*

4.3. Receiving Water Characterization Summary

Water quality in the receiving waters of the Narrow River has been a concern for more than 40 years, since water quality sampling has consistently revealed elevated bacteria levels. After reviewing the available data, several trends emerge. The highest in-stream concentrations have historically been found in the southern portion of Pettaquamscutt Cove. The middle section of the river between Lacey Bridge and Middlebridge Bridge also consistently exceeds allowable limits. Concentrations appear to peak in the warmest summer months, usually August or September, and are highest immediately following a significant rainfall event.

Weighted Geometric Mean Calculation

RIDEM has developed an approach to assessing waterbodies in all conditions by calculating a "weighted" geometric mean (WGM) from available water quality data. Pollutant concentrations in surface waters tend to vary significantly depending on rainfall and runoff conditions. Utilization of the WGM approach allows wet and dry weather data to be synthesized based on the percentage of wet and dry days that occur within the watershed annually so that representative conditions can be compared to regulatory standards. For the purposes of this assessment, the river was divided into six (6) segments, shown in Figure 4.3, having similar properties and assumed constant volumes.

WGM (for each segment) = [(% annual dry weather days) x (Segment dry weather geometric mean)] +

[(% annual wet weather days) x (Segment wet weather geometric mean)]

Initially, the amount of precipitation needed to produce enough runoff to impact water quality in the watershed was determined. Any precipitation event in the watershed that produces this quantity of runoff was considered to cause "wet" weather conditions. Based on Watershed Watch data collected, during the past eight years elevated receiving water concentrations can be expected from a 0.25-inch or greater precipitation event. The frequency of occurrence of 24-hour, 0.25-inch or greater precipitation events on an annual basis was determined using 20 years of rainfall data from the National Weather Service station at T.F. Green Airport (Warwick, RI).

Upon examination of meteorological data, it was determined that wet weather days, as determined above, occur 13.8 percent of the time, and dry weather days occur 86.2% percent of the time. This means that annually, wet weather conditions dominate the watershed approximately 13.8% of the time. The overall percentage of wet weather days was then adjusted to include recovery time (time required for receiving water fecal coliform concentrations to return to either pre-storm levels or to applicable water quality standards).

Analysis of wet weather data for the Narrow River show that typically, two (2) additional days are required for receiving water fecal coliform concentrations to decrease to either pre-storm levels or the Class SA criteria of 14 fc/100mL. Including the two additional recovery days, the percentage was tripled, making the percent of wet weather days equal to 41.4% (13.8% × 3). These values take into consideration wet weather bacteria violations not only for the day of the storm but also for the additional days it takes for the system to recover. Therefore, the percent of dry weather days is 58.6%.

A weighted geometric mean (WGM) calculation for the Narrow River receiving water, as determined from the information above, is shown below.

WGM (for each segment) = [(0. 586) × (Segment dry weather geometric mean)] +

[(0.414) × (Segment wet weather geometric mean)]

Current water quality conditions of each segment were assessed utilizing both dry and the wet weather datasets. The assessment of Segment 1 (Upper Pond) was determined from 1992-1999 NRPA data, since it was the only information available for that reach. The remainder of the watershed was evaluated using the RIDEM's 1999 dataset, because it was the most recent and comprehensive. Wet and dry weather fecal coliform concentration geometric means for each segment were determined by using the highest wet and dry values (shown in bold in Table 4.7), observed in that segment, regardless of specific location. The WGM was then calculated based on the formula above and compared to the geometric mean portion of the fecal coliform standard to determine if the segment was in violation of the standard. 90th percentile values were determined at each sampling station by compiling all observed fecal coliform concentration values and then using the 90th percentile function in Microsoft Excel to determine the value. The highest value calculated within a segment was taken to be the value for that segment. A summary of the geometric mean and 90th percentile values is provided in Table 4.7.

Table 4.7: Receiving water weighted geometric mean summary

Segment number	Station number	Dry weather geometric mean (fc/100mL)	Wet weather geometric mean (fc/100mL)	Segment weighted geometric mean (fc/100mL)	90th Percentile (fc/100mL)
1 – Upper Pond*	NR-2*	***5****	***30****	**15.4***	**45***
2 – Lower Pond	SW-2	***4***	7	**6.5**	**23**
	SW-4	3	***10***		
3 – Upper River	SW-7	10	*NS*	**27.3**	**70**
	SW-8	7	31		
	SW-9	9	*NS*		
	SW-9E	8	*NS*		
	SW-9W	5	*NS*		
	SW-11	13	***39***		
	SW-11E	13	*NS*		
	SW-11W	7	*NS*		
	SW-12	15	35		
	SW-12E	18	*NS*		
	SW-12W	13	*NS*		
	SW-13	17	38		
	SW-13E	15	*NS*		
	SW-13W	***19***	*NS*		
4 – Lower River**	SW-17	***20***	***44***	**29.9**	**88**
	SW-17E	23	*NS*		
	SW-17W	35	*NS*		
	SW-18	15	27		
5 – Pettaquamscutt Cove	SW-21	3	40	**120.8**	**454**
	SW-22	6	139		
	SW-24	***26***	***255***		
6 – The Narrows	SW-19	8	***36***	**20.2**	**70**
	SW-20	***9***	22		

Numbers *italicized* in **bold** were used to calculate segment WGM.
NS – indicates that sample location was not sampled during wet weather conditions
* - Value was obtained from 1992-99 Watershed Watch data
** - Dry weather geometric mean value of 20 fc/100mL at SW-17 was used for this segment, since the higher 35 fc/100mL at SW-17W was based on a single sample and was not considered representative

5.0 SOURCE CHARACTERIZATION

5.1 Dry Weather

Information regarding the loadings from tributaries, storm sewers and other sources is available from Watershed Watch's annual water quality monitoring, sampling performed in support of the Tri-Town Study and RIDEM's 1999 TMDL monitoring. Watershed Watch samples Gilbert Stuart Stream and Mumford Brook approximately 5 times annually. The 1992-1999 Watershed Watch dry weather sampling results are shown below in Table 5.1. The data indicate that both tributaries violate fecal coliform geometric mean and variability standards. Gilbert Stuart Stream concentrations are quite variable with no significant trend observed. Watershed Watch added the Mettatuxet Brook station during the 1996 sampling season. Since 1996, fecal coliform concentrations in the brook have exceeded acceptable levels during every sampling survey. In general, concentrations in the brook are lowest during the early Spring and late Fall sampling surveys and highest during the warmest summer months. The summer month sampling of Mettatuxet Brook occurs when the flow of the brook has essentially stopped and the volunteers are collecting water from pools of stagnant water. The Tri-Town study reports that the discharge of the Brook is below 0.01 cfs for all dry weather measurements made between the beginning of July and early September during 1993. The Brook ran dry between July and August during the 1999 TMDL monitoring. Mettatuxet is therefore considered to be an insignificant dry weather source during the summer season. Similar results were seen for the other small streams sampled during the Tri-town study: Girl Scout Stream, Seven Farms Stream, Mettatuxet Pipe (aka Mettatuxet Culvert), Wampum Pipe, Lakeside Pipe, and Crew Brook.

Table 5.1: 1992-1999 Watershed Watch dry weather fecal coliform source data

Gilbert Stuart Stream (NR-1)				**Mettatuxet Brook (NR-11)**	
Sample Date	**fc/100mL**	**Sample Date**	**fc/100mL**	**Sample Date**	**fc/100mL**
5/2/92	84	5/11/96	20	5/11/96	22
6/27/92	70	7/20/96	34	7/20/96	6300
8/8/92	100	11/2/96	10	11/2/96	66
9/19/92	35	5/10/97	7	5/10/97	52
11/7/92	17	6/14/97	34	6/14/97	NS
5/1/93	3	6/15/97	NS	6/15/97	100
6/19/93	35	9/6/97	12	9/6/97	NS
7/31/93	14	7/18/98	40	7/18/98	640
6/18/94	NS	9/12/98	16	9/12/98	560
7/30/94	130	10/17/98	12	10/17/98	120
9/10/94	280	5/8/99	90	5/8/99	130
10/29/94	19	6/26/99	2280	6/26/99	670
5/6/95	18	8/7/99	100	8/7/99	580
6/18/95	105	9/18/99	239	9/18/99	2730
7/29/95	12				
9/9/95	22				
Geometric Mean		***Gilbert Stuart – 38 fc/100mL***		***Mettatuxet = 285 fc/100mL***	

NS – indicates that location was not sampled

Ten dry weather source monitoring stations (shown in Figure 3.2) were established in the Narrow River watershed during the 1993 Tri-Town Study monitoring program. Gilbert Stuart Stream, Mumford Brook and Crooked Brook maintained substantial flow throughout the summer season. However, as previously mentioned most of the remaining streams had essentially stopped flowing during the summer and were not considered significant dry weather sources.

A summary of the Tri-Town Study fecal coliform results is provided in Table 5.2. According to the data, Gilbert Stuart Stream was found to have elevated fecal coliform levels between June and September. Mumford Brook consistently had extremely high fecal coliform levels. Concentrations in Crooked Brook, although elevated, were similar to those observed in other natural low-flow freshwater streams.

Table 5.2: Tri-Town Study dry weather source fecal coliform data*

Location	Map Key	Sampling dates					*Geometric Mean*
		4/21/93	5/15/93	6/28/93	8/6/93	9/25/93	
Route 138 culvert	1	20	53	190	60	83	*63*
Gilbert Stuart Stream	2	8	18	46	32	20	*21*
Girl Scout Stream	3	1	*ND*	850	160	58	*53*
Mettatuxet Road outfall	4	48	40	2900	1300	440	*317*
Wampum Road outfall	5	*ND*	4	7900	780	440	*323*
Lakeside Drive outfall	6	2	2	1400	120	300	*46*
Crooked Brook	7	9	8	660	500	340	*96*
Mumford Brook	8	280	780	12000	29000	23000	*4452*
Walmsley Brook	9	5	14	380	57	140	*46*
Crew Brook	10	62	*ND*	7	9	720	*41*

* All values are in units of fecal coliforms per 100 milliliters.
ND indicates that fecal coliform was not detected

A summary of the 1999 RIDEM fecal coliform data for dry weather sources is presented in Table 5.3. In dry weather conditions, every tributary sampled exceeded the fresh water fecal coliform standard for Class A waters of 20 fc/100mL. Gilbert Stuart Stream, which discharges to Upper Pond, is the largest tributary to the river and the second largest contributor of fecal loadings. Concentrations in the stream ranged from a low of 7 fc/100mL to a high of 5700 fc/100mL with a geometric mean of 182 fc/100mL. Mumford Brook, which discharges to the southern end of Pettaquamscutt Cove, is the second largest tributary to Narrow River. However, it is the largest contributor of fecal coliform loadings. It consistently had the highest fecal coliform concentrations with an unusual low of 28 fc/100mL, a high of 37,000 fc/100mL and a geometric mean of 4,966 fc/100mL. Crooked Brook, which also discharges to Pettaquamscutt Cove, is the third largest tributary source of fecal coliform. Concentrations in the brook ranged from a low of 140 fc/100mL to a high of 3,700 fc/100mL with a geometric mean of 527 fc/100mL. Mettatuxet Brook (Mettatuxet Road outfall), located in the middle section of the river, also consistently exhibited fecal coliform concentrations well above the allowable limit with a low of 390 fc/100mL, a high of 1900 fc/100mL and a geometric mean of 631 fc/100mL. Flow in the brook, however, was extremely low or nonexistent during the course of this study. Therefore, Mettatuxet Brook is reasonably assumed to have no measurable dry weather impact on the Narrow River.

The results of RIDEM's supplemental monitoring to identify sources to Mumford Brook and Gilbert Stuart Stream are presented in Table 5.4. The data confirms the presence of a significant fecal coliform source to Mumford Brook in close proximity to East Narragansett Avenue in South Kingstown. Supplemental sampling at Gilbert Stuart Stream provided no additional insight to a local fecal coliform source. The low concentrations measured at Gilbert Stuart Stream during the supplemental sampling were most likely due to the timing of the survey. The Gilbert Stuart Birthplace Museum was closed for the season and use of the suspected outhouse had stopped. The lower concentrations observed at all monitored locations during the November surveys were expected since concentrations typically decline rapidly with the advent of colder weather.

Table 5.3: RIDEM 1999 dry weather source monitoring data*

Station	**Gilbert Stuart Stream**		**Mettatuxet Brook** (Mettatuxet Road outfall)			**Crooked Brook**	**Mumford Brook**		**Sprague Pond**	**Upper Crooked**
	SW-0	**SW-1**	**SW-14**	**SW-15**	**SW-16**	**SW-23**	**SW-25**	**SW-26**	**SW-27**	**SW-28**
6/23/99	NS	400	20	740	510	630	4,900	220	10	440
7/9/99	10	100	*NF*	*NF*	1900	3,700	7,200	290	10	600
7/22/99	*NS*	370	*NF*	*NF*	390	1,100	6,500	110	100	700
8/20/99	40	1,100	1,000	*NF*	420	200	6,200	160	6	100
8/25/99	*NS*	5700	*NF*	*NF*	*NF*	300	28	310	*NS*	*NS*
9/15/99	7	7	*NF*	*NF*	*NF*	140	37,000	310	*NS*	*NS*
9/29/99	5	10	*NF*	*NF*	*NF*	*NS*	16,000	750	*NS*	*NS*
10/8/99	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	6,000	330	*NS*	*NS*
10/13/99	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	13,000	*NS*	*NS*	*NS*
Geomean	***11***	***182***	***141***	***740***	***631***	***527***	***4966***	***268***	***16***	***369***

* All values are in units of fecal coliforms per 100 milliliters.
NF - Indicates that the tributary stream was either not flowing or dry at sample location
NS - Indicates that location was not sampled

At the time of the October 8, 1999 supplemental sampling survey of Mumford Brook, upstream concentrations in the area of the brook that RIDEM judged to be unaffected by anthropogenic fecal coliform sources, are between 310 fc/100mL and 340 fc/100mL, as indicated by the concentrations at SW-26 (Table 5.3), SW-25B, SW-25C, SW-25D, and SW-25E. Concentrations increased to 1,500 fc/100mL closer to Mumford Road (SW-25A) and peaked at 6,000 fc/100mL at Mumford Road (SW-25 (Table 5.3)). During the October 13, 1999 survey, the source to Mumford Brook was isolated to the western channel of the brook that most closely approaches the abutting homes in South Kingstown.

Table 5.4: RIDEM 1999 TMDL supplemental dry weather source monitoring data*

Station	**Mumford Brook Swamp**							
	SW-25A	SW-25B	SW-25C	SW-25D	SW-25E	SW-25-1	SW-25-2	SW-25-3
10/8/99	1500	340	340	310	310	*NS*	*NS*	*NS*
10/13/99	*NS*	*NS*	*NS*	*NS*	*NS*	10,000	16,000	780

Station	**Gilbert Stuart Stream**				**Mumford Brook**		
	F-0	F-01	F-01A	F-02	F-25	F-25-1	F-26
11/9/99	16	10	5	13	820	310	17

* All values are in units of fecal coliforms per 100 milliliters.
NS Indicates that location was not sampled

At the time of the November 9, 1999 survey, fecal coliform concentrations were substantially diminished at all locations. Upstream (assumed background) fecal coliform concentrations are approximately 17 fc/100mL based on the value at F-26 (same location as SW-26). The results confirm that the fecal coliform source is located along the western channel of the brook. The most likely source of these consistently very elevated concentrations is a failing septic system in close proximity. Based on a simple mass-balance approximation, the bacteria loading from this source is sufficient to degrade water quality in Pettaquamscutt Cove.

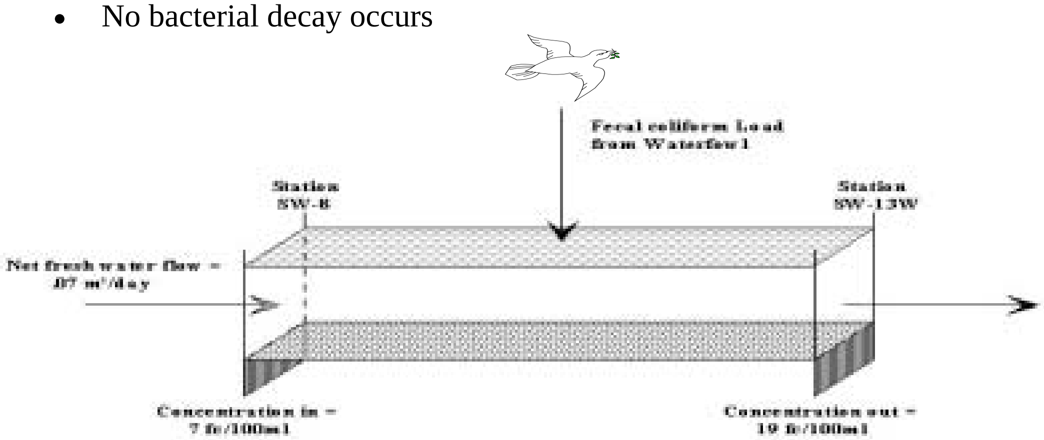
Sources to the Upper River (Segment 3)
In segment three in the river's middle section, fecal coliform concentrations increase from 7 fc/100mL at SW-8 to 19 fc/100mL at SW-13W. Field investigations determined that no dry weather point sources or tributaries discharged to the river anywhere along this reach during the course of the monitoring program. RIDEM staff did observe the continuous presence of a significant number of birds and a considerable amount fecal material on nearby docks and lawns.

In an effort to determine if waterfowl alone could be causing an impairment of the reach, RIDEM performed the following calculation:

Load = [(Concentration out – Concentration in) × Net flow]

Based on the following assumptions:

- Net freshwater flow through the reach is constant (tributary sources in the reach do not significantly add to the net flow)
- No bacterial decay occurs



The 1999 RIDEM monitoring data provided the following information:

- At the upstream boundary to the reach, sampling station SW-8 has a geometric mean fecal coliform concentration of 7 fc/100mL.
- At the downstream boundary, station SW-13W has a fecal coliform concentration geometric mean of 19 fc/100mL.
- The typical freshwater flux (net flow) through the reach during summer months is 0.07 m^3/s (ASA et al, 1995).

[Conversion factor]

$$\textbf{Load} = [(19\ \text{fc/100mL} - 7\ \text{fc/100mL}) \times .07\ m^3/s] \times \mathit{8.64 \times 10^8} = 7.3\times10^8\ \text{fc/day}$$

Waterfowl contributions to the Upper River (Segment 3) were estimated based on the observed differences in fecal coliform concentrations and the typical net freshwater flux (flow) through the reach during the summer season. The loading to the river segment was calculated to be approximately 7.3 x 10^8 fc/day. One duck or swan emits 10^9 fc/day (Hussong et al, 1979; Metcalf and Eddy, 1991) while, depending on the source, one goose emits between 10^8 fc/day (Hussong et al, 1979) and 10^9 fc/day (LIRPB, 1982). The loading to this segment of the river, therefore, was less than the daily fecal coliform emission from one duck or swan or several geese. The calculated loading is consistent with the number of birds typically observed in the segment. In the absence of other identified sources, it has been deduced that waterfowl cause this elevation.

5.2 Wet Weather

Both the Tri-Town Study and RIDEM's 1999 TMDL characterized wet weather fecal coliform loadings to the Narrow River. The Tri-Town Study focused on storm sewer outfall discharges, while RIDEM broadened the scope of its monitoring to include storm sewer outfall and tributary discharges. During the Tri-Town Study, fecal coliform concentrations were measured during four rain events at four representative direct-discharge storm sewer outfalls (Lakeside Drive, Wampum Road, Conanicus Road, and Mettatuxet Brook at Mettatuxet Road) to obtain an estimate of event mean fecal coliform concentrations from these sources.

Results from the Tri-Town Study monitoring show that fecal coliform concentrations are very high (two to three orders of magnitude above RIDEM standards) in roadway runoff at every location monitored. Station W4 at Mettatuxet Brook had the highest count of 100,000 fc/100mL during Storm 2. Station W3 at Conanicus Road and Circuit Drive had the highest fecal coliform levels during Storm 1 (91,000 fc/100mL) and Storm 4 (34,000 fc/100mL). Sampling Station W1 showed the highest fecal coliform counts during Storm 3 with a maximum concentration of 30,000 fc/100mL. As can be seen from the data in Table 5.5, pollutant loadings at each location can fluctuate significantly throughout a single runoff event and are highly variable from storm to storm.

The event mean concentrations (EMC) for fecal coliform are given in Table 5.6. The EMC was calculated by integrating the mass loading curve for storm loads and dividing this value by the volume of storm water. It is obvious from the data that fecal coliform concentrations observed during Storm 1 were similar to those seen during Storm 2, and concentrations observed during Storm 3 were similar to those seen during Storm 4. The measured event mean concentrations were quite variable most likely due to variations in storm duration and peak rainfall intensity. The intensities of Storms 1 and 2 were 0.49 and 0.41 in/hr, respectively, and for Storms 3 and 4 were 0.15 and 0.21 in/hr, respectively. Since the design storm, as defined a more conservative (i.e. higher) estimate of the area's pollutant loadings. For these reasons, the fecal coliform average EMC of Storms 1 and 2 were extrapolated to other catchment areas with engineered controls. A listing of the twelve largest contributing storm sewer outfalls as determined by this study is presented in Table 5.7.

Table 5.5: Tri-Town Study wet weather monitoring data

Location	STORM 1 27 July 1993		STORM 2 26 September 1993		STORM 3 27 October 1993		STORM 4 3 November 1993	
	Time	fc/100 ml	Time	fc/100 ml	Time	Fc/100 ml	Time	fc/100 ml
Lakeside Road Outfall	530	62,000	410	1,800	400	660	1600	1,600
	615	50,000	730	1,000	500	23,000	1700	2,600
	945	25,000	800	8,000	800	30,000	1800	6,700
	1100	18,000	830	58,000	930	11,000	1900	1,600
	1200	13,000	900	22,000	1100	7,000	2130	4,800
	1300	17,000	1000	19,000	1200	11,000	2300	11,000
Wampum Road Outfall	545	46,000	750	130	525	130	1815	170
	625	36,000	820	10,000	730	100	1900	210
	1000	14,000	845	6,200	835	1,000	1950	440
	1120	12,000	910	7,000	950	2,700	2040	1,100
	1215	13,000	935	9,800	1050	18,000	2145	1,300
	1320	5,400	1115	25,000	1200	2,900	2250	1,600
Conanicus Road Outfall	550	9,500	807	1,700	420	220	1725	34,000
	630	26,000	840	3,200	745	180	1845	1,300
	1020	91,000	900	3,500	845	470	1930	1,300
	1135	37,000	925	5,300	1005	590	2015	770
	1230	25,000	1010	6,400	1100	580	2145	830
	1330	25,000	1125	5,600	1215	470	2255	1,600
Mettatuxet Road Outfall	600	22,000	735	1,200	330	2,200	1455	190
	645	26,000	830	100,000	430	11,000	1615	1,200
	1030	16,000	900	14,000	730	5,300	1800	25,000
	1145	5,100	930	19,000	830	29,000	2000	18,000
	1245	8,000	1000	30,000	930	14,000	2100	13,000
	1345	4,100	1030	27,000	1230	15,000	2300	10,000

Table 5.6: Tri-Town Study event mean concentrations

EMC (fc/100mL)				Average EMC (fc/100mL)	
Storm 1	Storm 2	Storm 3	Storm 4	All Storms	Storms 1 and 2
22,000	16,000	4,200	5,400	12,000	19,000

RIDEM's 1999 TMDL study monitoring data from Storm #1 and Storm #2 are provided in Tables 5.8 and 5.9, respectively. Measured concentrations were highest at the Wampum Road outfall (SW-10) during Storm 1 with a peak concentration of 90,000 fc/100mL and highest at the Pettaquamscutt Lake Shores outfall location (SW-3) during Storm 2 with a peak concentration of 34,000 fc/100mL. In general, fecal coliform concentrations at every outfall location monitored were quite variable and at least two to three orders of magnitude above RIDEM standards for the receiving water. Observed fecal coliform concentrations were significantly higher during the first storm event as compared to the second. This is likely due to the fact that the first storm was a short duration (1.5 hours), high-intensity event with a long antecedent dry period (13 days). The second storm was a longer duration (8.25 hours), lower intensity event with a relatively short antecedent dry period (3 days).

Table 5.7: Estimated fecal coliform loadings from storm sewer outfalls

Rank	**Map ID** (Figure 3.4)	**Location name**	**Discharge volume (m^3/storm)***	**Estimated EMC** (fc/100 ml)**	**Approximate fecal coliform loading per storm event**
1	10	Mettatuxet Road outfall	489.94	19,000	9.3×10^{10}
2	2	Shadbush Trail outfall	226.84	19,000	4.3×10^{10}
3	6	Wampum Road outfall	195.97	19,000	3.7×10^{10}
4	7	Conanicus Road outfall	181.53	19,000	3.4×10^{10}
5	3	Lakeside Drive outfall	172.19	19,000	3.3×10^{10}
6	8	Old Pine Road outfall	170.49	19,000	3.2×10^{10}
7	11	Shagbark Road outfall	132.82	19,000	2.5×10^{10}
8	5	Pettaquamscutt Avenue	116.68	19,000	2.2×10^{10}
9	12	Woodbridge Road outfall	98.84	19,000	1.9×10^{10}
10	1	Indian Trail outfall	95.44	19,000	1.8×10^{10}
11	9	Mettatuxet Beach outfall	81.84	19,000	1.6×10^{10}
12	4	South Ferry Road outfall	43.61	19,000	8.3×10^{9}

* - Based on SWMM storm water runoff model assuming a 0.5-inch, 15-minute rain event (ASA et al, 1995)
** - Based on sampling accomplished in conjunction with the Tri-Town Study (ASA et al, 1995)

Measured concentrations from tributary inputs were extremely variable. Mumford Brook consistently had the highest fecal coliform concentrations, while Gilbert Stuart Stream consistently had the lowest. During the first rain event, concentrations in Mumford Brook (SW-26) peaked at 1,600,000 fc/100mL and remained extremely elevated (1,200,000 fc/100mL) for at least four hours. During the same storm, concentrations at Gilbert Stuart Stream (SW-1) peaked momentarily at 28,000 fc/100mL from apparent "first-flush" effects then quickly diminished. During the second rain event, concentrations in Mumford Brook (SW-25) peaked at 150,000 fc/100mL and remained quite elevated (112,000 fc/100mL) for at least five hours before diminishing substantially. Meanwhile, concentrations at Gilbert Stuart Stream (SW-1) peaked at only 780 fc/100mL. Flow in Mettatuxet brook originates as storm sewer discharge. It is understandable that concentrations observed in Mettatuxet Brook were consistent with those observed at other storm sewer outfall locations during each event. Peak concentrations at Mettatuxet Brook were 76,000 fc/100mL during the first storm event and 20,000 fc/100mL during the second.

Insufficient wet weather data was gathered in Crooked Brook (SW-23) during RIDEM's monitoring program to completely characterize its fecal coliform impairment. Sampling of the brook was prevented during the bulk of the first rain event since the sample location was inundated by high tidal conditions at the time. Safety and accessibility concerns precluded sampling during the second rain event because the storm occurred at night and the sample location was rather remote and difficult to reach. The limited data obtained indicates that concentrations are similar to those typically noted at the upstream (background) Mumford Brook location (SW-26).

Table 5.8: RIDEM 1999 wet weather monitoring data – Storm #1

Station	**Date**	**Time**	**Hours After Start of Rainfall**	**Fecal Coliform per 100ml**
SW-0 – Gilbert Stuart Stream (upstream)	9/29/99	1310	pre-storm	5
	9/30/99	1025	1.5	130
	9/30/99	1325	3.5	700
	10/1/99	1250	27	31
SW-1- Gilbert Stuart Stream (downstream)	9/29/99	1300	pre-storm	10
	9/30/99	1020	1	28,000
	9/30/99	1315	3	690
	9/30/99	1535	5.5	1,500
	9/30/99	1834	8.5	1,200
	10/1/99	1245	27.5	20
	10/2/99	1140	50.5	64
	10/3/99	1110	74	25
SW-3 – Pettaquamscutt Lake Shores outfall	9/29/99	--	pre-storm	*NF*
	9/30/99	1005	1	840
	9/30/99	1110	2	70,000
	9/30/99	1155	3	43,000
	9/30/99	1305	4	39,000
SW-5 – Lakeside Drive outfall	9/29/99	--	pre-storm	*NF*
	9/30/99	0950	1	530
	9/30/99	1145	3	40,000
	9/30/99	1250	4	4,100
SW-10 – Wampum Road outfall	9/29/99	--	pre-storm	*NF*
	9/30/99	1025	1.5	14,000
	9/30/99	1125	2.5	90,000
	9/30/99	1225	3.5	82,000
SW-14 – Mettatuxet Road outfall (upstream)	9/29/99	--	pre-storm	*NF*
	9/30/99	1040	1.5	29,000
	9/30/99	1145	2.5	34,000
	9/30/99	1240	3.5	35,000
	9/30/99	1340	4.5	28,000
	9/30/99	1440	5.5	9,000
SW-15 – Mettatuxet Road outfall (downstream)	9/29/99	--	pre-storm	*NF*
	9/30/99	1035	1.5	76,000
	9/30/99	1135	2.5	37,000
	9/30/99	1235	3.5	30,000
	9/30/99	1335	4.5	25,000
	9/30/99	1435	5.5	22,000
SW-23 – Crooked Brook	9/30/99	1923	10	7,000
SW-25 – Mumford Brook (downstream)	9/29/99	1115	pre-storm	16,000
	9/30/99	1040	1.5	630,000
	9/30/99	1215	3	1,300,000
	9/30/99	1400	5	1,200,000
	9/30/99	1455	6	1,200,000
	9/30/99	1911	10	100,000
	10/1/99	1210	27	23,000
	10/2/99	0725	46.5	15,000
	10/3/99	0725	70.5	2,600
SW-26 – Mumford Brook (upstream)	9/29/99	1130	pre-storm	750
	9/30/99	1050	1.5	370,000
	9/30/99	1230	3.5	1,600,000
	9/30/99	1945	10.5	7,600
	10/1/99	1220	27	730

NF – Indicates that location had no flow at time of sampling

Table 5.9: RIDEM 1999 wet weather monitoring data – Storm #2

Station	**Date**	**Time**	**Hours After Start of Rainfall**	**Fecal Coliforms per 100ml.**
SW-1 Gilbert Stuart Stream	10/17/99	0945	pre-storm	20
	10/17/99	2151	1	780
	10/17/99	2300	2	66
	10/17/99	2350	3	350
	10/18/99	0050	4	150
	10/18/99	0320	6.5	610
	10/18/99	1134	14.5	60
	10/19/99	1112	38	130
SW-3 – Pettaquamscutt Lake Shores outfall	10/17/99	--	pre-storm	*no flow*
	10/17/99	2140	1	6,400
	10/17/99	2245	2	34,000
	10/17/99	2350	3	11,000
	10/18/99	0038	4	5,200
	10/18/99	0305	6.5	3,700
	10/18/99	0950	13	3,700
	10/19/99	1042	38	210
SW-5 – Lakeside Drive outfall	10/17/99	--	pre-storm	*no flow*
	10/17/99	2130	1	5,200
	10/17/99	2235	2	7,500
	10/17/99	2340	3	2,700
	10/18/99	0030	4	4,000
	10/18/99	300	6.5	4,000
	10/18/99	1120	14	27,000
	10/19/99	1030	37	27,000
SW-10 – Wampum Road outfall	10/17/99	--	pre-storm	*no flow*
	10/17/99	2145	1	24,000
	10/17/99	2245	2	3,200
	10/17/99	2345	3	3,300
	10/18/99	0045	4	11,000
	10/18/99	0250	6	12,000
	10/18/99	1115	14.5	12,000
	10/19/99	--	--	*no flow*
SW-14 – Mettatuxet Road outfall (upstream)	10/17/99	0930	pre-storm	120
	10/17/99	2135	1	6,400
	10/17/99	2235	2	25,000
	10/17/99	2335	3	2,200
	10/18/99	0035	4	9,000
	10/18/99	0245	6	12,000
	10/18/99	1110	14.5	1,700
	10/19/99	1015	37.5	180
SW-15 – Mettatuxet Road outfall (downstream)	10/17/99	0920	pre-storm	410
	10/17/99	2130	1	11,000
	10/17/99	2230	2	5,700
	10/17/99	2330	3	20,000
	10/18/99	0030	4	12,000
	10/18/99	0240	6	10,000
	10/18/99	1100	14.5	5,000
	10/19/99	1004	37.5	250
SW-25 – Mumford Brook (downstream)	10/17/99	0840	pre-storm	10,000
	10/17/99	2230	1.5	150,000
	10/17/99	2330	2.5	56,000
	10/18/99	0002	3	77,000
	10/18/99	0100	4	94,000
	10/18/99	0230	6.5	112,222
	10/18/99	1025	14.5	50,000
	10/19/99	0930	37.5	9,000

5.3 Source Characterization Summary

Dry weather

Known dry weather sources of fecal coliform contamination in the Narrow River watershed include impaired tributaries, failing septic systems and directly deposited fecal material from domesticated animals, wildlife and waterfowl. Fecal coliform concentrations in each of the tributaries sampled exceeded state water quality standards. Mumford Brook, which discharges to Pettaquamscutt Cove, has consistently been the largest fecal coliform source to the river. Gilbert Stuart Stream, which discharges to Upper Pond, was identified as the second largest source of fecal coliform bacteria to Narrow River. Fecal coliform concentrations in Crooked Brook have also consistently been elevated.

It was initially felt that the failing septic systems of homes adjacent to the river were potential contributors to the bacterial impairment of Segments 3 and 4. It was proposed that homes reportedly connected to the sanitary sewers could, in fact, still be discharging to failing septic systems, thereby, contaminating groundwater and impacting Narrow River water quality. At the urging of RIDEM, the towns of Narragansett and South Kingstown have investigated the potential for homes in Narrow River neighborhoods to be discharging to septic systems. Tax assessor parcel information in both towns was compared to sanitary sewer and/or water billing information to identify any incongruity. According to the Town of Narragansett Engineering Department and discussions with South Kingstown officials, virtually all of the homes in these segments, located in close proximity to the river, have been connected to the sanitary sewers. Also, the summer of 1999 was exceptionally dry resulting in a lower than ordinary groundwater table and, therefore, less groundwater discharge to the river and no dry weather flows from tributaries or storm sewer outfalls were observed in Segment 3. Though the possibility of a failing septic system still exists in the watershed, RIDEM believes that failing septic systems are not a widespread problem based on the available information.

A dry weather comparison can be made between 1981-1985 RIDEM Shellfish Program data, 1992-1999 Watershed Watch data and 1999 RIDEM data (Figure 5.1). Monitoring data seems to indicate a recent (after 1985) localized increase in fecal coliform concentrations near Middlebridge Bridge. Otherwise, despite the introduction of sewers to much of the watershed, it appears that fecal coliform trends and concentrations have not changed markedly over the past twenty years. One explanation of these results is that contaminated groundwater from failing septic systems has not historically been a substantial source of fecal coliform to the river during dry weather. Another is that new development-related sources of fecal coliform have offset the decreases made by the introduction of sewers to the reach.

A substantial, year-round bird population inhabits the Narrow River watershed. Gulls and other native birds are plentiful throughout the watershed. Hussong et al (1979) and Koppelman and Tanenbaum (1982) calculated theoretical loading values for fecal coliform inputs from waterfowl. Ducks and swans were reported to produce 10^9 coliforms per day, while geese contributions were estimated at 10^7 fecal coliforms per day. During site visits, it was not uncommon to observe between twenty and thirty waterfowl in the reach opposite Mettatuxet Neighborhood. Pettaquamscutt Cove is also a popular habitat for waterfowl. In several instances, during late summer and early fall, more than one hundred waterfowl (mainly ducks and geese) have been observed in this area. Based on the documented loadings of waterfowl in

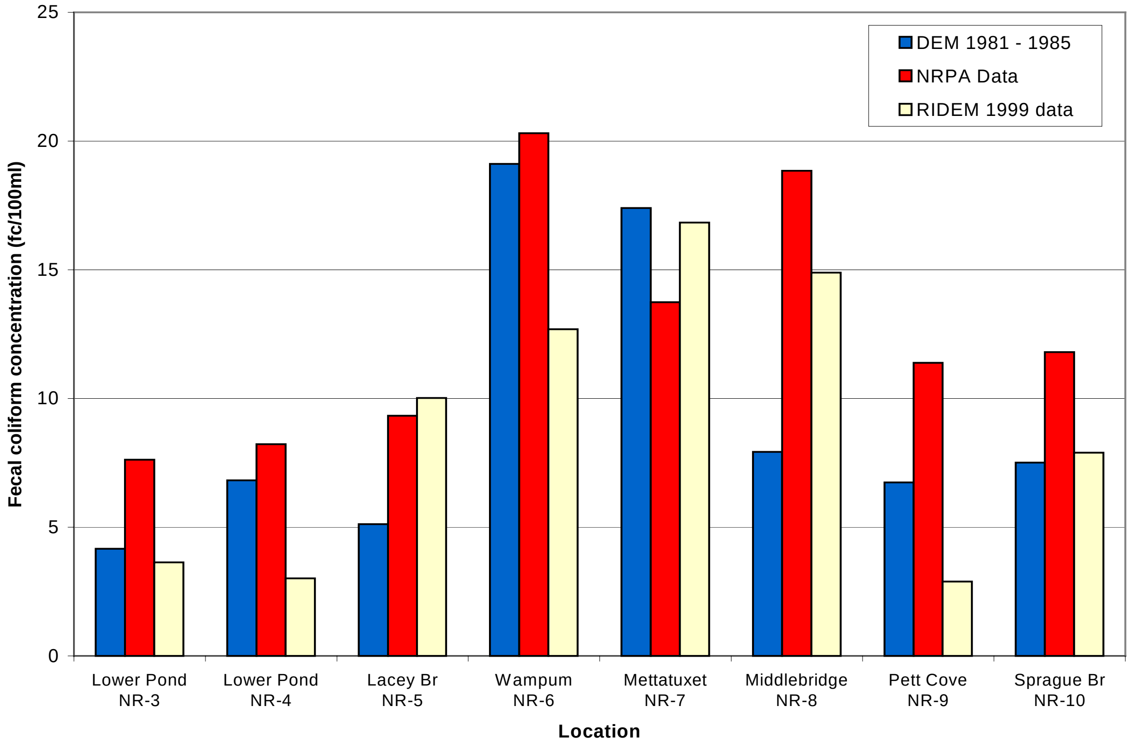


Figure 5.1 Dry weather fecal coliform trends 1981-1999

literature and the potential impact of the loading as discussed in Chapter 5.1, RIDEM has concluded that the dry weather fecal coliform elevations in Segments 3 and 4 are largely due to waterfowl. Additionally, it is presumed that waterfowl contribute quite substantially to the impairment of Pettaquamscutt Cove.

Wet weather

All dry weather sources continue to contribute during wet weather conditions to a larger or lesser degree. However, wet weather sources of fecal coliform to the Narrow River are dominated by storm water runoff entering the river through tributary channels, storm sewer outfalls, and overland as sheet flow. Fecal matter from domestic animals, wildlife, waterfowl and failing septic systems is deposited on streets, parking lots, docks, and along the shoreline. It accumulates during dry periods and is subsequently washed off and efficiently transported to receiving waters during rain events. Burnhart (1992) showed that in rural areas, runoff from streets was the primary contributor of fecal coliform bacteria. Fecal coliform concentrations measured in runoff ranged from 56,000 fc/100mL on moderate traffic roads to 92,000 fc/100mL on low-traffic roads. Levels approximating 25,000-58,000 fc/100mL were observed from runoff through a residential area (Betson and Buckingham 1969 as cited in Heufelder 1988). Event mean fecal coliform concentrations were estimated at 19,000 fc/100mL in this watershed during the Tri-Town Study.

Source Contribution Summary

Tributary Contributions

The weighted geometric mean approach discussed in section 4.3 of this report was also utilized to evaluate each of the three largest tributaries. Pollutant concentrations in surface waters tend to vary significantly depending on rainfall and runoff conditions. Utilization of the WGM approach allows wet and dry weather data to be synthesized based on the percentage of wet and dry days that occur within the watershed annually so that representative conditions can be compared to regulatory standards.

Based on Watershed Watch data collected during the past eight years, elevated fecal coliform concentrations in tributaries can be expected from a 0.25-inch or greater precipitation event. The frequency of occurrence of 24-hour, 0.25-inch or greater precipitation events on an annual basis was determined to occur 13.8 percent of the time, so dry weather days occur 86.2% percent of the time. This means that annually, wet weather conditions dominate the watershed approximately 13.8% of the time. The overall percentage of wet weather days was again adjusted to include recovery time (time required for in-stream fecal coliform concentrations to return to either pre-storm levels or to applicable water quality standards.

Analysis of RIDEM's 1999 wet weather data for Gilbert Stuart Stream and Mumford Brook shows that concentrations typically return to pre-storm conditions within 48 hours. Therefore, the percent of wet weather days for the tributary calculations is calculated to be 27.6% (13.8% × 2). These values take into consideration wet weather bacteria violations not only for the day of the storm but also for the additional day it takes for the system to recover. The percent of dry weather days is then 72.4%.

For the tributaries, the following formula applies:

WGM (tributary) = [(0. 276) × (Wet weather geometric mean)] +
[(0.724) × (Dry weather geometric mean)]

Once computed, the weighted geometric mean was compared to the geometric mean portion of the fecal coliform standard to determine if a reduction was required.

90th percentile values for the three tributaries were calculated using RIDEM's 1999 fecal coliform results. The value was determined by compiling daily means of all fecal coliform concentrations from the most impacted station on a given tributary, then using the 90th percentile function in Microsoft Excel to calculate the value. Because the sampling frequency was much greater during the wet weather events, it was decided to use daily mean concentration values so that the calculated 90th percentiles would not be so disproportionately weighted by wet weather sample data. The results of these calculations are shown in Table 5.10.

Table 5.10: Tributary geometric mean and 90th percentile summary

Location	**Existing dry weather geometric mean concentrations (fc/100 ml)**	**Existing wet weather event mean concentrations (fc/100 ml)**	***Weighted geometric mean (fc/100mL)***	***90th Percentile (fc/100mL)***
Gilbert Stuart Stream	182	573	*290*	*4,320*
Mumford Brook	4,966	228,519	*66,667*	*74,892*
Crooked Brook	527	7000*	*2,314*	*2,400*

*Value is derived from a single sample and may not be representative of actual wet weather conditions.

Non-tributary sources

Loadings from identified point and nonpoint sources are shown in Table 5.11. Bacterial loadings from waterfowl to the Upper and Lower River (Segments 3 and 4) were estimated using the mass-balance approach explained in Section 5.1 to be 7.3 x 10^8 fc/day. Point source loadings from storm sewers were estimated during the Tri-Town Study through the use of the SWMM storm water runoff model and limited outfall sampling.

Table 5.11: Waterfowl and storm sewer loadings

Impacted Segment	**Sources**	**Dry weather estimated loading**	**Wet weather Estimated loading**
2 - Lower Pond	Storm sewers	N/A	1.1×10^{11} fc/storm *****
3 and 4 – Middle river	Storm sewers	N/A	3.4×10^{11} fc/storm *****
	Waterfowl	7.3×10^{8} fc/day ± ******	7.3×10^{8} fc/day ± ******

***** - Based on SWMM modeling and sampling accomplished in conjunction with the Tri-Town Study (ASA et al, 1995)

****** - Calculated based on observed receiving water concentrations

6.0 WATER QUALITY IMPAIRMENTS

This section characterizes the fecal coliform impairments to the Narrow River and its three most significant tributaries. The section further specifies the violations of state water quality criteria that have restricted or threatened designated uses of these waterbodies. Investigations in the Narrow River watershed have consistently documented high fecal coliform levels. Fecal coliform is often utilized as an indicator bacterium to measure a waterbody's potential for disease transmission. Fecal coliforms may not necessarily cause disease, but as an indicator of the presence of fecal matter, may be accompanied by disease causing microorganisms known as pathogens. Pathogens can infect humans through skin contact or ingestion of water or contaminated fish. Elevated fecal coliform levels in surface waters increase the likelihood that associated pathogens are also present. Exposure to these waters presents a human health risk.

Both dry and wet weather data were used to characterize water quality conditions in the Narrow River watershed. In seeking to identify sources of pathogen contamination, RIDEM staff reviewed aerial photos, topographic maps, GIS land use data, and other available sources. In addition, RIDEM staff conducted extensive wet and dry weather field reconnaissance and, where possible, talked to area residents regarding potential sources of bacteria pollution

6.1 Receiving Water

The Narrow River is designated a Class SA water body by the State of Rhode Island. The water quality standard for fecal coliform concentrations in Class SA waters are *"not to exceed a geometric mean MPN value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution,"*(RIDEM, 1997) where MPN is the most probable number of fecal coliform bacteria per 100ml. Class SA seawaters are *"designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities and fish and wildlife habitat*

The Narrow River currently violates Class SA water quality standards for fecal coliform. Because of this impairment, the river is not fully supporting its designated uses. The river has been closed to shellfishing since 1986 and safe primary and secondary recreational activities are threatened.

<u>Segment 1 – Upper Pond</u>
The Upper Pond, located at the head of the Narrow River in the northern portion of the watershed, violates the geometric mean criteria of the fecal coliform standard. Based on the monitoring data, impairments to the Upper Pond are predominantly wet weather related. The dry weather geometric mean of the Segment 1 is 5 fc/100mL, while the wet weather geometric mean is 30 fc/100mL, based on 1992-1999 Narrow River Preservation Association data. The weighted geometric mean calculated for the segment is 15.4 fc/100mL. The 90^{th} percentile concentration is 44.7 fc/100mL.

Identified sources
Although wildlife and storm water runoff may contribute significant fecal coliform loadings to Upper Pond, the largest single source is Gilbert Stuart Stream. Based on a simple mass-balance calculation utilizing only the dilution volume of the upper five meters of Upper Pond (it is

assumed that salt water stratification effectively prevents any substantial mixing below this depth), summer season dry weather flows from the stream at current concentrations are sufficient to increase concentrations within the pond approximately 1.5 fc/100mL. During wet weather conditions, however, Gilbert Stuart Stream, which drains approximately 3,300 acres (85% of the Upper Pond drainage area), contributes sufficient loadings to cause fecal coliform concentrations to exceed standards.

Segment 2 – Lower Pond

The Lower Pond, located just south (downstream) of the Upper Pond, near the head of the Narrow River, meets fecal coliform water quality standards based on the available monitoring data, however, four of the larger storm sewer outfalls currently discharge to this segment. RIDEM recognizes that these storm sewer outfalls release substantial bacteria loads during wet weather conditions that threaten water quality in Lower and contribute to water quality impairments in downstream segments. The dry weather geometric mean of the segment is 4 fc/100mL, while the wet weather geometric mean is 10 fc/100mL, based on RIDEM's 1999 data. The weighted geometric mean calculated for the segment is 6.5 fc/100mL. The 90^{th} percentile concentration is 23 fc/100mL.

Identified sources

Identified dry weather sources to Lower Pond include two intermittent streams, Walmsley Brook and Crew Brook, trickling discharges from storm sewer outfalls and direct deposition by waterfowl and wildlife. Wet weather sources are dominated by storm water runoff entering the pond from storm sewer outfalls, tributary streams or overland as sheet flow.

Segment 3 – Upper River

Segment 3 extends south from the southern end of Lower Pond to just south of the Mettatuxet Yacht Club in the Mettatuxet neighborhood. This river segment violates both parts of the fecal coliform standard. Based on RIDEM's 1999 data, the highest dry and wet weather geometric means of the segment are 19 fc/100mL (at SW-13W) and 39 fc/100mL (at SW-11), respectively. The calculated weighted geometric mean for the segment is 27.3 fc/100mL. The 90^{th} percentile concentration is 70 fc/100mL.

Identified sources

The principal dry weather source of fecal coliform identified in this segment is wildfowl. Virtually all of the homes along this segment of the river have been connected to municipal sewers for over a decade, which makes significant loadings to the river from failing septic systems unlikely. In addition, during the summer of 1999, Rhode Island was experiencing drought conditions, which are typically accompanied by a lowering of groundwater. No significant dry weather flow was observed from storm sewer outfalls, which makes significant loadings from illicit storm sewer connections equally unlikely.

Wet weather sources to this segment are dominated by storm water runoff entering the reach from storm sewer outfalls, tributary streams or overland as sheet flow. Fecal matter from birds, wild and domesticated animals and failing septic systems is washed off the shoreline and surrounding areas into the river.

Segment 4 – Lower River

Segment 4 extends south from Segment 3 to Pettaquamscutt Cove. This segment also violates both portions of the fecal coliform standard. Based on RIDEM's 1999 data, the highest dry and wet weather geometric means are 20 fc/100mL and 44 fc/100mL, respectively and were observed at SW-17. The calculated weighted geometric mean for the segment is 29.9 fc/100mL. The 90th percentile concentration is 88 fc/100mL.

Identified sources

Identified dry weather sources to this segment include cumulative upstream loadings, Mettatuxet Brook (intermittent) and direct deposition by waterfowl and wildlife. Similar to Segment 3, substantial loadings from failing septic systems or illicit connections are not considered likely.

Wet weather sources to this segment are also dominated by storm water runoff entering the reach from storm sewer outfalls, tributary streams or overland as sheet flow. Fecal matter from birds, wild and domesticated animals and failing septic systems is washed off the shoreline and surrounding areas into the river.

Segment 5 – Pettaquamscutt Cove

Segment 5 encompasses Pettaquamscutt Cove. This segment violates both portions of the fecal coliform standard. Based on RIDEM's 1999 data, the dry weather geometric mean of the segment is 26 fc/100mL, while the wet weather geometric mean is 255 fc/100mL as measured in the southern portion of the Cove. The weighted geometric mean calculated for the segment is 120.8 fc/100mL. The 90th percentile concentration is 454 fc/100mL.

Identified sources

Identified dry weather sources to this segment include Mumford Brook, Crooked Brook and direct deposition by waterfowl and wildlife. Mumford Brook, the largest fecal coliform source to the Narrow River, appears to be impacted by a failing septic system(s) in the vicinity of East Narragansett Avenue in South Kingstown. Crooked Brook has elevated fecal coliform concentrations as well. Because the sampling station in the brook is fairly remote from human activity in the watershed, most of the fecal coliform loading to the brook may not originate from anthropogenic sources. The southern portion of Pettaquamscutt Cove has been designated as a wildlife refuge. Large populations of permanent and migratory bird species, which undoubtedly contribute significantly to fecal coliform loadings, inhabit the area.

Wet weather sources to this segment are dominated by storm water runoff entering from Mumford and Crooked Brooks, intermittent tributary streams or overland as sheet flow

Segment 6 – The Narrows

Segment 6 includes the portion of the river that extends from Sprague Bridge to the mouth at Rhode Island Sound. This river segment also violates both portions of the fecal coliform standard. The dry weather geometric mean of the segment is 9 fc/100mL at SW-20, while the wet weather geometric mean is 36 fc/100mL at SW-19 in the southern portion of the Cove, based on RIDEM's 1999 data. The calculated weighted geometric mean for the segment is 20.2 fc/100mL. The 90th percentile concentration is 69.5 fc/100mL.

Identified sources
Identified dry weather sources to this segment are limited to cumulative upstream impacts. Impaired waters from the Lower River and Pettaquamscutt Cove are flushed out to Rhode Island Sound through the Narrows. Wet weather sources to this segment include upstream impacts and storm water runoff from Boston Neck Road.

6.2 Tributaries

The State of Rhode Island designates all of the freshwater tributaries discharging to the Narrow River as Class A waterbodies. The water quality standard for fecal coliform concentrations in Class A waters are *"not to exceed a geometric mean MPN value of 20 (per 100 ml) and not more than 10% of the samples shall exceed an MPN value of 200,"* where MPN is the most probable number of fecal coliform bacteria per 100ml (RIDEM, 1997). Class A freshwaters are *"designated as a source of public drinking water supply, for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses".* (RIDEM, 1997).

Fecal coliform concentrations in all of the tributaries sampled exceeded allowable levels. Due to the excessively high fecal coliform concentrations, these tributaries do not support their designated use as public drinking water supplies or fully support their designated use as resources for primary and secondary contact activities, which includes swimming and boating.

6.2.1 Gilbert Stuart Stream

Gilbert Stuart Stream, which discharges to the Upper Pond (Segment 1) in the northern portion of the watershed, violates both parts of the fecal coliform standard. At SW-1 located immediately downstream from the Gilbert Stuart Birthplace Museum (the Birthplace), the dry weather geometric mean of the stream is 182 fc/100mL, while the wet weather geometric mean is 573 fc/100mL, based on RIDEM's 1999 data. The calculated weighted geometric mean for the segment is 290 fc/100mL. The 90th percentile value is 4,320 fc/100mL.

Identified sources
Although wildlife and storm water runoff may contribute significant fecal coliform loadings to the stream, human activity appears to be the dominant source. The highest fecal coliform concentrations were localized to the immediate vicinity of the Birthplace, indicating a nearby source. Sampling station (SW-0) located just upstream from the Birthplace in Carr Pond was found to meet both parts of the fecal coliform standard, while a station immediately downstream (SW-1) did not. Since the septic system at the museum had been replaced within the previous two years, the only likely anthropogenic source of fecal coliform in the area was an outhouse still in use at the site. The privy, located within thirty-five feet of the pond's edge, has since been abandoned and replaced by a portable toilet. Recent sampling indicates a marked improvement in water quality.

6.2.2 Mumford Brook

Mumford Brook, which discharges to Pettaquamscutt Cove (Segment 5) in the southern end of the watershed, also violates both portions of the fecal coliform standard. The stream originates at a small spring-fed pond near Route 1 in South Kingstown. From the pond's discharge, the brook meanders northerly through a fairly remote wooded swamp upstream of sampling station SW-26. Below SW-26, the brook is culverted under an abandoned railroad bed and an electric utility easement. It then fragments into multiple poorly defined channels through a mixed scrub-shrub and *Phragmites* swamp. In close proximity to East Narragansett Avenue, the brook forms two prominent channels that join when culverted under the roadway just upstream of SW-25, then discharges to Pettaquamscutt Cove. Measured fecal coliform concentrations at SW-25 have consistently been the highest measured in the watershed. At SW-25, the dry weather geometric mean of the stream is 4,966 fc/100mL, while the wet weather geometric mean is 228,519 fc/100mL, based on RIDEM's 1999 data. The calculated weighted geometric mean for the segment is 66,667 fc/100mL. The 90th percentile value is 74,892 fc/100mL.

Identified sources
Although wildlife and stormwater runoff may contribute significant fecal coliform loadings to the brook, human activity appears to be the dominant source. The highest concentrations in Mumford Brook have consistently been measured in close proximity to East Narragansett Avenue in South Kingstown. The consistent nature and extremely high concentrations noted indicate an anthropogenic source. After extensive reconnaissance and sampling in the area, RIDEM has narrowed its focus to several homes in close proximity to the *Phragmites* swamp, one or more of which may have a failing septic system. All of the homes in this area utilize on-site sewage disposal systems and are situated on thin mantles of high-risk soils (excessively draining or restrictive soils) overlying shallow bedrock. RIDEM also feels that significant non-anthropogenic sources to the brook may be present in the fairly remote southern portion of the watershed since concentrations well in excess of state water quality standards were observed at the upstream (background) location, SW-26. Additional sampling will be conducted in the brook to identify potential sources.

6.2.3 Crooked Brook
Crooked Brook, which also discharges to Pettaquamscutt Cove (Segment 5) in the southern end of the watershed, also violates both portions of the fecal coliform standard. The brook drains two distinct subwatersheds designated as Crooked Brook and Sprague Pond via separate streams. The Crooked Brook watershed is sparsely settled with mostly forested and some low-density residential land-uses. The Sprague Pond watershed, conversely, drains predominantly high to medium density residential and industrial/commercial land-uses. Both watersheds are fully sewered. As the streams draining each watershed exit the developed portions, they are culverted under Kingstown Road, run through a small public park, then enter a large secluded hardwood swamp. The streams meander through the swamp over 700 meters, eventually join, and discharge to Pettaquamscutt Cove. The dry weather geometric mean of the stream draining the Crooked Brook watershed just prior to its entering the swamp (SW-28) is 369 fc/100mL. The dry weather geometric mean of the stream draining the Sprague Pond watershed just prior to entering the swamp (SW-27) is 16 fc/100mL. At SW-23, located near the discharge to the Cove, the dry weather geometric mean of the combined streams is 527 fc/100mL, while the wet weather geometric mean is 7,000 fc/100mL, based on RIDEM's 1999 data. The calculated weighted geometric mean for the segment is 2,314 fc/100mL and the 90th percentile value is 2,400 fc/100mL.
Identified sources

Measured fecal coliform concentrations in Crooked Brook are lower upstream in the residential portion of the watershed than downstream after the brook traverses a fairly remote hardwood swamp area. It is likely that the principal sources contributing to the impairment of the brook are not anthropogenic. Additional sampling of the brook will be accomplished to identify potential sources during the Crooked Brook TMDL scheduled for completion in 2002.

7.0 ALLOCATION OF LOADINGS

The calculation of the TMDL returns the limit for pollutant loadings that a waterbody can assimilate while meeting applicable water quality standards. Provisions must be made to allow for future development and a margin of safety (MOS). The TMDL is calculated as the sum of loads allocated to point sources (WLA), nonpoint sources, including natural background (LA), and a margin of safety (MOS) where the source loadings are expressed in units of mass per unit time or other appropriate measure. For the allocation of fecal coliform sources, USEPA Region 1 has stated that the TMDL may alternately be expressed in concentration units (fc/100mL).

7.1 Receiving Water Reductions

As discussed in Section 5, loadings to Narrow River are relatively low during dry weather and high during wet weather. As a result, fecal coliform concentrations in the receiving water are typically in either a low, dry weather concentration condition or a high, wet weather concentration condition during the critical summer season. To determine whether the geometric mean criterion for fecal coliform concentration is met, a "weighted" geometric mean (WGM) concentration is calculated as discussed in Section 4.3 of this report, that "weighs" the wet and dry weather geometric mean concentrations according to their probability of occurrence. The loading reductions required by this TMDL, therefore, consist of a comparison of the present WGM concentration against the target concentrations for each receiving water segment. The loading reduction required for each segment is expressed as the difference between its present WGM concentration and the water quality goal (WQ Goal), divided by the WGM:

% Reduction = (WGM - WQ Goal)/ WGM

The water quality goal is the state's Class SA fecal coliform standard of 14 fc/100mL minus a 10% explicit MOS:

WQ Goal = 14 fc/100 ml – 10% MOS = 12.6 fc/100 ml

The reductions required to meet the water quality goal are presented in Table 7.1. These reductions ensure that each receiving water segment will meet both the geometric mean and 90^{th} percentile portions of the water quality standard if attained. They represent an overall reduction goal that is applicable to the composite of all tributary, point and nonpoint sources contributing to the water quality impairment.

7.2 Gilbert Stuart Stream and Mumford Brook reductions

The state's water quality regulations specify that freshwater tributaries to Class SA waterbodies are designated Class A. The principal tributaries to the Narrow River, Gilbert Stuart Stream, Mumford Brook, and Crooked Brook are, therefore, directly subject to Class-A water quality standards. Additionally, the allowable fecal coliform levels in tributaries must be adequately protective of the receiving water to ensure that its water quality is sufficient to meet all designated uses. In the absence of site specific data to indicate that Narrow River water quality goals could be met if each tributary discharges at the Class A standard, the TMDL requires that each tributary meet the Class SA standard at its point of discharge. A geometric mean of 14 fc/100mL and a 90th percentile value of less than 49 are, therefore, applied to the most downstream sampling stations in each of the tributaries. These values will serve as the numeric water quality targets for the Gilbert Stuart Stream and Mumford Brook TMDLs.

Table 7.1: Required Narrow River Reductions

Subwatershed	Target 90th percentile	Observed 90th percentile	Target geometric mean concentration (fc/100 ml)	Weighted geometric mean concentration (fc/100 ml)	Required percent reduction to meet both parts of the standard
Segment 1 – Upper Pond	49	45	12.6	15.4	18 %
Segment 2 – Lower Pond	49	23	12.6	6.5	*
Segment 3 – Upper River	49	70	12.6	27.3	54 %
Segment 4 – Lower River	49	88	12.6	29.9	58 %
Segment 5 – Pett. Cove	49	454	12.6	120.8	90 %
Segment 6 – The Narrows	49	70	12.6	20.2	38 %

* Lower Pond currently meets fecal coliform water quality standards based on the available monitoring data, however, four of the larger storm sewer outfalls currently discharge to this segment. RIDEM recognizes that these storm sewer outfalls discharge substantial bacteria loads during wet weather conditions that contribute to water quality impairments observed in downstream segments. This TMDL, therefore, targets these outfalls for water quality best management practices (BMPs) to mitigate pollutant loadings to the greatest extent practicable.

Reductions necessary to ensure that both parts of the standard are met for these two tributaries are specified in Table 7.2. These reductions again represent overall reduction goals that are applicable to the composite of all point and nonpoint sources contributing to the water quality impairments. Crooked Brook reductions are not determined in this report since the brook is the focus of additional monitoring in conjunction with a future TMDL.

Table 7.2: Required Gilbert Stuart Stream and Mumford Brook reductions

Subwatershed	Target 90th Percentile	Current 90th Percentile	Target geometric mean concentration (fc/100 ml)	Weighted geometric mean concentration (fc/100 ml)	Reduction required to meet water quality standards
Gilbert Stuart Stream	49	4,320	14	290	98.9 %
Mumford Brook	49	74,892	14	66,667	99.9 %

7.3 Margin of Safety (MOS)

There are two basic methods for incorporating the MOS into the TMDL. One can implicitly incorporate the MOS using conservative assumptions to develop the allocations or explicitly specify a portion of the TMDL as a portion of the final TMDL allocation. This TMDL uses a combination of the two approaches to ensure an adequate MOS. The primary causes of fecal coliform impairments in the Narrow River watershed are nonpoint in nature. Even loadings from storm sewer outfalls typically originate from nonpoint sources. Because nonpoint source loadings are inherently difficult to quantify with any certainty, this TMDL uses the following conservative assumptions:

- Conservative estimates of both the amount of rainfall needed to produce runoff and recovery time were used in the weighted geometric mean calculations.
- No allowances were made for bacterial decay.
- The dilution effects of groundwater infiltration were not considered when calculating receiving water fecal coliform concentrations
- The weighted geometric means were developed using annual averages for the number of wet and dry weather days. However, the actual monitoring data used in the calculation of the weighted geometric means were from warm weather when fecal coliform concentrations are typically much higher. As a result, the calculated weighted geometric mean and related reductions are conservative in nature.

Also included in the allocation of these TMDLs was an explicitly expressed MOS. The target geometric mean concentration for the Narrow River was set at 12.6 fc/100 ml, providing a 10% margin of safety below the Class-SA standard of 14 fc/100 ml. The target geometric mean concentration for the fresh water tributaries was set at the Class-SA standard of 14, which provides a 30% MOS below the applicable Class-A freshwater standard of 20 fc/100mL while adequately protecting the receiving water. The inclusion of an explicit MOS provides an additional buffer to allow for data variability and the presence of unknown sources.

8.0 RECOMMENDED MITIGATION MEASURES

The purpose of this section is to inventory identified sources and to recommend mitigation measures to achieve necessary water quality improvements in the Narrow River. The three largest perennial streams entering the Narrow River act as the principal pathways by which nonpoint loadings enter the Narrow River during periods of dry and wet weather. Other identified sources include birds, wildlife, pet waste, and storm water runoff.

Tributaries

As previously discussed, the principal tributaries to the Narrow River, Gilbert Stuart Stream, Mumford Brook, and Crooked Brook are directly subject to water quality standards. The required load reduction for the Upper Pond was calculated at 18%. The primary fecal coliform source to Upper Pond is Gilbert Stuart Stream. Based on a characterization of sources, RIDEM believes that if concentrations in Gilbert Stuart Stream are reduced by 98.9% as specified, water quality in Upper Pond will meet water quality standards. Mumford Brook and Crooked Brook are the principal sources of fecal coliform contamination to southern Pettaquamscutt Cove. If the fecal coliform concentrations in these two tributaries meet specified targets, water quality in the Cove will improve. Because other substantial sources (i.e. birds and waterfowl) are present in the Cove, it is unknown if water quality standards will be met in this area even if the large loadings from the tributaries are eliminated. Therefore, additional monitoring will be required in Pettaquamscutt Cove to determine the effectiveness of remedial actions in the tributaries.

Remedial measures are recommended for Gilbert Stuart Stream and Mumford Brook (see Table 8.1), since it appears that the bacterial contamination to these tributaries originates from human sources. Pollutant sources to Mumford Brook are currently under investigation by the RIDEM Office of Compliance and Inspection. It appears that fecal coliform loadings to Crooked Brook may be from non-anthropogenic sources. Additional monitoring will be performed in the brook in conjunction with the Crooked Brook TMDL planned for completion in 2002.

Table 8.1: Summary of current and proposed work on Narrow River tributaries.

Description of Impacted Area	Jurisdiction	Abatement Measure	Status
Gilbert Stuart Stream	Town of North Kingstown/Gilbert Stuart Birthplace/RIDEM	Discontinue use of outhouse near Carr Pond. Replace with portable toilet.	Use discontinued in October 1999. 2000 sampling indicates that the major source was eliminated.
Mumford Brook	RIDEM/ South Kingstown	Identify/repair failing septic system(s) near Mumford Road	Suspected septic system(s) are being investigated.

Birds, wildlife, pet wastes, and storm water runoff

Mitigation of these types of sources can best be addressed by the application of nonstructural BMPs or “good housekeeping” measures. The Narrow River Preservation Association has an ongoing informational program designed to inform local residents about how to live responsibly in the watershed. Also, the Southern Rhode Island Conservation District has recently received funding through RIDEM’s Aquafund Grant Program to implement a watershed-wide educational program. The focus of this program is to organize a watershed action team comprised of local residents to will identify effective measures to minimize nonpoint sources of pollution to the river. The SRICD program is scheduled for implementation in the Spring of 2001.

Obvious measures to limit pollutant loadings from human sources include connecting to the town sanitary sewers and eliminating elicit sanitary and gray-water connections to storm sewers. Other important actions include policing pet wastes, minimizing fertilizer applications, minimizing impervious cover and restoring the beneficial value of destroyed or degraded wetlands. Pet wastes should be disposed away from the river, tributary streams and all storm water conveyances. The application of fertilizers and pesticides to gardens and lawns should be limited to recommended doses and avoided prior to rain events. Impervious surfaces in the watershed should be minimized to decrease the volume of runoff generated during storm events. Wetland areas should be created or restored to increase the flood storage capacity and runoff residence times in the watershed.

There are several measures that residents can take to minimize bird-related impacts. They can allow tall, coarse vegetation to grow along the banks of the river segments frequented by waterfowl. Waterfowl, especially grazers like geese, desire easy access from the water to the riverbanks. Leaving an uncut vegetated buffer will make the habitat less desirable to geese and encourage migration. As an alternative, residents along the waterfront can also install commercially available fencing specifically designed for this purpose. Residents should also stop feeding the birds. Eliminating this practice should also help to decrease summer bird populations and make the area less attractive to the year-round residence of migratory birds.

Storm sewer discharges

Storm water runoff is the largest wet weather source of bacteria to the Narrow River and its tributaries. Storm sewers magnify the problem by rapidly collecting, concentrating and directly routing polluted runoff to receiving waters. Storm sewer outfalls discharging to Segments 2, 3 and 4 represent the only point sources of fecal coliform to Narrow River. They supply the majority of the fecal coliform load to the middle portion of the river during wet weather. The twelve largest storm sewer outfalls (shown on Figure 3.4), representing an estimated ninety-three (93) percent of the total fecal coliform load from outfalls to the Narrow River, are listed in Table 5.7. Consistent with the goals of this TMDL, these outfalls are targeted for water quality best management practices to mitigate pollutant loadings to the greatest extent practicable. The largest outfalls should receive priority for BMP implementation, however, special consideration should be given to those outfalls discharging to, or immediately upstream of, Segments 3 and 4. These two segments are shallow and narrow with relatively little dilution volume available to absorb the impact of pollutant loadings. Consequently, significant loading reductions in these reaches would lead to substantive in-stream water quality improvements during wet weather. Ultimately all direct discharge outfalls that contribute to the impairment of the Narrow River should be addressed as necessary to meet water quality goals".

“End-of-pipe” structural BMPs designed to treat current flows and pollutant loadings at the storm sewer outfalls would necessarily be rather expensive and/or require substantial land area. RIDEM suggests that a multi-faceted storm water management strategy be incorporated by the municipalities that utilizes a combination of end-of-pipe structural BMPs, smaller-scale structural retention/infiltration BMPs located up-gradient within the catchment areas and the implementation of nonstructural BMPs throughout the watershed.

As mandated by EPA, RIDEM is required to amend the existing Rhode Island Pollution Discharge Elimination System (RIPDES) regulations to include Phase II Storm Water Regulations. The new regulations will become effective in the Fall of 2001. Automatically designated municipalities must develop a storm water management program plan (SWMPP) that describes the Best Management Practices (BMPs) for each of the following minimum control measures:

1. a public education and outreach program to inform the public about the impacts storm water on surface water bodies,
2. a public involvement/participation program,
3. an illicit discharge detection and elimination program,
4. a construction site storm water runoff control program for sites disturbing more than 1 acre,
5. a post construction storm water runoff control program for new development and redevelopment sites disturbing more than 1 acre and
6. a municipal pollution prevention/good housekeeping operation and maintenance program.

The SWMPP must include the measurable goals for each control measure (narrative or numeric) that will be used to gauge the success of the overall program. It must also contain an implementation schedule that includes interim milestones, frequency of activities and reporting of results. In addition, the Director of RIDEM (Director) can require additional permit requirements based on the recommendations of a TMDL.

Operators of municipal separate storm sewer systems (MS4s) within urbanized areas (UAs) or densely populated areas (DPAs) will be required to develop a SWMPP and obtain a permit (for those portions within the UA or DPA) by March 10, 2003. DPAs include places that have equal to or greater than 1,000 people per square mile and have, or are part of, a block of contiguous census designated places with a total population of at least 10,000 people, as determined by the latest Decennial Census. Operators of MS4s located outside of UAs and DPAs and that discharge to Special Resource Protection Waters (SRPWs), Outstanding National Resource Waters (ONRWs), or impaired waters will also be required to obtain a permit (or expand permit coverage throughout the jurisdiction) by March 10, 2008, unless the operator has demonstrated effective protection of water quality to the satisfaction of the Director. The Director will also require permits for MS4s that contribute to a violation of a water quality standard, are significant contributors of pollutants to waters of the state or that require storm water controls based on waste load allocations (WLAs) determined through a TMDL.

The MS4s that discharge to the Narrow River are owned and operated by the Town of Narragansett, the Town of South Kingstown, or by the Rhode Island Department of Transportation (RIDOT). Based on the latest census data, an area within the Town of Narragansett meets the criteria of a DPA, including the portion of the Narrow River watershed south of Sprague Bridge. Accordingly, the Town of Narragansett will be required to apply for a RIPDES permit for that portion of their MS4 located within the DPA by March 10, 2003. The remaining Narragansett, South Kingstown and RIDOT storm sewer outfalls are part of MS4s that are not located in a DPA or UA. However, because they discharge significant loadings to an impaired waterbody (which is also a SRPW), because these loadings contribute to a violation of a water quality standard, and because it has been determined through this TMDL that storm water controls are necessary to restore water quality, the operators will be required to obtain a RIPDES permit (or expand coverage of an existing permit).

RIDEM will continue to work with the Coastal Resources Management Council (CRMC), Rhode Island Department of Transportation (RIDOT), the Southern Rhode Island Conservation District (SRICD) and the local municipalities to identify funding sources and to evaluate locations and designs for storm water control BMPs throughout the watershed. In accordance with the requirements of this phased TMDL, monitoring of Narrow River water quality will continue so that the effectiveness of ongoing remedial activities can be gauged.

Table 8.2: Summary of current and proposed mitigation measures

Description of Impacted Area	Jurisdiction	Abatement Measure	Status
Mettatuxet and Rio Vista neighborhoods	Narragansett	Illicit discharge to storm sewer detection and elimination	Scheduled to start in Fall of 2001
Mettatuxet Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Shadbush Trail Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Wampum Road and Conanicus Road Outfalls	Narragansett/CRMC	Structural storm water BMP(s)	Wet detention pond design plans completed. Application for 319 funding conditionally approved. Construction 2001
Lakeside Drive and South Ferry Road Outfalls	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Old Pine Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Shagbark Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Woodbridge Road Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP	Targeted for future BMP
Mettatuxet Beach Outfall	Narragansett/CRMC/Southern Rhode Island Conservation District (SRICD)	Structural/nonstructural storm water BMP(s)	Aquafund grant awarded to SRICD for feasibility study and preliminary BMP design.
Pettaquamscutt Avenue Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Indian Trail Outfall	Narragansett/CRMC	Structural/nonstructural storm water BMP(s)	Targeted for future BMP
Narrow River watershed	Narragansett/South Kingstown	Identify any residents not connected to sewers and require that they connect as failing systems are identified	Completed by Narragansett. South Kingstown is in process.
Middle river	Narragansett/RIDEM/ SRICD/NRPA	Deter waterfowl from river and waterfront areas and reduce storm water loadings by educating residents. Reduce pet waste impacts	Aquafund grant awarded to SRICD to launch an education campaign for neighborhood residents to minimize storm water-related loadings

9.0 PROPOSED MONITORING

This is a phased TMDL. Additional monitoring is required to ensure that water quality objectives are met as remedial actions are accomplished. The water quality monitoring conducted by NRPA volunteers through the URI Watershed Watch program was crucial to the development of this TMDL. This work should be continued to provide residents and RIDEM with the means to evaluate the effectiveness of water quality improvement efforts. RIDEM may conduct supplemental monitoring in Gilbert Stuart Stream and Mettatuxet Brook to confirm that the desired water quality standards have been achieved through the implementation of remedial measures. Monitoring will also be accomplished in Mumford Brook during the summer of 2001 to support the Office of Compliance and Inspection's ongoing investigation and to potentially identify any additional fecal coliform sources to the brook upstream of sample station SW-26. Crooked Brook is the subject of a separate TMDL scheduled for completion in 2002. Sampling in support of this TMDL will also commence in the summer of 2001. The monitoring will be designed to identify potential bacteria sources throughout the subwatershed. Finally, as proposed BMPs are installed in the watershed, additional sampling will be required to assess the effectiveness of these technologies.

10.0 PUBLIC PARTICIPATION

The public participation associated with this TMDL has been constant. Several meetings were held with local groups, which included all interested public, private, and government entities prior to TMDL development. An initial public meeting was held March 15, 1999 to disseminate information regarding TMDL issues in the watershed and to solicit input regarding pollution sources and/or other concerns. As the TMDL progressed, interested parties were continuously kept informed of progress and preliminary findings. After the main monitoring program had been completed, a public meeting, targeted primarily at state and local officials and local organizations was held December 1, 1999. The purpose of this post-monitoring meeting was to present RIDEM's preliminary findings and to elicit feedback. In addition, RIDEM presented the preliminary data at NRPA's January 4, 2000 meeting. An additional public meeting, cosponsored by NRPA, was held March 16, 2000 to relay the study findings and to discuss proposed remedial actions to the public.

The next component of the public outreach process for this TMDL is the public comment period associated with the review of this draft TMDL prior to its submittal to EPA by RIDEM. A third public meeting will be held to present this draft TMDL. All interested stakeholders will be given thirty days to review the document and submit comments. RIDEM will address all of the comments in a document to be submitted to the EPA with the final draft of the Narrow River TMDL document.

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APPENDIX A
NARROW RIVER WATERSHED
RIDEM RESPONSE TO COMMENTS RECEIVED

The draft TMDL was presented to the public for comment at a meeting held on October 4, 2001 at the University of Rhode Island Graduate School of Oceanography in Corless Auditorium. The following section addresses comments and questions that RIDEM received at this meeting. No additional public comments were received during the mandatory 30-day comment period, which began October 5, 2001 and closed on November 5, 2001.

Questions and Answers:

Q: Does the tide carry bacterial contamination from Pettaquamscutt Cove to the middle and upper portions of Narrow River?

A: It is not likely that the loadings to Pettaquamscutt Cove significantly impact the upper reaches of the river. Tidal range and flushing rates throughout the Narrow River are substantially dampened by the constricted geometry of "the Narrows" and because of the sand deltas that have developed downstream of Middle Bridge and at the entrance to Pettaquamscutt Cove. It is unlikely that the energy from the incoming tide is sufficient to move enough water from the Cove, especially the most impacted southern end, to impact water quality in the upper reaches. It is probable that water quality downstream, between Sprague Bridge and the mouth, is affected by water exiting the Cove with the outgoing tide.

Q: What is the status of the stormwater BMPs?

A: Final approval of the Circuit Drive project has been granted after much coordination and compromise between all involved parties. The Town of Narragansett recently received RIDEM approval of a sampling plan for sediment at the proposed location to determine disposal options. The last update received by RIDEM from the Town of Narragansett - Engineering Office prior to the meeting predicted completion of the project by the end of this year (2001). RIDEM has since learned that the project is now scheduled for early summer 2002 because of some property ownership oversights that could not be resolved before the onset of the wet season.

Preliminary designs for the Mettatuxett Beach stormwater BMP project are being prepared. Additionally, the Southern RI Conservation District is negotiating with the Mettatuxett Improvement Association to obtain the property (or an easement) at the site. Richard Grant, the interim Executive Director of NRPA, stated that the project is progressing. The preliminary plan is to eliminate a portion of the existing beach parking lot to install a small dry detention pond and constructed wetland. According to CRMC, the project should be kept 50 feet from the river edge to ease permitting.

Q: Is there some way to prioritize stormwater outfalls for BMPs and what is the enforcement mechanism?

A: The outfalls have been prioritized in the TMDL report according to projected loadings. The twelve largest outfalls have been specifically targeted for BMPs. The Phase II Rhode Island Pollution Discharge Elimination System (RIPDES) Regulations will require municipalities to obtain permits for their municipal separate storm sewer systems (MS4s). As part of the permit, municipalities will be required to develop stormwater management plan that meet six minimum measures in addition to any specific requirements of a TMDL. Because these twelve large MS4 outfalls have been targeted by this TMDL for fecal coliform loading reductions, the stormwater management plan submitted by the Town of Narragansett must contain specific pollution abatement strategies for them. If the requirements of a permit are not met, then enforcement can include fines.

Q: Are any funding sources available to assist towns in paying for required BMPs?

A: DEM is planning to issue a request for grant proposals in the winter of 2002 to provide grant funds for stormwater phase II planning. All Rhode Island municipalities will be encouraged to apply. DEM is committed to assisting municipalities with the implementation of stormwater BMPs;

however, funding opportunities are limited. It behooves municipalities seeking assistance to contact DEM as soon as possible. For further information, please contact John Manning of the DEM's State Revolving Funding Program (at 222-4700 Ext 7254) and James Riordan of the DEM's Nonpoint Source Management Program (at 222-4700 Ext 4421).

Q: Is money available to help people with failing septic systems make repairs or improvements?
A: The Community Septic System Loan Program (CSSLP) is available through the RIDEM administered State Revolving Fund and the Clean Water Finance Agency. Funding is available to municipalities that have developed wastewater management plans. The municipalities, in turn, can offer low interest loans to residents for septic system repairs or upgrades. Narragansett and South Kingstown do not currently have this program, but are in the process of meeting the necessary requirements to participate.

Q: How does the construction site portion of the Phase II Program work?
A: The Phase I Regulations required that a permit be obtained for construction activities disturbing 5 acres or more. Under Phase II that area has been decreased to 1 acre. Many municipalities have erosion control ordinances in place that already meet the new requirements and are adequately protective. If a municipality has no such protections, the new regulations will supercede.

Q: Has RIDEM closed the beaches in the Narrow River?
A: Beach closures are the responsibility of the RI Department of Health (HEALTH), which licenses and monitors public beaches. The only licensed beach on Narrow River has been at Camp Narrow River, which is owned by the Girl Scouts of America. HEALTH has required periodic bacteria monitoring at the beach during the swimming season. This beach was not operated or licensed during the 2001 season, therefore, HEALTH did not require any bacteria monitoring during that period.

HEALTH does not regulate or endorse swimming at unlicensed beaches.

Comments and Responses

C: The Narrow River watershed as shown on the maps appears to be in error. The ponds across from Narragansett Beach discharge to Pettaquamscutt Cove.
R: We were not initially aware of that fact. Our watershed delineation was based on Rhode Island Geographic Information System (RIGIS) coverage, which indicates that the ponds in question discharge towards the Narragansett Town Beach. Further investigation has revealed that, although these ponds may have discharged toward the beach at one time, they now drain to Pettaquamscutt Cove through a man-made channel.

RIDEM conducted a site visit on November 2, 2001. Observed flow in the channel appeared adequate to locally affect water quality in the cove, however, there are no anthropogenic sources immediately proximate to either the ponds or the excavated discharge stream. Water quality sampling will be accomplished in the stream during the summer of 2002 to fully evaluate the potential for contaminant loads from this tributary.

C: The Prout School and the neighboring convent consistently have ISDS problems and may be contributing to the impairment of the Narrow River, especially in Pettaquamscutt Cove.
R: The Prout School has a failing septic system. RIDEM investigated the potential for pollution to the river from this source during a site visit on October 12, 2001. School administrators and maintenance personnel confirmed that one leach field is failing and that they are actively pursuing a solution. According to Prout School personnel, the saturated land surface above the problem drainfield at certain times of the year has been the only observable indication of failure. It has resulted in the closure of an

overlying baseball field. Although no evidence of the problem was apparent during the site visit, it is likely that the problem becomes evident during the winter/spring wet season when the groundwater table rises.

Based on site observations, it is considered very unlikely that the septic system at the school is impacting the water quality in the Narrow River. The failing leaching field is located more than 600 meters (1/3 mile) from the water's edge. More than four hundred meters of this distance is forest and wetlands, which would drastically dampen any potential impact of contaminated stormwater runoff on the river. Additionally, no signs of wastewater breakout or channelization were noted at the drainfield site and there are no stormwater conveyances or tributary streams in close proximity.

The failing septic system represents a human health hazard irrespective of water quality issues. The situation has been forwarded to RIDEM's Office of Compliance and Inspection for resolution.

C: The Dunes Beach Club, located at the mouth of the Narrow River Estuary, had ISDS problems in the past and may be contributing to elevated fecal coliform concentrations in the area between Sprague Bridge and the mouth.

R: RIDEM has no record of any recent complaint of septic system failure or illicit discharge at the Dunes Club. Additionally, observed fecal coliform concentrations in this reach are generally low (meeting water quality standards during dry weather and just exceeding standards under wet weather conditions). Based on observed concentrations, there does not appear to be significant source in this area. It is more likely that observed wet weather concentration elevations at Sprague Bridge are attributable to (upstream) Pettaquamscutt Cove loadings.

C: The area along Torrey Road in South Kingstown is not sewered and soils in that area are not conducive to the proper function of conventional septic systems. Failing septic systems in this area may be contributing to degraded water quality in the Narrow River Estuary.

R: The area is not likely a dry weather problem since it is a substantial distance from the river and there are no nearby tributaries or storm sewers with dry weather flow. During wet weather, stormwater runoff from this area could contribute to the impairment of the river if septic systems are failing. At this time, RIDEM has no record of any failing septic system complaints along Torrey Road. Additionally, Office of Water Resources personnel have reconnoitered the area and found no evidence of obviously failing septic systems. Local residents should call RIDEM's Office of Compliance and Inspection at (401) 222-1360 if any specific occurrence is noted.

C: There is a subdivision proposed along South Pier Road in Narragansett in the Crooked Brook watershed that will not be connected to the sanitary sewer system. It could pose a threat to water quality in the watershed.

R: We were unaware of a proposed development at the time of the meeting. Plans for a 19-home subdivision on South Pier Road were submitted to RIDEM's Office of Water Resources – ISDS Permitting Section for review on the 25th of October. RIDEM is currently assessing the proposed development for regulatory compliance and the potential for environmental impact.

C: Richard Grant of the Narrow River Preservation Association (NRPA) stated that they have an education program and a strong community presence. NRPA would be willing to expand its current program with additional funding and assistance.

R: Jeff Nield (RIDEM) stated that assistance is available through several avenues. NRPA will contact RIDEM's Office of Strategic Planning for more information and coordination.