Final Massachusetts Statewide Total Maximum Daily Load for Pathogen-Impaired Waterbodies

Appendix J: Blackstone River Basin

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Rebecca L. Tepper, Secretary
Massachusetts Department of Environmental Protection
Bonnie Heiple, Commissioner
Bureau of Water Resources
Kathleen M. Baskin, Assistant Commissioner

December 2024

CN 515.1.10

Final Massachusetts Statewide Total Maximum Daily Load for Pathogen-Impaired Waterbodies

Appendix J: Blackstone River Basin

Prepared by:
TMDL Section, Watershed Planning Program
Division of Watershed Management, Bureau of Water Resources
Massachusetts Department of Environmental Protection

December 2024

CN 515.1.10

Suggested Citation
MassDEP. 2024. Final Massachusetts Statewide Total Maximum Daily Load for Pathogen-Impaired Waterbodies. CN 515.1, Massachusetts Department of Environmental Protection, Bureau of Water Resources, Division of Watershed Management, Watershed Planning Program. Worcester, MA.

Available Online

https://www.mass.gov/lists/total-maximum-daily-loads-by-watershed

Massachusetts Department of Environmental Protection

The mission of the Massachusetts Department of Environmental Protection (MassDEP) is to protect and enhance the Commonwealth's natural resources – air, water, and land – to provide for the health, safety, and welfare of all people, and to ensure a clean and safe environment for future generations. In carrying out this mission MassDEP commits to address and advance environmental justice and equity for all people of the Commonwealth; provide meaningful, inclusive opportunities for people to participate in agency decisions that affect their lives; and ensure a diverse workforce that reflects the communities we serve.

Watershed Planning Program

The mission of the Watershed Planning Program (WPP) in the Massachusetts Department of Environmental Protection is to protect, enhance, and restore the quality and value of the waters of the Commonwealth. Guided by the federal Clean Water Act, WPP implements this mission statewide through five Sections that each have a different technical focus: (1) Surface Water Quality Standards; (2) Surface Water Quality Monitoring; (3) Data Management and Water Quality Assessment; (4) Total Maximum Daily Load; and (5) Nonpoint Source Management. Together with other MassDEP programs and state environmental agencies, WPP shares in the duty and responsibility to secure the environmental, recreational, and public health benefits of clean water for all people of the Commonwealth.

Acknowledgements

FB Environmental Associates, under contractual agreements with MassDEP, previously prepared two separate documents for the Watershed Planning Program: (1) *Massachusetts TMDL for Pathogen-Impaired Inland Fresh Water Rivers* and (2) *Massachusetts Statewide TMDL for Pathogen-Impaired Coastal Waterbodies*. MassDEP combined these two documents into a single statewide approach encompassing both inland fresh water and coastal impairments to prepare the *Final Massachusetts Statewide Total Maximum Daily Load for Pathogen-Impaired Waterbodies*.

Disclaimer

References to trade names, commercial products, manufacturers, or distributors in this report constituted neither endorsement nor recommendations by the Massachusetts Department of Environmental Protection.

Contact Information

Watershed Planning Program
Division of Watershed Management, Bureau of Water Resources
Massachusetts Department of Environmental Protection
8 New Bond Street, Worcester, MA 01606
Website: https://www.mass.gov/guides/watershed-planning-program
Email address: dep.wpp@mass.gov

TABLE OF CONTENTS

1. Introduction

This appendix to the Massachusetts Statewide Total Maximum Daily Load (TMDL) for Pathogen-Impaired Waterbodies provides additional information to support the determination of the Total Maximum Daily Load (TMDL) for 19 pathogen-impaired river segments in the Blackstone River watershed (Figure 1-1). The core document and appendix together complete the TMDL for each of these pathogen-impaired river segments.

This appendix includes a description of the watershed and maps to identify the segments of focus for the TMDLs; the impaired uses, and the water classification and qualifiers as designated by the Massachusetts Surface Water Quality Standards (SWQS, 314 CMR 4.00); the water quality standards applicable to the impaired uses; the data supporting the pathogen impairment determination; and a description of the sources of pathogen loading with supporting maps. For water quality data, the Method Detection Limit (MDL) is reported and used for values below the MDL when calculating geometric means.

This appendix includes a summary of the allocation of the current indicator bacteria load into two categories: point sources (waste load allocation, WLA) and nonpoint sources (load allocation, LA), based on an analysis of watershed percent impervious cover. This appendix also identifies the percent reduction in indicator bacteria pollutant load from current conditions required to meet the TMDL, based on the highest levels of indicator bacteria recorded in the monitoring data. Refer to Tables 1-1 and 1-2.

Finally, for each impaired segment, this appendix presents existing local management efforts to reduce pathogen pollutant loading. General recommended next steps for implementation of this TMDL are provided in the Blackstone River Watershed Overview section.

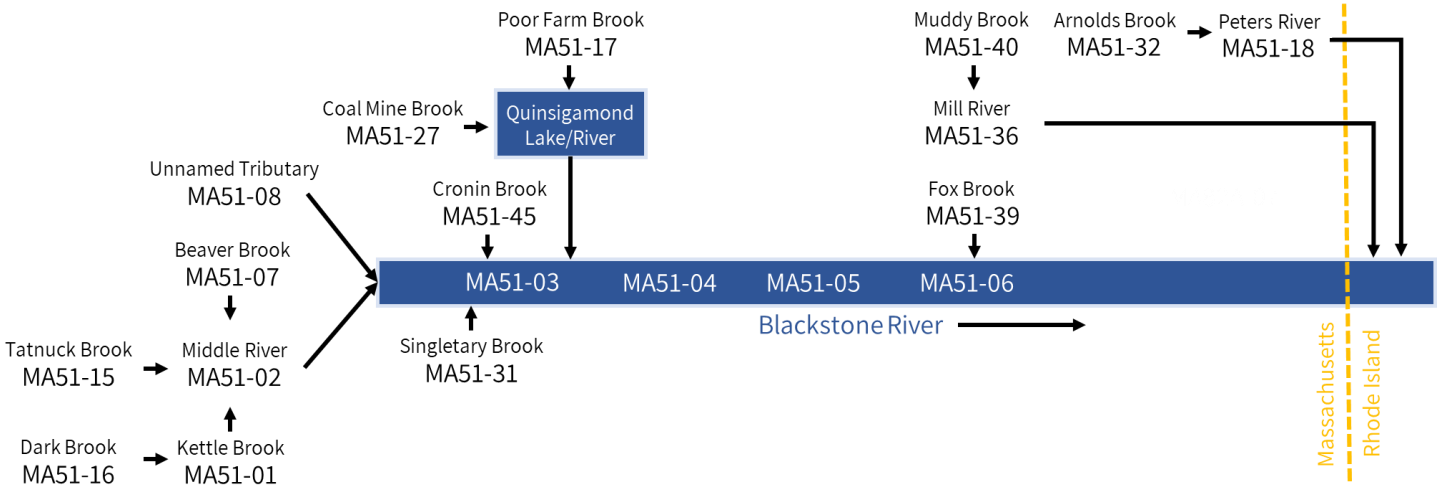


Figure 1-1. Conceptual diagram of water flow routing through the Blackstone River watershed for the 19 pathogen-impaired river segments. Mainstem segments of major waterbodies (i.e., Blackstone and Quinsigamond Lake/River) are highlighted in blue. Tributary segments to the major rivers are shown with arrows to the blue mainstem. Several segments outflow to the portion of the Blackstone River that extends into Rhode Island. Not to scale.

Table 1-1. ***E. Coli*** Total Maximum Daily Loads (TMDLs), the percent reductions needed to meet the TMDL target (126 CFU/100ml) based on the Massachusetts Surface Water Quality Standards (SWQS), and the flow-based TMDL allocations for pathogen-impaired **freshwater** assessment units in the Blackstone River Basin

Waterbody & Assessment Unit	Class (Qualifier)	TMDL Type	SWQS-Based TMDL target (CFU/100ml)	Maximum Geomean (CFU/100ml)	Geomean Percent Reduction	TMDL Allocation	*Flow (cfs)* 1	10	100	1,000	10,000	100,000
							Flow-Based Target TMDL (CFU/day*10^9)					
Kettle Brook		R	126	387	67%	WLA (11%)	0.3	3.3	33.3	333.2	3,331.6	33,315.8
MA51-01	B (WW)			(90 day)		LA (89%)	2.7	27.5	275.0	2,749.5	27,495.2	274,952.3
Middle River		R	126	894	86%	WLA (15%)	0.5	4.7	46.7	466.7	4,667.4	46,674.4
MA51-02	B (WW)			(90 day)		LA (85%)	2.6	26.2	261.6	2,615.9	26,159.4	261,593.6
Blackstone River		R	126	4,400	97%	WLA (19%)	0.6	5.9	59.0	589.8	5,897.6	58,975.9
MA51-03	B (WW, CSO)			(30 day)		LA (81%)	2.5	24.9	249.3	2,492.9	24,929.2	249,292.1
Blackstone River		R	126	3,108	96%	WLA (18%)	0.6	5.7	56.9	569.2	5,691.7	56,917.0
MA51-04	B (WW)			(30 day)		LA (82%)	2.5	25.1	251.4	2,513.5	25,135.1	251,351.0
Blackstone River		R	126	2,420	95%	WLA (14%)	0.4	4.2	41.9	419.4	4,194.4	41,944.2
MA51-05	B (WW)			(30 day)		LA (86%)	2.7	26.6	266.3	2,663.2	26,632.4	266,323.8
Blackstone River		R	126	685	82%	WLA (12%)	0.4	3.6	35.7	356.6	3,565.7	35,657.2
MA51-06	B (WW)			(30 day)		LA (88%)	2.7	27.3	272.6	2,726.1	27,261.1	272,610.9
Beaver Brook		R	126	9,800	99%	WLA (34%)	1.1	10.5	105.2	1,052.4	10,524.3	105,243.4
MA51-07	B (WW, HQW)			(90 day)		LA (66%)	2.0	20.3	203.0	2,030.2	20,302.5	203,024.7
Unnamed Tributary		R	126	4,946	97%	WLA (45%)	1.4	13.9	138.5	1,385.2	13,852.3	138,523.1
MA51-08	B (WW, CSO)			(30 day)		LA (55%)	1.7	17.0	169.7	1,697.4	16,974.5	169,744.9
Tatnuck Brook		R	126	245	49%	WLA (11%)	0.3	3.3	32.7	327.1	3,270.7	32,706.7
MA51-15	B			(90 day)		LA (89%)	2.8	27.6	275.6	2,755.6	27,556.1	275,561.3
Dark Brook		R	126	705	82%	WLA (14%)	0.4	4.3	43.2	431.5	4,315.4	43,153.6
MA51-16	B			(90 day)		LA (86%)	2.7	26.5	265.1	2,651.1	26,511.4	265,114.4
Poor Farm Brook		R	126	429	71%	WLA (25%)	0.8	7.6	75.7	757.4	7,573.9	75,738.8
MA51-17	B			(90 day)		LA (75%)	2.3	23.3	232.5	2,325.3	23,252.9	232,529.2
Peters River		R	126	869	86%	WLA (12%)	0.4	3.8	38.4	384.1	3,841.0	38,410.1
MA51-18	B			(90 day)		LA (88%)	2.7	27.0	269.9	2,698.6	26,985.8	269,858.0
Coal Mine Brook		R	126	565	78%	WLA (33%)	1.0	10.1	100.9	1,008.7	10,087.1	100,871.4
MA51-27	B (CW)			(90 day)		LA (67%)	2.1	20.7	207.4	2,074.0	20,739.7	207,396.6
Singletary Brook		R	126	380	67%	WLA (8%)	0.3	2.6	25.5	255.2	2,551.9	25,518.6
MA51-31	B			(90 day)		LA (92%)	2.8	28.3	282.7	2,827.5	28,274.9	282,749.4
Arnolds Brook		R	126	344	63%	WLA (20%)	0.6	6.2	62.1	621.2	6,211.7	62,117.0
MA51-32	B			(90 day)		LA (80%)	2.5	24.6	246.2	2,461.5	24,615.1	246,151.0
Mill River		R	126	686	82%	WLA (10%)	0.3	3.1	31.2	311.8	3,118.4	31,183.9
MA51-36	B (TWS, WW)			(30 day)		LA (90%)	2.8	27.7	277.1	2,770.8	27,708.4	277,084.1
Fox Brook		R	126	2,194	94%	WLA (7%)	0.2	2.2	21.6	216.2	2,162.3	21,623.1
MA51-39	B			(90 day)		LA (93%)	2.9	28.7	286.6	2,866.4	28,664.5	286,644.9
Muddy Brook		R	126	368	66%	WLA (8%)	0.3	2.6	26.1	260.9	2,609.3	26,093.2
MA51-40	B			(90 day)		LA (92%)	2.8	28.2	282.2	2,821.7	28,217.5	282,174.8
Cronin Brook		R	126	550	77%	WLA (7%)	0.2	2.3	23.0	230.0	2,300.1	23,000.9
MA51-45	B			(90 day)		LA (93%)	2.9	28.5	285.3	2,852.7	28,526.7	285,267.1

Table 1-2. **Enterococci** Total Maximum Daily Loads, the percent reductions needed to meet the TMDL target (35 CFU/100ml) based on the Massachusetts Surface Water Quality Standards (SWQS), and the flow-based TMDL allocations for pathogen-impaired **freshwater** assessment units in the Blackstone River Basin

Waterbody & Assessment Unit	Class (Qualifier)	TMDL Type	SWQS-Based TMDL target (CFU/100ml)	Maximum Geomean (CFU/100ml)	Geomean Percent Reduction	TMDL Allocation	*Flow (cfs)*					
							1	*10*	*100*	*1,000*	*10,000*	*100,000*
							Flow-Based Target TMDL (CFU/day*10^9)					
Kettle Brook		P	35	NA	-	WLA (11%)	0.1	0.9	9.3	92.5	925.4	9,254.4
MA51-01	B (WW)					LA (89%)	0.8	7.6	76.4	763.8	7,637.6	76,375.6
Middle River		P	35	NA	-	WLA (15%)	0.1	1.3	13.0	129.7	1,296.5	12,965.1
MA51-02	B (WW)					LA (85%)	0.7	7.3	72.7	726.6	7,266.5	72,664.9
Blackstone River		P	35	NA	-	WLA (19%)	0.2	1.6	16.4	163.8	1,638.2	16,382.2
MA51-03	B (WW, CSO)					LA (81%)	0.7	6.9	69.2	692.5	6,924.8	69,247.8
Blackstone River		P	35	NA	-	WLA (18%)	0.2	1.6	15.8	158.1	1,581.0	15,810.3
MA51-04	B (WW)					LA (82%)	0.7	7.0	69.8	698.2	6,982.0	69,819.7
Blackstone River		P	35	NA	-	WLA (14%)	0.1	1.2	11.7	116.5	1,165.1	11,651.2
MA51-05	B (WW)					LA (86%)	0.7	7.4	74.0	739.8	7,397.9	73,978.8
Blackstone River		P	35	NA	-	WLA (12%)	0.1	1.0	9.9	99.0	990.5	9,904.8
MA51-06	B (WW)					LA (88%)	0.8	7.6	75.7	757.3	7,572.5	75,725.2
Beaver Brook		P	35	NA	-	WLA (34%)	0.3	2.9	29.2	292.3	2,923.4	29,234.3
MA51-07	B (WW, HQW)					LA (66%)	0.6	5.6	56.4	564.0	5,639.6	56,395.7
Unnamed Tributary		P	35	NA	-	WLA (45%)	0.4	3.8	38.5	384.8	3,847.9	38,478.6
MA51-08	B (WW, CSO)					LA (55%)	0.5	4.7	47.2	471.5	4,715.1	47,151.4
Tatnuck Brook		P	35	NA	-	WLA (11%)	0.1	0.9	9.1	90.9	908.5	9,085.2
MA51-15	B					LA (89%)	0.8	7.7	76.5	765.4	7,654.5	76,544.8
Dark Brook		P	35	NA	-	WLA (14%)	0.1	1.2	12.0	119.9	1,198.7	11,987.1
MA51-16	B					LA (86%)	0.7	7.4	73.6	736.4	7,364.3	73,642.9
Poor Farm Brook		P	35	NA	-	WLA (25%)	0.2	2.1	21.0	210.4	2,103.9	21,038.6
MA51-17	B					LA (75%)	0.6	6.5	64.6	645.9	6,459.1	64,591.4
Peters River		P	35	NA	-	WLA (12%)	0.1	1.1	10.7	106.7	1,066.9	10,669.5
MA51-18	B					LA (88%)	0.7	7.5	75.0	749.6	7,496.1	74,960.5
Coal Mine Brook		P	35	NA	-	WLA (33%)	0.3	2.8	28.0	280.2	2,802.0	28,019.8
MA51-27	B (CW)					LA (67%)	0.6	5.8	57.6	576.1	5,761.0	57,610.2
Singletary Brook		P	35	NA	-	WLA (8%)	0.1	0.7	7.1	70.9	708.9	7,088.5
MA51-31	B					LA (92%)	0.8	7.9	78.5	785.4	7,854.1	78,541.5
Arnolds Brook		P	35	NA	-	WLA (20%)	0.2	1.7	17.3	172.5	1,725.5	17,254.7
MA51-32	B					LA (80%)	0.7	6.8	68.4	683.8	6,837.5	68,375.3
Mill River		P	35	NA	-	WLA (10%)	0.1	0.9	8.7	86.6	866.2	8,662.2
MA51-36	B (TWS, WW)					LA (90%)	0.8	7.7	77.0	769.7	7,696.8	76,967.8
Fox Brook		P	35	NA	-	WLA (7%)	0.1	0.6	6.0	60.1	600.6	6,006.4
MA51-39	B					LA (93%)	0.8	8.0	79.6	796.2	7,962.4	79,623.6
Muddy Brook		P	35	NA	-	WLA (8%)	0.1	0.7	7.2	72.5	724.8	7,248.1
MA51-40	B					LA (92%)	0.8	7.8	78.4	783.8	7,838.2	78,381.9
Cronin Brook		P	35	NA	-	WLA (7%)	0.1	0.6	6.4	63.9	638.9	6,389.1
MA51-45	B					LA (93%)	0.8	7.9	79.2	792.4	7,924.1	79,240.9

Class *defined in the Massachusetts Surface Water Quality Standards (SWQS) at 314 CMR 4.02.*
Qualifiers *that identify segments with special characteristics are defined at 314 CMR 4.06(1)(d).*

CSO *= Combined Sewer Overflow; waters identified as impacted by the discharge of CSOs without a long-term control plan approved or fully implemented*
CW *= Cold Water; waters that meet the cold water fisheries (CWF) definition at 314 CMR 4.02 and are subject to CWF dissolved oxygen and temperature criteria*
HQW *= High Quality Water; waters designated for protection under 314 CMR 4.04(2)*
TWS *= Treated Water Supply; Class B waters used as a source of public water supply after treatment and that may be subject to more stringent site-specific criteria*
WW *= Warm Water; waters that meet the warm water fisheries (WWF) definition at 314 CMR 4.02 and are subject to WWF dissolved oxygen and temperature criteria*

Pathogen bacteria units are presented in colony-forming units or CFU per 100 milliliter or ml.

TMDL Type *identifies the restorative or protective action approach:*
R *= Restorative TMDL addressing a pathogen impairment identified in the 2018/2020 Integrated List of Waters*
R* *= Restorative TMDL addressing a historic impairment of former indicator bacteria for which no current applicable criteria are available See Section 2.3 of the core document for summary of water quality criteria and designated use.*
P *= Protective TMDL addressing all applicable uses, regardless of impairment status, for the associated pathogen (refer to the Massachusetts SWQS: 314 CMR 4.00)*

Target TMDL or Total Maximum Daily Load is presented as both SWQS-Based and Flow-Based.
SWQS-Based TMDL Target *is the target concentration applicable to the TMDL pollutant indicator bacteria based on the Surface Water Quality Standards (314 CMR 4.00).*
Flow-Based Target TMD*L is the target concentration (CFU/100mL) multiplied by the standard flow volume (cubic feet per second or cfs). See Section 4.2.2 in core document for full equation and conversion factors.*
Maximum Geomean *is the highest calculated 30- or 90- day rolling geometric mean for TMDL pollutant indicator bacteria associated with the segment.*
Geomean Percent Reduction *is the percent reduction from the highest calculated 30- or 90- day rolling geomean needed to achieve the target concentration. Percent reductions are for planning purposes only.*

2. Blackstone River Watershed Overview

The Blackstone River watershed, from its origin in Worcester to the Massachusetts-Rhode Island state line, covers an area of approximately 408 square miles (mi^2) in southern Massachusetts and northern Rhode Island (Figure 2-1). The Blackstone River is formed by the confluence of Middle River and an unnamed tributary (also known as Mill Brook), and is joined with the Quinsigamond River in Grafton, MA. There are over 75 named rivers, more than 250 named river miles (National Hydrologic Database), many smaller unnamed streams, and 188 lakes, ponds, and impoundments in the watershed (MassDEP, 2010).

The Blackstone River has historically been used for hydropower and the watershed contains many impoundments and mill dams. On the mainstem, power is still generated at the Riverdale (Northbridge) and Synergics (Tupperware, in Blackstone) projects (MassDEP, 2010); nineteen of the 44 historical mill dams still exist (MassDEP, 2016).

The Blackstone Canal was constructed in the early nineteenth century to transport goods between Worcester and Providence, RI, and consisted of channels and locks connecting navigable sections of the Blackstone River. The canal was abandoned about two decades later and some channels were filled in, but long sections remain essentially intact and hydrologically connected to the Blackstone River, such as the 3.5 mile stretch in Uxbridge and Northbridge. The canal is a focal point for water-related recreation and represents possible flow paths for pathogen pollutants, especially considering its historical use as a sewer (Canal District of Worcester, 2019). Cultural/recreational facilities include the Blackstone Heritage Corridor (National Park Service)[1], Blackstone River and Canal Heritage State Park[2] (Uxbridge, MA), the Canal District of Worcester[3], and several municipal parks, all of which connect to pathogen-impaired waters addressed in this TMDL.

There are 19 pathogen-impaired river segments in the Blackstone River Watershed, including four pathogen-impaired-segments covering nearly the full length of the mainstem (32 impaired river miles). The upstream portion of the Blackstone River watershed is the most developed and includes ten pathogen-impaired river segments. The downstream portion of the watershed includes five pathogen-impaired river segments.

The Blackstone River itself drains 363 square miles from Worcester, MA to Woonsocket, RI. The river course is slowed and altered by many dams and receives effluent from five major wastewater treatment facilities (WWTF), which will be discussed later in this TMDL (MassDEP, 2016).

The Blackstone River watershed overlaps, at least partially, 27 Massachusetts and seven Rhode Island municipalities. Of these, 16 Massachusetts cities and towns were identified as being direct sources of pathogen loading to the impaired river segments in this TMDL. The efforts of these municipalities to address their contributions to pollutant loading are described in the segment-specific sections below. For each segment, the cities and towns that contain or border the impaired segment were identified. Towns comprising more than 10% of the impaired stream segment's sub-basin (that portion of its watershed not shared with upstream segments) were also included. In addition, towns which may not meet the above characteristics, but which have land area in the sub-basin near the impaired segment (e.g., City of Worcester for Kettle Brook segment MA51-01), were included on a case-by-case basis. See Figure 2-1 for a map showing impaired segments and municipalities.

Many municipalities operate and maintain municipal separate storm sewer systems (MS4s) in urban areas. These networks of drains and pipes convey stormwater runoff, often including pollutants, from streets and developed areas to streams. In addition, these networks are sometimes subject to direct wastewater inflows through illegal cross- connections, leaks from sewer pipes or on-site septic systems, dumping, and other unauthorized wastewater sources, and together these sources are termed illicit discharges.

EPA and MassDEP jointly issued the General Permits for Stormwater Discharges from MS4s, which became effective July 1, 2018. Communities that discharge to pathogen-impaired waterbodies with approved TMDLs are required to implement enhanced best management practices (BMPs) for public education and designate the catchments as Problem Catchments or High Priority under the Illicit Discharge Detection and Elimination (IDDE)

[1] https://blackstoneheritagecorridor.org/
[2] https://www.mass.gov/locations/blackstone-river-and-canal-heritage-state-park
[3] https://thecanaldistrict.com/

Program, in addition to the requirement to reduce pollutants to the Maximum Extent Practicable (USEPA, 2020, Appendix F).

In addition to municipalities, there are two Regional Planning Agencies (RPAs) working in the Blackstone River watershed. These are public organizations advising municipalities, private business groups, and state and federal governments on a range of matters. Their research, coordination, and technical assistance is especially valuable on watershed issues such as pathogen pollutants and stormwater that cross town boundaries.

- Central Massachusetts Regional Planning Commission (CMRPC), http://www.cmrpc.org/ (CMRPC, 2020)
- Metropolitan Area Planning Council (MAPC), http://www.mapc.org/ (MAPC, 2020)

The following RPA initiatives and tools are especially noteworthy:

- There are regional stormwater coalitions within some RPAs, and these are noted in the segment-specific sections below.
- The CMRPC offers local technical assistance to municipalities within their jurisdiction, and in the creation of master plans, new zoning bylaws, green energy technical assistance, and GIS mapping.
- MAPC created a *Stormwater Utility/Funding Starting Kit* (MAPC, 2014).
- MAPC and the Neponset River Watershed Association created a GIS toolkit to calculate MS4 outfall catchment areas, which is a requirement under the MS4 General Permit; this is available at https://www.mapc.org/resource-library/ms4-outfall-catchment-calculator/ (MAPC, 2018).

Beyond these activities, two stormwater coalitions exist that cover the Blackstone River Watershed that assist municipalities in meeting stormwater management regulatory requirements. The Massachusetts Statewide Municipal Stormwater Coalition (MSMSC) is composed of about 10 stormwater coalitions around the state and represent about 188 municipalities. MSMSC further coordinates with and assists municipalities on pathogen pollutant concerns in the “Think Blue” campaign (Think Blue Massachusetts, 2019). Think Blue Massachusetts, run by the MSMSC is a statewide educational campaign to help residents and businesses do their part to reduce polluted runoff and keep our state’s lakes, rivers, and streams clean and healthy. Another stormwater coalition that has members in the Blackstone River Watershed is the Central Massachusetts Regional Stormwater Coalition (CMRSWC). The CMRSWC was originally formed by a group of 13 communities in Central Massachusetts working together to address municipal stormwater management. Current active membership has grown to include 30 municipalities: Ashland, Auburn, Ayer, Charlton, Dudley, Fitchburg, Framingham, Grafton, Holden, Hopedale, Hopkinton, Lunenburg, Marlborough, Millbury, Natick, Northborough, Northbridge, Oxford, Palmer, Paxton, Rutland, Shrewsbury, Southbridge, Southborough, Spencer, Sterling, Sturbridge, Uxbridge, West Boylston, and Westborough. The CMRSWC has assisted its communities by developing templates for stormwater pollution prevention plans, standard operating procedures for municipal stormwater operations, help training courses for municipal officials on illicit discharge detection and elimination, created educational outreach material on stormwater for residents, among other things.

Additional watershed-scale initiatives are carried out by several organizations, including:

Blackstone River Watershed Association (BRWA) conducts water quality monitoring, outreach and education, and clean-ups in the geographic central portion of the watershed. The BRWA has produced water quality protection guides for homeowners, horse owners, and small farms.

Blackstone River Coalition (BRC), a partnership of private, municipal, and state organizations working to improve and protect the water quality and other environmental aspects of the Blackstone River and watershed. Initiatives include educational outreach to businesses and municipalities regarding stormwater and MS4 compliance, outreach to small farms and horse owners on protecting water quality, water quality monitoring, and recreational river guides.

Blackstone Headwaters Coalition (BHC) engages citizens, businesses, environmental organizations, and state and municipal officials in the active stewardship of water resources in headwater stream of the Blackstone

River, in the upper watershed. Initiatives include educating students and community members, conducting water quality monitoring, and planting rain gardens.

The following actions will help reduce pathogen loads to the impaired streams. The list is a starting point and is not comprehensive. For a more detailed discussion of pollutant reduction actions, see Section 5, "Implementation" of the core TMDL document.

- **CSO Removal:** Removal of all CSOs in the watershed is a top priority.
- Collect water quality data for those segments for which all existing data are more than five years old.
- **Municipalities:** Continue to implement requirements of the MS4 permit, which includes specific requirements for waterbodies with an approved Bacteria/Pathogen TMDL, such as prioritization and reporting, enhanced BMPs, IDDE actions, and education (USEPA, 2020).
- **Regional Planning Agencies (RPAs) and municipalities:** Continue and expand collaboration on MS4 and stormwater issues. Cooperatively developing tools and sharing knowledge has many advantages, including reduced costs, increased innovation, and more consistent and effective stream restoration efforts at the watershed scale.
    - Two tools developed by MAPC are potentially valuable to all MS4 communities in the state. Municipalities and other RPAs (with permission from MAPC) should consider adapting and/or expanding on these tools in their area:
        - *Stormwater Utility/Funding Starting Kit* (MAPC, 2014).
        - MAPC and the Neponset River Watershed Association created a GIS toolkit to calculate MS4 outfall catchment areas, which is a requirement under the MS4 General Permit (MAPC, 2018).
- **USDA NRCS and landowners:** Develop comprehensive nutrient management plans for agriculture, using local connections to farmers for outreach.
- **Parks departments, schools, private landowners, and others** who maintain large, mowed fields with direct access to water should consider maintaining a vegetative buffer along the water's edge. Buffers slow and filter stormwater runoff, provide a visual screen that can reduce large aggregations of waterfowl, and have many other water quality benefits at low cost.

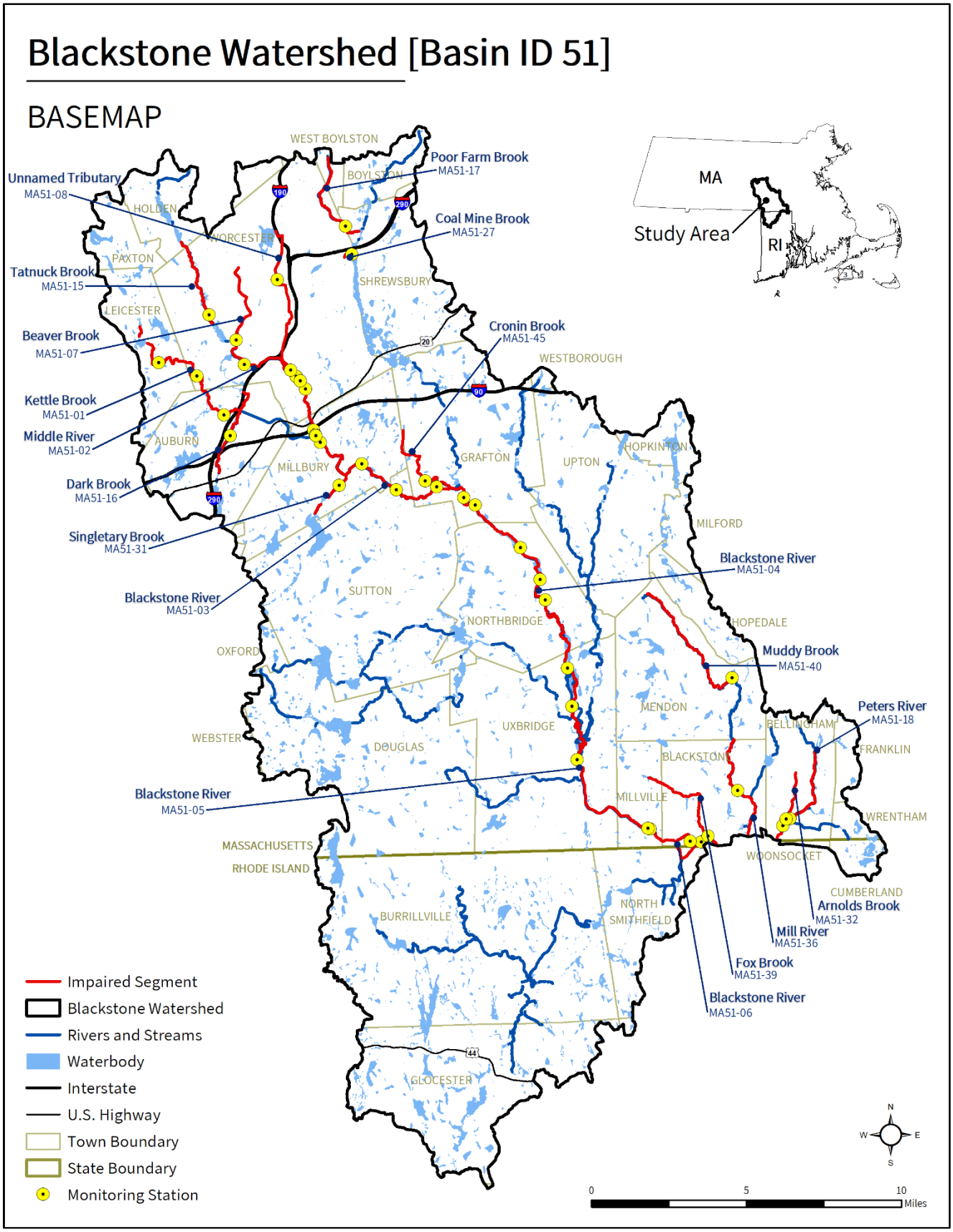


Figure 2-1: Map of all pathogen-impaired river segments, water quality monitoring stations, municipal borders, waterbodies, and roads in the Blackstone River watershed.

3. MA51-01 Kettle Brook

3.1. Waterbody Overview

Kettle Brook segment MA51-01 is seven miles long and begins about 3.5 miles northwest of I-290 at the outlet of the Kettle Brook Reservoir Number One in Leicester, MA. Kettle Brook then flows from Leicester through Worcester and Auburn where it passes beneath I-290. The segment is bound at the downstream end by Leesville Pond in Auburn, about 0.5 miles downstream of Kettle Brook's confluence with Ramshorn Brook.

Kettle Brook flows through Waite Pond, though the assessment unit excludes the approximately 0.4 miles of the stream within that impoundment. It also flows through City, Smiths, and Jamesville Ponds (the latter is now a vegetated wetland). Then, the segment flows through the northern half of Stoneville Pond. Although Stoneville Reservoir is just upstream of Stoneville Pond, the impaired segment does not flow through it. Additional tributary flow comes from several wooded and emergent wetlands adjacent to the stream corridor. Impaired tributaries to this section of Kettle Brook include the pathogen-impaired Dark Brook (MA51-16) from the south. To the north, the Lynde Brook Reservoir, and the Kettle Brook Reservoirs (Numbers 1, 2, 3, and 4) have been identified as Public Water Supply Reservoir Watersheds and contribute to the flow of Kettle Brook.

Protected lands in the watershed include Cider Mill Conservation Area, Southwick Pond Brook Conservation Area, Asnebumskit Ridge Conservation Area and the Muir Meadow Water Supply Area. Kettle Brook flows through a southwestern suburb of Worcester, including the Cherry Valley neighborhood in Leicester.

Road crossings include Main Street/MA-9 in Leicester, Stafford Street in Worcester, and Oxford Street N in Auburn, before reaching the I-290 overpass. This brook also flows around a recreational facility with two ball fields and a soccer field off Stafford Street near Ludlow Street.

Kettle Brook (MA51-01) drains an area of 30 mi^2, of which 3 mi^2 (11%) is covered with impervious surfaces, and 2 mi^2 (7%) is considered directly connected impervious area (DCIA). The

Reduction from Highest Calculated Geomean: 67%

Watershed Area (Acres): 19,433

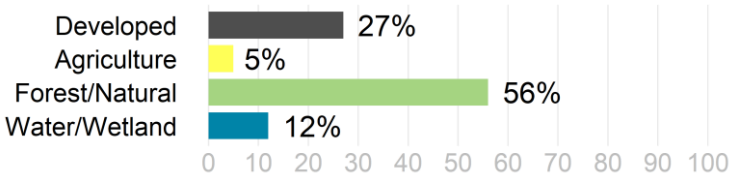
Segment Length (Miles): 7.0

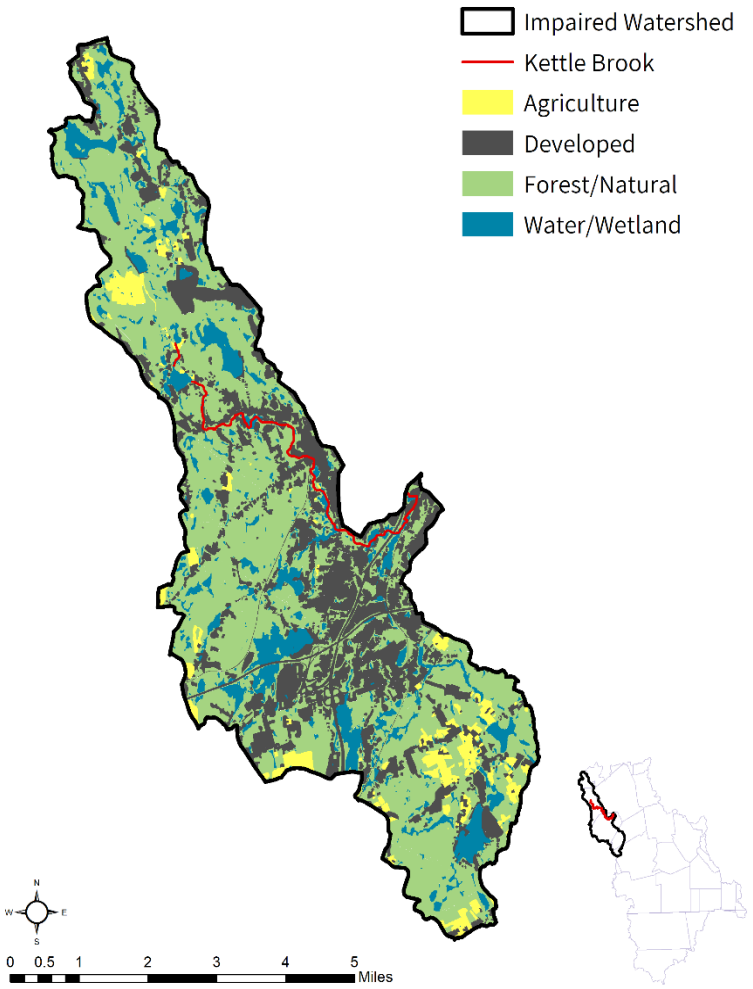
Impairment(s): *E. coli*, fecal coliform (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water)

Impervious Area (Acres, %): 2,100 (11%)

DCIA Area (Acres, %): 1,381 (7%)





watershed is served partially[4] by public sewer and 51% is subject to stormwater regulations under the National Pollutant Discharge Elimination System (NPDES) General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file governing point source discharges of pollutants to surface waters, nor are there any NPDES permits on file for wastewater treatment facilities or groundwater discharge permits for on-site wastewater discharge within this watershed. Two closed landfills and one inactive dump exist in the watershed north of I-90. There are no known unpermitted land disposal dumping grounds within the segment watershed. See Figure 3-1.

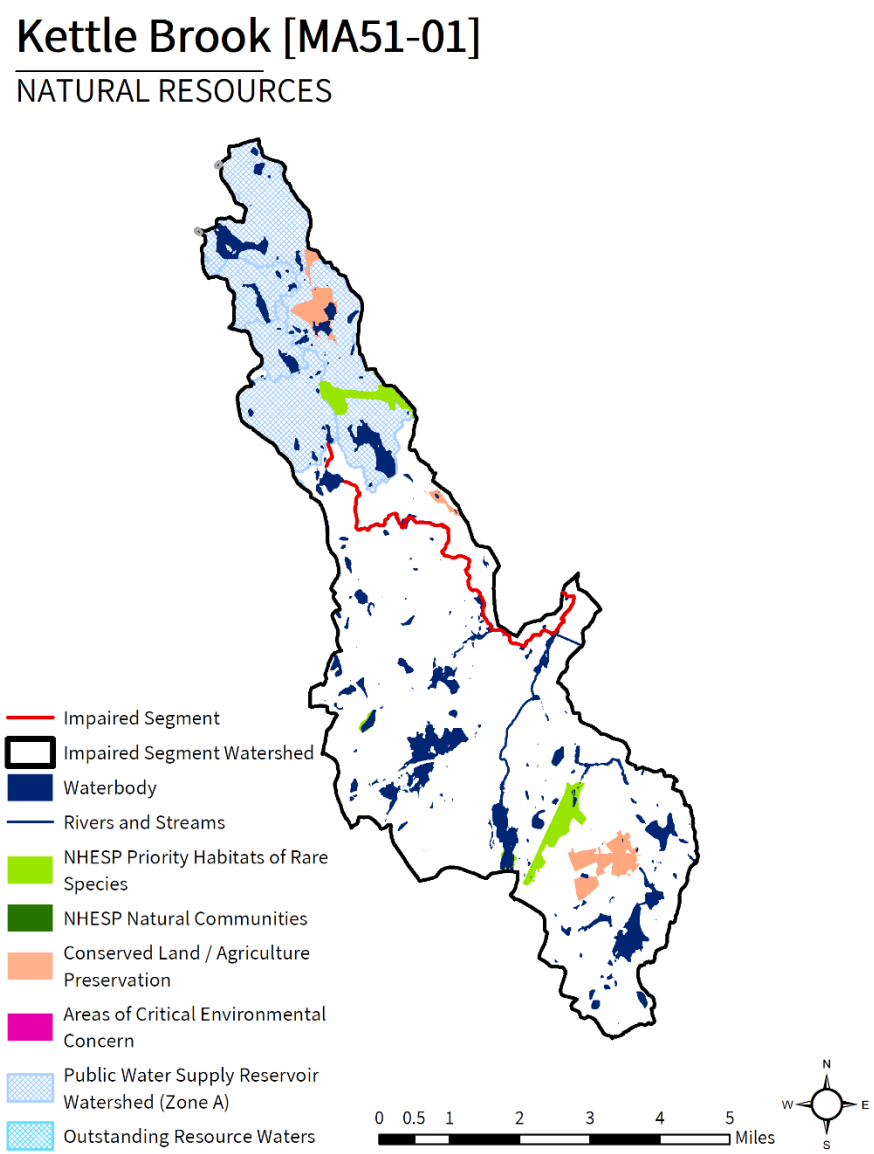
Forest land dominates land uses in the watershed (56%), followed by developed land (27%), wetlands (12%), and agriculture (5%). The segment flows through medium- to high-density mixed development. Kettle Brook flows through underground conduits in some areas, including the Stafford Street road crossing just south of Ludlow Street in Worcester. While the upstream segment's riparian corridor is wooded, the downstream segment, beginning at the New Balance Fields (ball fields), is confined to a narrow vegetated strip often just 2-5 meters wide. Most of the land in agricultural use is distant from the segment, located in the northern and southern parts of the watershed.

In the watershed contributing to this segment (MA51-01), under the Natural Heritage and Endangered Species Program, there are 461 acres (2%) of Priority Natural Vegetation Communities. There are 4,560 acres (23%) under Public Water Supply protection, and no Areas of Critical Environmental Concern or Outstanding Resource Waters. Over 504 acres (3%) of land are protected in perpetuity[5], which is part of a total of 3,800 acres (20%) of Protected and Recreational Open Space[6]. See Figure 3-1.

[4] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[5] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[6] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



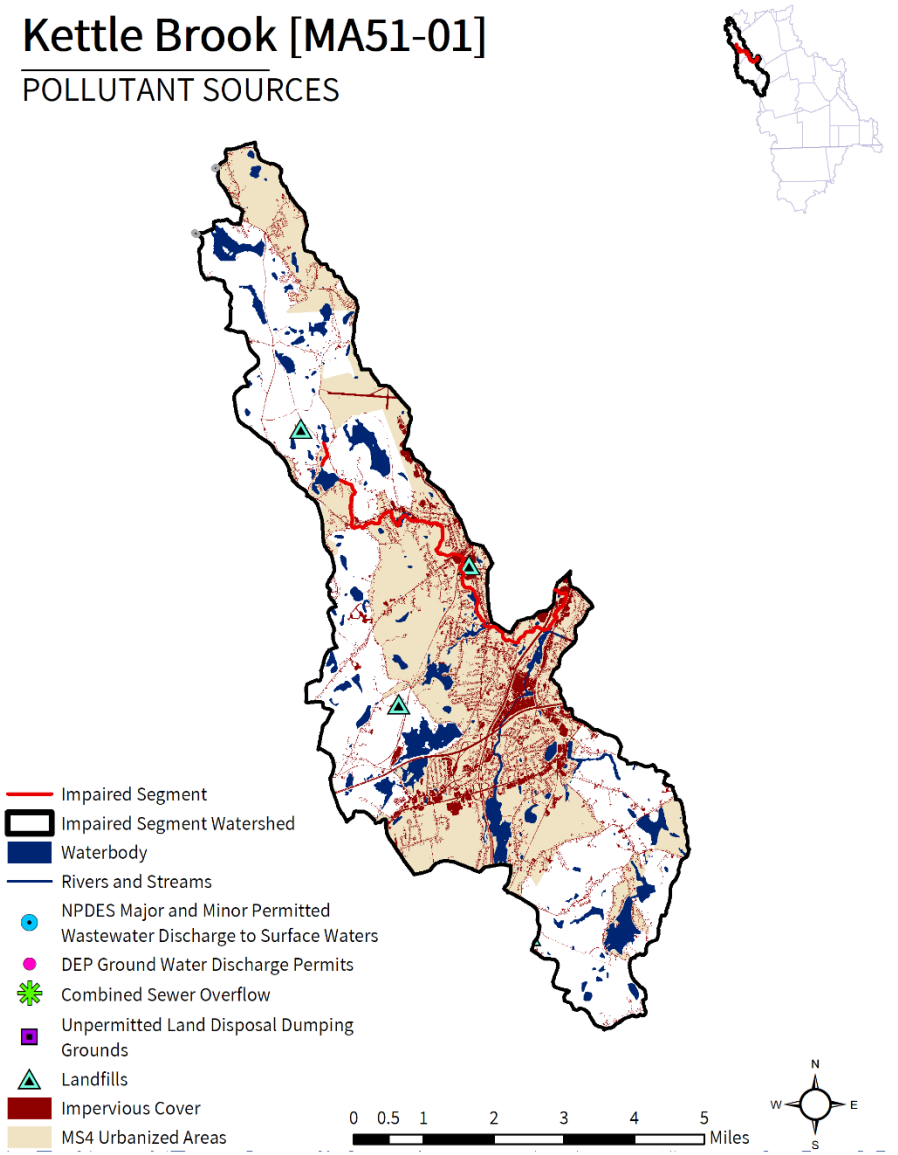


Figure 3-1. Natural resources and potential pollution sources draining to the Kettle Brook segment MA51-01. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

3.2. Waterbody Impairment Characterization

Kettle Brook (MA51-01) is a Class B, Warm Water (MassDEP, 2021).

The Primary Contact Recreation uses were assessed for attainment of the Massachusetts Surface Water Quality Standard (SWQS) at the stations listed below (refer to Tables 3-1, 3-2; Figure 3-2), using the indicator bacteria *E. coli*. Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

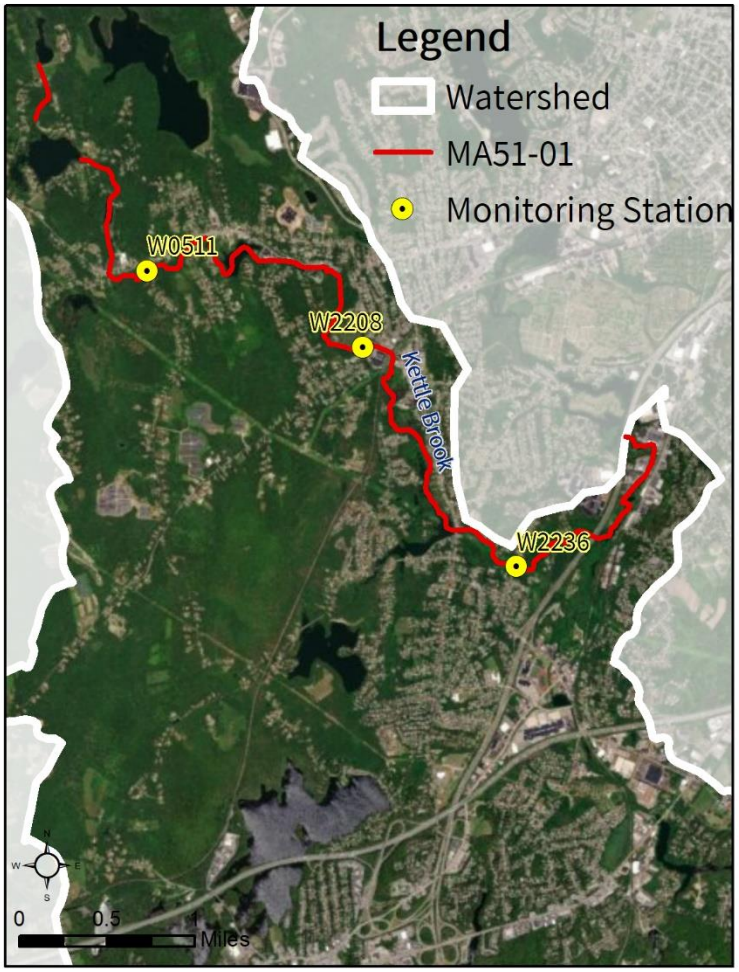


Figure 3-2. Location of monitoring station(s) along the impaired river segment.

- In 2011, seven samples were collected at W0511, resulting in one day when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the Statistical Threshold Value (STV) criterion was applied to single sample results. Out of seven samples, one exceeded the STV criterion during wet weather.
- In 2011, six samples were collected at W2208, resulting in one day when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, none exceeded the STV criterion.
- In 2011, seven samples were collected at W2236, resulting in seven days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, one exceeded the STV criterion during wet weather.

Table 3-1. Summary of indicator bacteria sampling results by station for Kettle Brook (MA51-01). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 colony-forming units (CFU)/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the STV criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0511	5/5/2011	10/12/2011	7	128	1	1
W2208	5/17/2011	9/26/2011	6	261	1	0
W2236	5/5/2011	10/12/2011	7	387	7	1

Table 3-2. Indicator bacteria data by station, indicator and date for Kettle Brook (MA51-01). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W0511	*E. coli*	5/5/11	DRY	68	68	
W0511	*E. coli*	6/9/11	DRY	51	59	
W0511	*E. coli*	7/7/11	DRY	105	71	
W0511	*E. coli*	7/21/11	DRY	18	51	
W0511	*E. coli*	8/29/11	WET	2420	124	
W0511	*E. coli*	9/15/11	DRY	58	128	
W0511	*E. coli*	10/12/11	DRY	15	78	
W2208	*E. coli*	5/17/11	WET	261	261	
W2208	*E. coli*	6/9/11	DRY	60	125	
W2208	*E. coli*	6/21/11	DRY	27	75	
W2208	*E. coli*	7/26/11	DRY	167	92	
W2208	*E. coli*	8/23/11	DRY	6	36	
W2208	*E. coli*	9/26/11	DRY	114	49	
W2236	*E. coli*	5/5/11	DRY	387	387	
W2236	*E. coli*	6/9/11	DRY	121	216	
W2236	*E. coli*	7/7/11	DRY	126	181	
W2236	*E. coli*	7/21/11	DRY	153	173	
W2236	*E. coli*	8/29/11	WET	2420	274	
W2236	*E. coli*	9/15/11	DRY	178	302	
W2236	*E. coli*	10/12/11	DRY	114	294	

3.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria data for Kettle Brook (MA51-01) were elevated during wet weather at stations W0511 and W2236, a result which is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The Kettle Brook (MA51-01) watershed is 27% developed land cover, with 51% in MS4, and 7% as DCIA. The impaired segment itself flows through these developed areas. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With some of the watershed sewered and most (51%) of the watershed designated as MS4 area, illicit storm drain connections and/or illicit discharges from failing infrastructure such as leaky sewer lines or SSOs are likely sources of pathogens.

On-Site Wastewater Disposal Systems: Areas within the watershed depend on on-site septic systems for wastewater treatment. It is likely that a portion of these systems are not properly maintained and are discharging untreated effluent to the environment.

Agriculture: While there is a moderate amount of agriculture (5% of land area), most areas are distant from the impaired segment and located in the northern and southern portions of the watershed. Agricultural activities related to manure storage and spreading, if not well managed, are possible sources of pollutant loading.

Pet Waste: Protected and Recreational Open Space makes up a large proportion (20%) of the land uses within this watershed. There are several conservation lands and ballfields adjacent to the stream corridor, and much of the brook flows through residential neighborhoods. Areas popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent possible sources of pathogens.

Wildlife Waste: There is a large, mowed field around the outlet of Kettle Brook Reservoir Number One in the headwaters of the brook, along with other large conservation lands and wetlands within the watershed. Large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

3.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Auburn

Most of the Town of Auburn is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit, and the town (Permit ID #MAR041088) has an EPA-approved Notice of Intent (NOI). Auburn has a Stormwater Management Plan on file at the Town Office. The town mapped all of its MS4 stormwater system and submitted the map attached to the NOI. It adopted an illicit discharge detection and elimination (IDDE) plan, erosion and sedimentation control (ESC) plan, and post-construction stormwater regulations in 2011. According to the NOI, there are 17 stormwater outfalls into Kettle Brook MA51-01 and 86 stormwater outfalls into Dark Brook/Ramshorn Brook MA51-16, both of which are impaired for *E. coli*.

Auburn has the following ordinances and bylaws:

- Stormwater Management component to Town Bylaws, chapter XVII: https://www.rrstormwater.com/compliance_item/town-of-auburn/ (Aqualis, 2020)
- Wetlands Protection component, General Bylaws, Chapter XII section 12.14: https://www.auburnguide.com/DocumentCenter/View/486/General-By-Laws-PDF (Town of Auburn, 1979)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

The Town of Auburn's web site is the source of information for ongoing projects (Town of Auburn, 2020). Auburn's 2006 Master Plan is currently being updated and is not yet available to the public. The 2016 Open Space and Recreation Plan (available at https://www.auburnguide.com/DocumentCenter/View/6014/Approved-2014-Open-Space-Plan-PDF), approved through 2020, states the town aims to maintain environmental quality and public health through extending sanitary sewers to residential neighborhoods with high rates of on-site septic system failures (Town of Auburn, 2014). The plan mentions that stormwater runoff from Auburn's steep terrain, worsened by large areas of impervious surface associated with development, now presents flood hazards to the City of Worcester. An aqueduct was bored through Pakachoag Hill to divert water from Kettle Brook directly to the Blackstone River to reduce flooding in the Webster Square area of Worcester. The plan also sets a goal to

protect the town's water resources for drinking supply and recreation, considering both water quality and quantity, with a focus on the town's well-fields and recharge areas.

Town of Leicester

About a third of Leicester is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041202) and has an EPA-approved Notice of Intent (NOI). Leicester plans to complete their Stormwater Management Plan (SWMP) within the required time frame stated on the permit, after which the SWMP will be stored at the Leicester Highway Department Office and will be available on the town website. The town has mapped all of its MS4 stormwater system and submitted the map as an attachment to the NOI. Leicester adopted an illicit discharge detection and elimination (IDDE) plan in 2014, and an erosion and sedimentation control (ESC) plan and post-construction stormwater management regulations in 2011. According to the NOI, there are no stormwater outfalls into the impaired segment of Kettle Brook MA51-01.

Leicester has the following ordinances and bylaws:

- Stormwater Management Bylaw, in Town Zoning Bylaws, updated June 2, 2020: https://www.leicesterma.org/planning-board/pages/zoning-bylaws-map (Town of Leicester, 2020)
- Wetland Protection Bylaw: https://www.leicesterma.org/sites/leicesterma/files/uploads/leicester_wetland_regulations_11-18-2015_-_copy_1.pdf (Town of Leicester, 2015)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

The Natural Resources Chapter in Leicester's Master Plan (Town of Leicester 2009; starting on page 7-1) emphasizes the Leicester Open Space and Recreation Plan as providing an action plan to protect and improve the quality of natural resources for recreational, and cultural and historical purposes (Town of Leicester, 2015). Under the stormwater management section on page 6-14, the plan provides a detailed explanation of the NPDES Phase II Stormwater Program and MS4 Permit. The plan cites the protection of ground and surface water quality as a high priority under facilities and services goals.

Leicester's Master Plan: https://www.leicesterma.org/sites/g/files/vyhlif781/f/uploads/2009mp.pdf (Town of Leicester, 2009)

Open Space and Recreation Plan: https://www.leicesterma.org/planning/pages/2015-open-space-recreation-plan (Town of Leicester, 2015).

Town of Paxton

A small portion of Paxton is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041148) and has an EPA-approved Notice of Intent (NOI). Paxton has a Stormwater Management Plan on file at the Town Hall, which is available to the public. The town has mapped all of its MS4 stormwater system. The town also adopted an illicit discharge detection and elimination (IDDE) plan and erosion and sedimentation control plan (ESC) in 2017, and post-construction stormwater management plan in 2006. According to the NOI, there are no stormwater outfalls into impaired segments within the Blackstone watershed.

Paxton has the following ordinances and bylaws:

- Stormwater Bylaw: https://www.townofpaxton.net/sites/g/files/vyhlif4846/f/uploads/storm_water_bylaw_amend._5.6.19_read_only_.pdf (Town of Paxton, 2019)
- Wetland Protection Bylaw: (Town of Paxton, 2018)
- Pet Waste: https://www.townofpaxton.net/stormwater-awareness/pages/dog-waste (Town of Paxton, n.d.)
- Stormwater Utility (or similar): None found.

In addition, Paxton's Master Plan has a Natural Features, Open Space, and Recreation Chapter which includes a water resources section. Paxton does not currently have a municipal sewer system, and the plan notes that Paxton's poor soils make the installation of on-site septic systems difficult.

Paxton Master Plan: https://www.townofpaxton.net/master-plan-implementation-committee/pages/master-plan (Town of Paxton, 2008)

Paxton Stormwater Page: https://www.townofpaxton.net/?SEC=B3706735-7F7E-4632-8E1C-8E8B1E765ED6 (Town of Paxton, 2020)

Open Space and Recreation Plan: https://www.townofpaxton.net/open-space-recreation-committee/pages/open-space-plan (Town of Paxton, 2013)

City of Worcester

Worcester has the following ordinances and bylaws:

- Stormwater Bylaw: None found.
- Stormwater Utility: None found. http://www.worcesterma.gov/water-sewer/stormwater
- Wetland Ordinance: http://www.worcesterma.gov/uploads/46/04/46040c720fab869be6e1f8acb6c7ab5b/wetland-ordinance.pdf (City of Worcester, 2019a)
- Pet Waste: None found.

The city has an Integrated Water Resources Management Plan managed by the Department of Public Works, described at http://www.worcesterma.gov/cww/integrated-plan.pdf (City of Worcester, 2019b).

A Master Plan for Worcester was not found, however, there are Master Plans for individual municipal properties, found at http://www.worcesterma.gov/parks/document-center (City of Worcester, 2020).

Open Space and Recreation Plan: http://www.worcesterma.gov/uploads/b2/cf/b2cf512db5d833bbf34e564180a42b07/open-space-plan.pdf (City of Worcester, 2006).

The city's Open Space and Recreation Plan has a water resources section including surface water, water supplies, flood hazard areas, vernal pools, and wetlands (City of Worcester, 2006). The plan describes the city's Infrastructure system on page 14 and notes that over 90% of the city is served by Public sewers. Stormwater is mentioned in the Erosion and Sediment Section on page 35.

4. MA51-02 Middle River

4.1. Waterbody Overview

The Middle River segment MA51-02 is 3.4 miles long and begins at the outlet of Coes Pond in Worcester, near the intersection of Park Avenue/MA-9 and Beaver Street. The segment flows about 300 feet before converging with Beaver Brook (downstream of Coes Reservoir). The two streams join to form the rest of the impaired segment MA51-02. The Middle River flows east to the Worcester neighborhoods of South Worcester and College Hill, where it converges with an unnamed impaired tributary MA51-08, known locally as "Mill Brook," in Worcester.

City of Worcester officials have used the alternate names of either Beaver Brook or Halfway River for the portion of the stream from Coes Pond to Kettle Brook, and from that point, the Middle River (MassDEP, 2010). The USGS National Map currently labels the upstream portion of the segment as Beaver Brook, the middle section as the Middle River, and the downstream section as the Blackstone River (USGS, 2019).

The entire impaired Middle River segment MA51-02 is within the Town of Worcester. The Middle River watershed however spans seven towns, including Paxton, Holden, Leicester, Worcester, Auburn, Millbury, and Sutton.

Pathogen-impaired tributaries in the watershed include Kettle Brook MA51-01, Beaver Brook MA51-07, Tatnuck Brook MA51-15, and Dark Brook MA51-16. The Middle River drains the Coes Reservoir, Coes Pond, and Curtis Ponds subwatersheds.

Major landmarks in the watershed include the Worcester State University, Clark University, the Worcester Regional Airport, and Hope Cemetery, all located in Worcester, along with a portion of the densely populated South Worcester commercial and residential neighborhood.

Road crossings include Park Avenue/MA-9, Mill Street, Main Street, Webster Street, Fremont Street, and I-290. The downstream portion of the Middle River flows directly through Hope Cemetery before paralleling I-290 for about 0.5 miles.

The Middle River MA51-02 drains an area of 50 mi^2, of which 8 mi^2 (15%) is covered with

Reduction from Highest Calculated Geomean: 86%

Watershed Area (Acres): 32,143

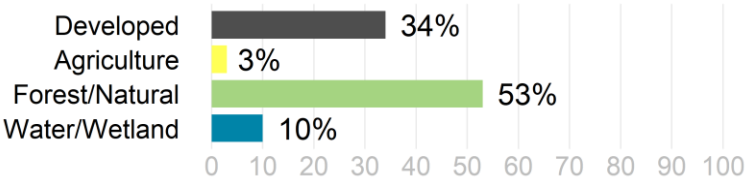
Segment Length (Miles): 3.4

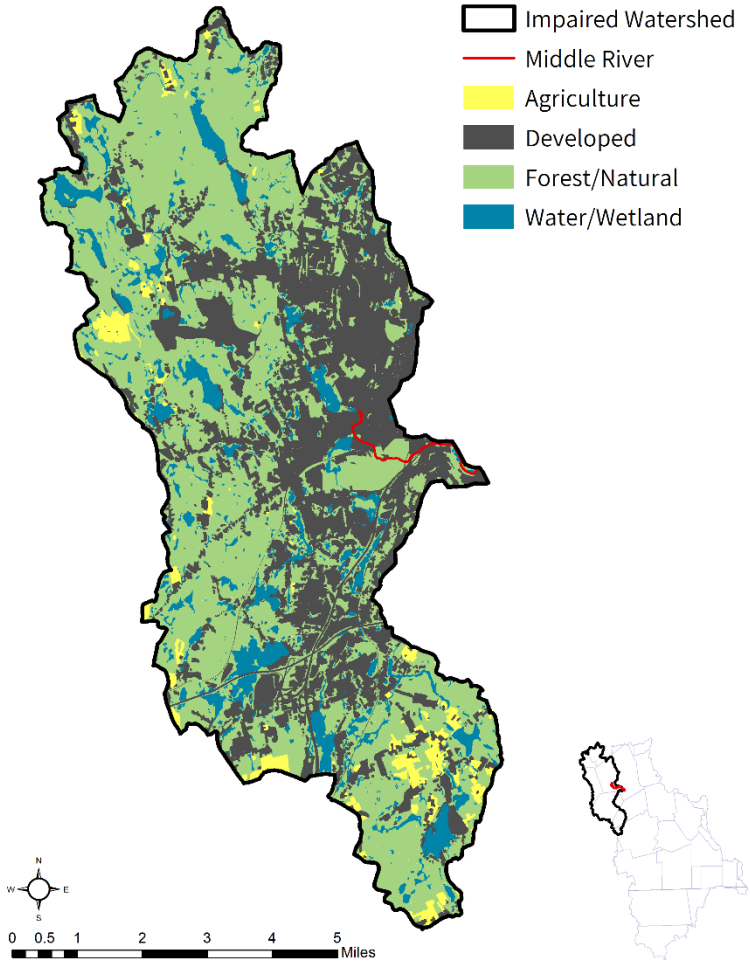
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water)

Impervious Area (Acres, %): 4,867 (15%)

DCIA Area (Acres, %): 3,441 (11%)





impervious surfaces, and 5 mi^2 (11%) is considered directly connected impervious area (DCIA). The watershed is served partially[7] by municipal sewer systems, and 60% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are four NPDES permits on file governing point source discharges of pollutants to surface waters. There are no NPDES permits on file for wastewater treatment facilities, no groundwater discharge permits for on-site wastewater discharge, no landfills, and no unpermitted land disposal dumping grounds within the segment watershed. There is one NPDES Industrial discharge permitted within the watershed segment (Table 4-1). See Figure 4-1.

Table 4-1 NPDES permits for Industrial Stormwater discharges (WWTF). Only permits unique to this segment watershed are shown.

NPDES ID	NAME	TOWN
MA0040483	POLAR BEVERAGES	WORCESTER

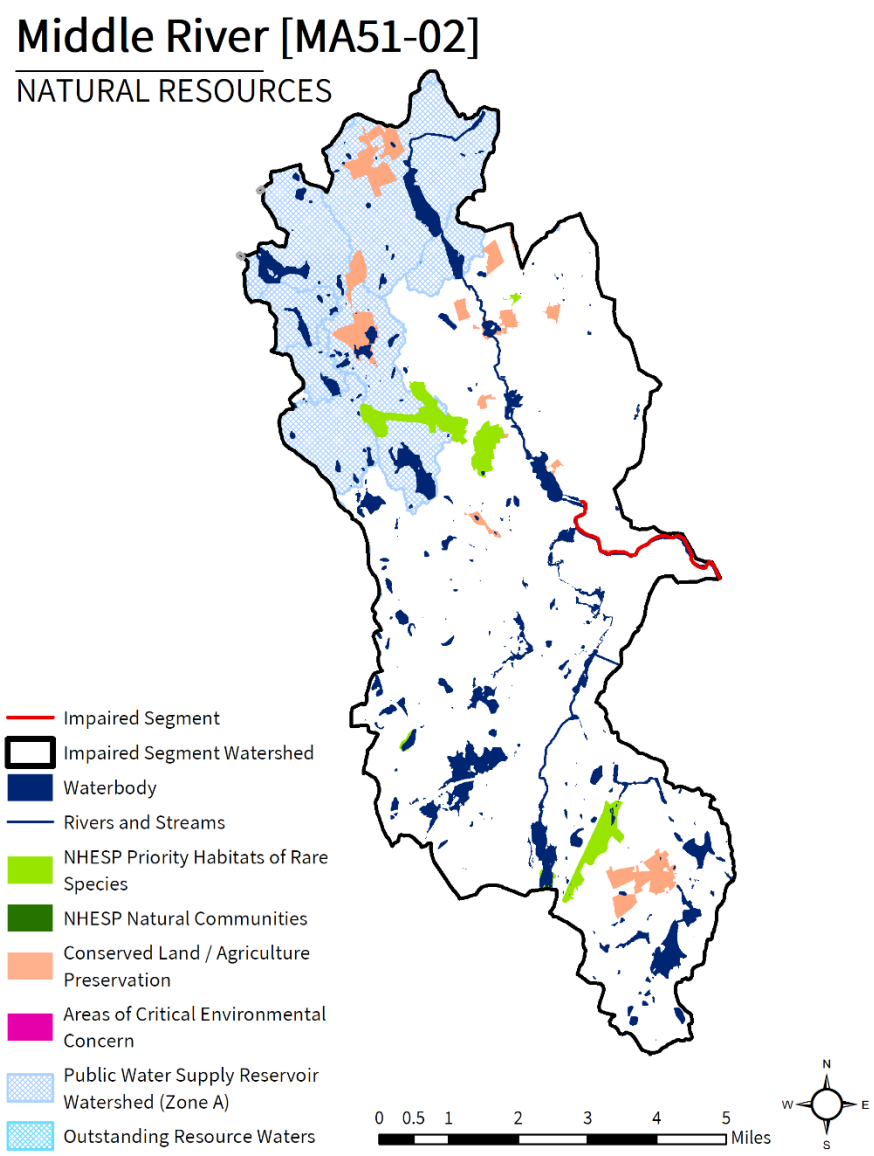
The watershed is 34% developed, and the segment itself flows through high density commercial and residential development, including the downstream third which flows along several divided highways and near a large freight rail yard. Most agricultural lands (3%) are distant from the impaired segment.

In the watershed of the Middle River (MA51-02), under the Natural Heritage and Endangered Species Program, there are 728 acres (2%) of Priority Habitats of Rare Species. There are 7,966 acres (25%) under Public Water Supply protection, and no Areas of Critical Environmental Concern or Outstanding Resource Waters. Over 1,046 acres (3%) of land are protected in perpetuity[8] within the segment watershed, which is part of a total of 7,372 acres (23%) of Protected and Recreational Open Space[9]. See Figure 4-1.

[7] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[8] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[9] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



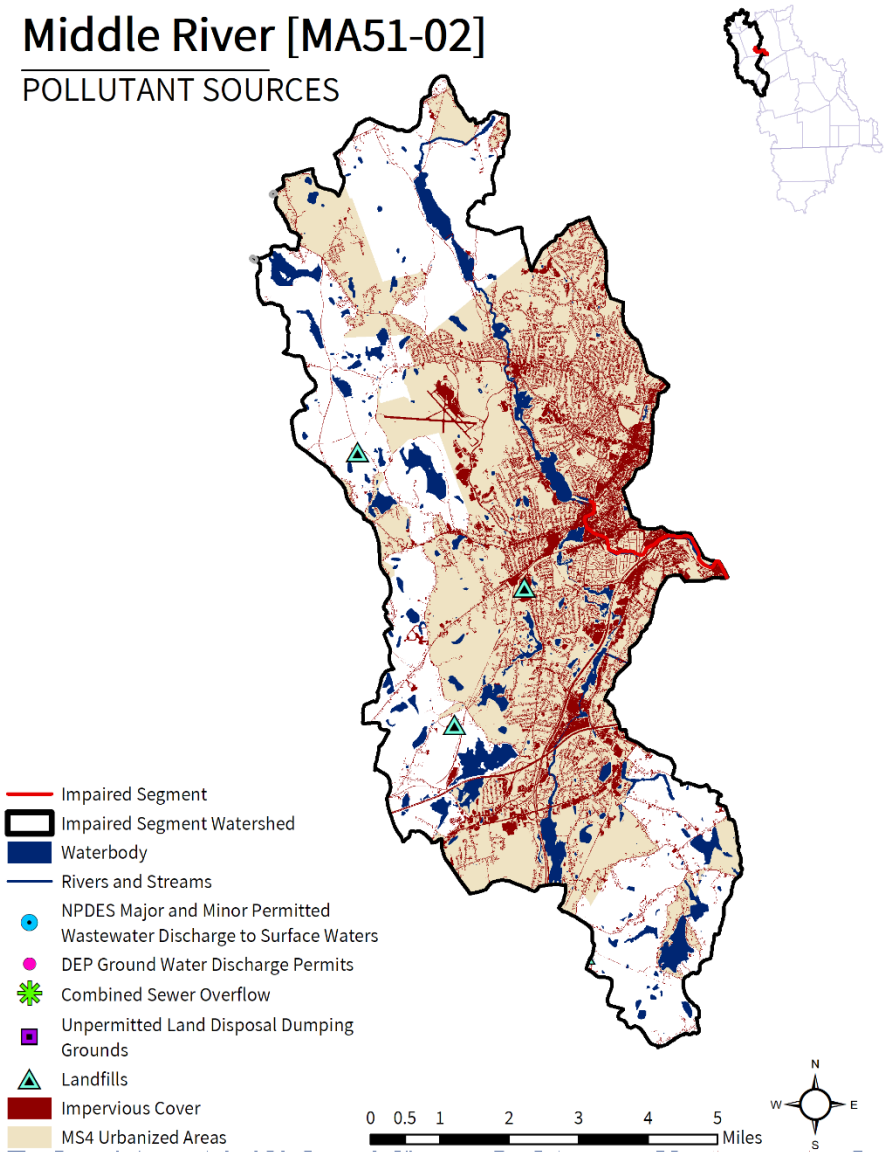


Figure 4-1. Natural resources and potential pollution sources draining to the Middle River segment MA51-02. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

4.2. Waterbody Impairment Characterization

The Middle River (MA51-02) is a Class B, Warm Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS at the stations listed below (refer to Tables 4-2, 4-3; Figure 4-2), using the indicator bacteria *E. coli*. Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

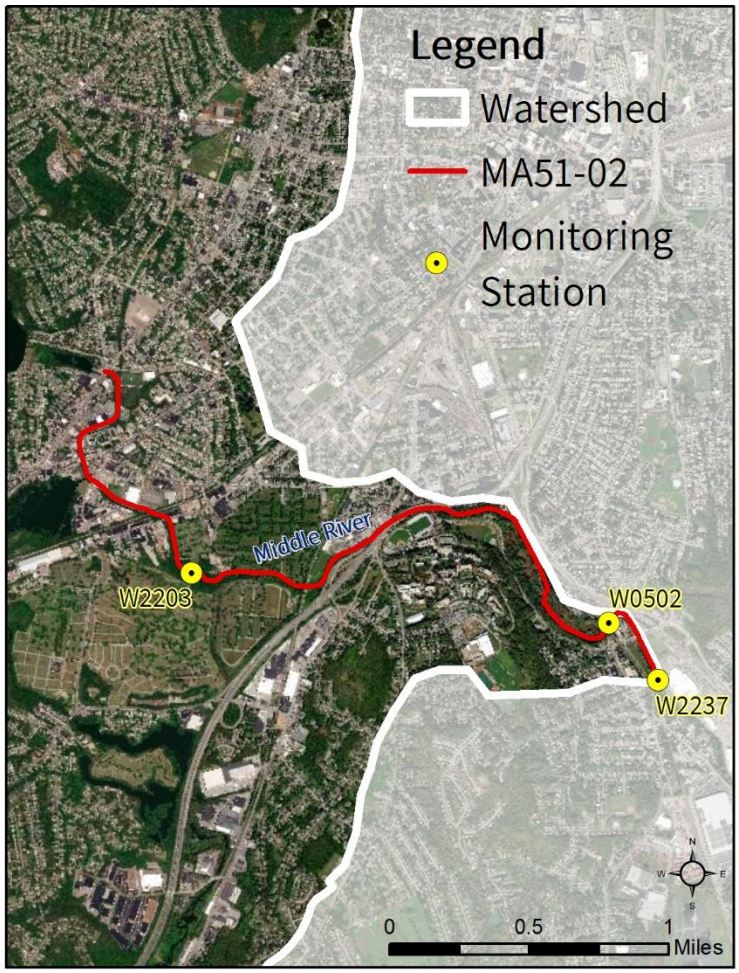


Figure 4-2. Location of monitoring station(s) along the impaired river segment.

- In 2008, seven samples were collected at W0502, resulting in seven days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, four exceeded the STV criterion during both wet and dry weather.
- In 2011, six samples were collected at W2203, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, four exceeded the STV criterion during both wet and dry weather.
- In 2011, seven samples were collected at W2237, resulting in seven days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, four exceeded the STV criterion during both wet and dry weather.

Table 4-2. Summary of indicator bacteria sampling results by station for the Middle River (MA51-02). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0502	4/29/2008	11/6/2008	7	890	7	4
W2203	5/17/2011	9/26/2011	6	894	6	4
W2237	5/5/2011	10/12/2011	7	519	7	4

Table 4-3. Indicator bacteria data by station, indicator, and date for the Middle River (MA51-02). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W0502	*E. coli*	4/29/2008	WET	890	890	
W0502	*E. coli*	5/27/2008	DRY	450	633	
W0502	*E. coli*	6/24/2008	WET	1400	825	
W0502	*E. coli*	7/8/2008	DRY	390	684	
W0502	*E. coli*	8/5/2008	DRY	310	525	
W0502	*E. coli*	8/26/2008	DRY	400	510	
W0502	*E. coli*	11/6/2008	WET	980	626	
W2203	*E. coli*	5/17/2011	WET	816	816	
W2203	*E. coli*	6/9/2011	DRY	980	894	
W2203	*E. coli*	6/21/2011	DRY	272	601	
W2203	*E. coli*	7/26/2011	DRY	1410	744	
W2203	*E. coli*	8/23/2011	DRY	980	779	
W2203	*E. coli*	9/26/2011	DRY	272	722	
W2237	*E. coli*	5/5/2011	DRY	488	488	
W2237	*E. coli*	6/9/2011	DRY	225	331	
W2237	*E. coli*	7/7/2011	DRY	866	456	
W2237	*E. coli*	7/21/2011	DRY	132	335	
W2237	*E. coli*	8/29/2011	WET	687	365	
W2237	*E. coli*	9/15/2011	DRY	921	519	
W2237	*E. coli*	10/12/2011	DRY	308	400	

4.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which

then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

The indicator bacteria data for Middle River (MA51-02) were elevated during both wet and dry weather conditions. Elevated indicator bacteria during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogens being major sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated indicator bacteria during dry weather indicate baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are also present.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the Middle River (MA51-02) watershed are highly developed, with 60% of the land area in MS4, 11% as DCIA, and the river corridor surrounded by high density mixed development. The downstream part of the segment is surrounded by mixed commercial and industrial land uses, and much of the rest of the watershed is residential. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: Most of the area around the Middle River is served by municipal sewer system(s), and dry weather indicator bacteria levels were elevated. Sewer-related pathogen sources include leaking infrastructure (pipes, pump stations, etc.), as well as sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. One example is the 2008 broken sewer line in Auburn that resulted in 10,000 gallons of raw sewage entering this segment (MassDEP, 2010). Illicit connections of wastewater to stormwater drains are known to have occurred throughout the City of Worcester, and have been a significant source of pathogens.

On-Site Wastewater Disposal Systems: Much of the watershed outside of the urban area of Worcester is served by on-site septic systems. It is likely that a portion of these systems are not properly maintained and are discharging untreated effluent to the environment.

Agriculture: The Middle River watershed has 3% agricultural land, although none of these areas appear to be close to the segment itself. Agricultural activities related to manure storage and spreading, if not well managed, are possible sources of pathogens to waterbodies. Additionally, any areas adjacent to upstream tributaries or storm drains could also serve as pathogen conduits to the river.

Pet Waste: The Middle River flows through high density residential neighborhoods, with ballfields and the wetland conservation area of Middle River Park adjacent to the river. Areas popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent possible sources of pathogens.

Wildlife Waste: Despite the urban nature of the river, there are several areas of mowed lawn adjacent to the impaired segment, such as the outlet of Curtis Pond, downstream of St. Johns Cemetery, and at Middle River Park. Conservation lands with large open mowed areas with a clear sightline to a waterbody, along with open meadow wetlands, may attract large congregations of waterfowl and elevate bacteria counts in the water.

4.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

City of Worcester. See Section 3.4.

5. MA51-03 Blackstone River

5.1. Waterbody Overview

The Blackstone River segment MA51-03 is 10.5 miles long and is the longest pathogen-impaired segment within the Blackstone River watershed. This Blackstone River segment begins at the convergence of Middle River and Mill Brook (downstream of the railroad spur bridge west of Tobias Boland Way) in Worcester. The segment flows through the southernmost part of the City of Worcester, and the towns of Millbury and Sutton, and is bound at the downstream end by Fisherville Pond Dam (NATID: MA00577) in Grafton, which is the start of pathogen-impaired Blackstone River segment MA51-04.

Major lakes and ponds within the Blackstone River segment MA51-03 watershed include Eddy Pond, Holden Reservoirs 1 and 2, the Coes and Patch Reservoirs, Mud Pond, Lake Quinsigamond, Lake Ripple, and Fisherville Pond. Major tributaries to this section of the Blackstone River include Sewall Brook, the Quinsigamond River, and the Worcester Land Protection Project (also known as the Kettle Brook Flood Diversion Channel). Impaired segment tributaries to this Blackstone River segment include Kettle Brook (MA51-01), Middle River (MA51-02), Beaver Brook (MA51-07), an unnamed tributary (MA51-08; Mill Brook), Tatnuck Brook (MA51-15), Dark Brook (MA51-16), Poor Farm Brook (MA51-17), Coal Mine Brook (MA51-27), Singletary Brook (MA51-31), and Cronin Brook (MA51-45).

Key landmarks in the watershed include: large industrial and transportation infrastructure with railyards, shipping container loading yards, and the Blackstone Industrial Park in the upstream portion of the segment; the multiple highway interchanges of I-90, MA-20, MA-146 and MA-122A spanning the river; the village centers of Millbury, Wilkinsonville (Sutton), and Saundersville (Grafton); the Upper Blackstone Clean Water facility (formerly known as the Upper Blackstone Water Pollution Abatement District); and the Blackstone River Greenway (part of the East Coast Greenway).

This segment crosses the divided highway MA-122A twice before flowing under US-20, I-90, and MA-122/146 west of Millbury. The Blackstone River segment MA51-03 then parallels MA-122A

Reduction from Highest Calculated Geomean: 97%

Watershed Area (Acres): 86,589

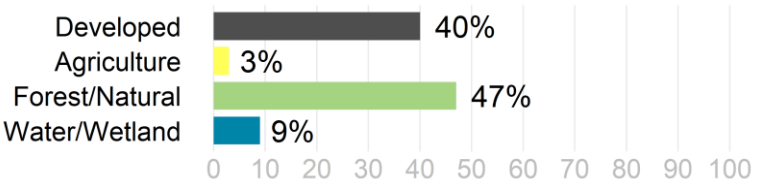
Segment Length (Miles): 10.4

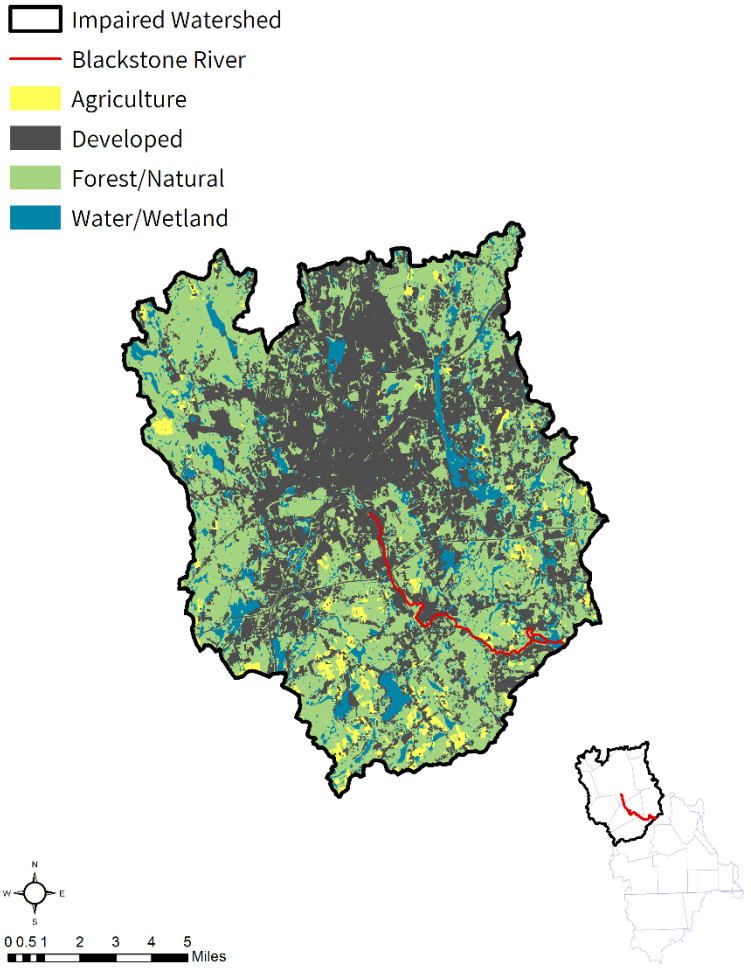
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water, CSO Receiving Water)

Impervious Area (Acres, %): 16,566 (19%)

DCIA Area (Acres, %): 12,064.75 (14%)





for a little way past the village of Wilkinsonville, ending at the Fisherville Pond Dam in the village of Fisherville. The Worcester Line railroad runs along the entire segment, crossing it four times.

The Blackstone River (MA51-03) drains an area of 135 mi^2, of which 26 mi^2 (19%) is covered with impervious surfaces, and 19 mi^2 (14%) is considered directly connected impervious area (DCIA). The watershed is served partially[10] by public sewer, and 76% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are 10 additional NPDES permits on file governing point source discharges of pollutants to surface waters in the upstream watershed, not including the NPDES wastewater treatment facility that discharges directly to this segment (Table 5-1). There is one groundwater discharge permit for on-site wastewater discharge (Table 5-2), one combined sewer overflow (CSO) (Table 5-3), 12 landfill sites and one known unpermitted land disposal dumping ground within the segment watershed. See Figure 5-1.

The Worcester CSO Treatment Facility (MA0100633) is authorized to discharge a maximum of 350 MGD of screened and disinfected (chlorine) combined sewer overflow to “Mill Brook”, a tributary to the Blackstone River. The flow is typically (dry weather) pumped to the Upper Blackstone WPAD [Water Pollution Abatement District] for treatment. When necessary (storm events >0.5 inches of rain), the CSO facility provides primary treatment, and the treated flow is discharged into Mill Brook (MASSDEP, 2001). CSO discharges can occur multiple times during the year.

Table 5-1. National Pollutant Discharge Elimination System (NPDES) permits for Wastewater Treatment Facilities (WWTF) in the segment watershed. Only permits unique to this segment watershed are shown. WWTF are identified as either municipal (MUN) or other (OTH), if applicable.

NPDES ID	NAME	TOWN	WWTF
MA0102369	UPPER BLACKSTONE WPAD	MILLBURY	MUN

Table 5-2. Groundwater discharge permits in the segment watershed. Only permits unique to this segment watershed are shown. PERR = permit number plus renewal number. TYPE = type of groundwater discharge. FLOW = permitted effluent in gallons per day (gpd).

PERR	NAME	TOWN	TYPE	FLOW (GPD)
641-2M1	SUTTON PUBLIC SCHOOLS	SUTTON	Sanitary Discharge	10,880

Table 5-3 Combined Sewer Overflows (CSOs) discharging to the segment.

NPDES ID	NAME	TOWN	DEP OUTFALL ID
MA0102997	CITY OF WORCESTER	Worcester	WOR001

The entire segment flows through a patchwork of land uses ranging from forested (47%) to densely developed commercial, industrial, and residential areas (40%). Just upstream of the segment is the heavily urbanized area of the City of Worcester. The expansive parking lots, street, rooves and other impervious features surrounding the upstream portion of the segment cause rapid changes in stream flow in response to precipitation and snow melt (MassDEP, 2010). Most of the agricultural lands (3%) are in the southern third of the segment watershed, with a few adjacent parcels to the segment.

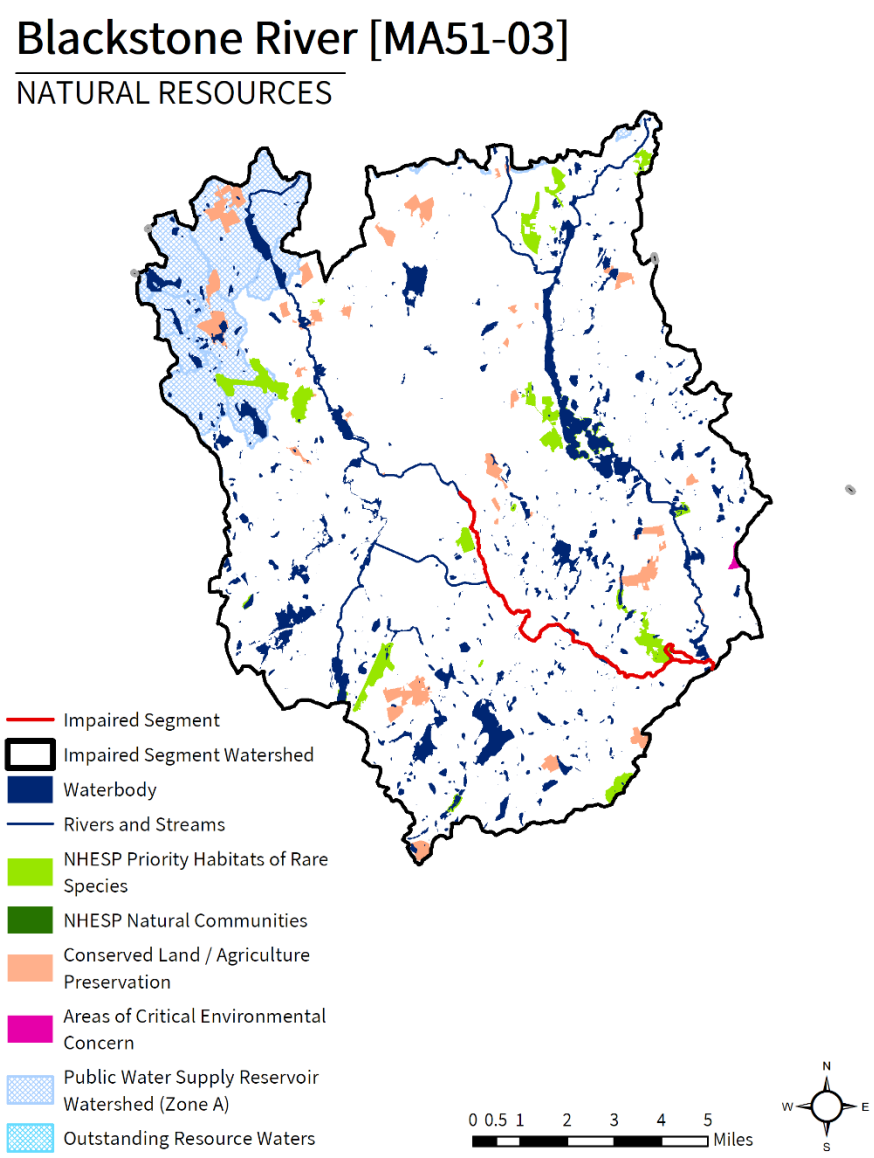
The watershed draining to this Blackstone River segment (MA51-03) includes Miscoe and Warren Brooks; these subwatersheds are part of the Miscoe-Warren-Whitehall Area of Critical Environmental Concern (45 acres, <1%). Under the Natural Heritage and Endangered Species Program, there are 2,256 acres (3%) of Priority Habitats of Rare Species. There are 8,138 acres (9%) under Public Water Supply protection, but no Outstanding

[10] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP’s Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

Resource Waters identified in the watershed. Over 1,989 acres (2%) of land are protected in perpetuity[11] within the segment watershed, which is part of a total of 13,171 acres (15%) of Protected and Recreational Open Space[12]. See Figure 5-1.

[11] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[12] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



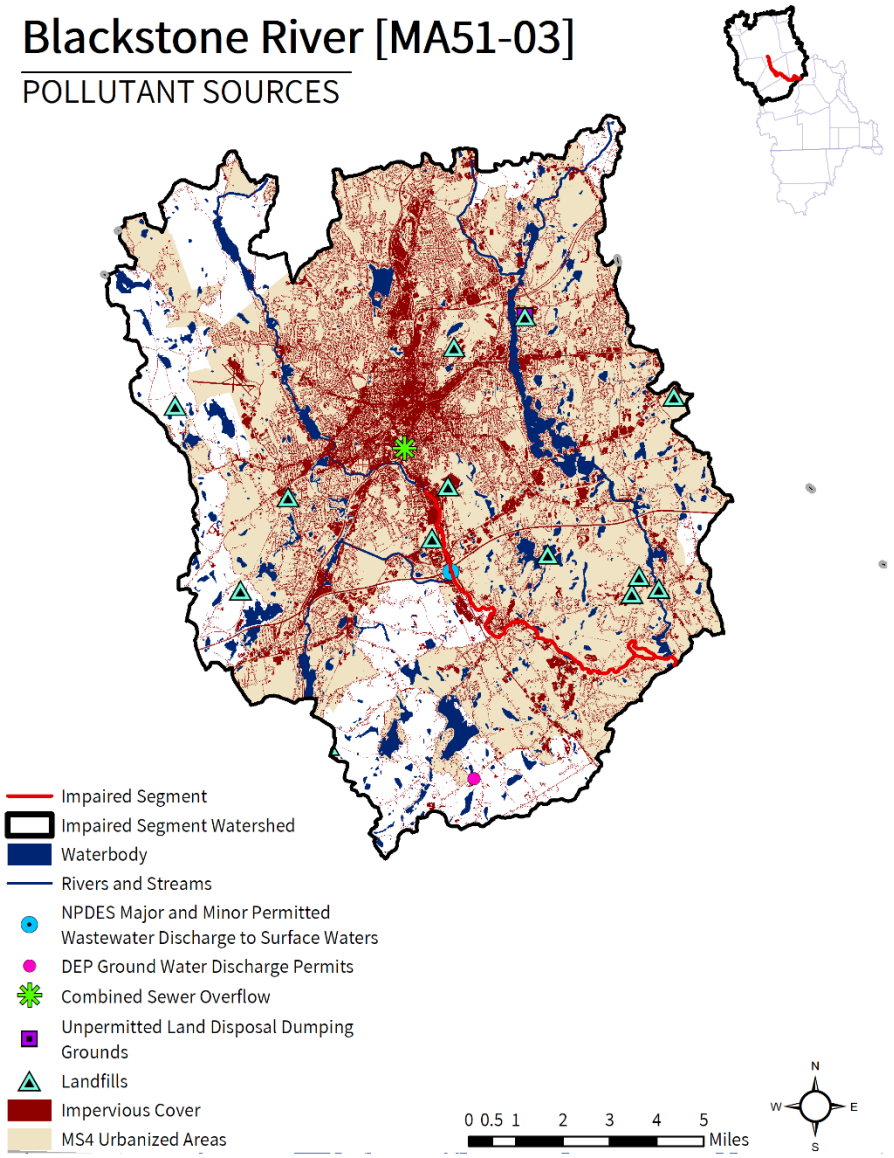


Figure 5-1. Natural resources and potential pollution sources draining to the Blackstone River segment MA51-03. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

5.2. Waterbody Impairment Characterization

The Blackstone River (MA51-03) is a Class B, Warm Water and CSO Receiving Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS at the stations listed below (see Tables 5-4, 5-5; Figure 5-2) using the indicator bacteria *E. coli*. Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

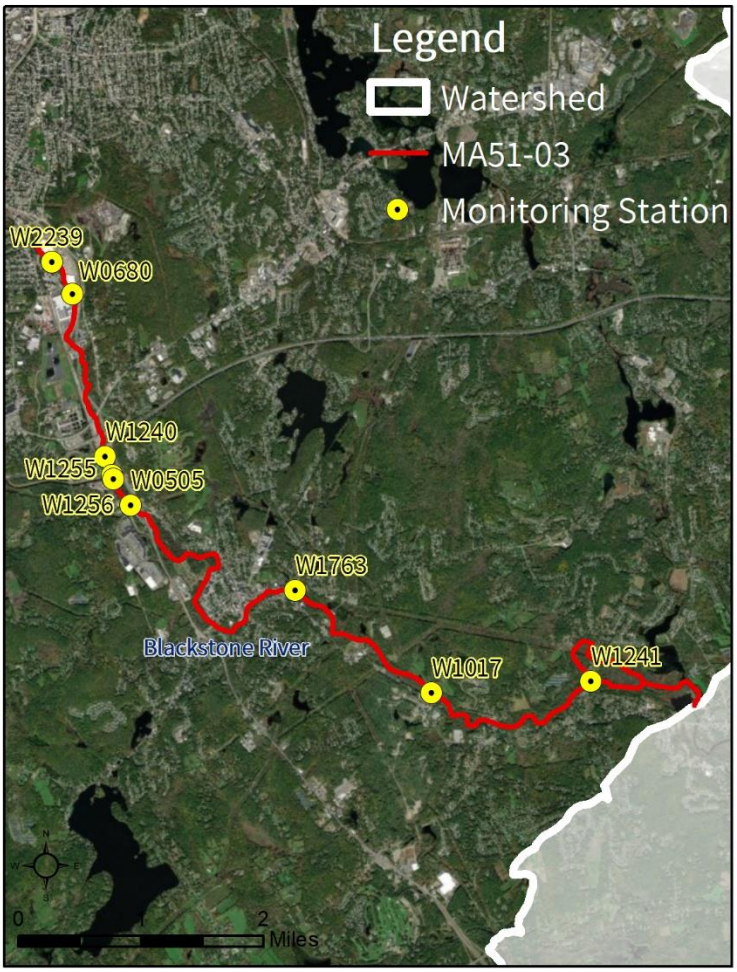


Figure 5-2. Location of monitoring station(s) along the impaired river segment.

- In 2008, seven samples were collected at W0505, resulting in seven days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, 3 exceeded the STV criterion in 2008 during wet weather.
- From 2007-2013, 32 samples were collected at W0680, resulting in 32 days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of 32 samples, 25 exceeded the STV criterion during both dry and wet weather conditions.
- In 2008, six samples were collected at W1017, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.
- In 2008, seven samples were collected at W1240, resulting in seven days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, five exceeded the STV criterion during both wet and dry weather.
- In 2008, six samples were collected at W1241, resulting in four days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.
- In 2008, seven samples were collected at W1255, resulting in seven days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, three exceeded the STV criterion during both wet and dry weather.
- In 2008, one sample was collected at W1256, resulting in one day when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. The one sample exceeded the STV criterion during wet weather.

- In 2008, six samples were collected from W1763, resulting in five days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.
- In 2011, seven samples were collected from W2239, resulting in seven days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of seven samples, seven exceeded the STV criterion during both wet and dry weather.

Table 5-4. Summary of indicator bacteria sampling results by station for the Blackstone River (MA51-03). The maximum 30-day rolling geomean, the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the STV criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0505	4/29/2008	11/6/2008	7	2420	7	3
W0680	7/25/2007	5/21/2013	32	2420	32	25
W1017	4/29/2008	8/26/2008	6	1100	6	2
W1240	4/29/2008	11/6/2008	7	1265	7	5
W1241	4/29/2008	8/26/2008	6	2100	4	2
W1255	4/29/2008	11/6/2008	7	2420	7	3
W1256	4/29/2008	4/29/2008	1	4400	1	1
W1763	4/29/2008	8/26/2008	6	940	5	2
W2239	5/5/2011	10/12/2011	7	2420	7	7

Table 5-5. Indicator bacteria data by station, indicator, and date for the Blackstone River (MA51-03). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0505	*E. coli*	4/29/08	WET	1000	1000	
W0505	*E. coli*	5/27/08	DRY	77	277	
W0505	*E. coli*	6/24/08	WET	2700	456	
W0505	*E. coli*	7/8/08	DRY	380	1013	
W0505	*E. coli*	8/5/08	DRY	220	289	
W0505	*E. coli*	8/26/08	DRY	100	148	
W0505	*E. coli*	11/6/08	WET	2420	2420	
W0680	*E. coli*	7/25/07	DRY	517	517	
W0680	*E. coli*	9/19/07	DRY	613	613	
W0680	*E. coli*	11/14/07	DRY	2420	2420	
W0680	*E. coli*	3/5/08	WET	1410	1410	
W0680	*E. coli*	4/29/08	WET	770	770	
W0680	*E. coli*	5/27/08	DRY	1050	899	

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0680	*E. coli*	8/5/08	DRY	488	488	
W0680	*E. coli*	8/26/08	DRY	722	594	
W0680	*E. coli*	10/15/08	DRY	579	579	
W0680	*E. coli*	11/6/08	WET	2420	1184	
W0680	*E. coli*	2/4/09	DRY	2420	2420	
W0680	*E. coli*	3/25/09	DRY	435	435	
W0680	*E. coli*	5/27/09	DRY	2420	2420	
W0680	*E. coli*	7/29/09	DRY	461	461	
W0680	*E. coli*	9/30/09	DRY	2420	2420	
W0680	*E. coli*	11/18/09	DRY	326	326	
W0680	*E. coli*	2/25/10	WET	1120	1120	
W0680	*E. coli*	9/1/10	DRY	261	261	
W0680	*E. coli*	10/27/10	DRY	2420	2420	
W0680	*E. coli*	3/30/11	DRY	548	548	
W0680	*E. coli*	5/25/11	DRY	387	387	
W0680	*E. coli*	7/27/11	DRY	435	435	
W0680	*E. coli*	9/28/11	DRY	248	248	
W0680	*E. coli*	11/9/11	DRY	1300	1300	
W0680	*E. coli*	2/28/12	DRY	1200	1200	
W0680	*E. coli*	4/25/12	WET	579	579	
W0680	*E. coli*	6/27/12	WET	816	816	
W0680	*E. coli*	8/29/12	DRY	1200	1200	
W0680	*E. coli*	11/6/12	DRY	365	365	
W0680	*E. coli*	1/30/13	DRY	1050	1050	
W0680	*E. coli*	3/27/13	DRY	205	205	
W0680	*E. coli*	5/21/13	DRY	345	345	
W1017	*E. coli*	4/29/08	WET	1100	1100	
W1017	*E. coli*	5/27/08	DRY	100	332	
W1017	*E. coli*	6/24/08	WET	3100	557	
W1017	*E. coli*	7/8/08	DRY	140	659	
W1017	*E. coli*	8/5/08	DRY	240	183	
W1017	*E. coli*	8/26/08	DRY	100	155	
W1240	*E. coli*	4/29/08	WET	830	830	
W1240	*E. coli*	5/27/08	DRY	210	417	
W1240	*E. coli*	6/24/08	WET	2500	725	
W1240	*E. coli*	7/8/08	DRY	640	1265	
W1240	*E. coli*	8/5/08	DRY	500	566	
W1240	*E. coli*	8/26/08	DRY	310	394	
W1240	*E. coli*	11/6/08	WET	1050	1050	
W1241	*E. coli*	4/29/08	WET	2100	2100	
W1241	*E. coli*	5/27/08	DRY	90	435	
W1241	*E. coli*	6/24/08	WET	3100	528	
W1241	*E. coli*	7/8/08	DRY	120	610	
W1241	*E. coli*	8/5/08	DRY	130	125	
W1241	*E. coli*	8/26/08	DRY	87	106	

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W1255	*E. coli*	4/29/08	WET	400	400	
W1255	*E. coli*	5/27/08	DRY	55	148	
W1255	*E. coli*	6/24/08	WET	1900	323	
W1255	*E. coli*	7/8/08	DRY	440	914	
W1255	*E. coli*	8/5/08	DRY	200	297	
W1255	*E. coli*	8/26/08	DRY	160	179	
W1255	*E. coli*	11/6/08	WET	2420	2420	
W1256	*E. coli*	4/29/08	WET	4400	4400	
W1763	*E. coli*	4/29/08	WET	940	940	
W1763	*E. coli*	5/27/08	DRY	140	363	
W1763	*E. coli*	6/24/08	WET	1700	488	
W1763	*E. coli*	7/8/08	DRY	180	553	
W1763	*E. coli*	8/5/08	DRY	200	190	
W1763	*E. coli*	8/26/08	DRY	70	118	
W2239	*E. coli*	5/5/11	DRY	2420	2420	
W2239	*E. coli*	6/9/11	DRY	1120	1120	
W2239	*E. coli*	7/7/11	DRY	2420	1646	
W2239	*E. coli*	7/21/11	DRY	1730	2046	
W2239	*E. coli*	8/29/11	WET	2420	2420	
W2239	*E. coli*	9/15/11	DRY	2420	2420	
W2239	*E. coli*	10/12/11	DRY	1300	1774	

5.3. Potential Pathogen Sources

Comparing data under wet versus dry conditions provides a useful indication of what types of sources are present, which can then be used to focus pollutant reduction efforts. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for the Blackstone River (MA51-03) were elevated during both wet and dry weather. Elevated indicator bacteria counts during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in high wet weather bacteria levels. Elevated indicator bacteria counts during dry weather suggest the possible presence of baseflow pollutant sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems.

The highest geomeans in all conditions (wet, dry) were found at the upstream-most sample station (W2239), and the second highest levels at the next downstream station (W0680). This suggests an especially large pathogen source at the upstream end of the segment which is then progressively diluted as distance increases moving downstream. The upstream end of the segment receives flow from two underground tributaries: pathogen-impaired unnamed tributary MA51-08 and another unnamed tributary. High bacteria levels in underground streams may be from illicit discharges, and possibly wildlife such as rodents. The area is also just downstream

of the wetland conservation area Middle River Park, the neighborhoods of Vernon Hill and North Quinsigamond Village, and several large commercial and transportation developments.

Each potential pathogen source relevant to this segment is described in further detail below.

Combined Sewer Overflow (CSO): There is one CSO in the segment's watershed, which by design releases untreated wastewater to surface waters when flows exceed system capacity, and therefore must be eliminated. For this reason, it is set as the highest priority source of pathogens.

Urban Stormwater: Much of the Blackstone River (MA51-03) watershed is highly urbanized, with 76% of the land area in MS4, 14% as DCIA, and the upstream portion of the segment flowing through the urban center of Worcester. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: Much of the watershed is served by public sewer, though both sanitary sewers and septic systems are possible pathogen sources. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk. An exceptional example of a large scale illicit discharge to this segment resulted from the failure of two electric grids and lack of backup generator at the Upper Blackstone WWTF on October 2, 2003, releasing approximately nine million gallons of untreated wastewater over six hours and resulting in maximum observed in-stream *E. coli* levels of 390,000 CFU/100mL near the discharge (MassDEP, 2010). By 2006 the Upper Blackstone WWTF mitigated the risk with the addition of standby power generators at the disinfection facility and headworks, as well as the complete replacement of electrical transmission and power feeds. Most recently, the facility is procuring additional standby generators to further improve system resiliency, reliability, and reduce dependence on the utility grid. These facility upgrades are designed to prevent this type of event from occurring in the future (see Appendix AC, pg. 59).

On-Site Wastewater Disposal Systems: Areas of the watershed are likely served by septic systems, especially outside of the urban center of Worcester, and there is one groundwater discharge permit for on-site wastewater discharge, which are large-capacity septic systems (non-residential). In addition, the Open Space and Recreation Plan for Sutton, 2013-2020, reports that high water tables lead to septic system malfunctions in some areas (see section 4.4). These factors in combination with the likelihood that a portion of septic systems are not being properly maintained, indicate that onsite wastewater disposal systems are a source of pathogens in the watershed.

Agriculture: The land cover in the watershed is 3% agriculture, mostly in the southern portion of the watershed. Recent aerial photos show most agricultural lands adjacent to the river as open fields. Nonetheless, agricultural activities adjacent to upstream tributaries or storm drains could also provide a direct conduit to the river. Manure storage and spreading, if not well managed, are also a possible source of pollutant loading.

Pet Waste: This segment of the Blackstone River flows through several dense residential neighborhoods in Worcester and Millbury, and there are over 3,000 acres of recreational open space in the watershed. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Most of the river has a wooded riparian buffer, although there are a few areas with lawns mowed to the water's edge. Conservation and recreational lands having large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate bacteria counts in the water.

5.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Grafton

Most of Grafton is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. Grafton (Permit ID #MAR041119) has an EPA-approved Notice of Intent (NOI). Grafton has a Stormwater Management Plan, recently updated in June, 2020; it is available online at https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/swmp-grafton-2020-final-compiled.pdf (Town of Grafton, 2020a). The Town has mapped 100% of its MS4 stormwater system. It adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater regulations in 2009. According to the NOI, there are eight stormwater outfalls into the Blackstone River MA51-03, and 13 stormwater outfalls into the Blackstone River segment MA51-04; both are impaired for *E. coli*.

Grafton has the following ordinances and bylaws:

Stormwater Bylaw and Stormwater Regulations: https://www.grafton-ma.gov/conservation-commission/pages/stormwater-bylaw (Town of Grafton, 2013)

- Title V Supplementary Regulations: None, but considering adopting more stringent on-site septic system standards
- Pet Waste Ordinance: None, but information provided on website: https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/pick_up_the_pet_waste_4-17-2012.pdf (Town of Grafton n.d., a)
- Stormwater Utility: No

Grafton's Master Plan has a Natural Resources Chapter which provides information on the town's surface waters and regionally shared water resources, including the Blackstone River (page 101). The plan mentions that the town's Stormwater Management Plan will help manage pollution in the Blackstone River from wastewater discharge and toxic sediments. The plan has a brief section on sewer and wastewater, recommending the extension of the sewer service "to areas of high development activity/septic failure" (page 188).

Town Website: https://www.grafton-ma.gov/ (Town of Grafton, 2020b)

Master Plan: https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/2001_master_plan.pdf (Town of Grafton, 2001)

Stormwater page: https://www.grafton-ma.gov/department-public-works-engineering/pages/stormwater-npdes-phase-ii-information (Town of Grafton, n.d., b)

Open Space and Recreation Plan DRAFT updated in 2018: https://www.grafton-ma.gov/sites/graftonma/files/uploads/01_osrp_consolidated_draft-11_6_2018.pdf (Town of Grafton, 2019).

Town of Millbury

Most of Millbury is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041136) and has an EPA-approved Notice of Intent (NOI). Millbury's Stormwater Management Plan will be completed during the first Permit Year and will be posted to the town website (2018-2019). The town has mapped all of its MS4 stormwater system, and the map was attached the NOI. The town also adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater management in 2006-07. According to the NOI, there are 26 stormwater outfalls into the Blackstone River MA51-03/MA51-10, and seven stormwater outfalls into Singletary Brook MA51-31, both impaired for *E. coli.*

Millbury has the following ordinances and bylaws:

- Stormwater Management Bylaw, in Town Subdivision Rules and Regulations, page 46: https://www.millbury-ma.org/sites/g/files/vyhlif4706/f/uploads/section6_0.pdf (Town of Millbury, 2010)
- Wetland Protection: None beyond state guidelines
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

Millbury has a draft Comprehensive Master Plan written in 2019, available at https://www.millbury-ma.org/master-plan-committee (Town of Millbury, 2019). The plan has a section on Natural Resources including wetlands and waterways. The plan also has an extensive section on MS4 community status, stormwater discharges, and NPDES, starting on page 77. Millbury's future SWMP goals include continued outreach and public education on stormwater impacts and green infrastructure, continued Best Management Practices maintenance and infrastructure mapping efforts, and IDDE bylaw enforcement. The section on Town Sewer starts on page 98 of the plan.

Millbury's stormwater page: https://www.millbury-ma.org/town-manager/pages/ms4 (Town of Millbury, n.d.)

Open Space and Recreation Plan: https://www.millbury-ma.org/planning-development/pages/open-space-recreation-plan (Town of Millbury, 2008).

A watershed-based plan has been created for this watershed by the Millbury Department of Planning & Development and Geosyntec Consultants, Inc. (Geosyntec, 2019).

Town of Sutton

About a third of Sutton is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041241) and has an EPA-approved Notice of Intent (NOI). Sutton does not have a Stormwater Management Plan available. The town has mapped 90% of its MS4 Stormwater system, though the map was not found online or with the permit. Sutton adopted illicit discharge detection and elimination (IDDE) in 2009 and plans to adopt erosion and sedimentation control (ESC) and post-construction stormwater management in 2019-2020. According to the NOI, there are two outfalls into the Blackstone River MA51-03, impaired for *E. coli.*

Sutton has the following ordinances and bylaws:

- Wetland Protection Bylaw: https://www.suttonma.org/sites/suttonma/files/uploads/bylaws.pdf (Town of Sutton, 2019)
- Stormwater Management Bylaw: No additional bylaw beyond MA DEP Stormwater Management Guidelines.
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

Some elements of Sutton's Master Plan are available online at https://www.suttonma.org/planning-board/pages/master-plan-2012 (Town of Sutton, 2012). The Open Space and Recreation Plan for Sutton, 2013-2020, states water resources protection as an objective of the plan (Town of Sutton, 2013). The plan has an extensive section on water resources starting on page 29. The Groundwater and Surface Water Pollution section notes "there are limited developed areas of town where high water tables exist, leading to septic failures and the related environmental impacts" and that the town has "invested significant time in [their] Stormwater Management Planning efforts."

Sutton's Master Plan Committee page: https://www.suttonma.org/planning/pages/master-plan-2012 (Town of Sutton, 2012)

Open Space and Recreation Bylaw: https://www.suttonma.org/sites/suttonma/files/uploads/osrp.pdf (Town of Sutton, 2013).

City of Worcester. See Section 3.4.

6. MA51-04 Blackstone River

6.1. Waterbody Overview

The Blackstone River segment MA51-04 is 8.8 miles long and begins at Fisherville Pond Dam (NATID: MA00577) in Grafton, where segment MA51-03 ends. The segment then flows southeast through Northbridge, including the village center, through Riverdale Impoundment (formerly segment MA51136) and Rice City Pond (formerly segment MA51131), before ending at Rice City Pond Dam in Uxbridge, near the river crossing at Hartford Avenue East.

Tributaries to this section of the Blackstone River include Rockdale Pond and Electric Pond (both mostly vegetated wetlands). There are also fringing wetlands along the river corridor. Pathogen-impaired segments which are within the watershed of the Blackstone River segment MA51-04 include Kettle Brook (MA51-01), Middle River (MA51-02), Blackstone River (MA51-03), Beaver Brook (MA51-07), unnamed tributary (MA51-08), Tatnuck Brook (MA51-15), Dark Brook (MA51-16), Poor Farm Brook (MA51-17), Coal Mine Brook (MA51-27), Singletary Brook (MA51-31), and Cronin Brook (MA51-45). Major lakes and ponds within the watershed include Rice City Pond, Eddy Pond, Holden Reservoirs 1 and 2, Coes Reservoir, and Lake Quinsigamond.

Major landmarks in the watershed include the villages of South Grafton, Farnumsville, and Northbridge; Riverdale Dam; Fisher Park; and the large conservation and recreational lands between Church Street in Northbridge and Rice City Pond Dam in Uxbridge, including Goat Hill and many trails.

Road crossings include Main Street and Depot Street in Grafton; and Sutton Street, Providence Road/MA-122, and Church Street Extension in Northbridge. The Providence and Worcester Railroad Main Line runs along the western bank along most of the segment and has modified the stream course by damming off a bend in Northbridge. Another course modification is the abandoned canal just north of Goat Hill in Northbridge.

The Blackstone River (MA51-04) drains an area of 147 square miles, of which 27 mi^2 (18%) is impervious, and 20 mi^2 (13%) is directly connected impervious area (DCIA). The

Reduction from Highest Calculated Geomean: 96%

Watershed Area (Acres): 94,167

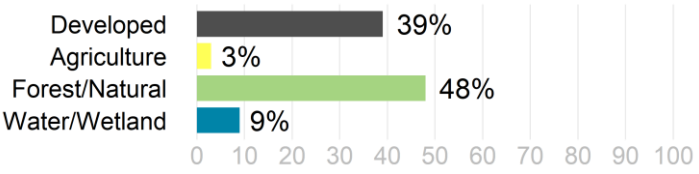
Segment Length (Miles): 8.8

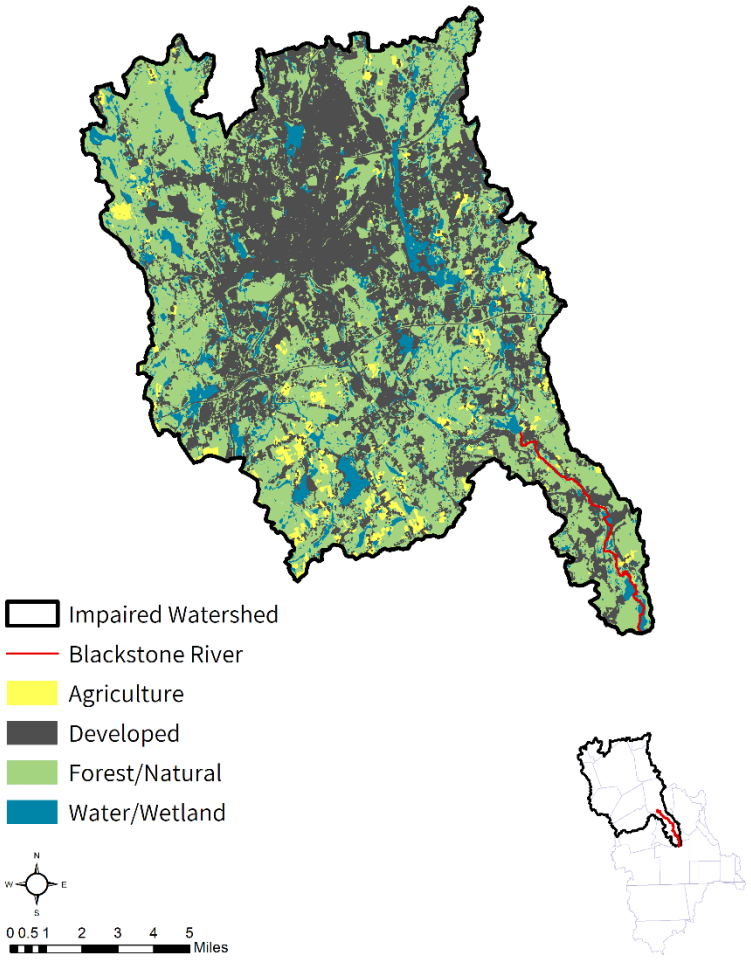
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water)

Impervious Area (Acres, %): 17,387 (18%)

DCIA Area (Acres, %): 12,641(13%)





watershed is served partially[13] by public sewer and 76% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are 11 additional NPDES permits on file governing point source discharges of pollutants to surface waters. In addition to the 11 NPDES permits, there are three NPDES permits for wastewater treatment facilities (2 of which are within the immediate drainage area to the impaired segment, Table 6-1). There is one combined sewer overflow (CSO) (See Section 5.1). One groundwater discharge permit exists for on-site wastewater discharge within this watershed (not within the immediate drainage area to the impaired segment). There are also 15 landfills and one unpermitted land disposal dumping ground present within the segment watershed. See Figure 6-1.

Table 6-1. National Pollutant Discharge Elimination System (NPDES) permits for Wastewater Treatment Facilities (WWTF) in the segment watershed. Only permits unique to this segment watershed are shown. WWTF are identified as either municipal (MUN) or other (OTH), if applicable.

NPDES ID	NAME	TOWN	WWTF
MA0100722	NORTHBRIDGE WWTP	NORTHBRIDGE	MUN
MA0101311	GRAFTON WWTP	GRAFTON	MUN

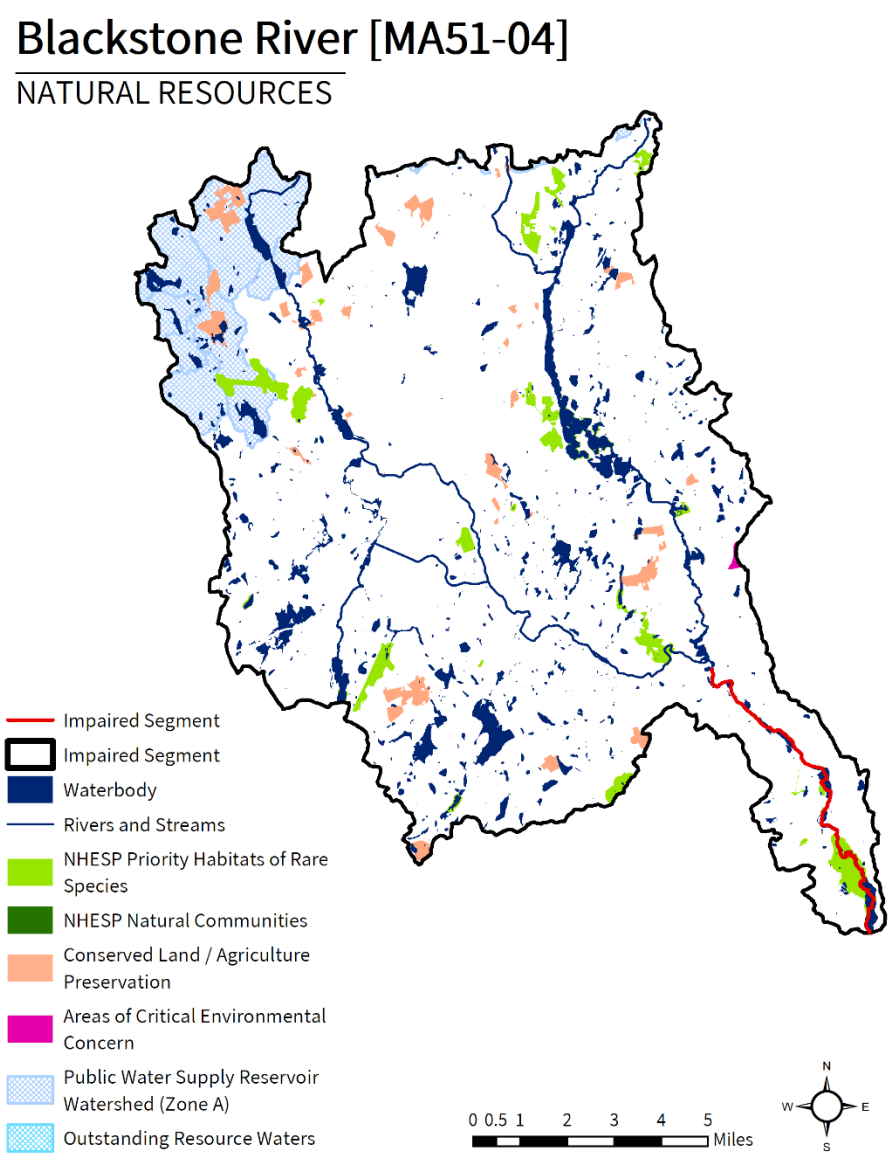
The northern part of the Blackstone River segment MA51-04 flows through medium to low density residential and commercial land uses (39% of the watershed), with large areas of forested land cover (48%). The southern portion of the segment runs through large emergent wetlands with braided stream channels and large forested conservation lands. Agriculture (3%) is scattered throughout the downstream watershed, with some areas adjacent to the stream. The dense urban areas of Worcester and Auburn are about nine miles upstream of the segment, and the associated impervious surfaces cause rapid changes in flow in this segment (MassDEP, 2010).

The watershed of the Blackstone River (MA51-04) contains 44 acres (<1%) of Areas of Critical Environmental Concern, from the “Miscoe, Warren and Whitehall watersheds”. Under the Natural Heritage and Endangered Species Program, there are 2,922 acres (3%) of Priority Habitats of Rare Species. There are 8,318 acres (9%) under Public Water Supply protection, but no Outstanding Resource Waters identified in this watershed. Over 1,994 acres (2%) of land protected in perpetuity[14] exist within the segment watershed, which is part of a total of 14,395 acres (15%) of Protected and Recreational Open Space[15]. See Figure 6-1.

[13] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP’s Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[14] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[15] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



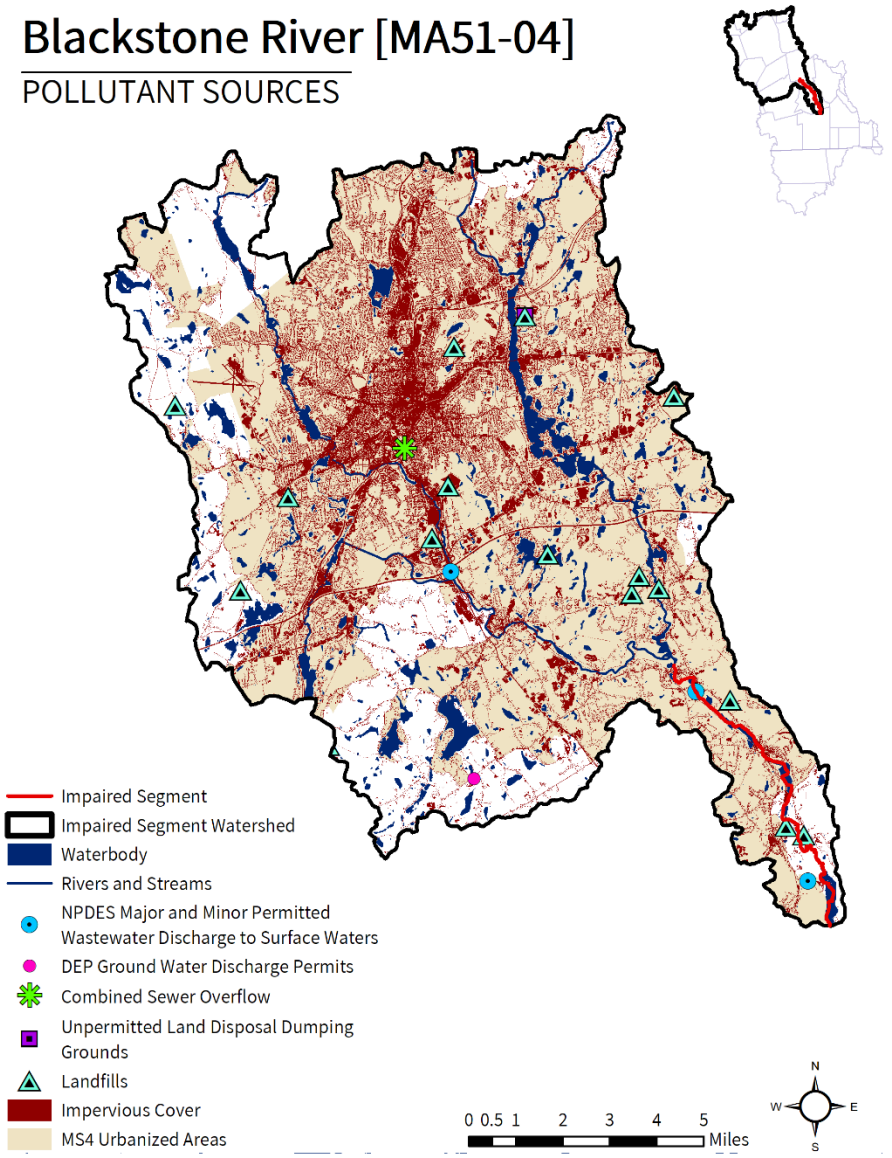


Figure 6-1. Natural resources and potential pollution sources draining to the Blackstone River segment MA51-04. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

6.2. Waterbody Impairment Characterization

The Blackstone River (MA51-04) is a Class B, Warm Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 6-2, 6-3; Figure 6-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

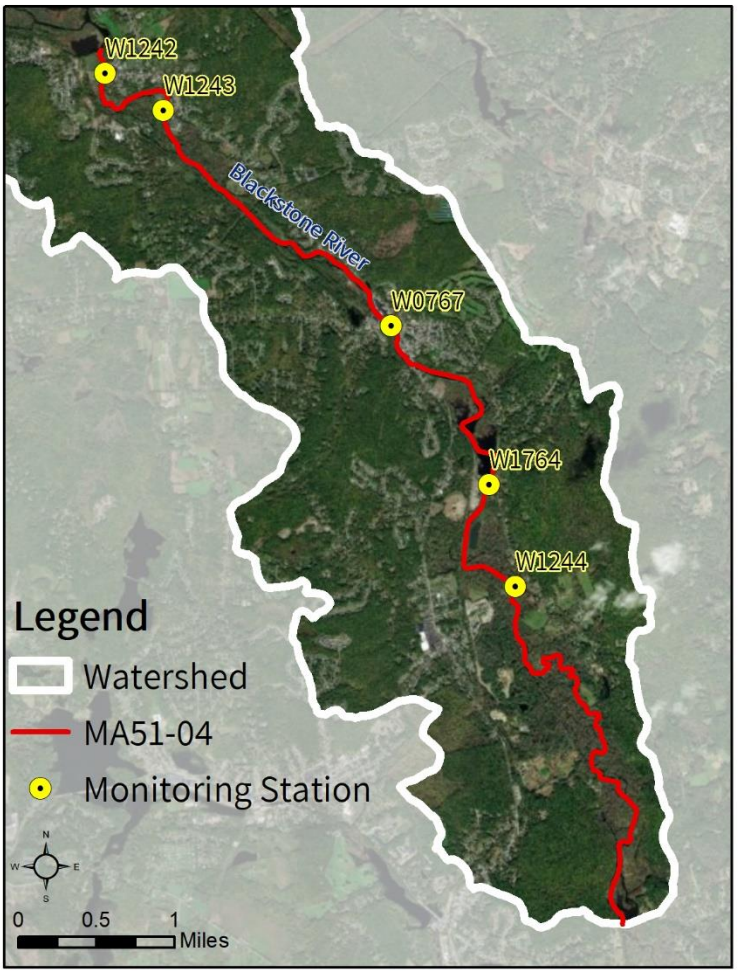


Figure 6-2. Location of monitoring station(s) along the impaired river segment.

- From 2007-2013, 31 samples were collected at W0767, resulting in 30 days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of 31 samples, 16 exceeded the STV criterion from 2007-2013 during both wet and dry weather.
- In 2008, six samples were collected at W1242, resulting in five days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.
- In 2008, six samples were collected at W1243, resulting in four days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.
- In 2008, six samples were collected at W1244, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, five exceeded the STV criterion during both wet and dry weather.
- In 2008, six samples were collected at W1764, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, four exceeded the STV criterion during both wet and dry weather.

Table 6-2. Summary of indicator bacteria sampling results by station for the Blackstone River (MA51-04). The maximum 30-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0767	7/25/2007	5/21/2013	31	2420	30	16
W1242	4/29/2008	8/26/2008	6	1000	5	2
W1243	4/29/2008	8/26/2008	6	2400	4	2
W1244	4/29/2008	8/26/2008	6	3108	6	5
W1764	4/29/2008	8/26/2008	6	3003	6	4

Table 6-3. Indicator bacteria data by station, indicator, and date for the Blackstone River (MA51-04). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0767	*E. coli*	7/25/07	DRY	90	90	
W0767	*E. coli*	9/19/07	DRY	153	153	
W0767	*E. coli*	11/14/07	DRY	980	980	
W0767	*E. coli*	3/5/08	WET	2420	2420	
W0767	*E. coli*	4/29/08	WET	1300	1300	
W0767	*E. coli*	5/27/08	DRY	108	375	
W0767	*E. coli*	8/5/08	DRY	2420	2420	
W0767	*E. coli*	8/26/08	DRY	1120	1646	
W0767	*E. coli*	10/15/08	DRY	387	387	
W0767	*E. coli*	2/4/09	DRY	770	770	
W0767	*E. coli*	3/25/09	DRY	2420	2420	
W0767	*E. coli*	5/27/09	DRY	144	144	
W0767	*E. coli*	7/29/09	DRY	148	148	
W0767	*E. coli*	9/30/09	WET	129	129	
W0767	*E. coli*	11/18/09	DRY	2420	2420	
W0767	*E. coli*	2/25/10	WET	2420	2420	
W0767	*E. coli*	9/1/10	DRY	178	178	
W0767	*E. coli*	10/27/10	DRY	238	238	
W0767	*E. coli*	3/30/11	DRY	2420	2420	
W0767	*E. coli*	5/25/11	DRY	210	210	
W0767	*E. coli*	7/27/11	DRY	1200	1200	
W0767	*E. coli*	9/28/11	DRY	276	276	
W0767	*E. coli*	11/9/11	DRY	548	548	
W0767	*E. coli*	2/28/12	DRY	1050	1050	

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0767	*E. coli*	4/25/12	WET	727	727	
W0767	*E. coli*	6/27/12	WET	345	345	
W0767	*E. coli*	8/29/12	WET	1410	1410	
W0767	*E. coli*	11/6/12	DRY	161	161	
W0767	*E. coli*	1/30/13	DRY	461	461	
W0767	*E. coli*	3/27/13	DRY	210	210	
W0767	*E. coli*	5/21/13	DRY	199	199	
W1242	*E. coli*	4/29/08	WET	1000	1000	
W1242	*E. coli*	5/27/08	DRY	170	412	
W1242	*E. coli*	6/24/08	WET	3500	771	
W1242	*E. coli*	7/8/08	DRY	70	495	
W1242	*E. coli*	8/5/08	DRY	210	121	
W1242	*E. coli*	8/26/08	DRY	110	152	
W1243	*E. coli*	4/29/08	WET	2400	2400	
W1243	*E. coli*	5/27/08	DRY	160	620	
W1243	*E. coli*	6/24/08	WET	4100	810	
W1243	*E. coli*	7/8/08	DRY	110	672	
W1243	*E. coli*	8/5/08	DRY	130	120	
W1243	*E. coli*	8/26/08	DRY	58	87	
W1244	*E. coli*	4/29/08	WET	2800	2800	
W1244	*E. coli*	5/27/08	DRY	200	748	
W1244	*E. coli*	6/24/08	WET	9600	1386	
W1244	*E. coli*	7/8/08	DRY	510	2213	
W1244	*E. coli*	8/5/08	DRY	4200	1464	
W1244	*E. coli*	8/26/08	DRY	2300	3108	
W1764	*E. coli*	4/29/08	WET	1700	1700	
W1764	*E. coli*	5/27/08	DRY	120	452	
W1764	*E. coli*	6/24/08	WET	10000	1095	
W1764	*E. coli*	7/8/08	DRY	320	1789	
W1764	*E. coli*	8/5/08	DRY	4100	1145	
W1764	*E. coli*	8/26/08	DRY	2200	3003	

6.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria data at all stations for the Blackstone River (MA51-04) were elevated during wet weather, suggesting urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system

malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels.

Indicator bacteria data were also elevated during dry weather at the three downstream stations. These results indicate baseflow sources, such as leaking pipes, illegal cross connections and other illicit discharges, and failing septic systems, may be present. These stations are located downstream of electric pond, and the village of Northbridge and the Riverdale Mills Corporation impoundment.

Each potential pathogen source relevant to this segment is described in further detail below.

Combined Sewer Overflow (CSO): There is one CSO in the watershed, though it is well upstream of the segment itself. CSOs by design release untreated wastewater to surface waters when flows exceed system capacity, and therefore must be eliminated. For this reason, it is set as the highest priority pathogen source.

Urban Stormwater: The land cover around the Blackstone River segment MA51-04 is medium density mixed development. In the overall watershed, 76% of the land area is in MS4 and 13% is DCIA. The pattern of development as well as the elevated wet weather indicator bacteria levels indicate that stormwater runoff is a significant source of pathogens.

Illicit Sewage Discharges: The watershed is served by a mix of septic systems and public sewer, and there are three downstream stations with elevated indicator bacteria levels in dry weather. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

On-Site Wastewater Disposal Systems: Areas of the watershed are served by septic systems, and there is one groundwater discharge permit for on-site wastewater discharge, which are large-capacity septic systems (non-residential). It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: While there is relatively little agriculture (3% of land area), this is also a potential source of pathogen pollutant loading. Most of these areas occur in the southwest portion of the watershed and are not near the impaired segment. However, any areas adjacent to upstream tributaries or storm drains could also provide a direct conduit to the river. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: There are significant areas of recreational open space in the watershed, including many parks and ballfields along the segment, and the river flows though urban neighborhoods such as downtown Northbridge. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

6.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Grafton. See Section 5.4.

Town of Northbridge

Most of Northbridge is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041144) and has an EPA-approved Notice of Intent (NOI). Northbridge completed their Stormwater Management Plan in 2019, https://www.northbridgemass.org/sites/g/files/vyhlif981/f/uploads/swmp_-_30_june_2019.pdf.

The town has mapped 60% of their MS4 stormwater system and attached the partially completed MS4 outfall map to the NOI. Northbridge plans to adopt illicit discharge detection and elimination (IDDE) in 2020 and adopted erosion and sedimentation control (ESC) in 2011 and post-construction stormwater management in 2008. According to the NOI, there are 25 outfalls into the Blackstone River MA51-04, impaired for *E. coli.*

Northbridge has the following ordinances and bylaws:

- Stormwater Ordinance Bylaw: https://www.ecode360.com/14688531#14688531 (Town of Northbridge, 2008a)
- Title 5 supplemental Regulations: https://www.ecode360.com/14688505 (Town of Northbridge, 1999)
- Wetland Protection Bylaw: https://www.northbridgemass.org/conservation-commission/pages/wetland-bylaw-regulations (Town of Northbridge, 2008b)

The Northbridge Master Plan is currently being updated from the 1994 version (Town of Northbridge, 1994). The 1994 master plan has a water resources section, starting on page 4-3, which notes that the Blackstone River historically had pollutant issues. This section also details the town's groundwater, municipal water supply, floodplain and floodways, and wetlands. The master plan chapter on the Department of Public Works notes that the sewer system serves about 66% of the town's population.

Northbridge 1994 Master Plan: https://www.northbridgemass.org/community-planning-development/pages/master-plan (Town of Northbridge, 1994)

Open Space and Recreation Plan: https://www.northbridgemass.org/community-planning-development/pages/open-space-recreation (Town of Northbridge, 2002).

Town of Uxbridge

About half of Uxbridge is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041166) and has an EPA-approved Notice of Intent (NOI). Uxbridge has a Stormwater Management Plan on file at the Uxbridge Department of Public Works and has mapped all of its MS4 stormwater system. Uxbridge also adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater management in 2015. According to the NOI, there are 48 stormwater outfalls into the Blackstone River MA51-04/MA51-05, which are impaired for *E. coli.*

Uxbridge has the following ordinances and bylaws:

- Stormwater Management Bylaw: https://www.uxbridge-ma.gov/sites/g/files/vyhlif3971/f/uploads/stormwater_regulations.pdf (Town of Uxbridge, 2019)
- Wetland Protection: None beyond DEP Wetland Protection Regulations
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

Uxbridge is in the process of updating their master plan, although the 1992 "A Bright Future, Rich in History" is available online and dedicates an extensive section on groundwater, starting on page 55. The plan also notes how development negatively affects groundwater through runoff, limiting infiltration, and altering ground water quality.

Uxbridge 1992 Master Plan: https://www.uxbridge-ma.gov/sites/g/files/vyhlif3971/f/uploads/1992_master_plan_a_bright_future_rich_in_history.pdf (UMass, 1992).

Stormwater Management Page: https://www.uxbridge-ma.gov/stormwater-committee (Town of Uxbridge, 2020)

Open Space Plan: Not available online. Will be incorporated in the updated Master Plan.

7. MA51-05 Blackstone River

7.1. Waterbody Overview

The Blackstone River segment MA51-05 is 9.1 miles long and begins at the outlet of Rice City Pond Dam (NATID: MA00935) in Uxbridge, then flowing south to southeast before ending at the most downstream railroad trestle crossing in Millville (just above the Southern New England Trunkline Trail bridge), about 0.5 miles north of the Rhode Island border. The segment is bound at the upstream end by the Blackstone River segment MA51-04 and at the downstream end by segment MA51-06, both impaired for *E. coli*.

Tributaries to this section of the Blackstone River include the stream draining the Mumford River/Caprons Pond, the stream draining Calumet Pond, Meadow Brook which becomes the Hecla Canal, Still Corner Brook, and the stream draining Mansfield Pond. Directly upstream of this portion of the Blackstone River are 42 lakes and ponds, including Whitin Reservoir, Carpenters Reservoir, Manchaug Pond, Stevens Pond, Mumford River Reservoir, and Whitin Pond.

Pathogen-impaired tributaries flowing to this segment include: Kettle Brook (MA51-01), Middle River (MA51-02), Blackstone River (MA51-03), Blackstone River (MA51-04), Beaver Brook (MA51-07), an unnamed tributary (MA51-08), Tatnuck Brook (MA51-15), Dark Brook (MA51-16), Poor Farm Brook (MA51-17), Coal Mine Brook (MA51-27), Singletary Brook (MA51-31), and Cronin Brook (MA51-45).

Major landmarks along the segment include the village centers of Uxbridge, North Uxbridge, and Millville; Uxbridge High School and ballfields, adjacent to the segment; Blackstone National Golf Club and Whitinsville Golf Club; sections of the Blackstone River and Canal Heritage State Park with hiking trails along the river; and the Southern New England Trunkline Trail.

Road crossings include Hartford Avenue East, Mendon Street/MA-16, and Millville Road/MA-122 in Uxbridge; and Central Street in Millville; as well as four railroad crossings.

The Blackstone River (MA51-05) drains a total area of 262 square miles, of which 36 mi^2 (14%) is impervious, and 25 mi^2 (10%) is directly connected impervious area (DCIA). The

Reduction from Highest Calculated Geomean: 95%

Watershed Area (Acres): 167,753

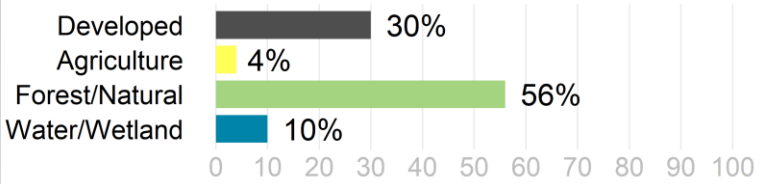
Segment Length (Miles): 9.1

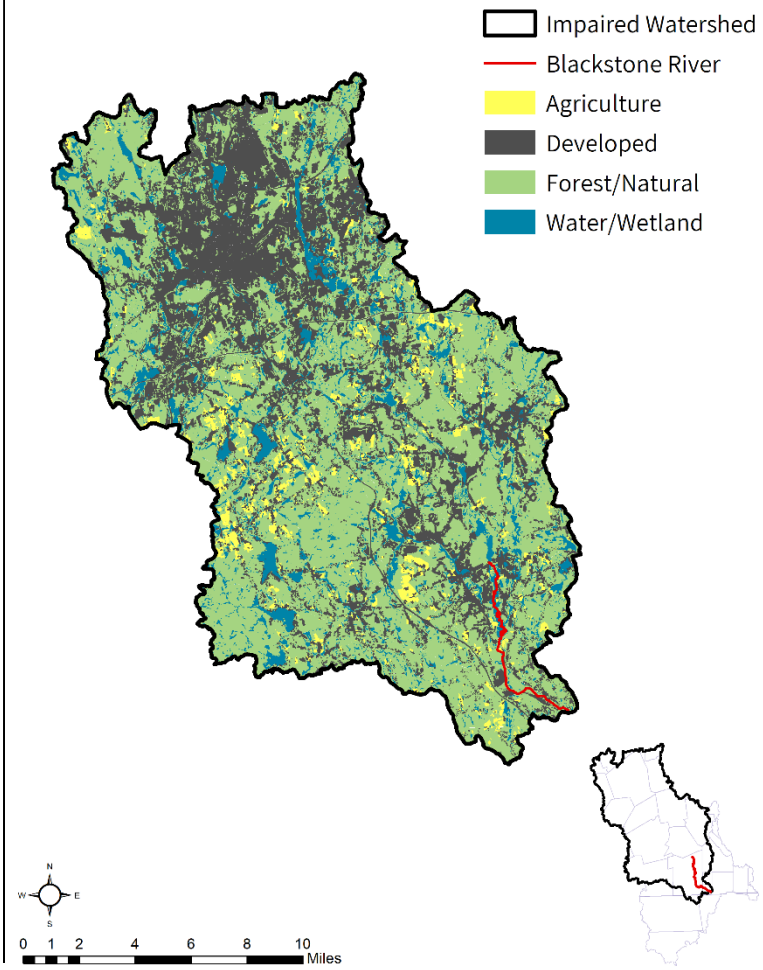
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water)

Impervious Area (Acres, %): 22,825 (14%)

DCIA Area (Acres, %): 16,017 (10%)





watershed also extends to the south into Rhode Island. Approximately 260 mi^2 of the total 262 mi^2 are within the State of Massachusetts (99%). The watershed is served partially[16] by public sewer and 58% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are 11 NPDES permits on file governing point source discharges of pollutants to surface waters. In addition to the 11 NPDES permits, six NPDES permits exist for wastewater treatment facilities (3 of which are within the immediate drainage area to the impaired segment, Table 7-1). There is one combined sewer overflow (CSO) upstream of the segment (See Section 5.1). Two groundwater discharge permits exist for on-site wastewater discharge within the watershed (one within the immediate drainage area, Table 7-2). There are also 21 landfills and one unpermitted land disposal dumping ground present within the watershed. See Figure 7-1.

Table 7-1. National Pollutant Discharge Elimination System (NPDES) permits for Wastewater Treatment Facilities (WWTF) in the segment watershed. Only permits unique to this segment watershed are shown. WWTF are identified as either municipal (MUN) or other (OTH), if applicable.

NPDES ID	NAME	TOWN	WWTF
MA0100196	UPTON W WTP	UPTON	MUN
MA0101095	DOUGLAS WWTP	DOUGLAS	MUN
MA0102440	UXBRIDGE WWTF	UXBRIDGE	MUN

Table 7-2. Groundwater discharge permits in the segment watershed. Only permits unique to this segment watershed are shown. PERR = permit number plus renewal number. TYPE = type of groundwater discharge. FLOW = permitted effluent in gallons per day (gpd).

PERR	NAME	TOWN	TYPE	FLOW (GPD)
760-2	SUTTON WWTF	SUTTON	Sanitary Discharge	110,000

In reference to the entire watershed of MA51-05, the upstream portion of the segment flows through low to medium density residential development (30% of the watershed), with large areas of wooded riparian buffer zones in addition to forests covering 56% of the watershed. The middle portion of the segment contains a few large areas of commercial and industrial activities, including a salvage yard, a quarry, and several large ground level solar installations. The downstream portion of the segment is mostly wooded, with small areas of low to medium density residential development. The 4% of the watershed which has been classified as agricultural is generally concentrated in the downstream portion of the watershed with some agricultural areas adjacent to the segment. The heavily urbanized areas in and around Worcester are approximately 19 miles upstream.

The watershed of the Blackstone River (MA51-05) contains one large Area of Critical Environmental Concern: the “Miscoe, Warren and Whitehall watersheds” (7,924 acres, 5%). Under the Natural Heritage and Endangered Species Program, there are 12,180 acres (7%) of Priority Habitats of Rare Species and 300 acres (<1%) designated as Priority Natural Vegetation Communities. There are 8,195 acres (5%) under Public Water Supply protection, but no Outstanding Resource Waters identified in the watershed. Over 4,110 acres (2%) of land protected in perpetuity[17] exist within the segment watershed, which is part of a total of 27,325 acres (16%) of Protected and Recreational Open Space[18]. See Figure 7-1.

[16] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP’s Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[17] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[18] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

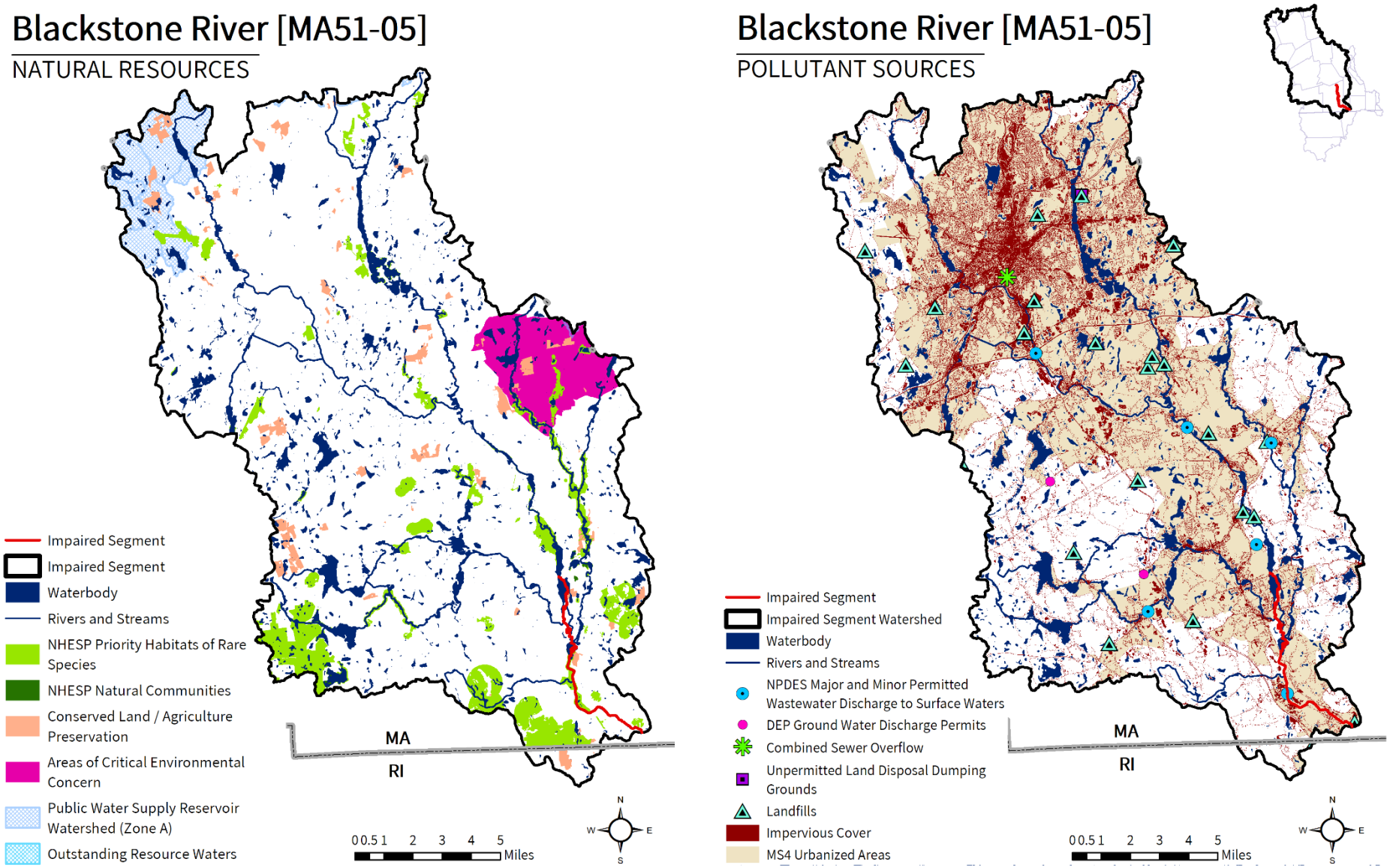


Figure 7-1. Natural resources and potential pollution sources draining to the Blackstone River segment MA51-05. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

7.2. Waterbody Impairment Characterization

Blackstone River (MA51-05) is a Class B, Warm Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 7-3, 7-4; Figure 7-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

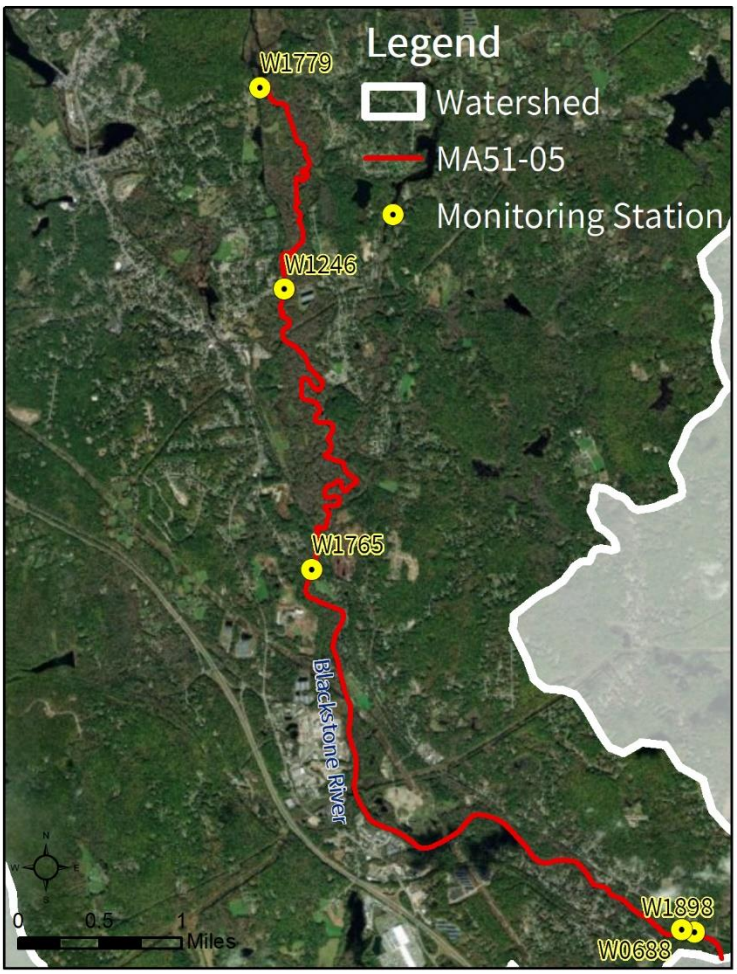


Figure 7-2. Location of monitoring station(s) along the impaired river segment.

- In 2013, one sample was collected at W0688, resulting in no days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of one sample, none exceeded the STV criterion.
- In 2008, six samples were collected at W1246, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, three exceeded the STV criterion during both wet and dry weather.
- In 2008, six samples were collected at W1765, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, three exceeded the STV criterion during both wet and dry weather.
- In 2008, six samples were collected at W1779, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, four exceeded the STV criterion during both wet and dry weather.
- From 2007-2013, 29 samples were collected at W1898, resulting in 16 days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of 29 samples, six exceeded the STV criterion from 2008-2013 during both wet and dry weather.

Table 7-3. Summary of indicator bacteria sampling results by station for the Blackstone River (MA51-05). The maximum 30-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0688	3/27/2013	3/27/2013	1	41	0	0
W1246	4/29/2008	8/26/2008	6	1386	6	3
W1765	4/29/2008	8/26/2008	6	980	6	3
W1779	4/29/2008	8/26/2008	6	1500	6	4
W1898	7/25/2007	9/23/2013	29	2420	16	6

Table 7-4. Indicator bacteria data by station, indicator, and date for the Blackstone River (MA51-05). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0688	*E. coli*	3/27/13	DRY	41	41	
W1246	*E. coli*	4/29/08	WET	1200	1200	
W1246	*E. coli*	5/27/08	DRY	55	257	
W1246	*E. coli*	6/24/08	WET	12000	812	
W1246	*E. coli*	7/8/08	DRY	160	1386	
W1246	*E. coli*	8/5/08	DRY	2400	620	
W1246	*E. coli*	8/26/08	DRY	180	657	
W1765	*E. coli*	4/29/08	WET	780	780	
W1765	*E. coli*	5/27/08	DRY	52	201	
W1765	*E. coli*	6/24/08	WET	9900	717	
W1765	*E. coli*	7/8/08	DRY	97	980	
W1765	*E. coli*	8/5/08	DRY	900	295	
W1765	*E. coli*	8/26/08	DRY	83	273	
W1779	*E. coli*	4/29/08	WET	1500	1500	
W1779	*E. coli*	5/27/08	DRY	70	324	
W1779	*E. coli*	6/24/08	WET	9700	824	
W1779	*E. coli*	7/8/08	DRY	220	1461	
W1779	*E. coli*	8/5/08	DRY	3500	877	
W1779	*E. coli*	8/26/08	DRY	520	1349	
W1898	*E. coli*	7/25/07	DRY	30	30	
W1898	*E. coli*	9/19/07	DRY	96	96	
W1898	*E. coli*	11/14/07	DRY	299	299	
W1898	*E. coli*	3/5/08	WET	2420	2420	
W1898	*E. coli*	4/29/08	WET	1200	1200	
W1898	*E. coli*	5/27/08	DRY	46	235	
W1898	*E. coli*	8/5/08	DRY	115	115	
W1898	*E. coli*	8/26/08	DRY	86	99	
W1898	*E. coli*	10/15/08	DRY	127	127	
W1898	*E. coli*	3/25/09	DRY	236	236	
W1898	*E. coli*	5/27/09	DRY	93	93	

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W1898	*E. coli*	7/29/09	DRY	172	172	
W1898	*E. coli*	9/30/09	WET	96	96	
W1898	*E. coli*	11/18/09	DRY	1200	1200	
W1898	*E. coli*	2/25/10	WET	2420	2420	
W1898	*E. coli*	10/27/10	DRY	99	99	
W1898	*E. coli*	3/30/11	DRY	517	517	
W1898	*E. coli*	5/25/11	DRY	79	79	
W1898	*E. coli*	7/27/11	DRY	272	272	
W1898	*E. coli*	9/28/11	DRY	91	91	
W1898	*E. coli*	11/9/11	DRY	199	199	
W1898	*E. coli*	2/28/12	DRY	167	167	
W1898	*E. coli*	4/25/12	WET	461	461	
W1898	*E. coli*	6/27/12	WET	121	121	
W1898	*E. coli*	8/29/12	WET	98	98	
W1898	*E. coli*	11/6/12	DRY	45	45	
W1898	*E. coli*	5/21/13	DRY	50	50	
W1898	*E. coli*	8/27/13	WET	172	172	
W1898	*E. coli*	9/23/13	DRY	326	237	

7.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria for the Blackstone River (MA51-05) were elevated during both wet and dry weather throughout the entire segment. Elevated indicator bacteria counts during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated indicator bacteria counts during dry weather indicate that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, may be present.

The most upstream sample station had elevated indicator bacteria results under both weather conditions, suggesting that pathogen sources may be coming from upstream. The area upstream of these sample sites includes the impounded river above Rice City Pond Dam, which is an emergent wetland surrounded mostly by woods, as well as medium density residential areas around North Uxbridge. It also receives water from an outfall of the Blackstone Canal, just southwest of the Rice City Pond Dam. The Blackstone Canal flows beside the Blackstone River and Canal Heritage State Park and portions of the village of North Uxbridge. Given the age of the canal (built in the 1820's), deteriorating wastewater infrastructure and undiscovered direct discharge pipes are possible sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Combined Sewer Overflow (CSO): There is one CSO in the watershed, though it is well upstream of the segment itself. CSOs by design release untreated wastewater to surface waters when flows exceed system capacity, and therefore must be eliminated. For this reason, it is set as the highest priority pathogen source.

Urban Stormwater: The land cover around the Blackstone River segment MA51-05 is primarily medium density residential development. In the overall watershed, 58% of the land area is in MS4 and 10% is DCIA. The pattern of development plus the elevated wet weather indicator bacteria levels indicate that stormwater runoff is a significant source of pathogens.

Illicit Sewage Discharges: The watershed is served by a mix of septic systems and public sewer, with indicator bacteria levels elevated in dry weather. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

On-Site Wastewater Disposal Systems: Areas of the watershed are served by septic systems, and there are two groundwater discharge permits for on-site wastewater discharge, which are large-capacity septic systems (non-residential). It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: While there is relatively little agriculture (4% of land area), this is also a potential source of pathogen pollutant loading. These areas are concentrated mostly in the central and western parts of the watershed (not adjacent to the impaired segment). However, any areas adjacent to upstream tributaries or storm drains could also provide a direct conduit to the river. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: There are significant areas of open space in the watershed designated for recreation. There are many parks and ballfields along the segment, including Blackstone River and Canal Heritage State Park. The river also flows near urban neighborhoods in Uxbridge. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: The elevated indicator bacteria levels in the upstream portion of the segment near the Rice City Pond Dam, which is largely impounded water and emergent wetland habitat surrounded by forest, indicate that wildlife may be a source. Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

7.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Douglas

A small portion of the northeastern corner of Douglas is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041106) and has an EPA-approved Notice of Intent (NOI). Douglas has not completed a Stormwater Management Plan but has mapped all its MS4 stormwater system. The town adopted illicit discharge detection and elimination (IDDE) in 2008 and erosion and sedimentation control (ESC) and post-construction stormwater regulations in 2012. According to the NOI, there are no stormwater outfalls into impaired segments in the Blackstone River watershed.

Douglas has the following ordinances and bylaws:

- Municipal Storm Drain Bylaw, page 59: http://www.douglasma.org/general/General_Bylaws_May2008.pdf (Town of Douglas, 2008)
- Wetland Protection Bylaw: https://douglas-ma.gov/DocumentCenter/View/421/Wetland-Bylaw-PDF?bidId= (Town of Douglas, 2003)
- Pet Waste: None found.

- Stormwater Utility (or similar): None found.

The Town of Douglas Master Plan, completed in 1998, has a Water Features section under the Natural and Cultural Resources Chapter on page 96, covering town floodplains, wetlands, surface waters, reservoirs, and aquifer recharge areas (Town of Douglas, 1998). The plan also discusses impacts of impervious surfaces, affecting the environmental quality in Douglas and surrounding communities, noting that "although impervious surfaces do not generate pollution, they contribute to the hydrologic changes that degrade waterways due to surface runoff" (Master Plan, page 109). The plan lays out goals to adjust zoning to create more stringent on-site stormwater treatment requirements or apply performance standards to specific elements of imperviousness within the landscape. Under the Water and Sewer Department Section, in the Services and Facilities Chapter starting page 133, the plan describes the capacity of the town water services. The plan notes the town may potentially extend sewer service to areas for economic development and will make recommendations to upgrade the existing aeration in the Douglas Wastewater Treatment Facility.

Town of Douglas Master Plan: http://www.douglasma.org/cdd/mpic/docs/masterplan.pdf (Town of Douglas, 1998)

Open Space and Recreation Plan: http://www.douglasma.org/cdd/os/reports/071130-openspaceplan.pdf (Town of Douglas, 2007)

Town of Millville

About half of Millville is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041138) and has an EPA-approved Notice of Intent (NOI). Millville has completed a Stormwater Management Plan and has mapped all of its MS4 stormwater system, both of which are available at https://www.millvillema.org/highway-department/pages/%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8Bstormwater (Town of Millville, n.d.). The town also adopted erosion and sedimentation control (ESC) and post-construction stormwater management in 2004 and illicit discharge detection and elimination (IDDE) in 2015. According to the NOI, there are stormwater outfalls into the Blackstone River MA51-05, impaired for *E. coli* (the number of stormwater outfalls is missing from NOI).

Millville has the following ordinances and bylaws:

- Stormwater Management Bylaw: https://www.millvillema.org/sites/millvillema/files/uploads/stormwater-management-regulations.pdf (Town of Millville, 2009)
- Wetland Protection Ordinance: https://ecode360.com/15640276 (Town of Millville, 2013)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

In addition, Millville's master plan provides information on the Blackstone River and Canal. The Blackstone River is mentioned as one of the town's important natural resources and that water quality should not be further degraded. The plan notes that efforts to improve the quality of the river have occurred over the last few decades, and increased standards for the wastewater treatment plants have reduced pollutant and nitrogen levels, although nonpoint source pollutants are still an issue. The plan sets improving regional solutions for extending water and sewer systems to adjacent communities as an infrastructure goal.

Millville Master Plan: https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-master-plan.pdf (Town of Millville, 2018a)

Millville's stormwater page. https://www.millvillema.org/highway-department/pages/%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8Bstormwater (Town of Millville, n.d.)

Open Space and Recreation Plan: https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-open-space-recreation-plan-.pdf (Town of Millville, 2018b)

Town of Upton

Less than a quarter of Upton is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. Upton (Permit ID #MAR041165) has an EPA-approved Notice of Intent (NOI). The town does not have a Stormwater Management Plan, according to the NOI. The town has mapped all of its MS4 stormwater system and submitted a map attached to the NOI. It adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater regulations in 2012. According to the NOI, there are no impaired waterway segments in the Town of Upton.

Upton has the following ordinances and bylaws:

- Stormwater Bylaw: https://www.uptonma.gov/sites/g/files/vyhlif5121/f/uploads/stormwater_regulations.pdf (Town of Upton, 2014)
- Wetland Bylaw: https://www.uptonma.gov/sites/uptonma/files/uploads/upton_wetland_bylaw.pdf (Town of Upton, 2004)
- Title V Regulations: No
- Stormwater Utility: No
- Pet Waste Ordinance: No

Upton's Master Plan has a water resource section in the Environmental Analysis Chapter, which includes surface waters, flood hazard areas, wetlands, and aquifer recharge areas (pages 71-72; Town of Upton, 2005). The plan also outlines goals to strengthen stormwater regulations in the town. Upton's wastewater treatment system serves West Upton and Upton Center. The infrastructure is aging and the plan notes "it will be critical for the wastewater replacement and improvement plan to keep pace with… significant land use changes" (page 112).

Town Website: https://www.uptonma.gov/ (Town of Upton, 2020a)

Stormwater Page: https://www.uptonma.gov/conservation-commission/pages/stormwater-management (Town of Upton n.d.)

Master Plan:
https://www.uptonma.gov/sites/g/files/vyhlif5121/f/pages/supp_03_upton_master_plan_adopted_july_2005.pdf

(Town of Upton, 2005)

Open Space and Recreation Plan:
https://www.uptonma.gov/sites/uptonma/files/uploads/open_space_recreation_plan.pdf (Town of Upton, 2020b).

Town of Uxbridge. See Section 6.4.

8. MA51-06 Blackstone River

8.1. Waterbody Overview

The Blackstone River segment MA51-06 is 3.8 miles long and begins at the most downstream railroad trestle crossing in Millville, and flowing southeast to end at the Rhode Island border, just west of Main Street/MA-122, in Blackstone. The river is diverted by a stone dam (from the abandoned Blackstone Canal) into two channels in the Town of Blackstone just upstream of the Blackstone Gorge. The southern flow path enters Rhode Island for approximately one mile, while the northern flow path remains in Massachusetts before converging again at the state border. The segment is bound upstream by the Blackstone River segment MA51-05 and downstream by the state border. The watershed of the Blackstone River segment MA51-06 spans 178,442 acres (77%) in Massachusetts and 53,601 acres (23%) in Rhode Island.

Tributaries to this section of the Blackstone River include Aldrich Brook, Fox Brook, and the Branch River (RI). Upstream of the Branch River, the watershed contains a large number of lakes, impoundments, and streams in Rhode Island, including the Burlingame Reservoir, Echo Lake (Pascoag Reservoir), Slatersville Reservoir, Smith & Sayles Reservoir, Wilson Reservoir, Keech Pond, Nichols Pond, Spring Grove Pond, Spring Lake (Herring Pond), Sucker Pond, Tarkiln Pond, Wallum Lake, Clear River, Pascoag River, Hearing Brook, and Branch River.

Impaired tributaries upstream of this segment include Kettle Brook (MA51-01), Middle River (MA51-02), Blackstone River (MA51-03), Blackstone River (MA51-04), Blackstone River (MA51-05), Beaver Brook (MA51-07), unnamed tributary (MA51-08), Tatnuck Brook (MA51-15), Dark Brook (MA51-16), Poor Farm Brook (MA51-17), Coal Mine Brook (MA51-27), Singletary Brook (MA51-31), and Cronin Brook (MA51-45).

Major landmarks along the segment include the Southern New England Trunkline Trail, Tupperware Park, Roosevelt Park, sections of the Blackstone River and Canal Heritage State Park, the Blackstone Gorge, and channels and dams of the abandoned nineteenth century Blackstone Canal.

Reduction from Highest Calculated Geomean: 82%

Watershed Area (Acres): 232,043

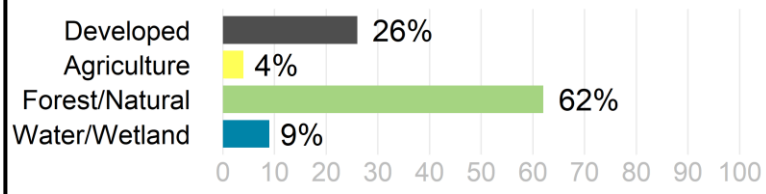
Segment Length (Miles): 3.8

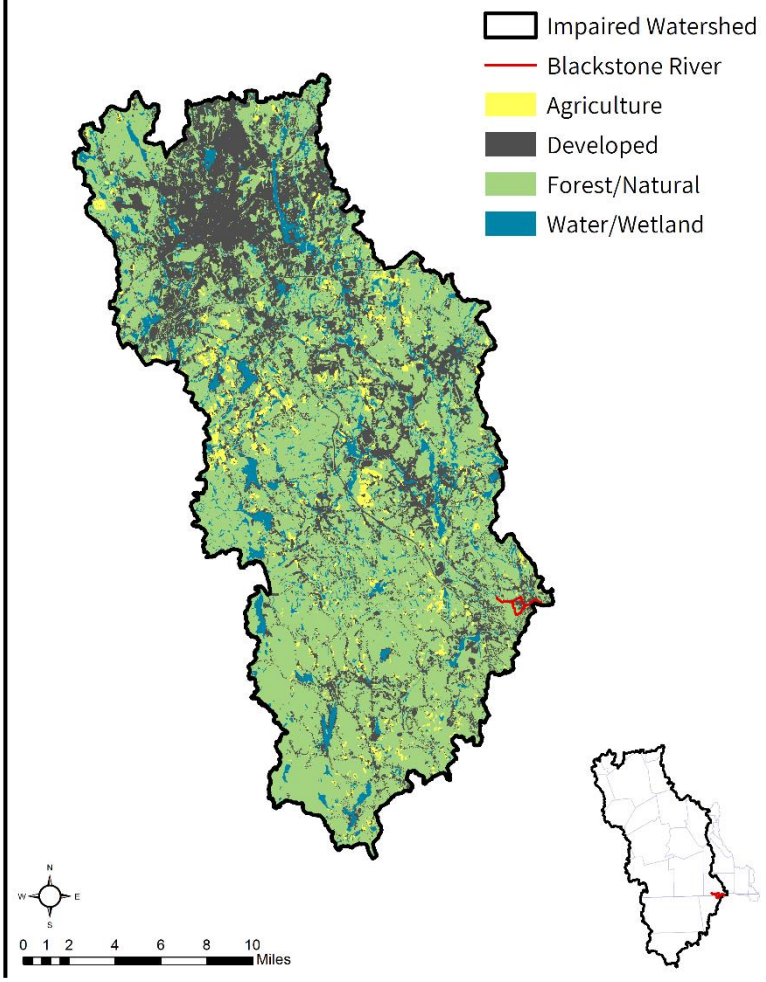
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water)

Impervious Area (Acres, %): 26,840 (12%)

DCIA Area (Acres, %): 17,914 (8%)





Road crossings include Main Street/MA-122 (twice), Canal Street, and Saint Paul Street, all in Blackstone. There are several railroad and rail-trail bridge crossings in Uxbridge and Blackstone.

The Blackstone River (MA51-06) drains an area of 363 square miles, with 42 mi^2 (12%) impervious and 28 mi^2 (8%) directly connected impervious area (DCIA). The watershed also extends to the south into Rhode Island. Approximately 279 mi^2 (77%) of the total 363 mi^2 watershed area is within Massachusetts. The full watershed is served partially[19] by public sewer and 48% of the land area of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are 20 NPDES permits on file governing point source discharges of pollutants to surface waters. In addition to the 20 NPDES permits, 10 NPDES permits exist for wastewater treatment facilities (none within the segment's immediate drainage area). There is one combined sewer overflow (CSO) far upstream of the segment (See Section 5.1). Two groundwater discharge permits exist for on-site wastewater discharge within this watershed (none within the immediate drainage area). There are 26 landfills and one unpermitted land disposal dumping grounds in the watershed. See Figure 8-1.

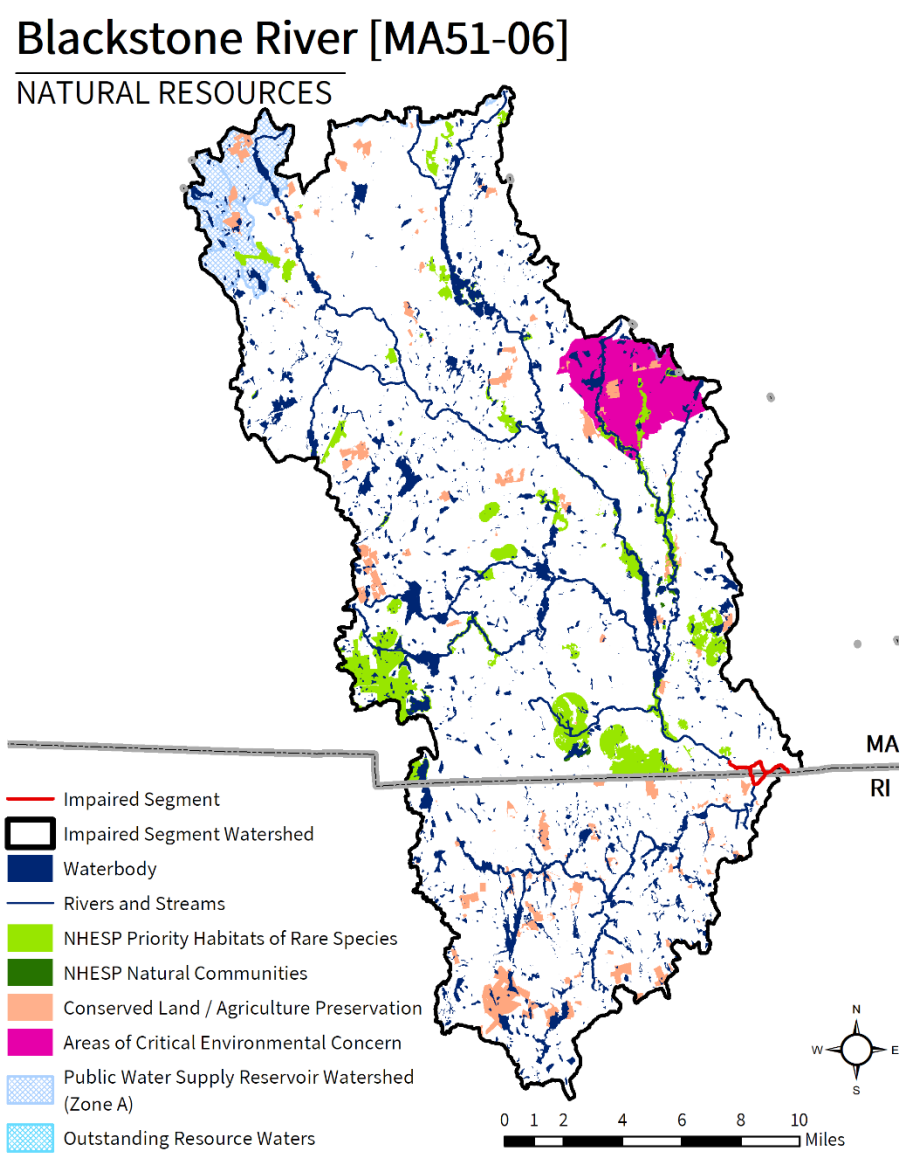
The upstream portion of the Blackstone River (MA51-06) flows through predominantly forested land (62% of the watershed), while the downstream portion is bordered by medium density residential and commercial development in Blackstone Village (26%). The 4% of the watershed in agriculture is largely in the middle of the watershed and not adjacent to the segment. The headwaters of the watershed, about 28 miles upstream, contains the heavily urbanized areas in and around Worcester.

The watershed of the Blackstone River (MA51-06) contains one Area of Critical Environmental Concern: "Miscoe, Warren and Whitehall watersheds" (7,924 acres, 3%). Under the Natural Heritage and Endangered Species Program, there are 12,663 acres (5%) of Priority Habitats of Rare Species and 457 acres (<1%) of Priority Natural Vegetation Communities. There are 8,225 acres (4%) under Public Water Supply protection, but no Outstanding Resource Waters identified in the watershed. Over 7,582 acres (3%) of land protected in perpetuity[20] exist within the segment watershed, which is part of a total of 31,800 acres (14%) of Protected and Recreational Open Space[21]. See Figure 8-1.

[19] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[20] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[21] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



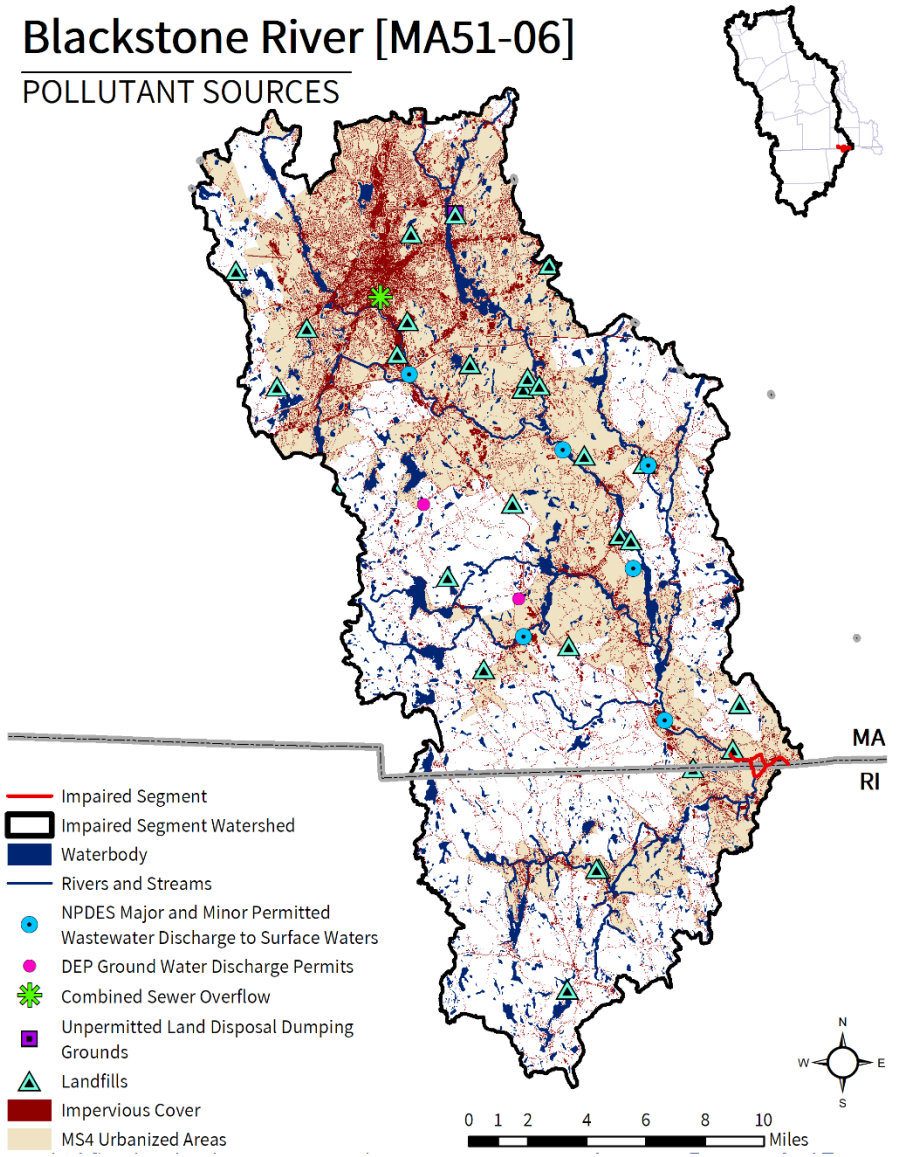


Figure 8-1. Natural resources and potential pollution sources draining to the Blackstone River segment MA51-06. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

8.2. Waterbody Impairment Characterization

The Blackstone River (MA51-06) is a Class B, Warm Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 8-1, 8-2; Figure 8-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

- In 2008, six samples were collected at W1023, resulting in three days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, one exceeded the STV criterion during wet weather.
- In 2008, six samples were collected at W1766, resulting in three days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion in during wet weather.

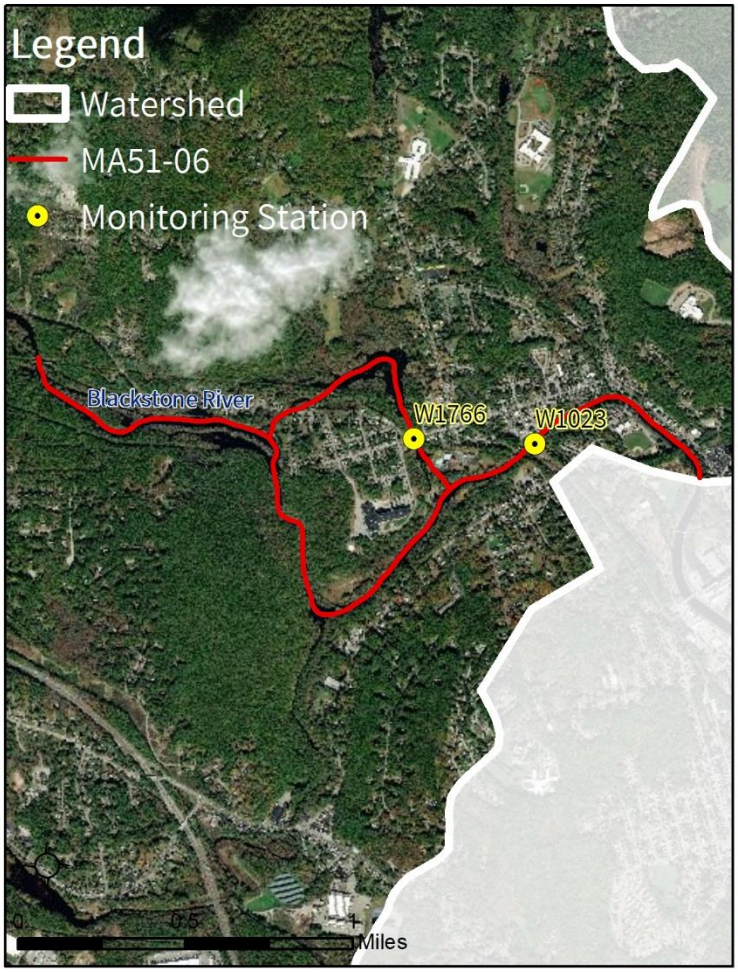


Figure 8-2. Location of monitoring station(s) along the impaired river segment.

Table 8-1. Summary of indicator bacteria sampling results by station for the Blackstone River (MA51-06). The maximum 30-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1023	4/29/2008	8/26/2008	6	657	3	1
W1766	4/29/2008	8/26/2008	6	685	3	2

Table 8-2. Indicator bacteria data by station, indicator, and date for the Blackstone River (MA51-06). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W1023	*E. coli*	4/29/08	WET	210	210	
W1023	*E. coli*	5/27/08	DRY	58	110	
W1023	*E. coli*	6/24/08	WET	4800	528	
W1023	*E. coli*	7/8/08	DRY	90	657	
W1023	*E. coli*	8/5/08	DRY	120	104	
W1023	*E. coli*	8/26/08	DRY	120	120	
W1766	*E. coli*	4/29/08	WET	540	540	
W1766	*E. coli*	5/27/08	DRY	29	125	
W1766	*E. coli*	6/24/08	WET	5400	396	
W1766	*E. coli*	7/8/08	DRY	87	685	
W1766	*E. coli*	8/5/08	DRY	130	106	
W1766	*E. coli*	8/26/08	DRY	39	71	

8.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria in the Blackstone River (MA51-06) were elevated during wet weather at both sampling stations along the impaired segment. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels.

Each potential pathogen source relevant to this segment is described in further detail below.

Combined Sewer Overflow (CSO): There is one CSO in the watershed, though it is far upstream of the segment itself. CSOs by design release untreated wastewater to surface waters when flows exceed system capacity, and therefore must be eliminated. For this reason, it is set as the highest priority pathogen source.

Urban Stormwater: The land cover around the Blackstone River segment MA51-06 is primarily medium density residential development, including the villages of Millville and Blackstone. In the overall watershed, 48% of the land area is in MS4 and 8% is DCIA. The pattern of development in addition to the elevated wet weather indicator bacteria levels indicate that stormwater runoff is a significant source of pathogens.

Illicit Sewage Discharges: The watershed is served by a mix of septic systems and public sewer. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows which may be

caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity.

On-Site Wastewater Disposal Systems: Areas of the watershed are served by septic systems, and there are two groundwater discharge permits for on-site wastewater discharge, which are large-capacity septic systems (non-residential). It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: While there is relatively little agriculture (4% of land area), this is also a potential source of pathogen pollutant loading. These areas are concentrated mostly near the center of the watershed and are not adjacent to the impaired segment. However, any areas adjacent to upstream tributaries or storm drains could also provide a direct conduit to the river. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: There are significant areas of open space in the watershed designated for recreation. There are several residential neighborhoods along the segment, as well as conservation land with recreational trails at Blackstone Gorge and the Southern New England Trunkline Trail. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Most of the riparian corridor maintains a wide wooded buffer zone, although there are a few large open areas in the village of Blackstone. Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

8.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Blackstone

Most of the Town of Blackstone is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041093) and has an EPA-approved Notice of Intent (NOI). Blackstone has a Stormwater Management Plan on file at the Department of Public Works and has mapped all of its MS4 stormwater system. According to the NOI, there are 20 stormwater outfalls into the Mill River MA51-36, impaired for *E. coli.* There are no reported stormwater outfalls to Fox Brook segment MA51-39.

Blackstone has the following ordinances and bylaws:

- Stormwater Management and Land Disturbance Bylaw: https://ecode360.com/15990110 (Town of Blackstone, 2011)
- Title 5 Supplemental Material & Revisions: https://ecode360.com/8905957 (Town of Blackstone, 1988)
- Wetlands Protection Bylaw: https://ecode360.com/8904497 (Town of Blackstone, 1986)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

In addition, the Town of Blackstone's Master Plan has a water resources section under the Natural and Cultural Resources chapter, starting on page 55 (Town of Blackstone, 2018). The Master Plan also mentions town sewer services and stormwater management systems under the Public Facilities section starting on page 101. The sewer system serves primarily the denser, southern part of Blackstone, including about 15 miles of sewer mains and 15 pump stations. Blackstone has a detailed Open Space and Recreation section of their master plan, serving as the town's open space and recreation plan.

Town of Blackstone Master Plan: https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-master-plan.pdf (Town of Blackstone, 2018).

Town of Millville. See Section 7.4.

9. MA51-07 Beaver Brook

9.1. Waterbody Overview

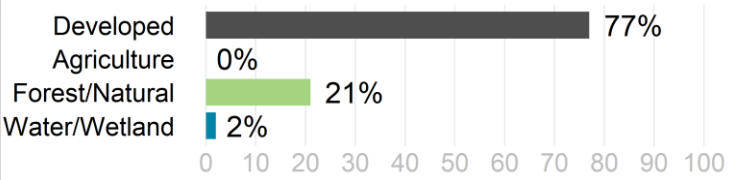
The Beaver Brook segment MA51-07 is three miles long and begins at the outlet of a small unnamed impoundment between Flag Street Elementary School and Beth Israel School in Worcester, entering a culvert just north of St Paul Drive to flow south underground for two miles before exiting the culvert south of Chandler Drive at Beaver Brook Park. The brook enters a culvert again north of May Street and flows underground along Beaver Brook Parkway for 0.4 miles until crossing Maywood Street. The segment ends at its confluence with pathogen-impaired Middle River (MA51-02), just south of Beaver Street, Worcester.

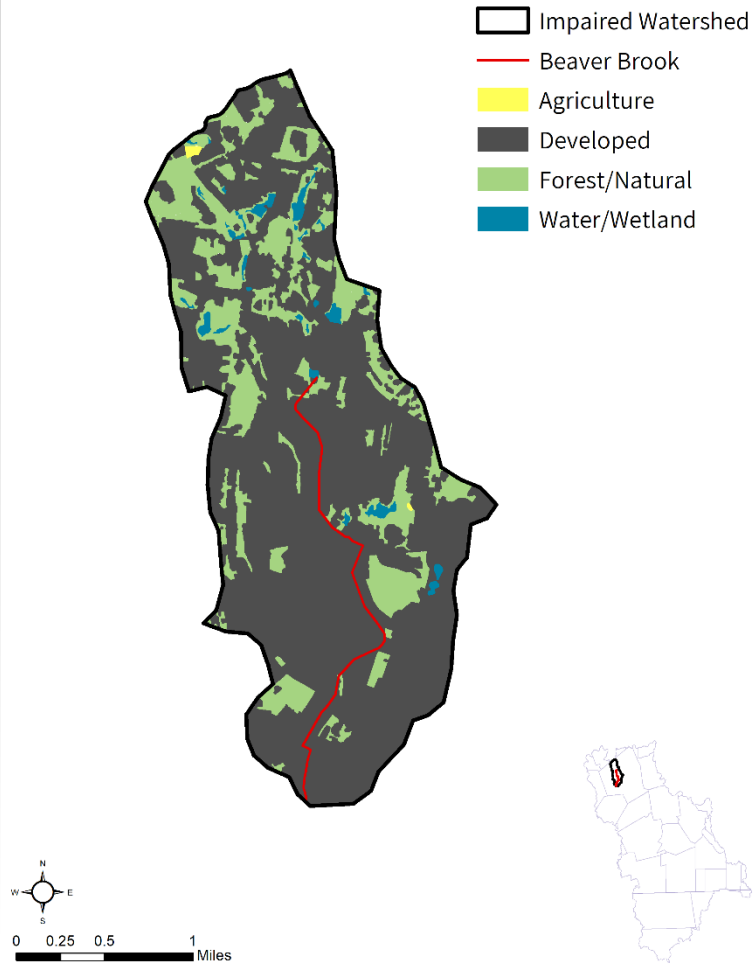
There are no tributaries to this segment or lakes, ponds, or reservoirs within the segment watershed. Major landmarks in the watershed include Assumption College north of the headwaters, Moreland Woods Conservation Restriction, Doherty Memorial High School, Newton Hill, Wetherell Park, General Foley Stadium, Beaver Brook Park, and Hadwen Arboretum. Most of the stream is buried beneath a dense network of residential streets and house lots, with additional road crossings at Park Avenue and Beaver Street. The City of Worcester restored a 0.2-mile section Beaver Brook in 2005, bringing it to the surface in Beaver Brook Park (MassDEP, 2010).

Beaver Brook (MA51-07) drains an area of 4.4 square miles, of which 1.5 mi^2 (34%) is impervious and 1.2 mi^2 (26%) is directly connected impervious area (DCIA). The watershed is served entirely[22] by public sewer and the entire watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. There are no NPDES permits on file governing point source discharges of pollutants to surface waters. There are no groundwater discharge permits, combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds within the segment watershed. See Figure 9-1.

The watershed is overwhelmingly developed (77%), with some forested land (20%), and two small agricultural areas (<1%). The residential neighborhoods consist of detached dwellings and

Reduction from Highest Calculated Geomean: 99%
Watershed Area (Acres): 2,799
Segment Length (Miles): 2.9
Impairment(s): *E. coli* (Primary Contact Recreation)
Class (Qualifiers): B (Warm Water, High Quality Water)
Impervious Area (Acres, %): 995 (34%)
DCIA Area (Acres, %): 733 (26%)





[22] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

some vegetated cover; however, the mostly buried stream channel indicates the high degree to which the riparian environment has been modified.

In the watershed of Beaver Brook (MA51-07), under the Natural Heritage and Endangered Species Program, there are no areas identified as Priority Natural Vegetation Communities or Priority Habitats of Rare Species. There are three acres (<1%) under Public Water Supply protection, but no Areas of Critical Environmental Concern or Outstanding Resource Waters identified in the watershed. Over 24 acres (1%) of land protected in perpetuity[23] exist within the segment watershed, which is part of a total of 172 acres (6%) of Protected and Recreational Open Space[24]. See Figure 9-1.

[23] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[24] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

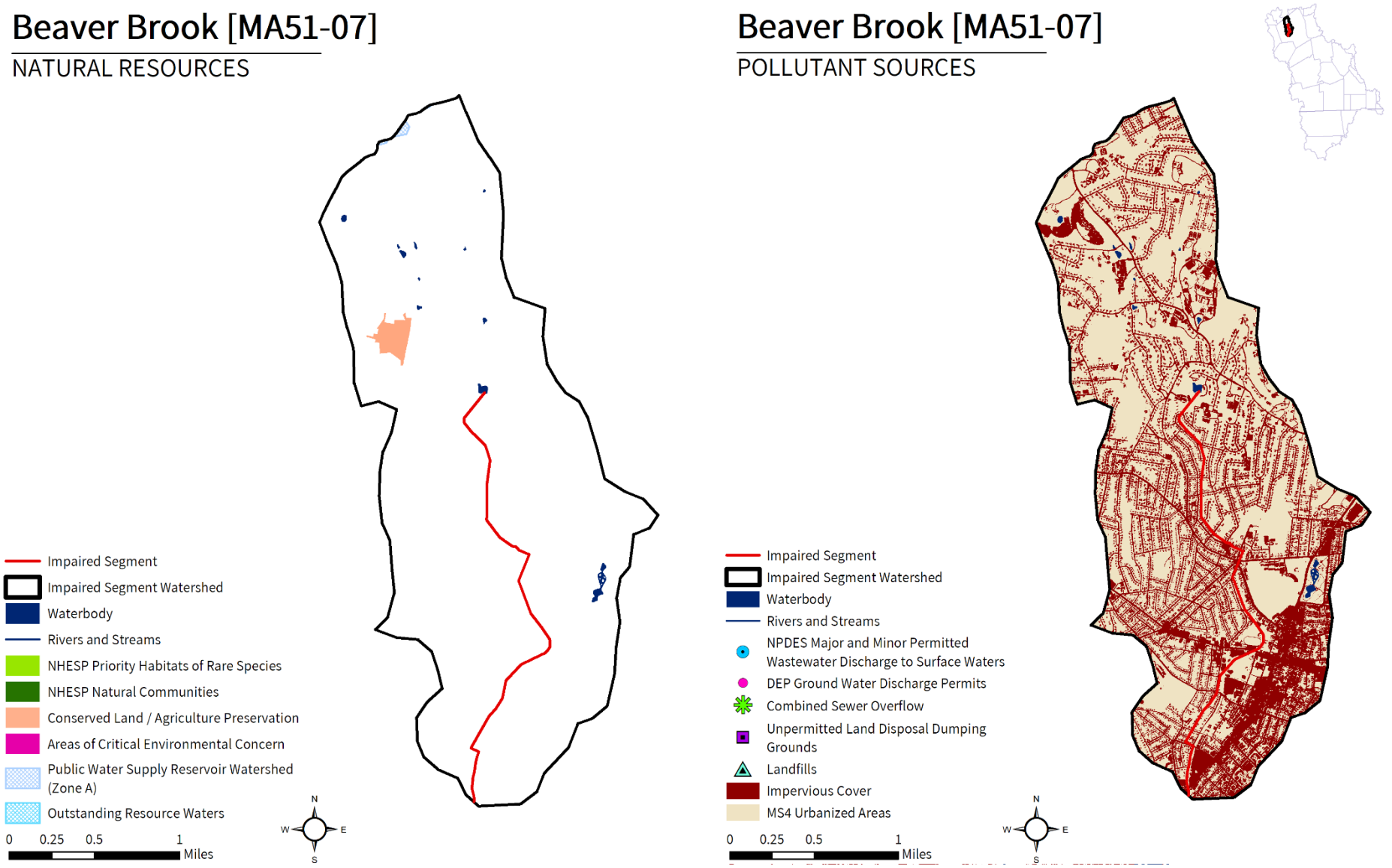


Figure 9-1. Natural resources and potential pollution sources draining to the Beaver Brook segment MA51-07. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

9.2. Waterbody Impairment Characterization

Beaver Brook (MA51-07) is a Class B, Warm Water and High Quality Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 9-1, 9-2; Figure 9-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W0499, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, six exceeded the STV criterion during both wet and dry weather.

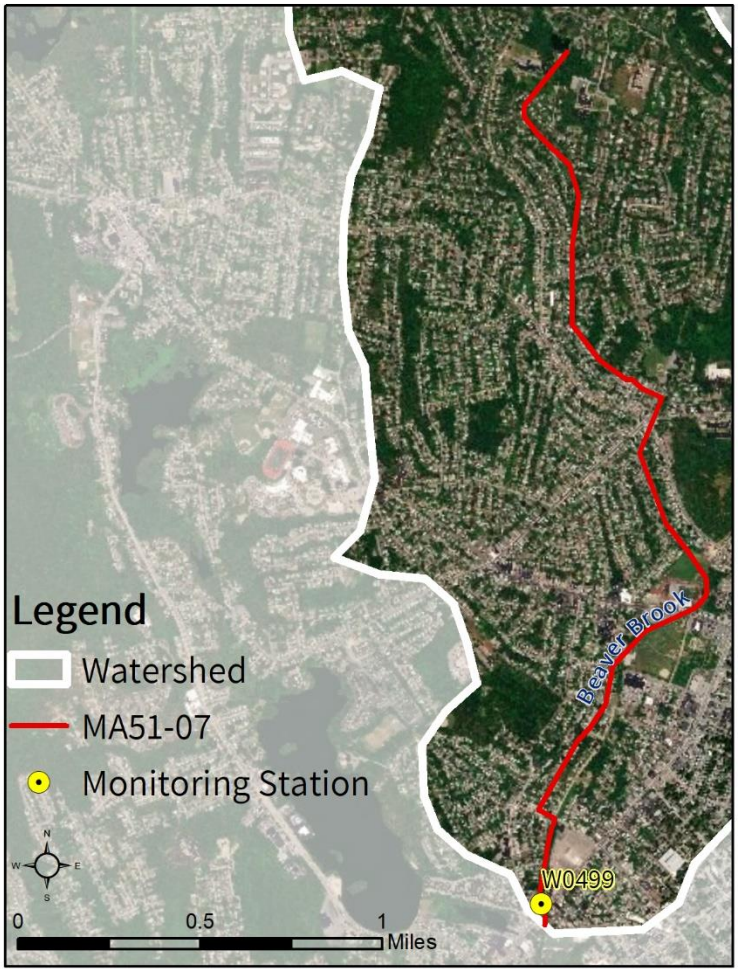


Figure 9-2. Location of monitoring station(s) along the impaired river segment.

Table 9-1. Summary of indicator bacteria sampling results by station for Beaver Brook (MA51-07). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0499	5/1/2008	8/28/2008	6	9800	6	6

Table 9-2. Indicator bacteria data by station, indicator, and date for Beaver Brook (MA51-07). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W0499	*E. coli*	5/1/08	DRY	9800	9800	
W0499	*E. coli*	5/29/08	DRY	6400	7920	
W0499	*E. coli*	6/26/08	DRY	4900	6748	
W0499	*E. coli*	7/10/08	WET	6900	6786	
W0499	*E. coli*	8/7/08	WET	1300	4095	
W0499	*E. coli*	8/28/08	DRY	2000	3062	

9.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

The indicator bacteria data for Beaver Brook segment MA51-07 were elevated during both wet and dry weather at station W0499. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying the sources of pollutants.

Each potential pathogen source relevant to this segment is described in further detail below.

Illicit Sewage Discharges: With the entire watershed served by public sewer and within an MS4 designated area, illicit discharges are a likely source. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

Urban Stormwater: The entire watershed is designated as MS4 with 26% as DCIA (77% of the watershed being developed). Stormwater runoff from urban areas is likely a significant source of pathogens.

Pet Waste: There are a several parks and ballfields adjacent to the segment, especially where the brook is not culverted. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

On-Site Wastewater Disposal Systems: There are no groundwater discharge permits for on-site wastewater discharge, and the entire watershed is served by public sewer, although there may be some older systems serving properties that have not connected to sewer. While it is likely that septic systems are not a major source

of pathogens to the watershed, it may still be worthwhile to research whether isolated properties are still served by septic systems.

Agriculture: While there is only a small amount (<1%) of agriculture in the watershed, activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Wildlife Waste: Since most of the brook is underground in an urban environment, wildlife living in storm drains, such as rodents, may be a source of pathogens to the brook. In addition, conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

9.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

City of Worcester. See Section 3.4.

10. MA51-08 Unnamed Tributary

10.1. Waterbody Overview

The unnamed tributary MA51-08, also known as Mill Brook, is 5.6 miles long and begins at the outlet of Indian Lake in Worcester. It then flows south through Salisbury Pond (formerly segment MA51142) and the city center of Worcester before ending at its confluence with Middle River (part of Blackstone River segment MA51-03) west of Tobias Boland Way in Worcester. The entire stream except for Salisbury Pond is underground.

Since the stream is underground, tributaries are difficult to discern, and maps show conflicting information. The USGS National Map shows an unnamed stream draining Green Hill Pond as a tributary (USGS, 2019). MassGIS hydrology data shows an unnamed stream at the southern end of the tributary that appears to cross MA51-08 to join MA51-02 (MassGIS, 2017). Other waterbodies in the watershed include Weasel Brook (upstream of Indian Lake), Green Hill Pond, and Bell Pond. The City of Worcester Quinsigamond Avenue Combined Sewer Overflow Storage and Treatment Facility (QCSOSTF) discharges to downstream Mill Brook during runoff conditions (MassDEP, 2010).

Major landmarks in the watershed include downtown Worcester and many urban neighborhoods, Union Station (rail), Port of Worcester (rail), and the CSX Intermodal Terminal, Worcester Polytechnic Institute, Bovenzi Conservation Park, Bell Hill Park, Green Hill Park and adjacent golf course, and Crompton Park.

The stream flows under or along Major Taylor Boulevard, Foster Street, Washington Street, Harding Street, and MA-146 south of I-290, and is crossed by over 20 streets. Before construction altered MA-146 in 2007, the stream's discharge point to Middle River was 1,800 feet upstream (MassDEP, 2010).

Unnamed tributary segment MA51-08 drains an area of 12.9 square miles, of which 5.8 mi^2 (45%) is impervious, and 4.8 mi^2 (37%) is directly connected impervious area (DCIA). The

Reduction from Highest Calculated Geomean: 97%

Watershed Area (Acres): 8,216

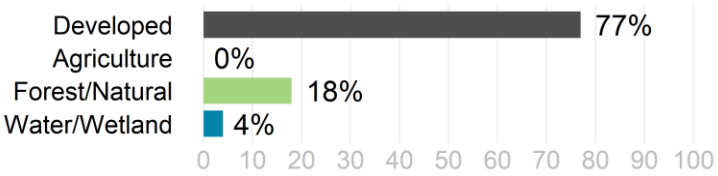
Segment Length (Miles): 5.6

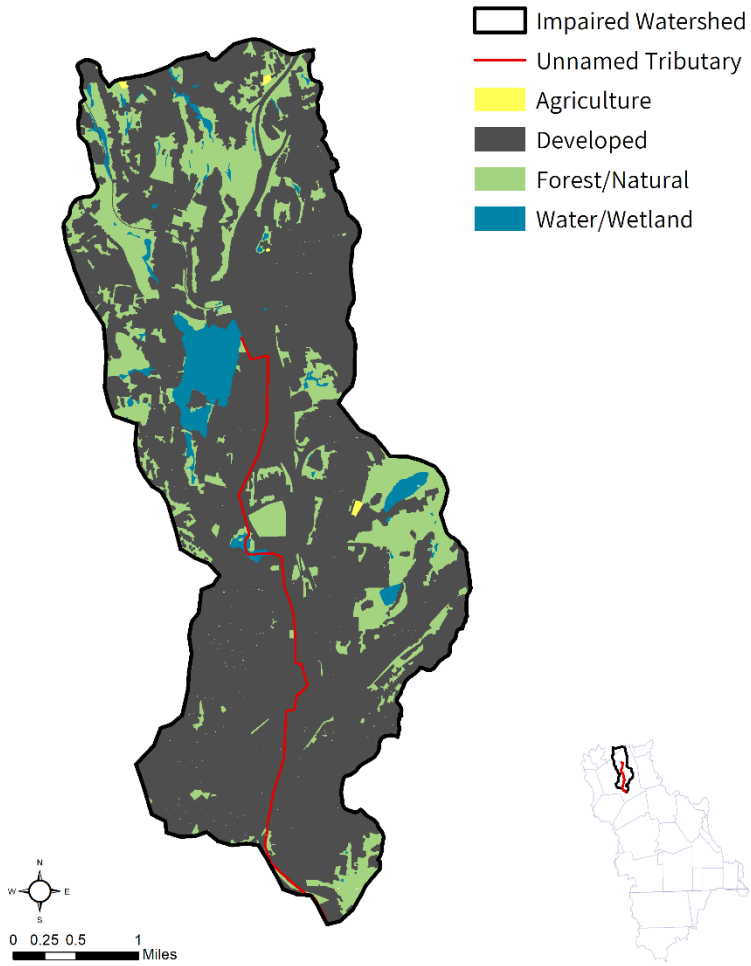
Impairment(s): *E. coli*, fecal coliform (Primary Contact Recreation)

Class (Qualifiers): B (Warm Water, CSO Receiving Water)

Impervious Area (Acres, %): 3,692 (45%)

DCIA Area (Acres, %): 3,066 (37%)





watershed is served mostly[25] by public sewer and the entire watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file governing point source discharges of pollutants to surface waters and no additional NPDES permits for wastewater treatment facilities. There are no groundwater discharge permits within the segment watershed for on-site wastewater discharge. There is one combined sewer overflow (CSO) (See Section 5.1) and one landfill, but no unpermitted land disposal dumping grounds within the segment watershed. There is one Industrial Stormwater discharge permit within the watershed for this segment (Table 10-1). See Figure 10-1.

Table 10-1 National Pollutant Discharge Elimination System (NPDES) permits for Industrial Stormwater discharges in the segment watershed. Only permits unique to this segment watershed are shown.

NPDES ID	NAME	TOWN
MA0000817	NORTON COMPANY	WORCESTER

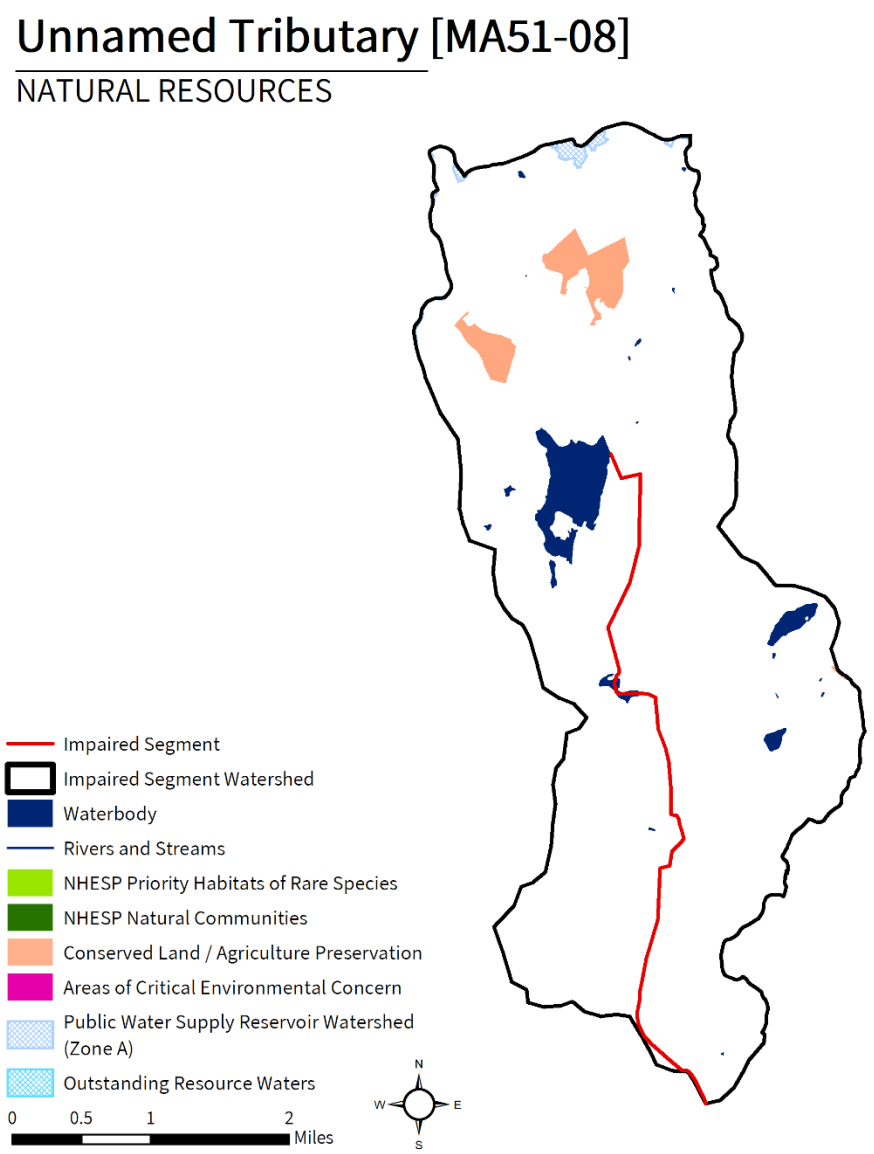
The entire segment flows underneath high density residential, commercial, industrial, and transportation development (77% of the watershed). The watershed upstream of the headwaters contains some medium density residential development and conservation lands. Forest land cover accounts for 18% of the watershed, though most is not near the stream. There is minimal agriculture (<1%). Building and impervious area density are generally highest along the stream corridor.

In the watershed of the unnamed tributary (MA51-08), under the Natural Heritage and Endangered Species Program, there are no areas identified as Priority Habitats of Rare Species or Priority Natural Vegetation Communities. There are 34 acres (<1%) under Public Water supply protection, but no Areas of Critical Environmental Concern or Outstanding Resource Waters. Over 185 acres (2%) of land protected in perpetuity[26] exist within the segment watershed, which is part of a total of 780 acres (9%) of Protected and Recreational Open Space[27]. See Figure 10-1.

[25] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[26] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[27] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).



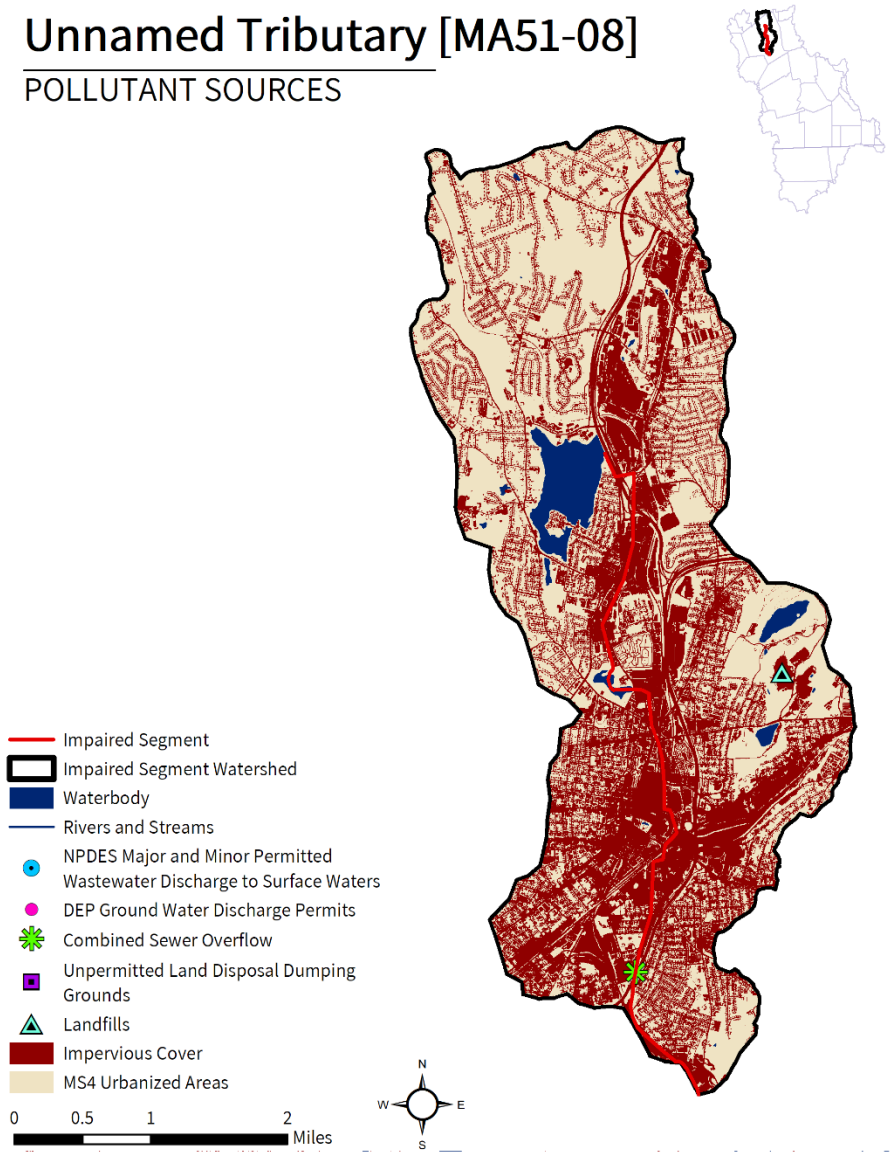


Figure 10-1. Natural resources and potential pollution sources draining to the unnamed tributary also known as Mill Brook segment MA51-08. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

10.2. Waterbody Impairment Characterization

The Unnamed tributary (MA51-08) is a Class B, Warm Water and CSO Receiving Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 10-2, 10-3; Figure 10-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

- In 2008, six samples were collected at W2062, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, three exceeded the STV criterion during both wet and dry weather.
- In 2011, six samples were collected at W2238, resulting in six days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, six exceeded the STV criterion during both wet and dry weather.

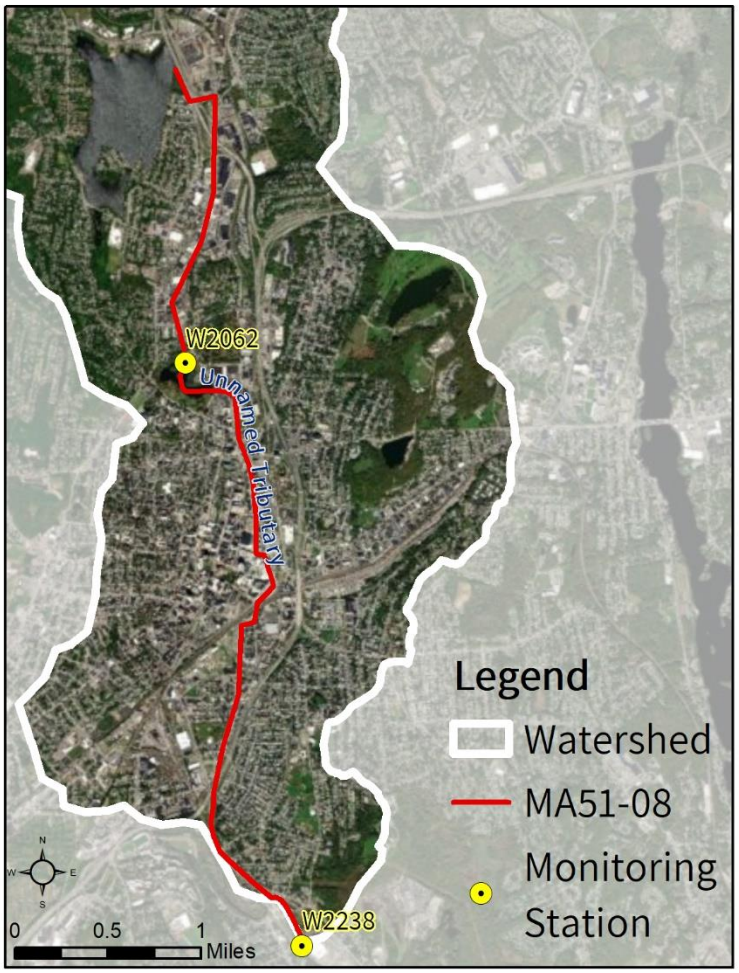


Figure 10-2. Location of monitoring station(s) along the impaired river segment.

Table 10-2. Summary of indicator bacteria sampling results by station for the unnamed tributary (MA51-08). The maximum 30-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W2062	5/1/2008	8/28/2008	6	1054	6	3
W2238	6/9/2011	10/12/2011	6	4946	6	6

Table 10-3. Indicator bacteria data by station, indicator, and date for the Unnamed tributary (MA51-08). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W2062	*E. coli*	5/1/08	DRY	280	280	
W2062	*E. coli*	5/29/08	DRY	2700	869	
W2062	*E. coli*	6/26/08	DRY	290	885	
W2062	*E. coli*	7/10/08	WET	3700	1036	
W2062	*E. coli*	8/7/08	WET	300	1054	
W2062	*E. coli*	8/28/08	DRY	500	387	
W2238	*E. coli*	6/9/11	DRY	2420	2420	
W2238	*E. coli*	7/7/11	DRY	2420	2420	
W2238	*E. coli*	7/21/11	DRY	2420	2420	
W2238	*E. coli*	8/29/11	WET	2420	2420	
W2238	*E. coli*	9/15/11	DRY	10110	4946	
W2238	*E. coli*	10/12/11	DRY	2420	4946	

10.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

The indicator bacteria data for the unnamed tributary (MA51-08) were elevated during both wet and dry weather at stations W2062 and W2238. Elevated results during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens.

Each potential pathogen source relevant to this segment is described in further detail below.

Combined Sewer Overflow (CSO): There is one CSO in the watershed, which by design releases untreated wastewater to surface waters when flows exceed system capacity, and therefore must be eliminated. For this reason, it is set as the highest priority pathogen source.

Illicit Sewage Discharges: With the entire watershed designated as MS4 area and served by sewer, a history of urbanization at a time when direct connections of wastewater to surface waters was not uncommon, and data which show elevated dry weather indicator bacteria levels, illicit discharges from sanitary sewers are likely a significant source of pathogens to this segment. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

Urban Stormwater: The watershed is highly developed, with all the land area in MS4 and 37% as DCIA, as well as areas of dense commercial, industrial, and residential neighborhoods. Stormwater runoff from urban areas is likely a significant source of pathogens, provided there is connectivity between the land surface and the underground stream via street drains.

On-Site Wastewater Disposal Systems: Portions of the upstream watershed may be served by septic systems, and it is likely that some septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Pet Waste: Despite the urban character of the watershed, 9% of the area is Protected and Recreational Open Space. The upstream watershed contains conservation lands, parks, and ballfields popular for dog-walking. There are also dense residential neighborhoods throughout the watershed, some concentrated along the impaired segment's underground flow path. Together, these factors indicate that pet waste is a source of pathogens to the stream.

Wildlife Waste: Given that the entire length of the stream runs underground beneath a highly urbanized landscape, wildlife living in storm drains, such as rodents, may be a source of pathogens to the stream. In the upstream watershed, conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

Agriculture: There is less than 1% of the watershed in agricultural use, and none appear adjacent to the impaired segment. Nonetheless, any agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

10.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Holden

A small portion of Holden is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. Holden (Permit ID #MAR041121) has an EPA-approved Notice of Intent (NOI). Holden does not have a Stormwater Management Plan but has mapped all of its MS4 stormwater system. It adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater regulations in 2011. The upstream portion of the unnamed tributary segment MA51-08 watershed is in Holden, though the segment itself is not. The NOI indicates 15 stormwater outfalls to tributaries to Indian Lake, upstream of the segment.

The Town of Holden has the following bylaws and ordinances:

- Stormwater Management and Erosion Control Bylaw, Chapter 2 Article XXIV of Town Bylaws: https://www.holdenma.gov/department-of-public-works/pages/chapter-2-by-laws (Town of Holden, 2018)
- Title 5 Supplementary Regulations: https://www.holdenma.gov/department-of-public-works/pages/chapter-50-board-of-health-title-5 (Town of Holden, 1999)
- Wetland Bylaw, Chapter 2 Article XXIII of Town Bylaws: https://www.holdenma.gov/department-of-public-works/pages/chapter-2-by-laws (Town of Holden, 2018)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

In addition, Holden's Master Plan has a Water Resources section under the Natural Resources chapter, starting on page 60 (CMRPC 2019). The plan discusses and maps sub-watersheds, as well as waterbodies, streams, and aquifers, noting that "it will be important for the Town of Holden to continue to work regionally to protect its valuable water resources from threats such as contamination, drought, and overuse (Master Plan, page 63).

Under supplementary Title 5 Regulations, the plan details buffer areas around hydrological features to prevent contamination of water supplies from private septic systems. The plan's section on Wastewater Systems, in the Public Facilities and Services chapter starting on page 291, notes the Town of Holden operates a network of approximately 80 miles of sanitary sewer mains and 29 pumps stations. The Stormwater Drainage section discusses stormwater management as an increasing concern for the Holden Department of Public Works as development increases.

Town of Holden Master Plan:
https://www.dropbox.com/s/j2hss4juo5t2f56/Holden%20Master%20Plan%202019.pdf?dl=0 (CMRPC, 2019)

Holden also has an Open Space and Recreation Plan written in 2020 that does not appear to be available online: https://www.holdenma.gov/open-space-and-recreation-committee (Town of Holden, 2020).

City of Worcester. See Section 3.4

The ***Indian Lake Watershed Association*** focuses on the lake and surrounding environment which forms the headwaters to unnamed tributary segment MA51-08. Recent activities include water quality monitoring and storm drain mapping. https://www.ilwa.org/ (ILWA, 2020).

11. MA51-15 Tatnuck Brook

11.1. Waterbody Overview

The Tatnuck Brook segment MA51-15 is 3.3 miles long and begins at the outlet of Holden Reservoir Number Two at Stonehouse Hill Road in Holden, then flows south into Worcester through Cook Pond, Patch Reservoir, Patch Pond, and Williams Millpond before ending at its confluence with the Coes Reservoir (MA51024) in Worcester.

Tributaries to this section of the Tatnuck Brook include several unnamed streams draining ponds and wetlands. Wadsworth Brook and Scott Brook are tributaries to Holden Reservoir Number One, in the upstream reaches of the watershed. The Holden Reservoirs supply 50 million gallons of water per day to surrounding communities. There are no other impaired streams within this segment watershed.

Major landmarks in the watershed include half of the Worcester Regional Airport, Worcester State University, Cascades Park and Cooks Pond Conservation Restrictions, Stonehouse Hill, and the Tatnuck Country Club and golf course.

Road crossings are concentrated near the middle of the segment in Worcester and include Dawson Road, Mower Street, Pleasant Street/MA-122, Mill Street, and June Street.

Tatnuck Brook (MA51-15) drains an area of 10.8 square miles, of which 1.1 mi^2 (11%) is impervious, and 0.8 mi^2 (7%) is directly connected impervious area (DCIA). The watershed is served partially[28] by public sewer and 52% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There is one NPDES permit on file governing point source discharges of pollutants to surface waters, and no additional NPDES permits for wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 11-1.

The watershed is predominately forest (67%) in the upstream portion of the watershed, while the

Reduction from Highest Calculated Geomean: 49%

Watershed Area (Acres): 6,881

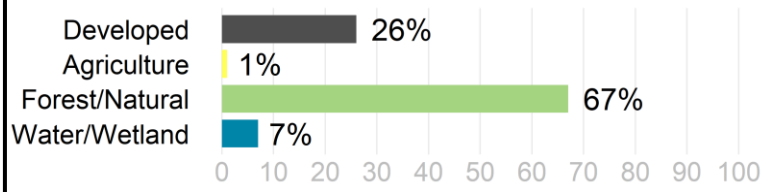
Segment Length (Miles): 3.3

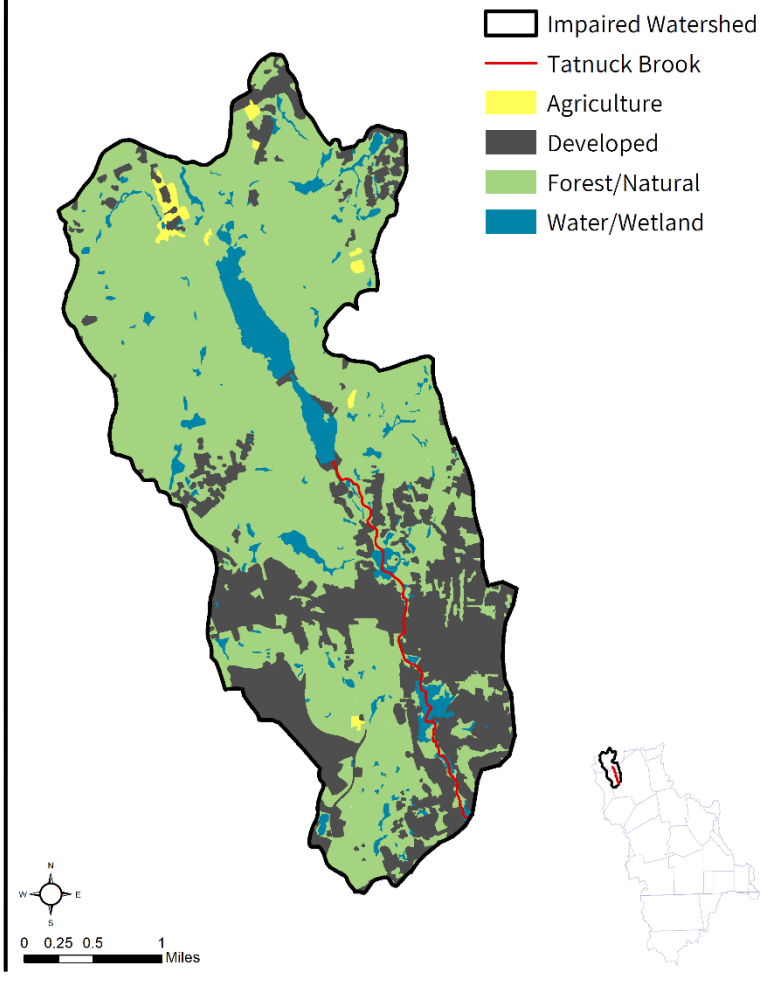
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 730 (11%)

DCIA Area (Acres, %): 502 (7%)





[28] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

watershed is largely developed (26%) with low to medium density residential areas in the downstream portion through which the segment flow. Development is concentrated along Pleasant Street/MA-122 and surrounding Worcester State University. There is minimal agricultural land (1%), with none adjacent to the stream.

In the watershed of Tatnuck Brook (MA51-15), under the Natural Heritage and Endangered Species Program, there are 266 acres (4%) identified as Priority Habitats of Rare Species. There are 3,402 acres (49%) under Public Water Supply protection, but no Areas of Critical Environmental Concern or Outstanding Resource Waters identified in the watershed. Over 504 acres (7%) of land protected in perpetuity[29] exist within the segment watershed, which is part of a total of 2,854 acres (41%) of Protected and Recreational Open Space[30]. See Figure 11-1.

[29] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[30] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

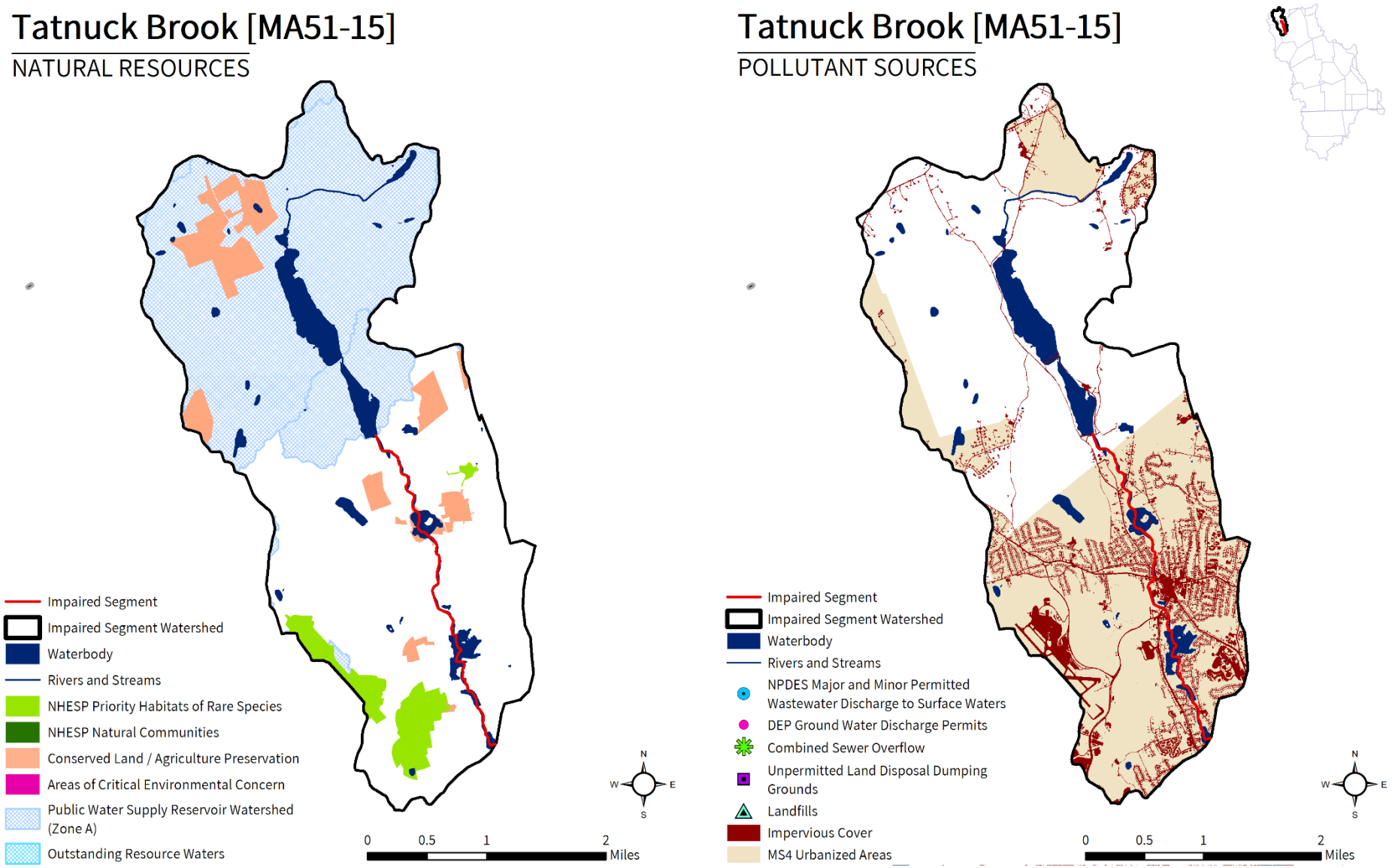


Figure 11-1. Natural resources and potential pollution sources draining to the Tatnuck Brook segment MA51-15. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

11.2. Waterbody Impairment Characterization

Tatnuck Brook (MA51-15) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for SWQS attainment using the indicator bacteria *E. coli* at the station listed below (refer to Tables 11-1, 11-2; Figure 11-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1426, resulting in three days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, one exceeded the STV criterion during wet weather only.

Figure 11-2. Location of monitoring station(s) along the impaired river segment.

Table 11-1. Summary of indicator bacteria sampling results by station for Tatnuck Brook (MA51-15). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1426	5/1/2008	8/28/2008	6	245	3	1

Table 11-2. Indicator bacteria data by station, indicator, and date for Tatnuck Brook (MA51-15). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1426	*E. coli*	5/1/08	DRY	76	76	
W1426	*E. coli*	5/29/08	DRY	110	91	
W1426	*E. coli*	6/26/08	DRY	130	103	
W1426	*E. coli*	7/10/08	WET	2300	224	
W1426	*E. coli*	8/7/08	WET	110	245	
W1426	*E. coli*	8/28/08	DRY	16	151	

11.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

The indicator bacteria data for Tatnuck Brook (MA51-15) were elevated during wet weather, which is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would clarify current conditions and help in identifying pathogen sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the Tatnuck Brook watershed are developed, with 52% of the land area in MS4, 7% as DCIA, and areas of dense commercial and residential development along the segment. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With some of the watershed serviced by sewer and most of the watershed designated as MS4 area, illicit storm drain connections and illicit discharges from failing infrastructure such as leaky sewer lines or SSOs are likely a source of pathogen pollutants.

On-Site Wastewater Disposal Systems: With only a portion of the land area served by sewers, septic systems are possible sources. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: About 1% of the watershed is in agriculture, although none appear adjacent to the impaired segment. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: There are several ballfields and conservation lands in the watershed, some directly adjacent to the segment, as well as many dense residential neighborhoods. Conservation lands, parks, and ballfields popular

for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: There is a large open lawn around the dam at Holden Reservoir Number 2 and the headwaters to the brook. Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

11.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Holden. See Section 10.4.

City of Worcester. See Section 3.4.

The ***Tatnuck Brook Watershed Association (TBWA***) is active the watershed, with recent events focusing on stormwater education, dam maintenance, and invasive plant removal. https://tatnuckbrook.org/ (TBWA, n.d.)

12. MA51-16 Dark Brook

12.1. Waterbody Overview

Dark Brook segment MA51-16 is 2.5 miles long and begins at the outlet of Eddy Pond, just east of the I-390 and US-20 junction in Auburn. The segment flows northeast, through Auburn Pond (formerly segment MA51004), and ends at its confluence with pathogen-impaired Kettle Brook (MA51-01) in Auburn.

Tributaries to this section of Dark Brook include Ramshorn Brook (entering Auburn Pond) and several unnamed streams draining small ponds and wetlands. The portion of segment MA51-16 downstream of Auburn Brook is labeled as Ramshorn Brook on the USGS National Map (USGS 2019). Other ponds within the watershed include Ramshorn Pond, Pondville Pond, Eddy Pond, and Auburn Pond.

Major landmarks in the watershed include the major highway junction linking I-90, I-290, I-395, US-20, and MA-12; Auburn town center, commercial district, and surrounding neighborhood; Auburn High School with ballfields adjacent to the brook; Goddard Park, the Auburn Mall and other commercial areas tightly restricting the brook along MA-12; and the West Millbury town center in the southeast.

Road crossings include Central Street, Water Street (twice), Church Street, I-90, Southbridge Street/MA-12, and Auburn Street.

Dark Brook (MA51-16) drains an area of 11.4 square miles, of which 1.6 mi^2 (14%) is impervious and 1.2 mi^2 (10%) is directly connected impervious area (DCIA). The watershed is served partially[31] by public sewer and 54% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file for either point source discharges of pollutants to surface waters or wastewater treatment facilities. There are no groundwater discharge permits, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds within the segment watershed. See Figure 12-1.

Reduction from Highest Calculated Geomean: 82%

Watershed Area (Acres): 7,275

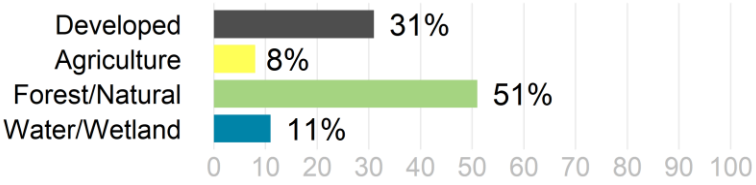
Segment Length (Miles): 2.5

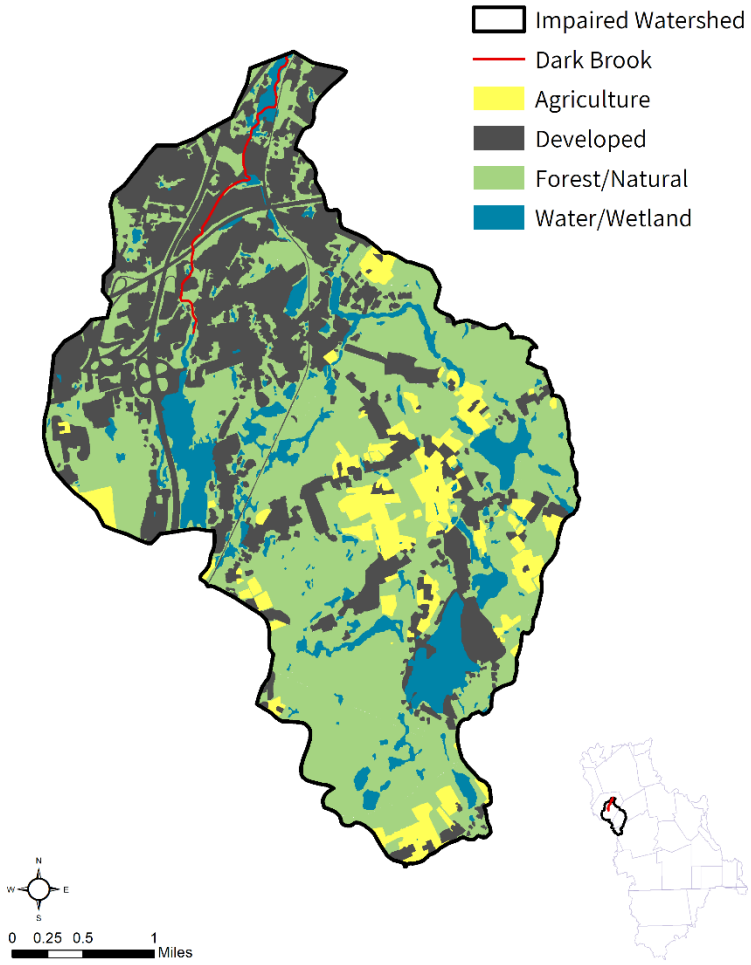
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 1,018 (14%)

DCIA Area (Acres, %): 733 (10%)





[31] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

While about half of the watershed is forested, the stream segment itself flows primarily through high density commercial development (31%) for much of its course. The stream is confined to a narrow riparian corridor about 15-20 meters wide between expansive parking lots and roads along Southbridge Street/MA-12 in an area between two interstate highways south of Auburn Pond. It also flows through a mown-grass driving range with no riparian vegetation near the Church Street and MA-12 intersection, and is confined to a narrow channel between ballfields, tennis courts, and commercial development near Auburn High School. The downstream section of the brook flows through a vegetated wetland. There is a relatively large amount of agricultural lands (8%), mostly in the more rural headwaters.

In the watershed of Dark Brook (MA51-16), under the Natural Heritage and Endangered Species Program, there are 248 acres (3%) of Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concerns, areas under Public Water Supply protection, or areas identified as Outstanding Resource Waters. Over 265 acres (4%) of land protected in perpetuity[32] exist within the segment watershed, which is part of a total of 1,210 acres (17%) of Protected and Recreational Open Space[33]. See Figure 12-1.

[32] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[33] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

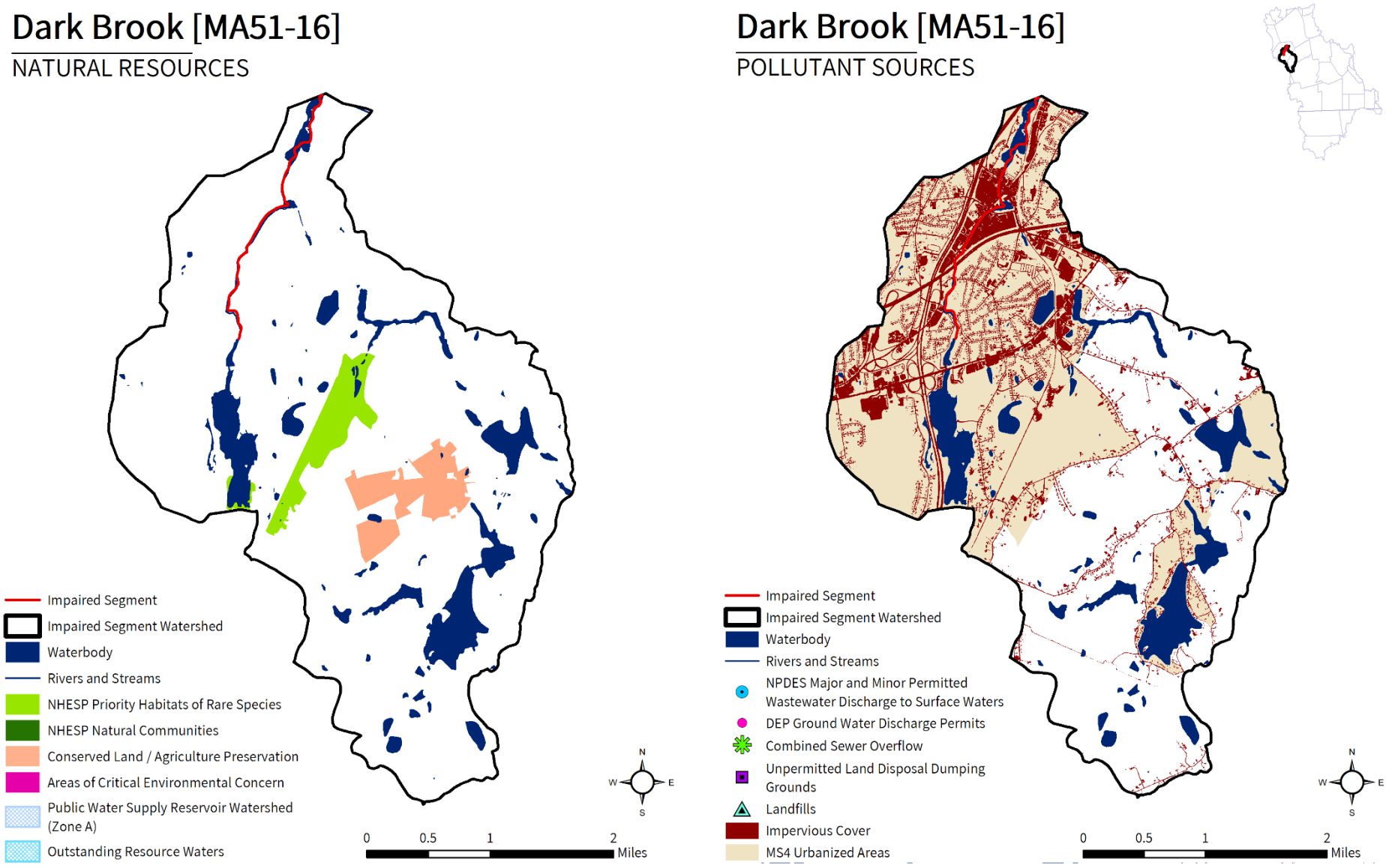


Figure 12-1. Natural resources and potential pollution sources draining to the Dark Brook segment MA51-16. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

12.2. Waterbody Impairment Characterization

Dark Brook (MA51-16) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 12-1, 12-2; Figure 12-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W0504, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.

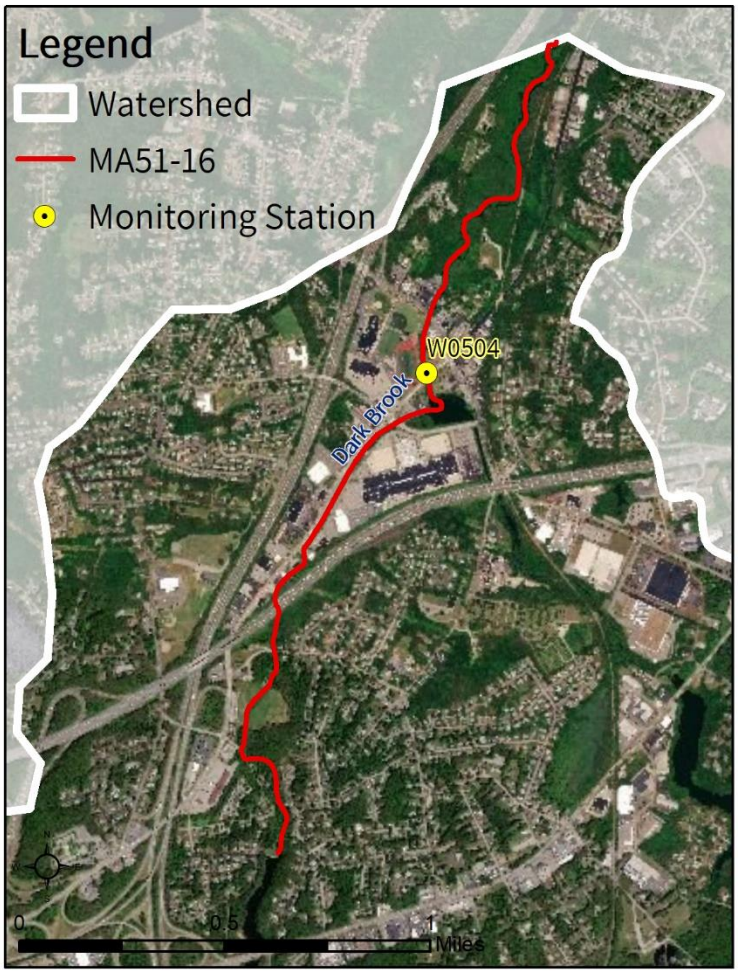


Figure 12-2. Location of monitoring station(s) along the impaired river segment.

Table 12-1. Summary of indicator bacteria sampling results by station for Dark Brook (MA51-16). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0504	5/1/2008	8/28/2008	6	705	6	2

Table 12-2. Indicator bacteria data by station, indicator, and date for Dark Brook (MA51-16). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W0504	*E. coli*	5/1/08	DRY	410	410	
W0504	*E. coli*	5/29/08	DRY	210	293	
W0504	*E. coli*	6/26/08	DRY	350	311	
W0504	*E. coli*	7/10/08	WET	990	416	
W0504	*E. coli*	8/7/08	WET	2100	625	
W0504	*E. coli*	8/28/08	DRY	340	705	

12.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria data for Dark Brook (MA51-16) were elevated during wet weather. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more locations, would likely help in identifying the sources of pollutants.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The segment flows through dense commercial and residential development and is tightly confined between parking lots and roads for about half of its length. About 54% of the watershed is designated as MS4 area and 10% is DCIA. For these reasons and given the pattern of elevated indicator bacteria levels during wet weather, stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With a portion of the land area in sewer service and most of the watershed (54%) designated as MS4 area, leaky sewer lines and illicit connections of wastewater to stormwater drains are potential sources of pathogens.

On-Site Wastewater Disposal Systems: With portions of the watershed served by septic systems, it is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: Based on land use data, agriculture accounts for about 8% of land area in the more rural and forested headwaters of the watershed. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: There are several parks, ballfields, recreational lands, and other open spaces along the impaired stream, as well as several large residential neighborhoods in the watershed. Conservation lands, parks, and

ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

12.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Auburn. See Section 3.4.

Town of Millbury. See Section 5.4.

Town of Sutton. See Section 5.4.

13. MA51-17 Poor Farm Brook

13.1. Waterbody Overview

Poor Farm Brook segment MA51-17 is 3.6 miles long and begins at its headwaters north of Hartwell Street in West Boylston, then flows south into Worcester, then Shrewsbury, ending at the inlet of Shirley Street Pond in Shrewsbury (through City Farm Pond, formerly segment MA51020).

Tributaries include the west branch of Poor Farm Brook (not listed as pathogen-impaired) and several unnamed streams draining small ponds and wetlands. Extremely low flow conditions have been noted in the downstream portion of the segment in the past (MassDEP 2010).

Major landmarks in the watershed include the Worcester Country Club and golf course (through which 0.2 miles of the stream flows and where the west branch confluence occurs), the Burncoat neighborhood of Worcester, Worcester County Jail, Clark Street Elementary School, and the Great Brook Valley Playground.

Road crossings include Angell Brook Road, Tivnan Drive, and Shrewsbury Street in North Boylston; Mountain Street East, Cobblestone Lane, Clark Street, and Northeast Cutoff in Worcester; and Clinton Street in Shrewsbury.

Poor Farm Brook (MA51-17) drains an area of 3.9 square miles, of which 1 mi^2 (25%) is impervious and 0.7 mi^2 (18%) is directly connected impervious area (DCIA). The watershed is served mostly[34] by public sewer and 93% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file for either point source discharges of pollutants to surface waters or wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds within the segment watershed. See Figure 13-1.

Just over half the watershed is developed areas (51%). The upstream reaches of the brook flow through light industrial development and

Reduction from Highest Calculated Geomean: 71%

Watershed Area (Acres): 2,478

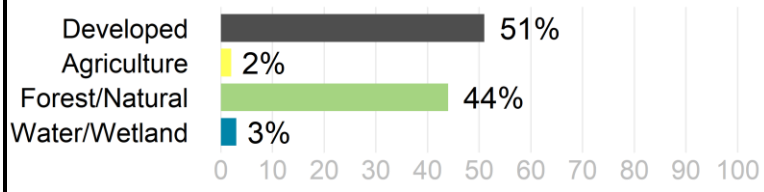
Segment Length (Miles): 3.6

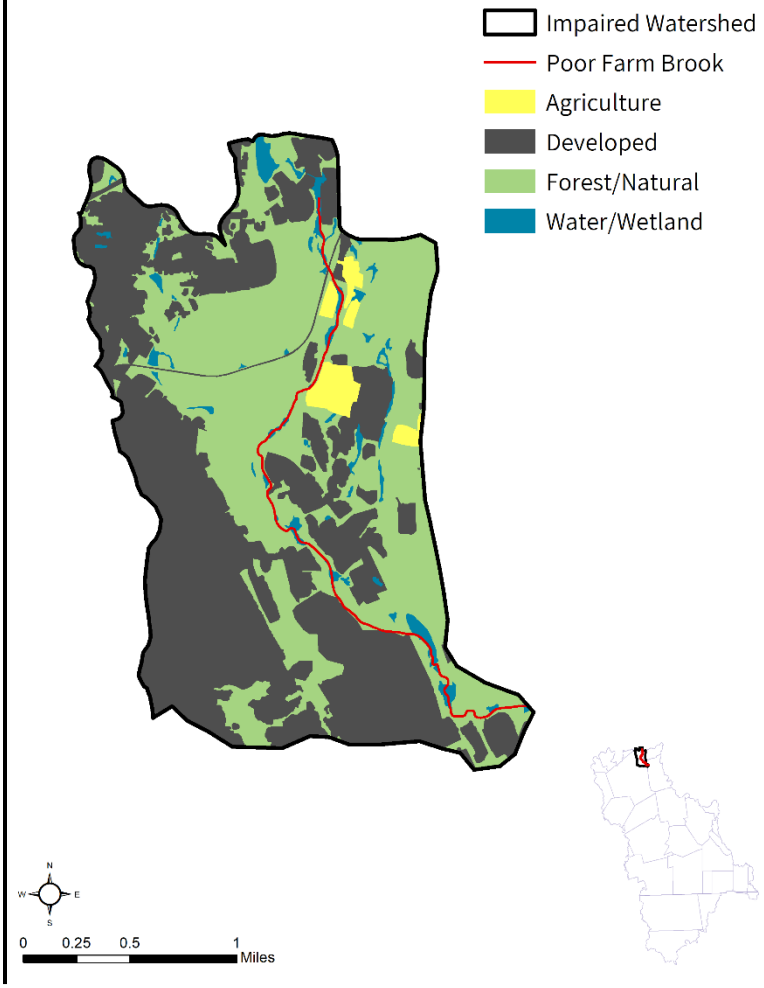
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 609 (25%)

DCIA Area (Acres, %): 437 (18%)





[34] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

agricultural areas, while the middle and downstream reaches flow through predominantly low to medium density residential, with some emergent wetlands and recreational lands. Many of the residential developments conform to a conservation model where homes and roads in each development are clustered and surrounded by woods. Vegetated riparian buffer is ample in some locations and nearly absent in others. The agricultural land (2%) appears on recent satellite photos to be row crops, with the largest plot is near the Worcester County Jail.

In the watershed of Poor Farm Brook (MA51-17), under the Natural Heritage and Endangered Species Program, there are 88 acres (4%) of Priority Habitats of Rare Species. There are 55 acres (2%) acres under Public Water Supply protection, but no Areas of Critical Environmental Concern or Outstanding Resource Waters identified in the watershed. Over 20 acres (1%) of land protected in perpetuity[35] exist within the segment watershed, which is part of a total of 79 acres (3%) of Protected and Recreational Open Space[36]. See Figure 13-1.

[35] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[36] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

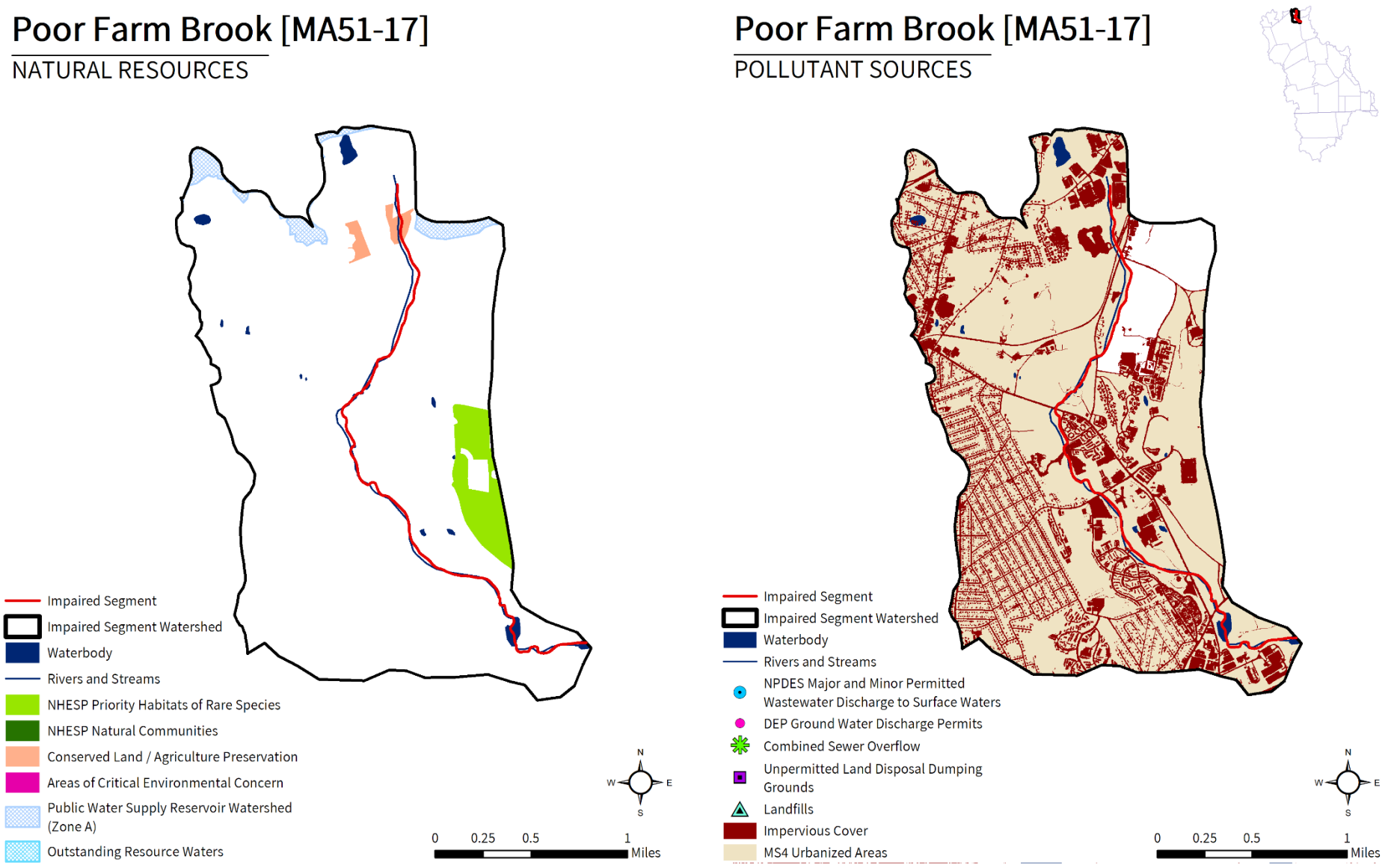


Figure 13-1. Natural resources and potential pollution sources draining to the Poor Farm Brook segment MA51-17. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

13.2. Waterbody Impairment Characterization

Poor Farm Brook (MA51-17) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 13-1, 13-2; Figure 13-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1753, resulting in three days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, one exceeded the STV criterion during wet weather.

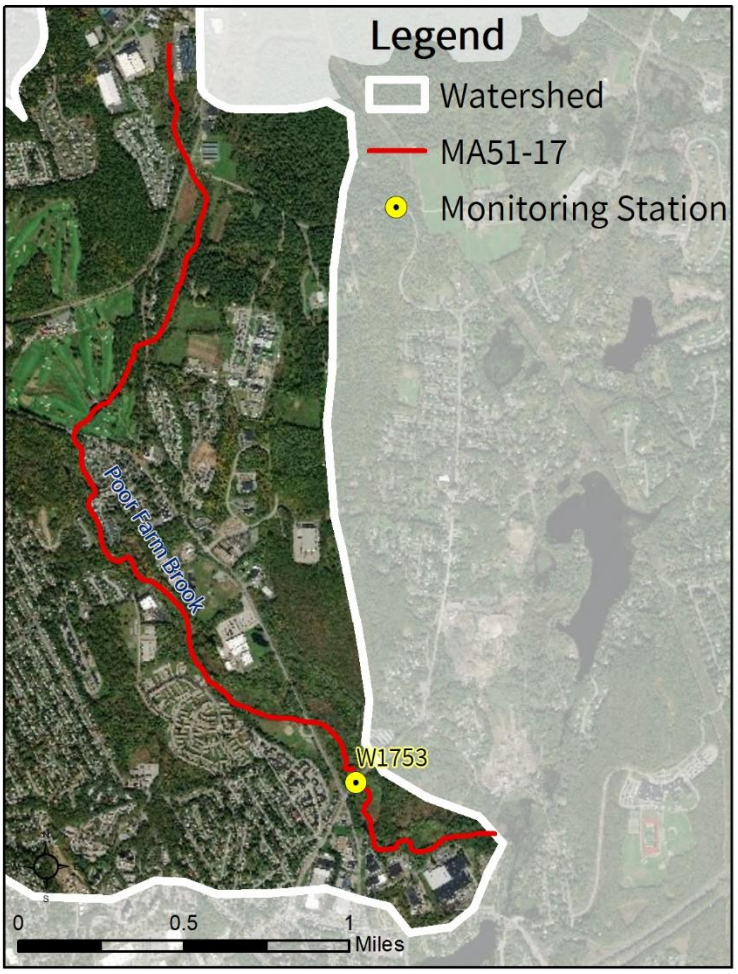


Figure 13-2. Location of monitoring station(s) along the impaired river segment.

Table 13-1. Summary of indicator bacteria sampling results by station for Poor Farm Brook (MA51-17). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1753	5/1/2008	8/28/2008	6	429	3	1

Table 13-2. Indicator bacteria data by station, indicator, and date for Poor Farm Brook (MA51-17). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1753	*E. coli*	5/1/08	DRY	10	10	
W1753	*E. coli*	5/29/08	DRY	200	45	
W1753	*E. coli*	6/26/08	DRY	300	84	
W1753	*E. coli*	7/10/08	WET	2100	188	
W1753	*E. coli*	8/7/08	WET	270	429	
W1753	*E. coli*	8/28/08	DRY	140	393	

13.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria data for Poor Farm Brook (MA51-17) were elevated during wet weather. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions would likely help in identifying sources of pollutants.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the watershed are highly developed, with 93% of the land area in MS4 and 18% as DCIA. The brook flows next to several large residential neighborhoods and commercial and light industrial zones. Stormwater runoff from urban areas is likely a significant source of pathogens.

Illicit Sewage Discharges: With some portion of the land area in sewer service and nearly the entire (93%) watershed designated as MS4 area, leaky sewer lines and illicit connections to storm drains are also possible sources. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity.

On-Site Wastewater Disposal Systems: Much of the residential development in the watershed uses septic systems for wastewater treatment; it is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: About 2% of the watershed is agricultural land, with some areas near the brook. Recent aerial photos show actively used fields near the intersection of Shrewsbury Street and Hospital Drive. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies. Additionally, any areas adjacent to upstream tributaries or storm drains could also provide a direct conduit to the brook.

Pet Waste: About 3% of the watershed is designated Protected and Recreational Open Space. There are several parks, playgrounds, and ballfields next to the brook. Areas popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody, such as the golf course off Briar Lane, may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

13.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

City of Worcester. See Section 3.4.

Town of Shrewsbury

All of Shrewsbury is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. Shrewsbury (Permit ID #MAR041158) has an EPA-approved Notice of Intent (NOI). The town has a Stormwater Management Plan available on file at the municipal office building. The town has mapped all of its MS4 stormwater system and submitted a map attached to the NOI. It adopted illicit discharge detection and elimination (IDDE), erosion and sediment control (ESC), and post-construction stormwater regulations in 2007. According to the NOI, there are no impaired waterway segments in the Town of Shrewsbury.

Shrewsbury has the following ordinances and bylaws:

- Stormwater Management Rules and Regulations: https://shrewsburyma.gov/DocumentCenter/View/4595/Stormwater-Management-Rules-and-Regulations?bidId= (Town of Shrewsbury, 2019a)
- Stormwater Utility: https://shrewsburyma.gov/DocumentCenter/View/4667/Stormwater-Utility-Rates (Town of Shrewsbury, 2019b)
- Wetland Protection Ordinance: Refers to MA DEP Protection Guidelines
- Pet Waste Ordinance, Section 5A of General Bylaws: https://shrewsburyma.gov/DocumentCenter/View/5624/General-Bylaws-May-22-2019 (Town of Shrewsbury, 2019c)
- Title V Supplementary Regulations: No

Shrewsbury's Master Plan has a section on water resources assets and protection in the Natural Resources chapter. The plan mentions "surface water quality is threatened by adjacent development, stormwater runoff containing pollutants, failing onsite wastewater treatment systems, and other land use activities that obstruct and degrade natural systems." The plan also mentions the town's involvement in NPDES Phase II (pages 61-62). In addition, the Sewer sub-section of the Public Facilities section of the plan notes "the town has municipal sewers serving approximately 85 percent of the town with a majority of the sewage discharging to the wastewater treatment plant in Westborough" (page 39).

Town Website: https://shrewsburyma.gov/ (Town of Shrewsbury, 2020a)

Stormwater Management Page: https://shrewsburyma.gov/803/Stormwater-Management (Town of Shrewsbury, 2020b)

Master Plan: https://horsleywitten.com/shrewsbury/pdf/Shrewsbury%20Master%20Plan_Mar%203%202016.pdf (Horsley & Witten Group, Inc. 2016)

Open Space and Recreation Plan: 2012, currently being updated: https://shrewsburyma.gov/DocumentCenter/View/323/2012-Open-Space-and-Recreation-Plan-PDF (Town of Shrewsbury, 2012)

Town of West Boylston

Less than half of West Boylston is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit. West Boylston (Permit ID #MAR041171) has an EPA-approved Notice of Intent (NOI). West Boylston has a Stormwater Management Plan on file: https://www.westboylston-ma.gov/public-works/pages/stormwater-management and has mapped all of its MS4 stormwater system (Town of West Boylston, n.d.). It adopted illicit discharge detection and elimination (IDDE), erosion and sediment control (ESC), and post-construction stormwater regulations from 2003-2007. There are 10 stormwater outfalls reported to pathogen-impaired Gates Brook (MA81-24) and several to pathogen-impaired Poor Farm Brook (MA51-17).

West Boylston has the following ordinances and bylaws:

- Pet waste: Article XIX Dog Control, Section 6 Removal of Dog Litter https://www.westboylston-ma.gov/sites/g/files/vyhlif1421/f/uploads/2020.10.17_gen_bylaws_master1.pdf (Town of West Boylston 2020)
- Sanitary Sewer Connection Loan and Zoning bylaws: Article XXVII pg. 64 and Special Permit and Procedure, pg. 34 https://www.westboylston-ma.gov/sites/g/files/vyhlif1421/f/uploads/zoning_bylaws_2018.10.15-_6_14.pdf (Town of West Boylston, 2018a)
- Stormwater bylaw: Article XXXIII, pg. 70: https://www.westboylston-ma.gov/sites/westboylstonma/files/uploads/general_bylaws_7.1.2019.pdf (Town of West Boylston, 2020)

West Boylston Master Plan: https://www.westboylston-ma.gov/town-wide-planning/pages/master-plan (Town of West Boylston, 2005)

West Boylston's Open Space and Recreation Plan: https://www.westboylston-ma.gov/sites/westboylstonma/files/uploads/2018_west_boylston_open_space_plan.pdf (Town of West Boylston, 2018b)

14. MA51-18 Peters River

14.1. Waterbody Overview

The Peters River segment MA51-18 is four miles long. Located entirely in the Town of Bellingham, it begins at the outlet of Silver Lake, flowing generally south, ending at the Rhode Island boundary, just east of Route 126. MA51-18 is the most eastern segment watershed within the Blackstone River watershed.

Tributaries to this section of Peters River include Hoag Brook, Jenks Reservoir, Bungay Brook, and pathogen-impaired Arnolds Brook (MA51-32). Lakes and ponds within the impaired segment watershed include Lakeview Pond, Curtis Pond, Long Pond, and Lily Hole as tributaries to Silver Lake (also referred to as Hoag Lake). Carls Pond (RI) and Hales Pond are tributaries to Bungay Brook.

Major landmarks in the watershed include the Southern New England Trunkline Trail which crosses the segment, several schools and ballfields on Harpin Street, and the village of Millerville (Bellingham).

Road crossings include Cross Street, Railroad Street, Pulaski Boulevard, Wrentham Road, and Paine Street.

Peters River (MA51-18) drains an area of 12 square miles, of which 1.5 mi^2 (12%) is impervious and 1 mi^2 (8%) is directly connected impervious area (DCIA). The watershed also extends to the south into Rhode Island. Of the total watershed area (12 mi^2), 10 mi^2 (84%) are within Massachusetts. In terms of land area, well under half the watershed[37] is likely served by public sewer and 80% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There is one NPDES permit on file governing point source discharges of pollutants to surface waters, and no additional NPDES permits for wastewater treatment facilities. There is one groundwater discharge permit for on-site wastewater discharge (Table 14-1). There are two landfills, no combined sewer overflows, and no unpermitted land disposal dumping grounds. See Figure 14-1.

Reduction from Highest Calculated Geomean: 86%

Watershed Area (Acres): 7,815

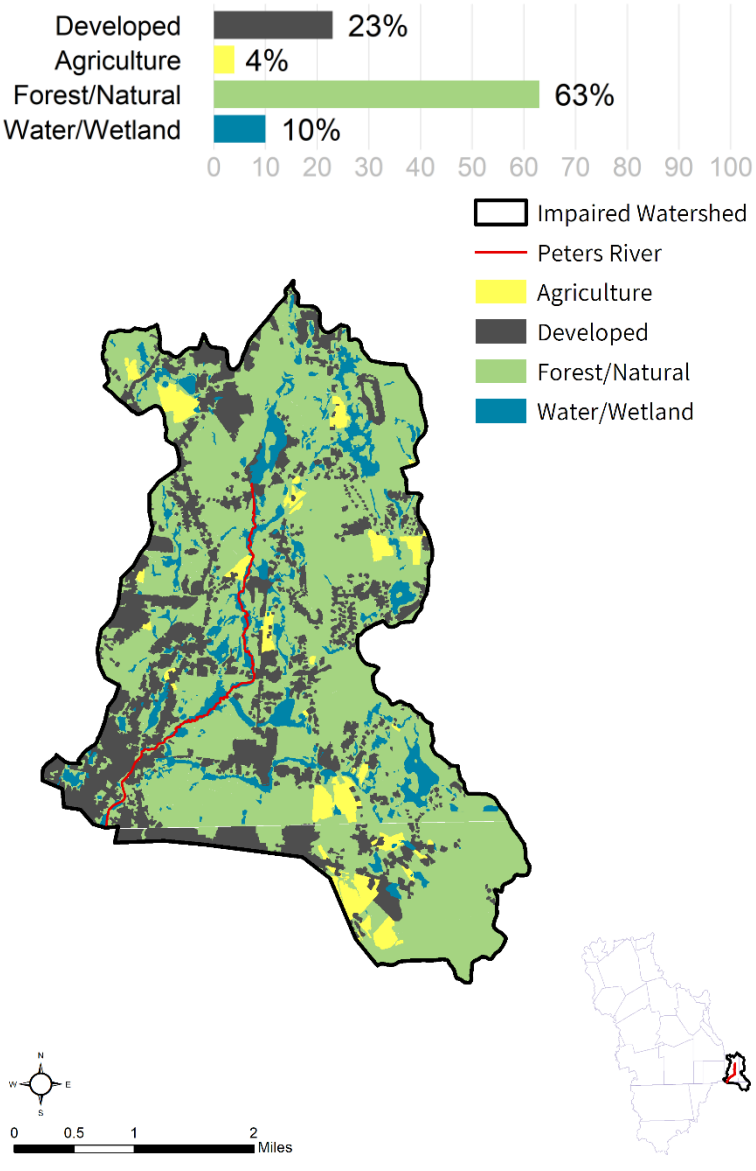
Segment Length (Miles): 4.0

Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 974 (12%)

DCIA Area (Acres, %): 659 (8%)



[37] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

Table 14-1. Groundwater discharge permits in the segment watershed. Only permits unique to this segment watershed are shown. PERR = permit number plus renewal number. TYPE = type of groundwater discharge. FLOW = permitted effluent in gallons per day (gpd).

PERR	NAME	TOWN	TYPE	FLOW (GPD)
828-2	THE PRESERVE @ OAK HILL	WRENTHAM	Sanitary Discharge	27,280

Forest is the predominant land cover within the segment watershed (63%), with low density residential and commercial development scattered throughout (23%). The agricultural land (4%), especially that along the river segment, appears on recent aerial photos to be open fields with minimal row crops. The riparian corridor is characterized by wooded and emergent wetlands and generally wide vegetative buffers. One of the golf courses also maintains extensive wooded land cover.

In the watershed of Peters River (MA51-18), under the Natural Heritage and Endangered Species Program, there are 225 acres (3%) of Priority Habitats of Rare Species. There are 32 acres (<1%) under Public Water Supply protection, but no Areas of Critical Environmental Concern or Outstanding Resource Waters identified in the watershed. Over 176 acres (2%) of land protected in perpetuity[38] exist within the segment watershed, which is part of a total of 1,210 acres (15%) of Protected and Recreational Open Space[39]. See Figure 14-1.

[38] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[39] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

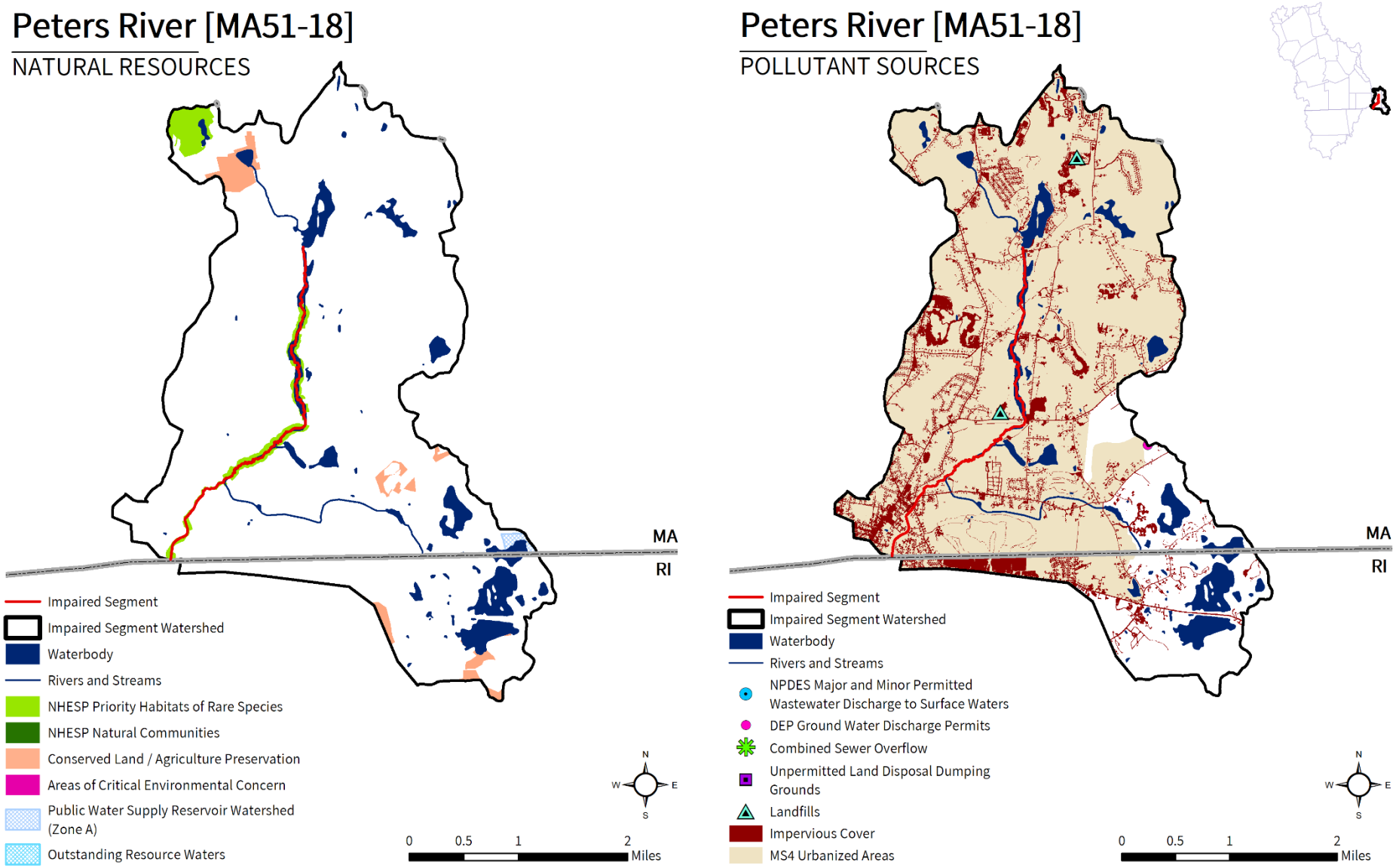


Figure 14-1. Natural resources and potential pollution sources draining to the Peters River segment MA51-18. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

14.2. Waterbody Impairment Characterization

Peters River (MA51-18) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 14-2, 14-3; Figure 14-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

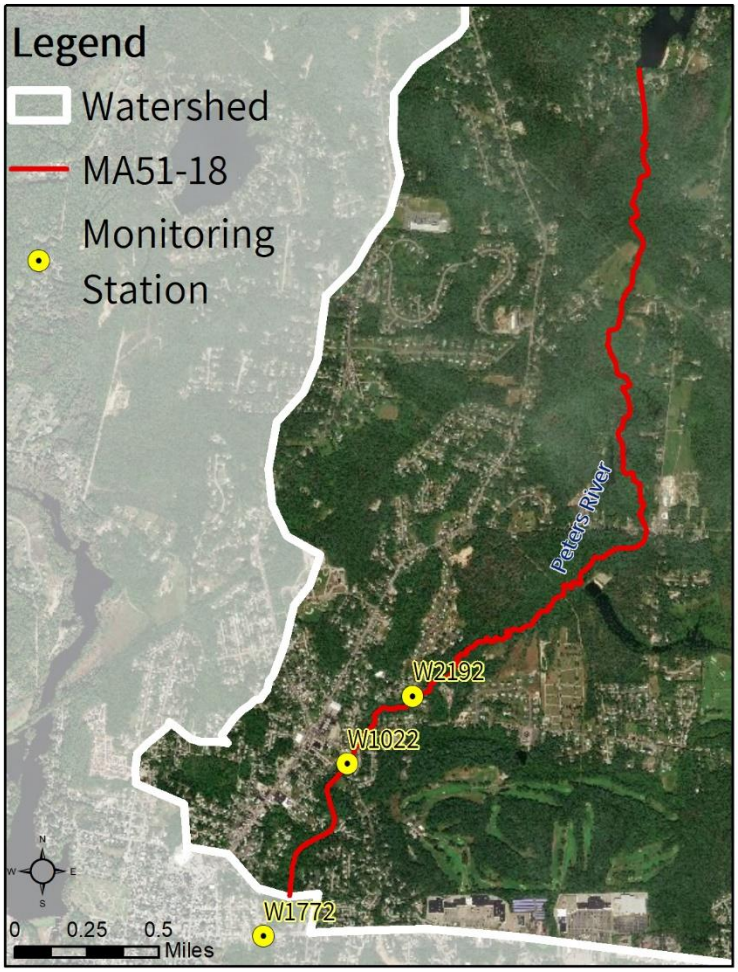


Figure 14-2. Location of monitoring station(s) along the impaired river segment.

- In 2008, six samples were collected at W1022, resulting in four days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, three exceeded the STV criterion during both wet and dry weather.
- In 2008, six samples were collected at W1772, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, six exceeded the STV criterion during both wet and dry weather.
- In 2011, six samples were collected at W2192, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during dry weather only.

Table 14-2. Summary of indicator bacteria sampling results by station for Peters River (MA51-18). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1022	5/1/2008	8/28/2008	6	560	4	3
W1772	4/29/2008	8/26/2008	6	869	6	6
W2192	5/17/2011	9/26/2011	6	360	6	2

Table 14-3. Indicator bacteria data by station, indicator, and date for Peters River (MA51-18). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1022	*E. coli*	5/1/08	WET	76	76	
W1022	*E. coli*	5/29/08	DRY	170	114	
W1022	*E. coli*	6/26/08	DRY	510	187	
W1022	*E. coli*	7/10/08	DRY	670	258	
W1022	*E. coli*	8/7/08	WET	1200	514	
W1022	*E. coli*	8/28/08	DRY	240	560	
W1772	*E. coli*	4/29/08	WET	830	830	
W1772	*E. coli*	5/27/08	DRY	910	869	
W1772	*E. coli*	6/24/08	DRY	690	805	
W1772	*E. coli*	7/8/08	DRY	520	722	
W1772	*E. coli*	8/5/08	DRY	850	726	
W1772	*E. coli*	8/26/08	DRY	450	609	
W2192	*E. coli*	5/17/11	WET	159	159	
W2192	*E. coli*	6/9/11	DRY	816	360	
W2192	*E. coli*	6/21/11	DRY	91	228	
W2192	*E. coli*	7/26/11	DRY	1050	334	
W2192	*E. coli*	8/23/11	DRY	194	351	
W2192	*E. coli*	9/26/11	WET	84	258	

14.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for Peters River segment MA51-18 were elevated during both wet and dry weather conditions. Elevated results during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens.

A bacteria source tracking study was conducted in Peters River in 2004 using *E. coli* and optical brightener tests. While the optical brightener tests were inconclusive, many pigeons were observed congregating under a bridge. Bacteria levels upstream of the bridge were consistently lower than those downstream, suggesting that the birds may have been a significant source of indicator bacteria to this segment (MassDEP, 2010). The relatively high bacteria levels during dry weather are consistent with this explanation, since the source would be protected from rain, and thus diluted rather than transported by precipitation and runoff.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The river segment generally flows through low density development (23%), with 80% of the watershed designated as MS4 and 8% as DCIA and the most concentrated development patterns in the watershed occur along the downstream portion of the watershed in suburbs to Woonsocket, RI. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With a portion of the land area in sewer service and 80% of the watershed designated as MS4 area, plus the relatively high dry weather indicator bacteria levels, leaky sewer lines and other illicit connections are possible pathogen sources. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

On-Site Wastewater Disposal Systems: Most of the residential development in the watershed uses septic systems for wastewater treatment. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: About 4% of the watershed is agricultural land, with some row crops upstream of the segment near Douglas Drive visible in recent aerial photos. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: Protected and Recreational Open Space makes up 15% of the watershed area. Peters River flows through residential neighborhoods in the downstream portion of the segment, and there are a few scattered parks near the river. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: A study in 2004 found that large numbers of pigeons congregating under a bridge were associated with elevated downstream indicator bacteria levels (MassDEP 2010), therefore installations which discourage pigeon lofts under bridges may be warranted. Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

14.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Bellingham

All of Bellingham is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041091) and has an EPA-approved Notice of Intent (NOI). Bellingham has a Stormwater Management Plan available online at https://www.bellinghamma.org/department-public-works (Town of Bellingham, 2020a) and has mapped all of its MS4 stormwater system; the map is available at https://www.bellinghamma.org/sites/g/files/vyhlif2796/f/uploads/noi_drainage_infrastructure_map.pdf (Tighe & Bond 2018) . The town also adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater regulations in 2006-07. According to the NOI, there are 17 stormwater outfalls into the Peters River (MA51-18) and six stormwater outfalls into Arnolds Brook (MA51-32), both impaired for *E. coli*.

Bellingham has the following ordinances and bylaws:

- Stormwater Management: https://www.ecode360.com/15958720 (Town of Bellingham, n.d., a)
- Wetlands Protection Bylaw: https://www.ecode360.com/15958364#15958364 (Town of Bellingham, n.d., b.)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

Bellingham's Master Plan also includes sections on Natural Resources and Environmental Protection, starting on page 32 (. Under the Open Space section of the plan, acquiring parcels that protect the pathogen-impaired Peters River aquifer is a prioritized implementation action. Under the Utilities section of the plan, the NPDES Phase II Storm Water Program under the town's Multi-Section Storm Sewer System Permit is mentioned through the goal of enhancing recharge of clean stormwater runoff. It also mentions that the Bellingham sewerage system serves less than 27% of its population, with the other 73% relying on on-site disposal systems.

Town of Bellingham Draft 2020 Master Plan: https://www.bellinghamma.org/home/news/draft-2020-master-plan-update-available-public-comment (Town of Bellingham, 2020b)

Open Space and Recreation Plan: https://www.bellinghamma.org/sites/g/files/vyhlif2796/f/uploads/open_space_plan.pdf (PGC Associates, Inc., 2017)

15. MA51-27 Coal Mine Brook

15.1. Waterbody Overview

The Coal Mine Brook segment MA51-27 is 0.4 miles long, located entirely in Worcester. The segment begins at the headwaters of its perennial section west of Plantation Street and ends at Lake Quinsigamond. It is bound at the upstream end by an ephemeral section of Coal Mine Brook, plus a southern branch of Coal Mine Brook (not listed as impaired) draining a small wetland.

There are no tributaries to the segment or named lakes, ponds, or reservoirs within the watershed. Major landmarks in the watershed include the Trinity Woods Conservation Restriction, Burncoat Park Pond, part of the Green Hill Golf Course, Coal Mine Brook Park with trails along the segment, Lincoln Plaza Shopping Center, and exits 20 and 21 of I-290. Coal Mine Brook is crossed by Plantation Street and North Lake Avenue.

Coal Mine Brook (MA51-27) drains an area of 1.3 square miles, of which 0.4 mi^2 (33%) is impervious and 0.3 mi^2 (26%) is directly connected impervious area (DCIA). The watershed is served completely[40] by public sewer and the entire watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file for point source discharges or wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 15-1.

The watershed is mostly developed (59%) and partly forested (36%). The northern half of the watershed contains a mix of high-density commercial development with expansive parking, an interstate highway, and mixed medium density development along Lincoln Street/MA-70. The southern half of the watershed which contains the brook is predominantly wooded interspersed with medium density mixed use development. The 2% of land

Reduction from Highest Calculated Geomean: 78%

Watershed Area (Acres): 801

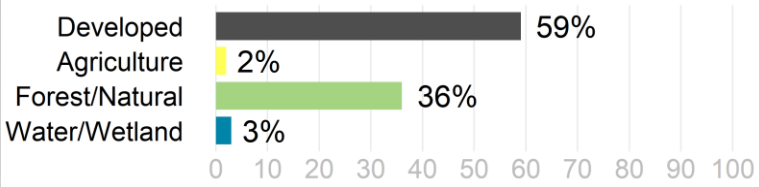
Segment Length (Miles): 0.4

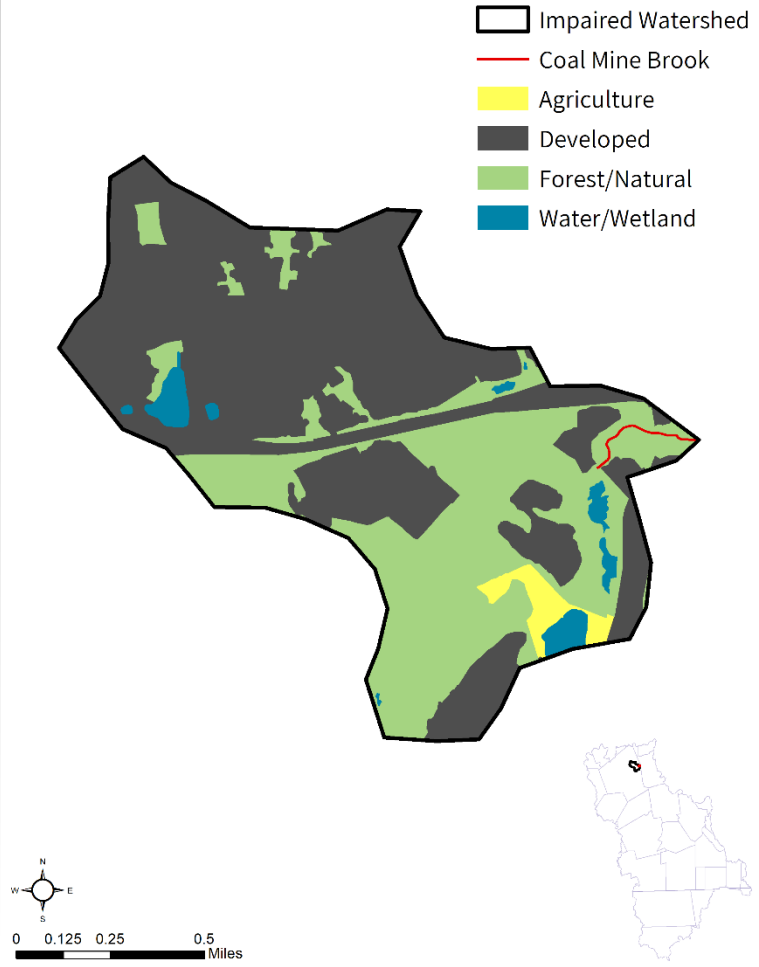
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 262 (33%)

DCIA Area (Acres, %): 206 (26%)





[40] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

cover shown as agriculture is a roughly mown conservation restriction adjacent to a multistory parking garage.

In the Coal Mine Brook (MA51-27) watershed, under the Natural Heritage and Endangered Species Program, there are no areas identified as Priority Natural Vegetation Communities or Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. Over 31 acres (4%) of land protected in perpetuity[41] exist within the segment watershed, which is part of a total of 205 acres (26%) of Protected and Recreational Open Space[42]. See Figure 15-1.

[41] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[42] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

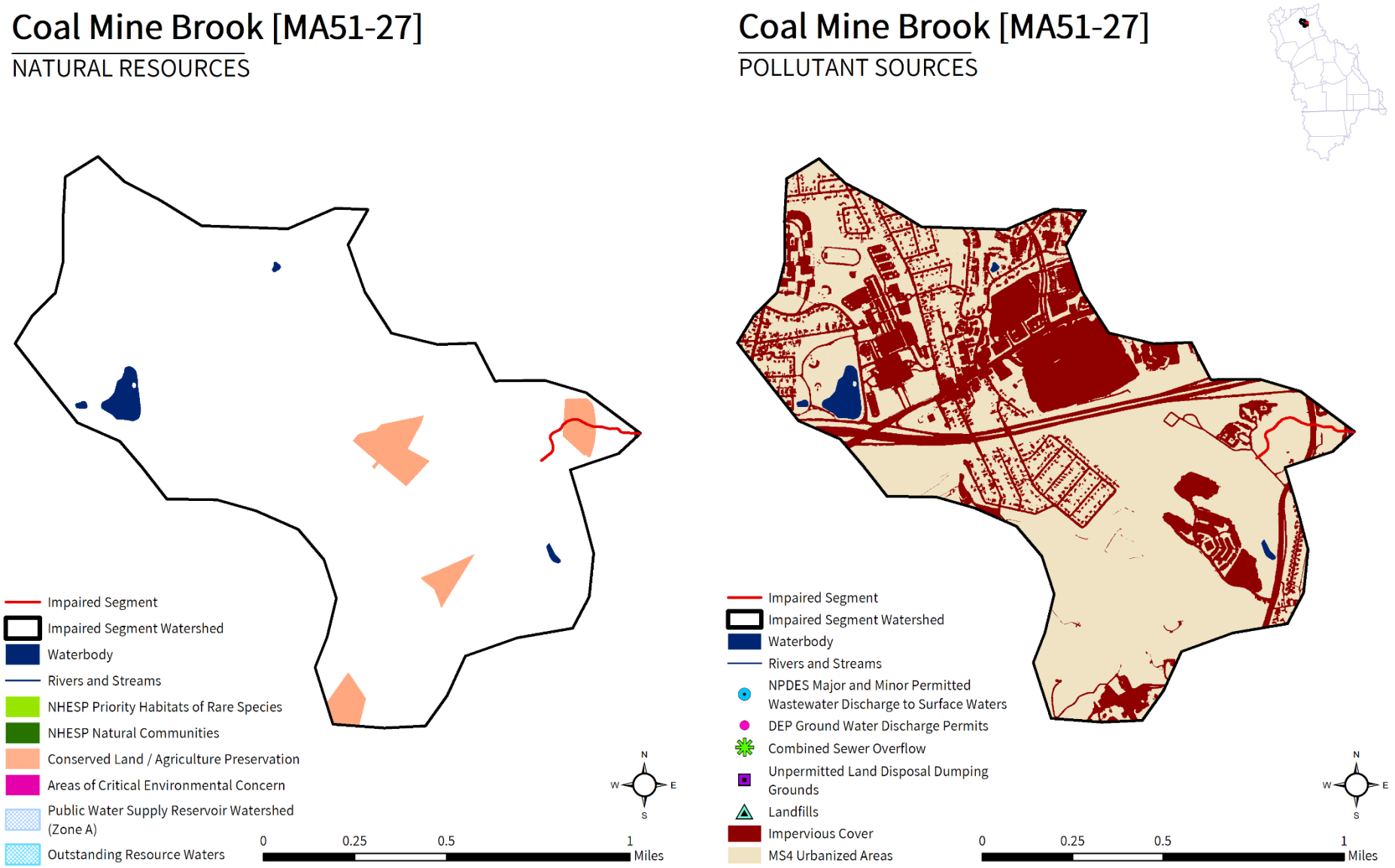


Figure 15-1. Natural resources and potential pollution sources draining to the Coal Mine Brook segment MA51-27. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

15.2. Waterbody Impairment Characterization

Coal Mine Brook (MA51-27) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 15-1, 15-2; Figure 15-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1282, resulting in five days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.

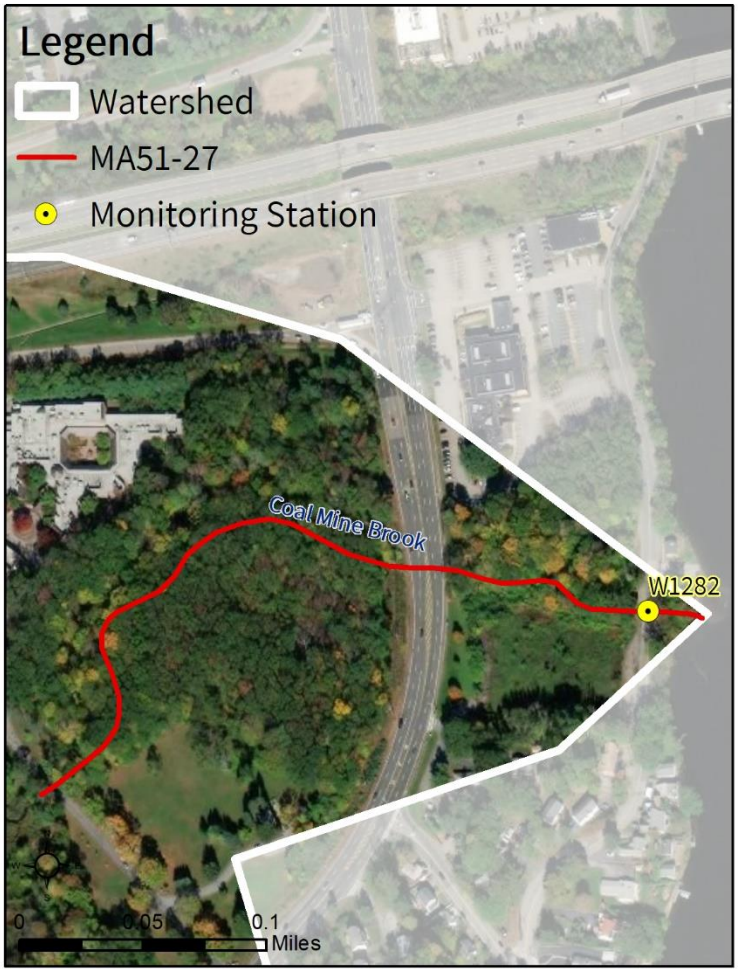


Figure 15-2. Location of monitoring station(s) along the impaired river segment.

Table 15-1. Summary of indicator bacteria sampling results by station for Coal Mine Brook (MA51-27). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1282	5/1/2008	8/28/2008	6	565	5	2

Table 15-2. Indicator bacteria data by station, indicator, and date for Coal Mine Brook (MA51-27). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1282	*E. coli*	5/1/08	DRY	100	100	
W1282	*E. coli*	5/29/08	DRY	280	167	
W1282	*E. coli*	6/26/08	DRY	320	208	
W1282	*E. coli*	7/10/08	WET	2000	366	
W1282	*E. coli*	8/7/08	WET	570	565	
W1282	*E. coli*	8/28/08	DRY	160	492	

15.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for Coal Mine Brook (MA51-27) were elevated during wet weather. Elevated results during wet weather are consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the watershed are highly developed, including expansive commercial developments in the northern half. The entire watershed is designated as MS4 area, with 26% as DCIA. These factors, combined with the elevated wet weather indicator bacteria levels, indicate that stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With the entire watershed served by sewer and designated as MS4 area, leaky sewer lines and illicit connections are also possible sources. Sewer related risks include leaking infrastructure (pipes, pump stations, etc.) and sanitary sewer overflows, which may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity. Illicit connections of wastewater to stormwater drains are also a risk.

Pet Waste: Protected and Recreational Open Space make up 26% of the watershed area. There are parks and conservation tracts along the river and dense residential neighborhoods in the watershed. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

On-Site Wastewater Disposal Systems: It is likely that septic systems are not a major source of pathogens to the watershed, but it may still be worthwhile to research whether isolated properties are still served by septic systems.

Agriculture: The agricultural land in the watershed does not appear to be actively farmed. Nonetheless, any agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

15.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

City of Worcester. See Section 3.4.

16. MA51-31 Singletary Brook

16.1. Waterbody Overview

The Singletary Brook segment MA51-31 is 1.5 miles long, located entirely in Millbury. It begins at the outlet of Singletary Pond, then flows northeast. The segment excludes the approximately 0.4 miles through Brierly Pond (MA51010) but includes Mayo Pond (currently emergent wetlands). The segment ends its confluence with the pathogen-impaired Blackstone River (MA51-03). The segment watershed beyond Millbury into Sutton.

Tributaries include four additional unnamed streams draining small ponds or wetlands. There are no named lakes, ponds, or reservoirs within the watershed.

Landmarks near the brook include Washington Street Playground and Exit 8 of MA-146. In the upstream section of the watershed are Merrill Pond Wildlife Management Area and Singletary Pond. Road crossings include Harris Avenue, West Main Street, Beach Street, Burbank Street, Rhodes Street, Sycamore Street, and MA-146 (divided highway) all in Millbury.

Singletary Brook (MA51-31) drains an area of 5.8 square miles, of which 0.5 mi^2 (8%) is impervious and 0.3 mi^2 (5%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[43] and 43% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file for either point source discharges of pollutants to surface waters or wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 16-1.

Half of the watershed is forested, though the segment flows primarily through medium density development (23%). The upstream reaches of the watershed have scattered agricultural lands (9%), such as tree farms and horse-riding facilities.

Reduction from Highest Calculated Geomean: 67%

Watershed Area (Acres): 3,701

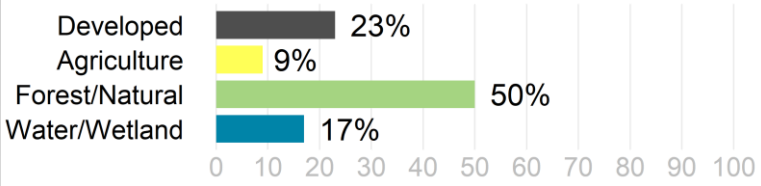
Segment Length (Miles): 1.5

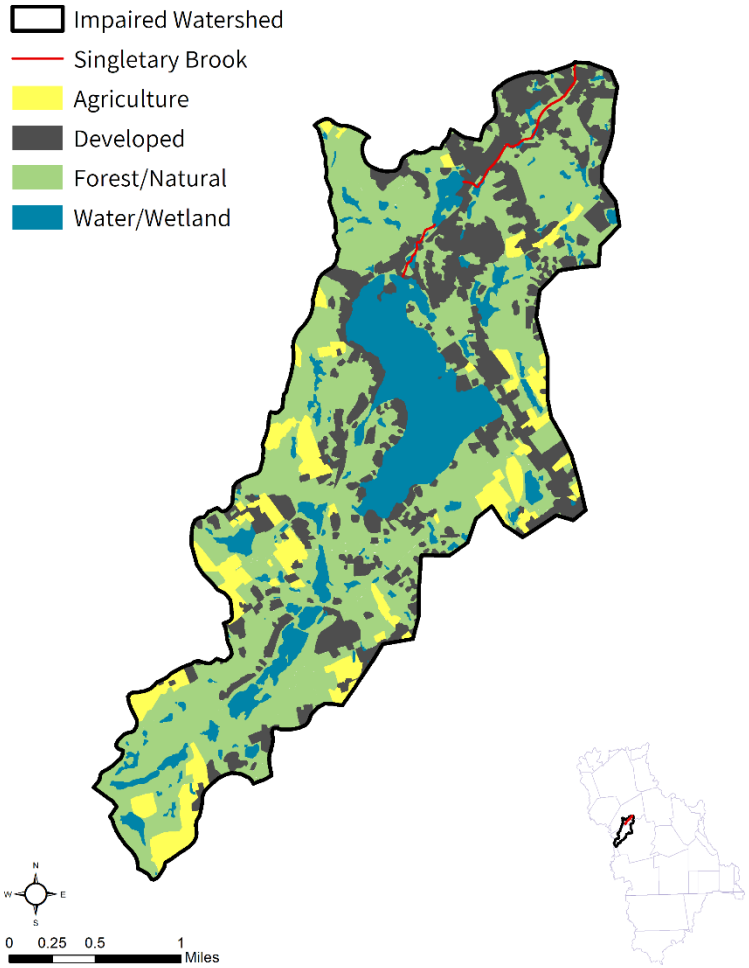
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 306 (8%)

DCIA Area (Acres, %): 170 (5%)





[43] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

In the watershed of Singletary Brook (MA51-31), under the Natural Heritage and Endangered Species Program, there are 39 acres (1%) of Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. Over 84 acres (2%) of land protected in perpetuity[44] exist within the segment watershed, which is part of a total of 437 acres (12%) of Protected and Recreational Open Space[45]. See Figure 16-1.

[44] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[45] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

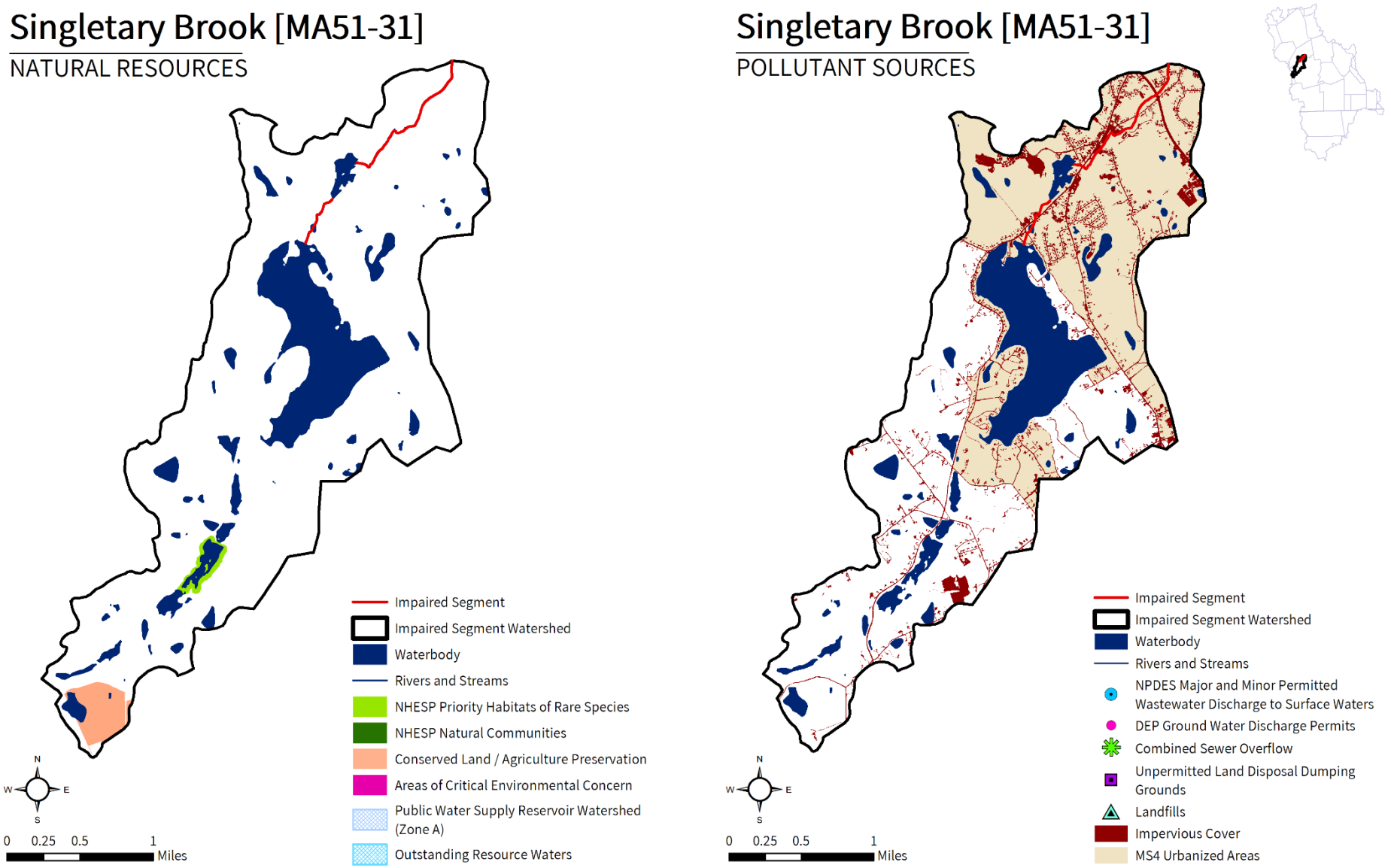


Figure 16-1. Natural resources and potential pollution sources draining to the Singletary Brook segment MA51-31. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

16.2. Waterbody Impairment Characterization

Singletary Brook (MA51-31) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 16-1, 16-2; Figure 16-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected from W1767, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, one exceeded the STV criterion during wet weather only.

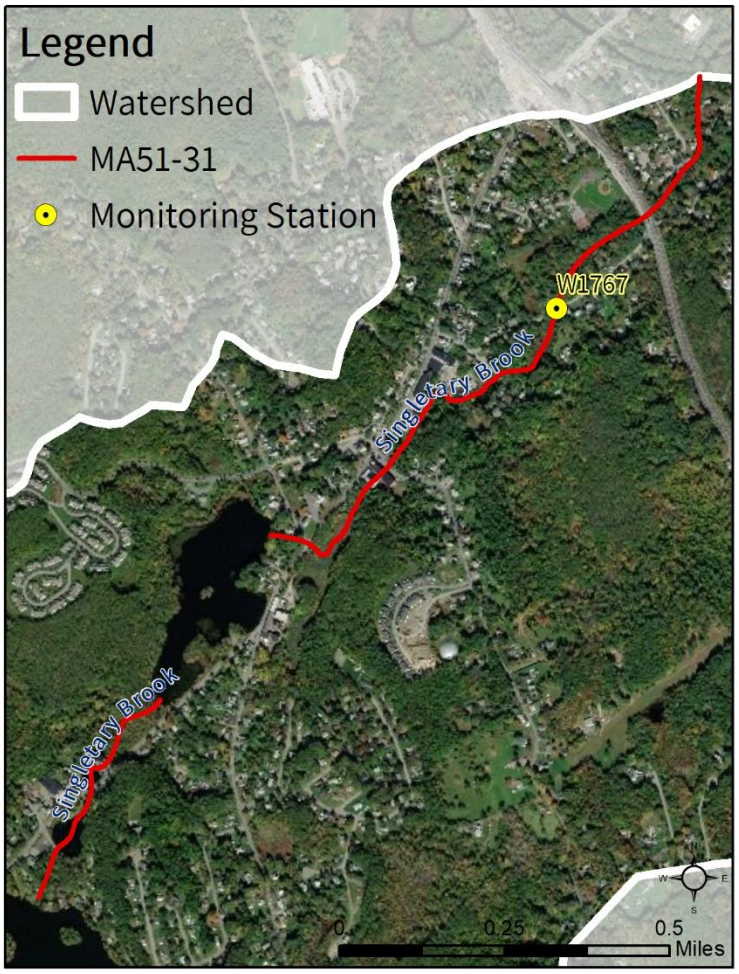


Figure 16-2. Location of monitoring station(s) along the impaired river segment.

Table 16-1. Summary of indicator bacteria sampling results by station for Singletary Brook (MA51-31). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1767	4/29/2008	8/26/2008	6	380	6	1

Table 16-2. Indicator bacteria data by station, indicator, and date for Singletary Brook (MA51-31). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1767	*E. coli*	4/29/08	WET	380	380	
W1767	*E. coli*	5/27/08	DRY	120	214	
W1767	*E. coli*	6/24/08	WET	500	284	
W1767	*E. coli*	7/8/08	DRY	370	303	
W1767	*E. coli*	8/5/08	DRY	120	227	
W1767	*E. coli*	8/26/08	DRY	32	163	

16.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria data for Singletary Brook (MA51-31) were elevated during wet weather. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the watershed are developed, with 43% of the land area in MS4 and 5% as DCIA. Although the development density is moderate, the stream segment itself flows through the most developed sections of the watershed. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: While there does not appear to be any public sewer service within the watershed, 43% of the land area is designated as MS4 area. Given the relatively moderate level of development, the most likely type of Illicit connection is from on-site wastewater systems to stormwater drains, such as leaky building drain lines and illicit connections to stormwater pipes or drains. In addition, illicit discharges may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater treatment. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to groundwater.

Agriculture: The watershed contains 9% agricultural land, with tree farms, open fields, and small areas of row crops visible on recent aerial photos. Agricultural activities related to manure storage and spreading, if not well

managed, are a possible source of pathogens to waterbodies. Additionally, any areas adjacent to upstream tributaries or storm drains could also provide a direct conduit to the river.

Pet Waste: About 12% of the watershed is Protected and Recreational Open Space. The impaired segment also flows through several residential neighborhoods. Streets and parks popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

16.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Millbury. See Section 5.4.

Town of Sutton. See Section 5.4.

17. MA51-32 Arnolds Brook

17.1. Waterbody Overview

Arnolds Brook segment MA51-32 is 1.8 miles long and located entirely in Bellingham. It begins at the headwaters of its perennial section at the outlet of an unnamed pond at Whitehall Way and flows south to end at its confluence with Peters River (MA51-18).

There are no tributaries to Arnolds Brook, although upstream of the headwaters pond is a section of ephemeral stream. There are no other named ponds within the watershed.

Major landmarks in the watershed include MA-126 along the western edge of the watershed, as well as portions of the schools and ballfields on Harpin Street. Road crossings include Fox Run Road, Newland Avenue, Dalmore Road, Lizotte Drive, Pulaski Boulevard, and Pine Grove Avenue. The Southern New England Trunkline Trail also crosses the stream.

Arnolds Brook (MA51-32) drains an area of 1.2 square miles, of which 0.3 mi^2 (20%) is impervious and 0.2 mi^2 (16%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[46] and the entire watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file for either point source discharges of pollutants to surface waters or wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 17-1.

The watershed land area is nearly equally forested (46%) and developed (45%). Most of the developed areas in the Arnolds Brook watershed are medium density residential and low density commercial, with a few institutional facilities. The 1% of watershed shown as agricultural on recent aerial photos appears to be mown fields. There are fringing wetlands along the stream course, and the riparian corridor is mostly wooded.

In the watershed of Arnolds Brook (MA51-32), under the Natural Heritage and Endangered

Reduction from Highest Calculated Geomean: 63%

Watershed Area (Acres): 795

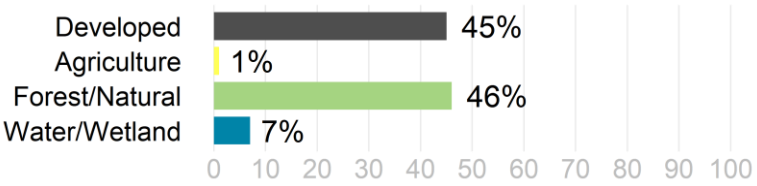
Segment Length (Miles): 1.7

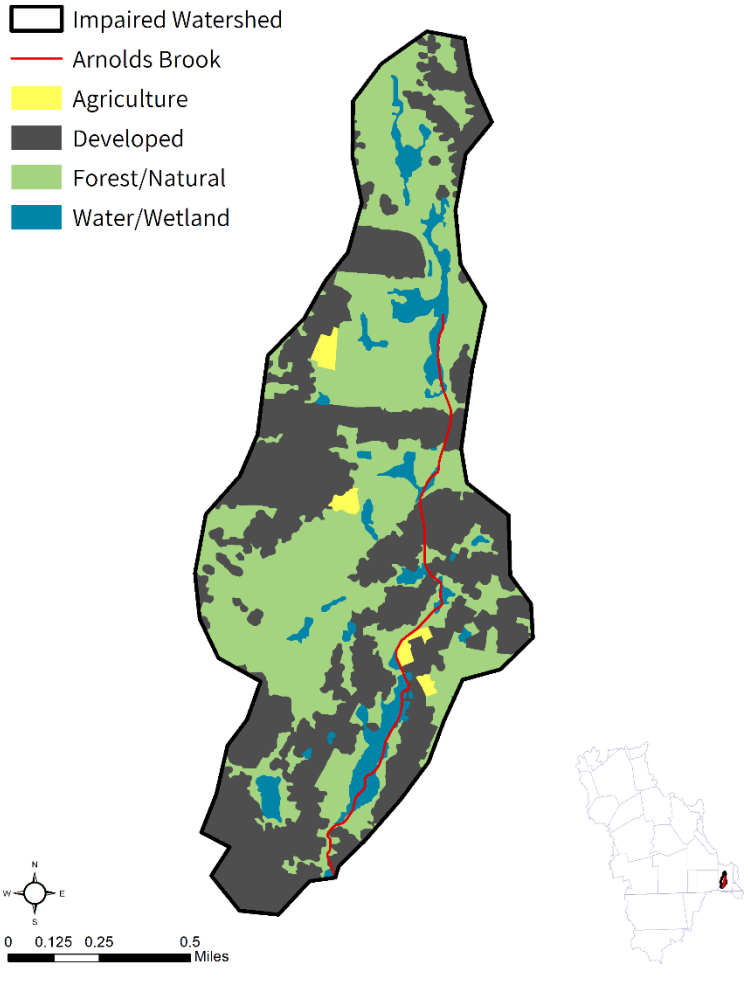
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 160 (20%)

DCIA Area (Acres, %): 123 (16%)





[46] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

Species Program, there are 0.4 acres (<1%) of Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. There is no land protected in perpetuity[47] within the segment watershed, but a total of 82 acres (10%) of Protected and Recreational Open Space[48]. See Figure 17-1.

[47] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[48] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

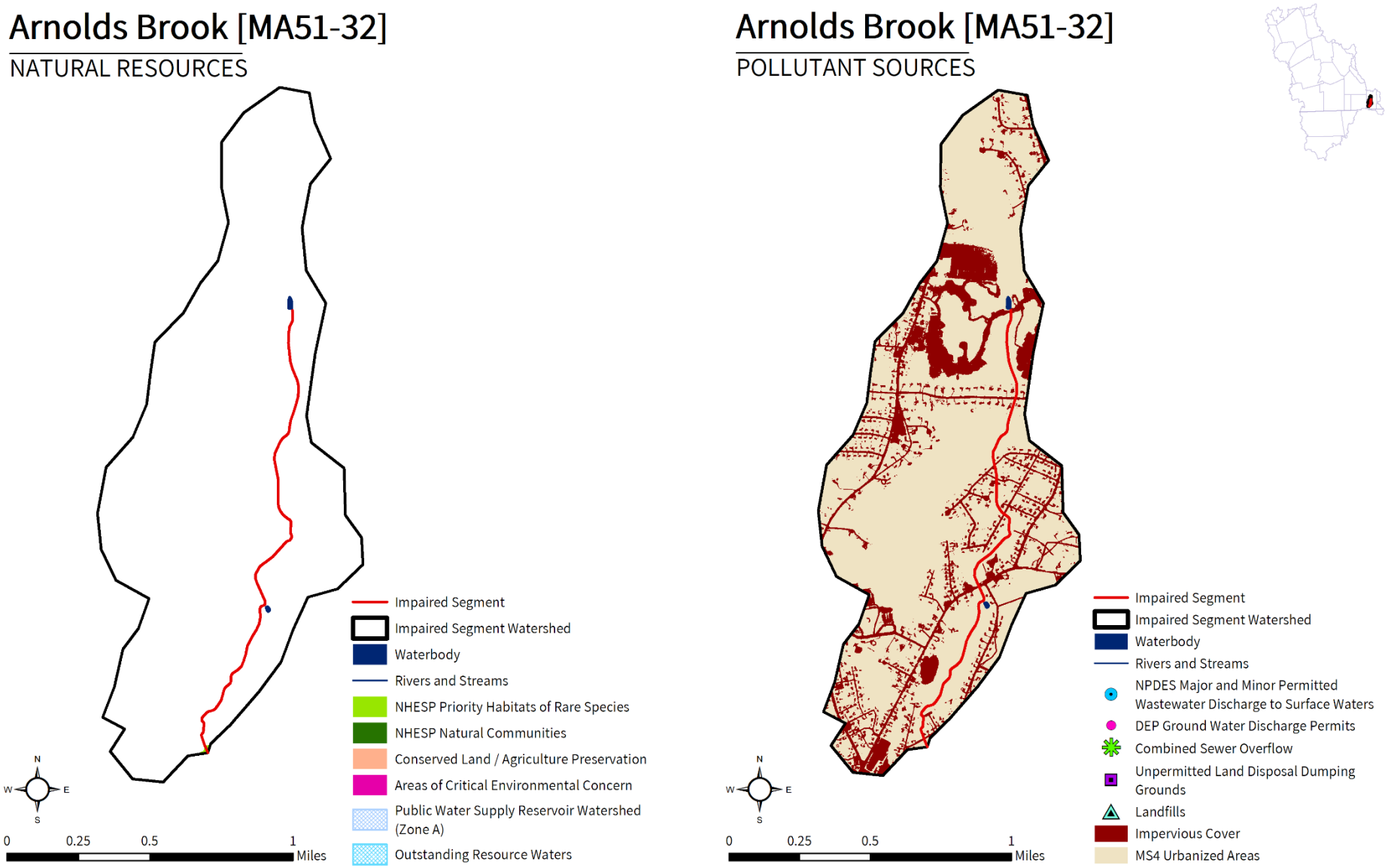


Figure 17-1. Natural resources and potential pollution sources draining to the Arnolds Brook segment MA51-32. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

17.2. Waterbody Impairment Characterization

Arnolds Brook (MA51-32) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 17-1, 17-2; Figure 17-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1756, resulting in two days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, one exceeded the STV criterion during wet weather only.

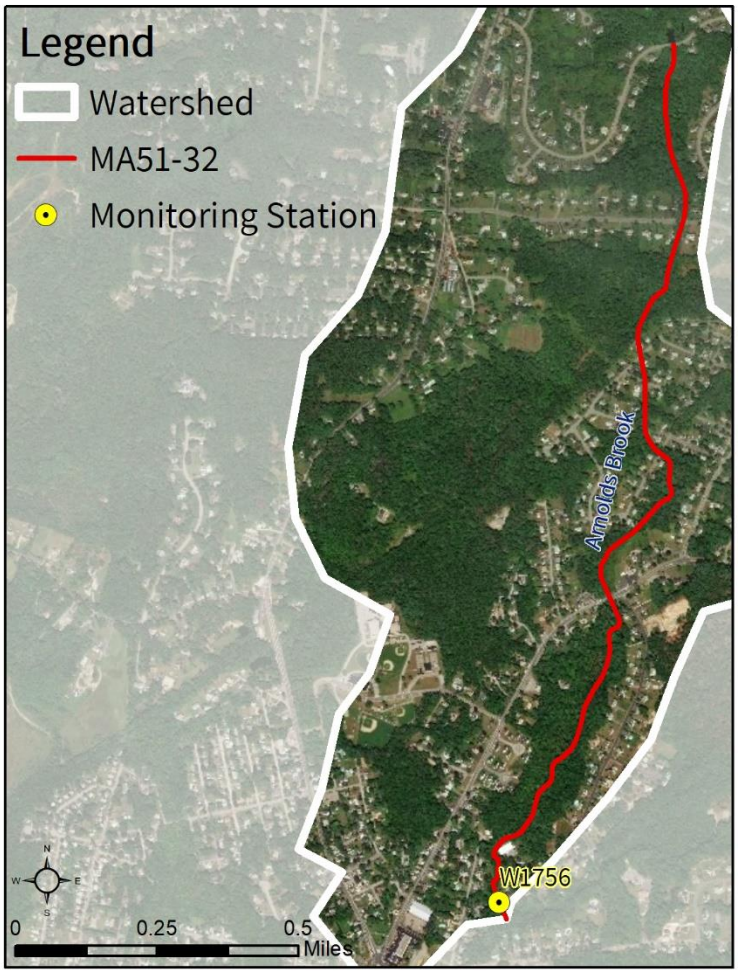


Figure 17-2. Location of monitoring station(s) along the impaired river segment.

Table 17-1. Summary of indicator bacteria sampling results by station for Arnolds Brook (MA51-32). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1756	5/1/2008	8/28/2008	6	344	2	1

Table 17-2. Indicator bacteria data by station, indicator, and date for Arnolds Brook (MA51-32). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1756	*E. coli*	5/1/08	WET	19	19	
W1756	*E. coli*	5/29/08	DRY	45	29	
W1756	*E. coli*	6/26/08	DRY	350	67	
W1756	*E. coli*	7/10/08	DRY	370	103	
W1756	*E. coli*	8/7/08	WET	490	231	
W1756	*E. coli*	8/28/08	DRY	220	344	

17.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels in Arnolds Brook (MA51-32) were elevated results during wet weather. Elevated indicator bacteria during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels.

A Bacteria Source Tracking study was conducted using *E. coli* bracket testing and optical brighteners in 2004. Results indicated poultry and livestock pens as a source in the upstream segment near Pulaski Boulevard, and illicit wastewater discharge(s) to the downstream segment near Pine Grove Avenue. Recent aerial photos do not appear to show any livestock activity in the upstream watershed. Bellingham DPW conducted intensive stormwater pipe testing and video inspections and narrowed the illicit discharge sources to a few dwellings in 2007 (MassDEP 2010).

Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: Portions of the watershed are highly developed, with the entire watershed designated as MS4 area and 16% as DCIA. Stormwater runoff from urban areas is likely a source of pathogens.

Illicit Sewage Discharges: While none of the watershed is served by public sewer, the entire watershed is designated as MS4 area. Illicit connections from private wastewater systems to stormwater drains have been found in this watershed in the past and remain a plausible source.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater treatment. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to the environment.

Pet Waste: There are significant areas of Protected and Recreational Open Space in the watershed (10%), and the brook flows through several residential neighborhoods. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Agriculture: Agriculture accounts for 1% of watershed land area, and poultry and livestock were determined in the past to be sources to the segment. No active farming appears adjacent to the brook in recent aerial photos. Nonetheless, agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

17.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Bellingham. See Section 14.4.

18. MA51-36 Mill River

18.1. Waterbody Overview

The Mill River segment MA51-36 is 4.1 miles long and located entirely in Blackstone, MA. It begins at the Mendon/Blackstone town boundary, then flows south to its end at the Rhode Island border. The segment flows through Harris Pond (formerly segment MA51058 and formerly part of segment MA51-10). The 1000 feet downstream are included in the designation "All Interstate surface waters that are public water supply in Rhode Island from 1000 feet upstream of the State Line" which are designated as Class A/PWS/ORW in 314CMR4.00, January 2007.

The Mill River segment MA51-36 is bound at the upstream end by formerly pathogen-impaired Mill River segment MA51-35 and the downstream end by the Woonsocket, RI-Blackstone, MA border, which runs approximately along the Harris Pond impoundment berm and dam. The upstream watershed extends from Hopkinton in the north through Upton, Milford, Mendon, Hopedale, Blackstone, and a small area in Bellingham, MA, in the southeast.

Tributaries to the impaired segment MA51-36 are the streams draining Fish Pond (upstream of which is Duck Pond) and Walsh Pond and Hop Brook, Quick Stream, and several other small streams draining wetlands. Major lakes and ponds within the segment watershed from upstream to downstream include Lake Maspenock (labeled North Pond in MassGIS), Fiske Millpond, Mill Pond, Hopedale Pond, and Spindleville Pond, all of which are upstream of the segment itself.

Major landmarks in the segment watershed include The Blackstone Plant, a large sand quarry owned by Kimball Sand Co. Inc., and the Blackstone natural gas power plant just north of the quarry, both off Elm Street; a large auto salvage yard on Rathbun Street; the Quisset Wildlife Management Area; and portions of the village of Millerville in Blackstone. Road crossings include Elm Street, Summer Street, and a large access road serving the sand quarry and natural gas power plant. The Southern New England Trunkline Trail also crosses the segment at Harris Pond.

The Mill River (MA51-36) drains an area of 33 square miles, of which 3.4 mi^2 (10%) is impervious

Reduction from Highest Calculated Geomean: 82%

Watershed Area (Acres): 21,193

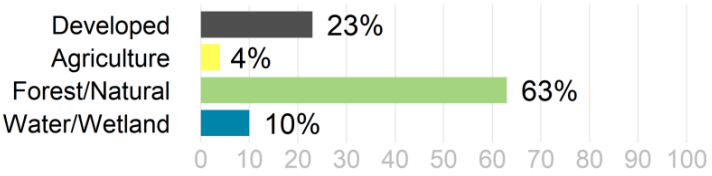
Segment Length (Miles): 4.1

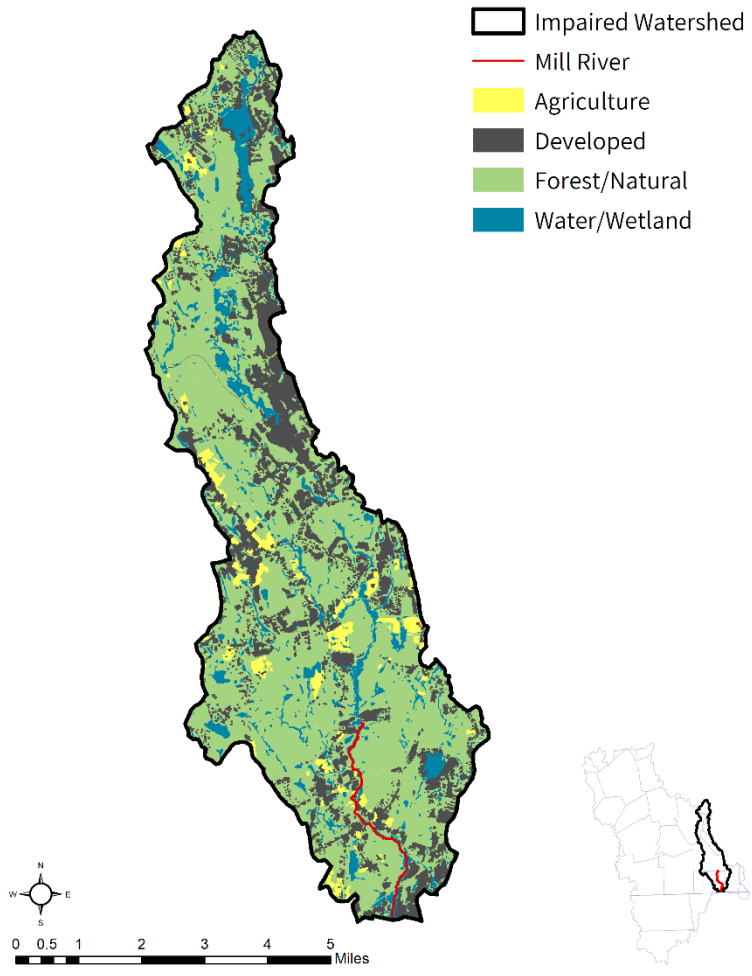
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B (Treated Water Supply, Warm Water)

Impervious Area (Acres, %): 2,144 (10%)

DCIA Area (Acres, %): 1,365 (6%)





and 2.1 mi^2 (6%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[49] and 57% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020), including the entire area surrounding the impaired segment watershed. There is one NPDES permit for the Hopedale wastewater treatment facility (Table 18-1), and one groundwater discharge permit (675-2) for on-site wastewater discharge (Table 18-2). Five landfills and one unpermitted land disposal dumping ground are present within this segment watershed, and there are no combined sewer overflows. See Figure 18-1.

Table 18-1. National Pollutant Discharge Elimination System (NPDES) permits in the segment watershed. Only permits unique to this segment watershed are shown. Wastewater Treatment Facilities (WWTF) are identified as either municipal (MUN) or other (OTH), if applicable.

NPDES ID	NAME	TOWN	WWTF
MA0102202	HOPEDALE WWTP	HOPEDALE	MUN

Table 18-2. Groundwater discharge permits in the segment watershed. Only permits unique to this segment watershed are shown. PERR = permit number plus renewal number. TYPE = type of groundwater discharge. FLOW = permitted effluent in gallons per day (gpd).

PERR	NAME	TOWN	TYPE	FLOW (GPD)
675-2	EMC CORPORATION	HOPKINTON	Sanitary Discharge	83,500

Forests accounts for most of the land use within the segment watershed (63%), with developed areas covering 23%. In the area surrounding impaired segment MA51-36, there are two large industrial land uses (sand quarry and natural gas power plant), along with low to medium density residential development, then medium density mixed development in the southern portion along Harris Pond. Most of the riparian corridor maintains at least a 10-15-meter wooded buffer. Agriculture covers 4% of the watershed, some situated along the impaired segment.

In the watershed of the Mill River (MA51-36), under the Natural Heritage and Endangered Species Program, there are 2,369 acres (11%) of Priority Habitats of Rare Species and nine acres (<1%) of Priority Natural Vegetation Communities. There are nine acres (<1%) of Areas of Critical Environmental Concern, 42 acres (<1%) under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. Over 428 acres (2%) of land protected in perpetuity[50] exist within the segment watershed, which is part of a total of 2,661 acres (13%) of Protected and Recreational Open Space[51]. See Figure 18-1.

[49] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

[50] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[51] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

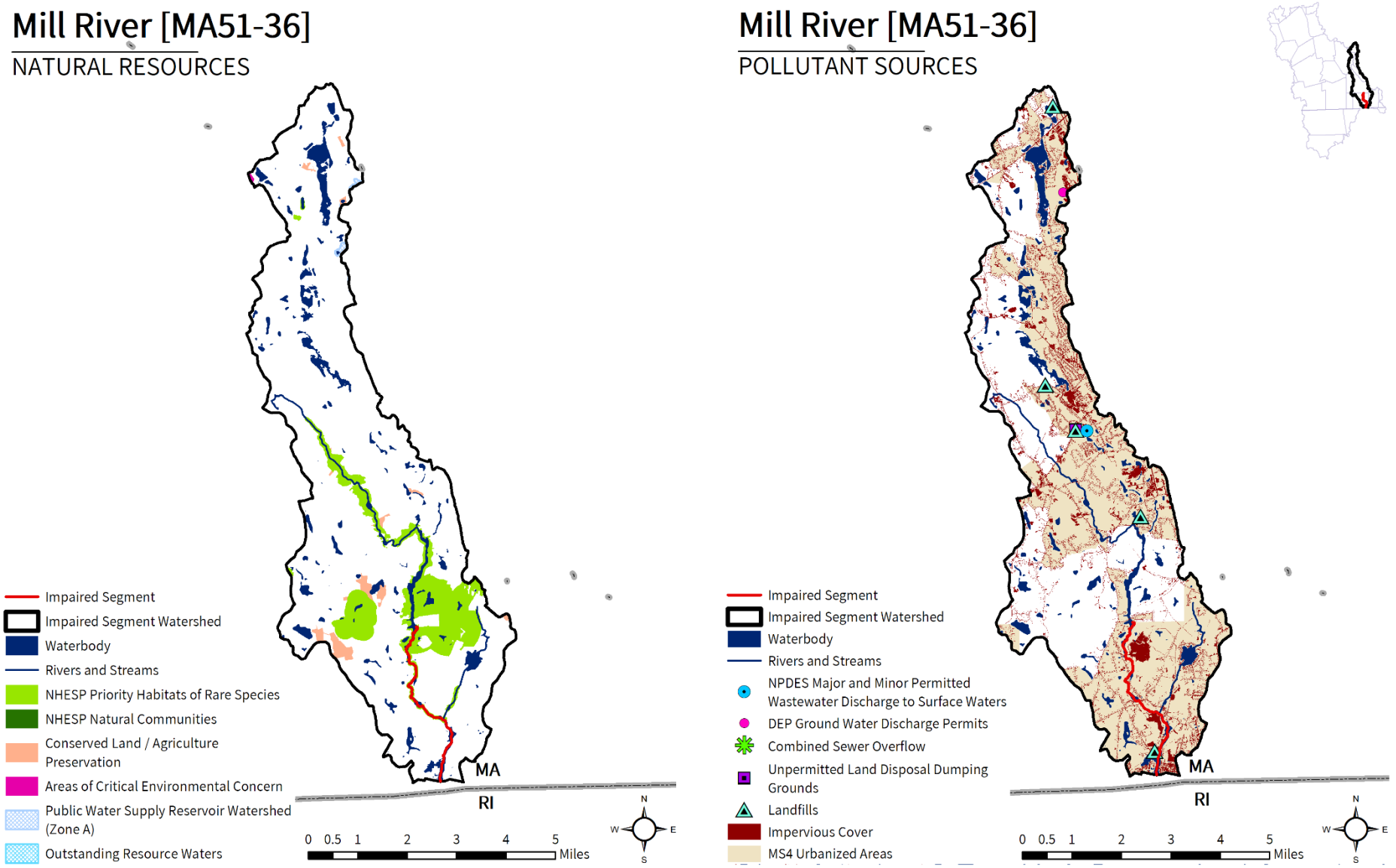


Figure 18-1. Natural resources and potential pollution sources draining to the Mill River segment MA51-36. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

18.2. Waterbody Impairment Characterization

The Mill River (MA51-36) is a Class B, Treated Water Supply, Warm Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the stations listed below (refer to Tables 18-3, 18-4; Figure 18-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 30-day rolling basis.

- In 2008, six samples were collected at W0508, resulting in two days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, none exceeded the STV criterion.
- In 2008, six samples were collected at W1771, resulting in three days when the 30-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during dry weather only.

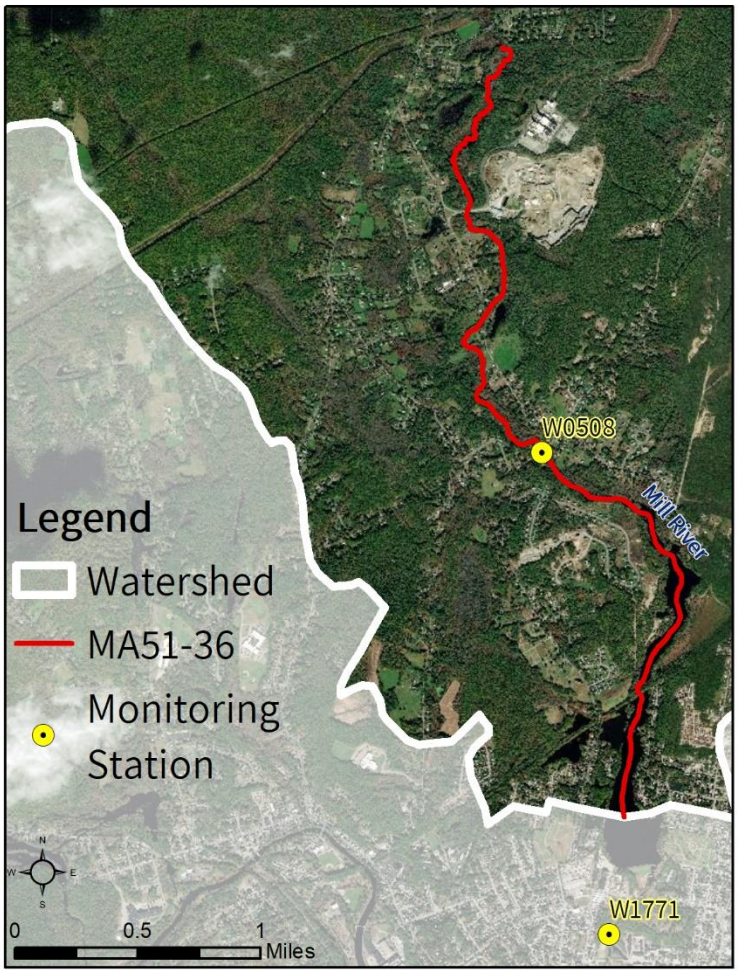


Figure 18-2. Location of monitoring station(s) along the impaired river segment.

Table 18-3. Summary of indicator bacteria sampling results by station for the Mill River (MA51-36). The maximum 30-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 30-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 30-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W0508	5/1/2008	8/28/2008	6	228	2	0
W1771	4/29/2008	8/26/2008	6	686	3	2

Table 18-4. Indicator bacteria data by station, indicator, and date for the Mill River (MA51-36). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 30-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	30-Day Rolling Geomean (CFU/100mL)	30-Day Rolling STV (CFU/100mL)
W0508	*E. coli*	5/1/08	WET	95	95	
W0508	*E. coli*	5/29/08	DRY	42	63	
W0508	*E. coli*	6/26/08	DRY	120	71	
W0508	*E. coli*	7/10/08	DRY	260	177	
W0508	*E. coli*	8/7/08	WET	200	228	
W0508	*E. coli*	8/28/08	DRY	70	118	
W1771	*E. coli*	4/29/08	WET	33	33	
W1771	*E. coli*	5/27/08	DRY	45	39	
W1771	*E. coli*	6/24/08	DRY	310	118	
W1771	*E. coli*	7/8/08	DRY	620	438	
W1771	*E. coli*	8/5/08	DRY	760	686	
W1771	*E. coli*	8/26/08	DRY	320	493	

18.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for the Mill River (MA51-36) were elevated during dry weather. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The watershed is generally developed, with 57% of the land area designated as MS4 and 6% as DCIA. The river segment flows through or near residential development for most of its length. Stormwater runoff from urban areas is likely a significant source of pathogens.

Illicit Sewage Discharges: Although the watershed is not served by public sewer, the entire length of the impaired segment is within an MS4 area, and monitoring data indicate elevated indicator bacteria levels during dry weather. Given the relatively moderate level of development, the most likely type of Illicit connections is from on-site wastewater systems to stormwater drains, such as leaky building drain lines and illicit connections to stormwater pipes or drains. In addition, illicit discharges may be caused by undersized infrastructure, blockages, or excessive infiltration of groundwater or rainwater into pipes, exceeding system capacity.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater treatment. There is one groundwater discharge permit for an on-site wastewater discharge, which is large-capacity septic

system (non-residential). It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to the environment.

Agriculture: Agriculture accounts for 4% of the watershed land area. Several agricultural areas indicated by recent aerial maps are adjacent to the impaired segment. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: The impaired segment flows through several residential neighborhoods, and there are parks and open spaces near the river, especially in the downstream portion of the watershed. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: There are many open fields along the river, including the impounded section of Harris Pond, and most of these fields appear to maintain a wooded vegetated buffer between the field and open water. Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

18.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Blackstone. See Section 8.4.

Town of Hopedale

Most of Hopedale is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041123) and has an EPA-approved Notice of Intent (NOI). Hopedale plans to complete their Stormwater Management Plan during Permit Year 2, after which it will be posted to the town's website (2019-2020). Hopedale has mapped 90% of its MS4 stormwater system. The Town of Hopedale adopted an illicit discharge detection and elimination (IDDE) plan on June 26, 2020, available at https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/pages/hopedale_idde_plan_06262020.pdf (Weston & Sampson 2020); erosion and sedimentation control (ESC) and post-construction stormwater regulations were adopted in 2014 (Town of Hopedale) and are available at https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/uploads/hopedale_zoning_by_laws_v2.0.pdf. According to the NOI, there are no stormwater outfalls into the impaired segments in the Blackstone River watershed.

Hopedale has the following bylaws and ordinances:

- Stormwater Runoff, Town Zoning Regulations Article V, page 16-34: https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/uploads/hopedale_zoning_by_laws_v2.0.pdf (Town of Hopedale 2014)
- Wetlands Protection Bylaw Town Zoning Regulations Article V, page 16-32: https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/uploads/hopedale_zoning_by_laws_v2.0.pdf (Town of Hopedale 2014)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

In addition, the Town of Hopedale's Master Plan provides a comprehensive overview of the town's water resources, describing features of the Mill River and Charles River. Most of the town's water is supplied by the Hopedale Water Department and most areas are served by the Hopedale Sewage Treatment Plant.

Hopedale Master Plan Community Development Chapter: https://www.hopedale-ma.gov/master-plan-steering-committee (Town of Hopedale 2020).

Town of Milford

All of Milford within the Blackstone River watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041135) and has an EPA-approved Notice of Intent (NOI). Milford has completed a Stormwater Management Plan, which is available online at https://www.milfordma.gov/planning-engineering/pages/town-milford-stormwater-management-plan (Environmental Partners 2019) and has mapped all of its MS4 stormwater system. The town also adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater management in 2005 (Town of Milford). According to the NOI, there are no stormwater outfalls into impaired segments in the Blackstone River watershed.

Milford has the following ordinances:

- Stormwater Management General By-law: https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/stormwater_management_by_law.pdf (Town of Milford 2005)
- Wetland Protection Bylaw: https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/wetlands_bylaw.pdf (Town of Milford, n.d.)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

The Town of Milford Comprehensive Plan also includes sections on natural resources, describing the two watersheds that Milford lies within – the Charles River watershed and the Blackstone River watershed (Town of Milford, 2003a). The plan also has a section on the town sewer system and stormwater management in the Infrastructure chapter, and 95% of Milford's residences and businesses are serviced by public sewer. Since 1986, stormwater has been treated separately than the sewer treatment. However, 50% of existing sewer pipes were laid before 1950 and are made of clay, and are now deteriorating, causing infiltration during storm events to become a significant problem.

Milford Comprehensive Plan: https://www.milfordma.gov/sites/milfordma/files/uploads/milford_comprehensive_plan_2003.pdf (Town of Milford, 2003)

Milford Stormwater Page: https://www.milfordma.gov/planning-engineering/pages/what-stormwater (Town of Milford, 2018)

Milford Township Comprehensive Park & Recreation Plan: https://milfordtownship.org/wp-content/uploads/2018/08/park_plan.pdf (Town of Milford, 2003b)

19. MA51-39 Fox Brook

19.1. Waterbody Overview

Fox Brook segment MA51-39 is 3.4 miles long. And begins at its perennial headwaters in a wetland northeast of the Thayer Street-Chestnut Hill Road intersection in Millville, it flows southeast into Blackstone and excludes the 0.1 miles through Crane Pond segment MA51030. It then turns south and flows through Briggs Pond towards Main Street/MA-122, ending at its confluence with the pathogen-impaired Blackstone River segment MA51-06 in the Town of Blackstone.

Tributaries to this section of Fox Brook include about seven miles on unnamed streams draining small ponds and wetlands, including drainage from Reilly Pond in Blackstone.

Major landmarks in the segment watershed include the Lyons Preserve, Blackstone Recycling Center and Landfill, agricultural areas and tree farms on Milk Street, Fox Brook Conservation Area, Blackstone Millville Regional High School, A. F. Maloney Elementary School, and Blackstone Public Library.

Road crossings include Mendon Street, Lincoln Street, and Main Street/MA-122, all in Blackstone.

Fox Brook (MA51-39) drains an area of 4.5 square miles, of which 0.3 mi^2 (7%) is impervious and 0.2 mi^2 (4%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[52] and 41% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file governing point source discharges of pollutants to surface waters. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, and no unpermitted land disposal dumping grounds. One landfill is present within this segment watershed. See Figure 19-1.

Forested areas (72%) account for most of the land use within the segment watershed with smaller areas of scattered development (18%). The agricultural areas in watershed (3%) are privately

Reduction from Highest Calculated Geomean: 94%

Watershed Area (Acres): 2,874

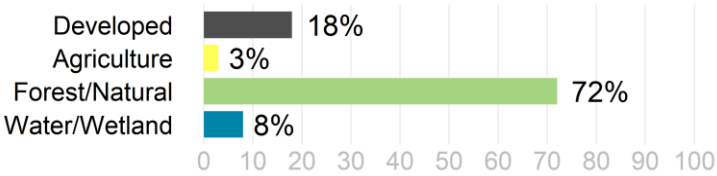
Segment Length (Miles): 3.4

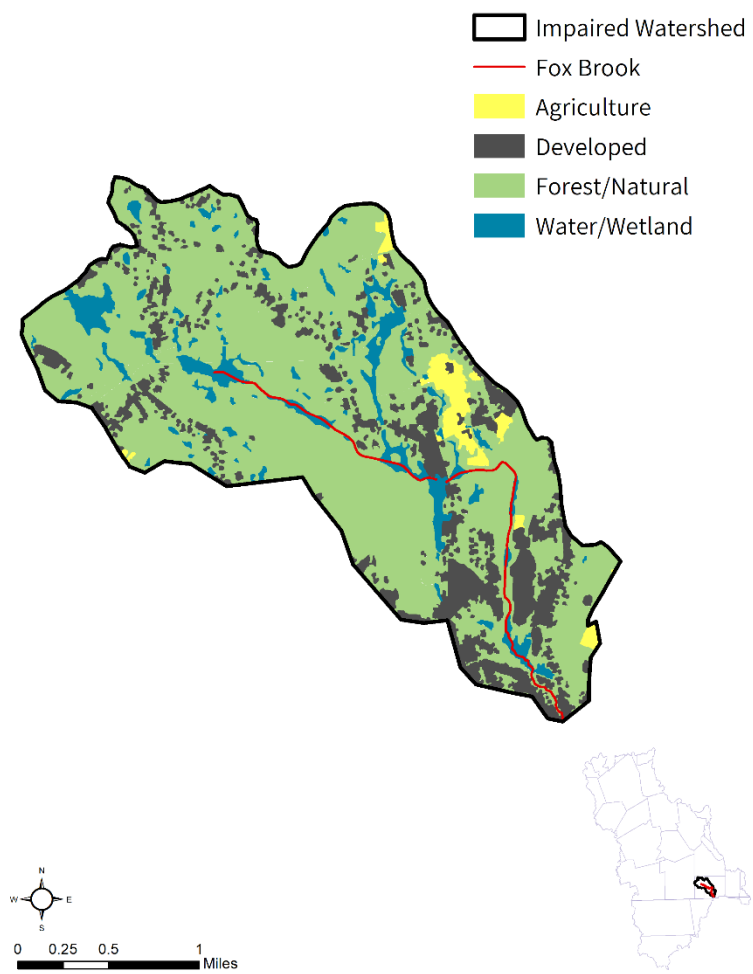
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 202 (7%)

DCIA Area (Acres, %): 128 (4%)





[52] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

owned Wojcik's Farm and a neighboring Christmas tree farm. The stream generally maintains wooded riparian buffer.

In the watershed of Fox Brook (MA51-39), under the Natural Heritage and Endangered Species Program, there are no areas identified as Priority Natural Vegetation Communities or Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. About nine acres (<1%) of land protected in perpetuity[53] exist within the segment watershed, which is part of a total of 81 acres (3%) of Protected and Recreational Open Space[54]. See Figure 19-1.

[53] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[54] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

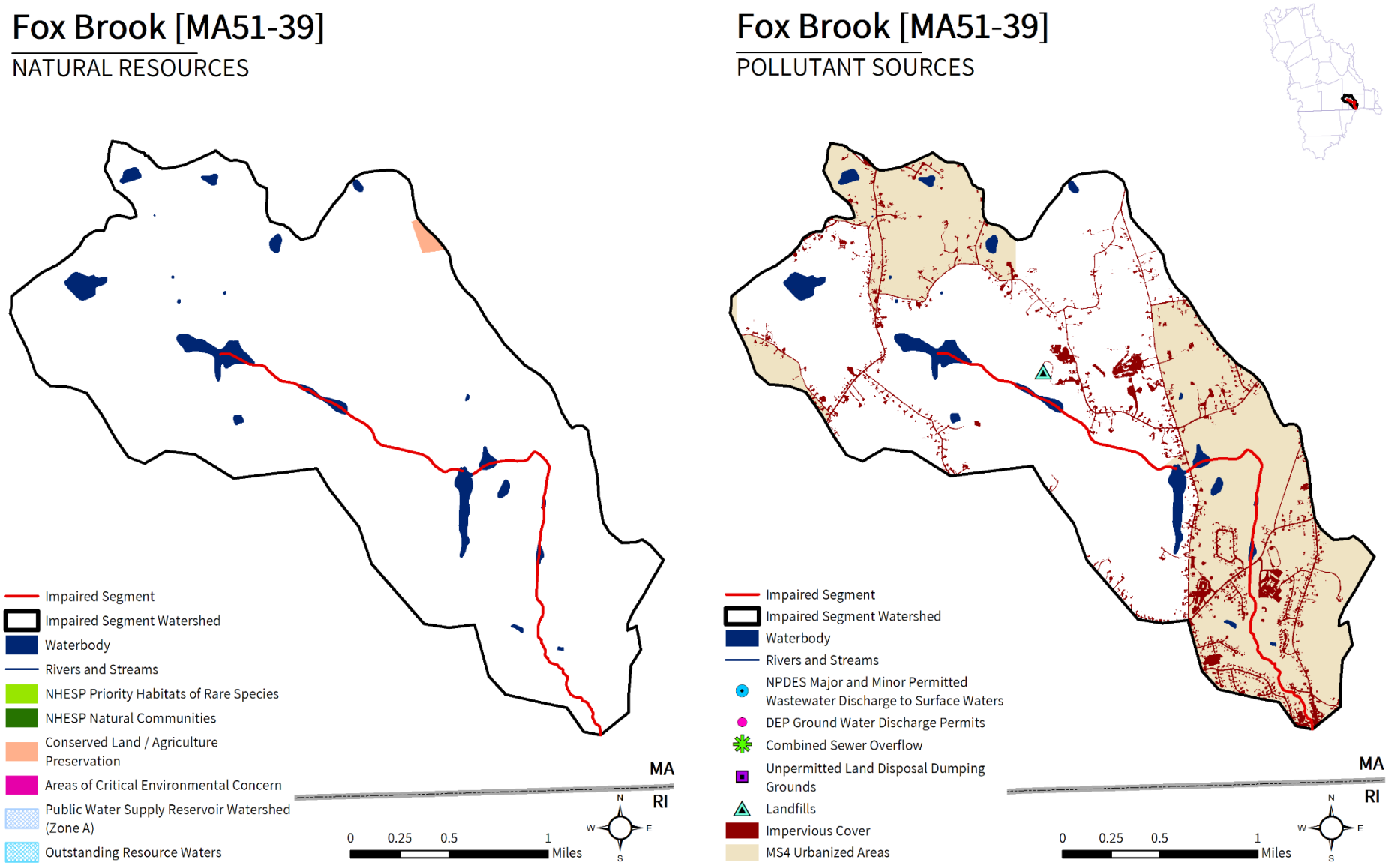


Figure 19-1. Natural resources and potential pollution sources draining to the Fox Brook segment MA51-39. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

19.2. Waterbody Impairment Characterization

Fox Brook (MA51-39) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 19-1, 19-2; Figure 19-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1762, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, three exceeded the STV criterion during both wet and dry weather.

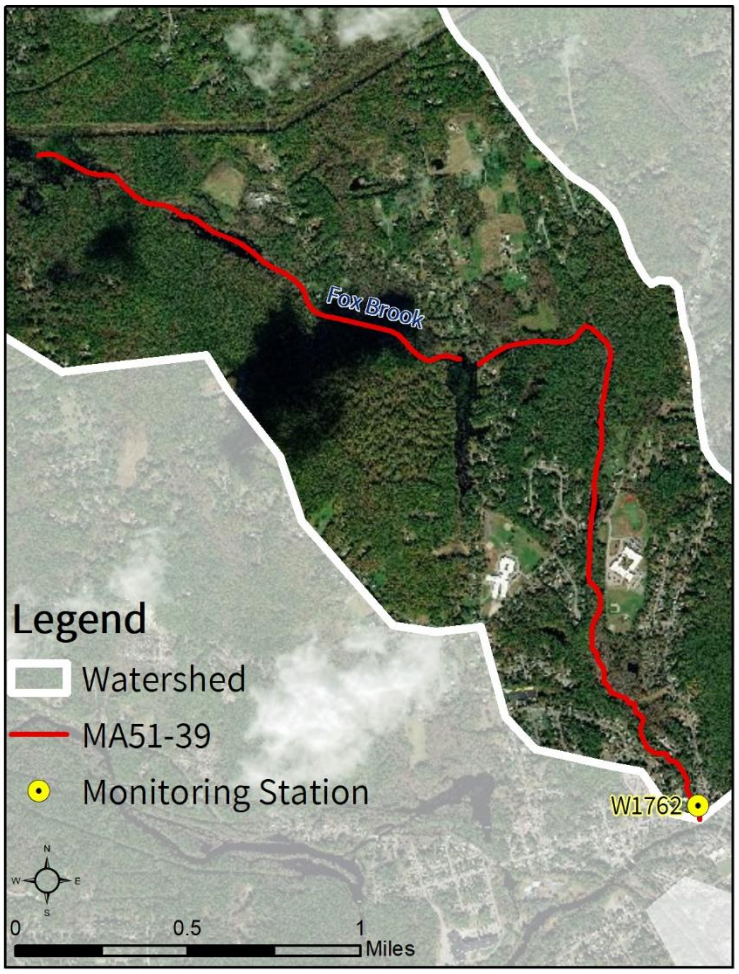


Figure 19-2. Location of monitoring station(s) along the impaired river segment.

Table 19-1. Summary of indicator bacteria sampling results by station for Fox Brook (MA51-39). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1762	5/1/2008	8/28/2008	6	2194	6	3

Table 19-2. Indicator bacteria data by station, indicator, and date for Fox Brook (MA51-39). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1762	*E. coli*	5/1/08	WET	270	270	
W1762	*E. coli*	5/29/08	DRY	190	226	
W1762	*E. coli*	6/26/08	WET	2200	483	
W1762	*E. coli*	7/10/08	DRY	18000	1194	
W1762	*E. coli*	8/7/08	WET	1500	1833	
W1762	*E. coli*	8/28/08	DRY	390	2194	

19.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for Fox Brook (MA51-39) were elevated during both wet and dry weather. Elevated indicator bacteria during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The watershed is moderately developed (though the brook flows through the most heavily developed portions of the watershed), with 41% of the land area in MS4 and 4% as DCIA. Stormwater runoff from urban areas is likely a significant source of pathogens.

Illicit Sewage Discharges: The watershed is not served by public sewer; however, the downstream half of the impaired segment flows through MS4 areas. In addition, there are several residential neighborhoods with homes next to the stream, including on Chestnut Street, Milk Street, Mendon Street, Dawn Street, Reilly Avenue, and in the village of Blackstone. Illicit connections from septic systems to stormwater drains or directly to the brook are the most likely risks. Some illicit discharges occur episodically, which would be consistent with a single extremely high indicator bacteria sample result.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater disposal. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to the environment. Some types of malfunctions may occur constantly or intermittently, and thus be present during dry weather, while others may be exacerbated by precipitation. The development pattern listed for illicit discharges above are similarly relevant to septic systems.

Agriculture: Agriculture accounts for 3% of watershed land area, including tree farms and row crops in the central part of the watershed. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: Protected and Recreational Open Space makes up 3% of the watershed, and the brook flows beside or through several residential neighborhoods. Areas popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water. Open lawns around Crane Pond (excluded from this impaired segment but draining to it) show this land use pattern.

19.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Blackstone. See Section 7.4.

Town of Millville. See Section 7.4.

20. MA51-40 Muddy Brook

20.1. Waterbody Overview

Muddy Brook segment MA51-40 is 5.1 miles long and located entirely in the Town of Mendon. It begins at the outlet of a small unnamed pond north of Miscoe Hill Middle School, then flows southeast to its confluence with Spring Brook (MA51-25), then east to end at its confluence with Mill River segment MA51-35, which is not pathogen-impaired. The segment watershed extends northwest into Upton and Hopedale.

Tributaries to this section of Muddy Brook include Spring Brook (with upstream tributary of Ohio Brook) and Willow Brook, as well as smaller unnamed streams. There are no named lakes or ponds in the watershed.

Major landmarks in the watershed include Miscoe Hill Middle School, the Mendon town center, and the farms along North Avenue. Road crossings include North Avenue and Hopedale Street at the start of the segment, then Milford Street/MA-16, George Street, Hartford Avenue East, Cemetery Street, and Bellingham Street.

Muddy Brook (MA51-40) drains an area of 6.2 square miles, of which 0.5 mi^2 (8%) is impervious and 0.3 mi^2 (5%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[55] and 46% of the watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file governing point source discharges of pollutants to surface waters and no additional NPDES permits for wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 20-1.

Muddy Brook (MA51-40) flows predominantly through forest, with low density residential and agricultural land cover adjacent to the stream in places. Overall, forest accounts for 63% of the watershed, with developed areas covering 23%. Agriculture represents 7% of the watershed land area, with some areas adjacent to the stream.

Reduction from Highest Calculated Geomean: 66%

Watershed Area (Acres): 3,983

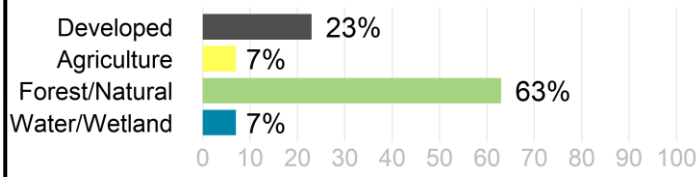
Segment Length (Miles): 5.1

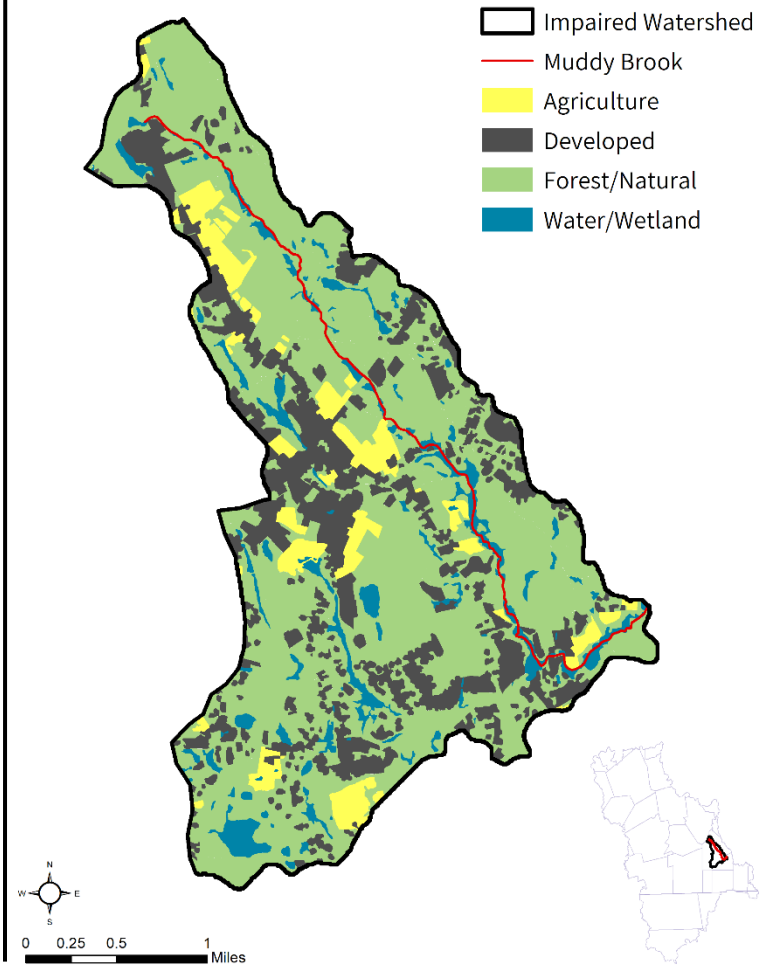
Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 337 (8%)

DCIA Area (Acres, %): 209 (5%)





[55] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

Agriculture appears to be primarily open fields, with a small area of row crops north of Trouey Lane, as well as the Mendon Community Garden at the intersection of Mendon Avenue and Hopedale Street.

In the watershed of Muddy Brook (MA51-40), under the Natural Heritage and Endangered Species Program, there are 442 acres (11%) of Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. Over 49 acres (1%) of land protected in perpetuity[56] exist within the segment watershed, which is part of a total of 158 acres (4%) of Protected and Recreational Open Space[57]. See Figure 20-1.

[56] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[57] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

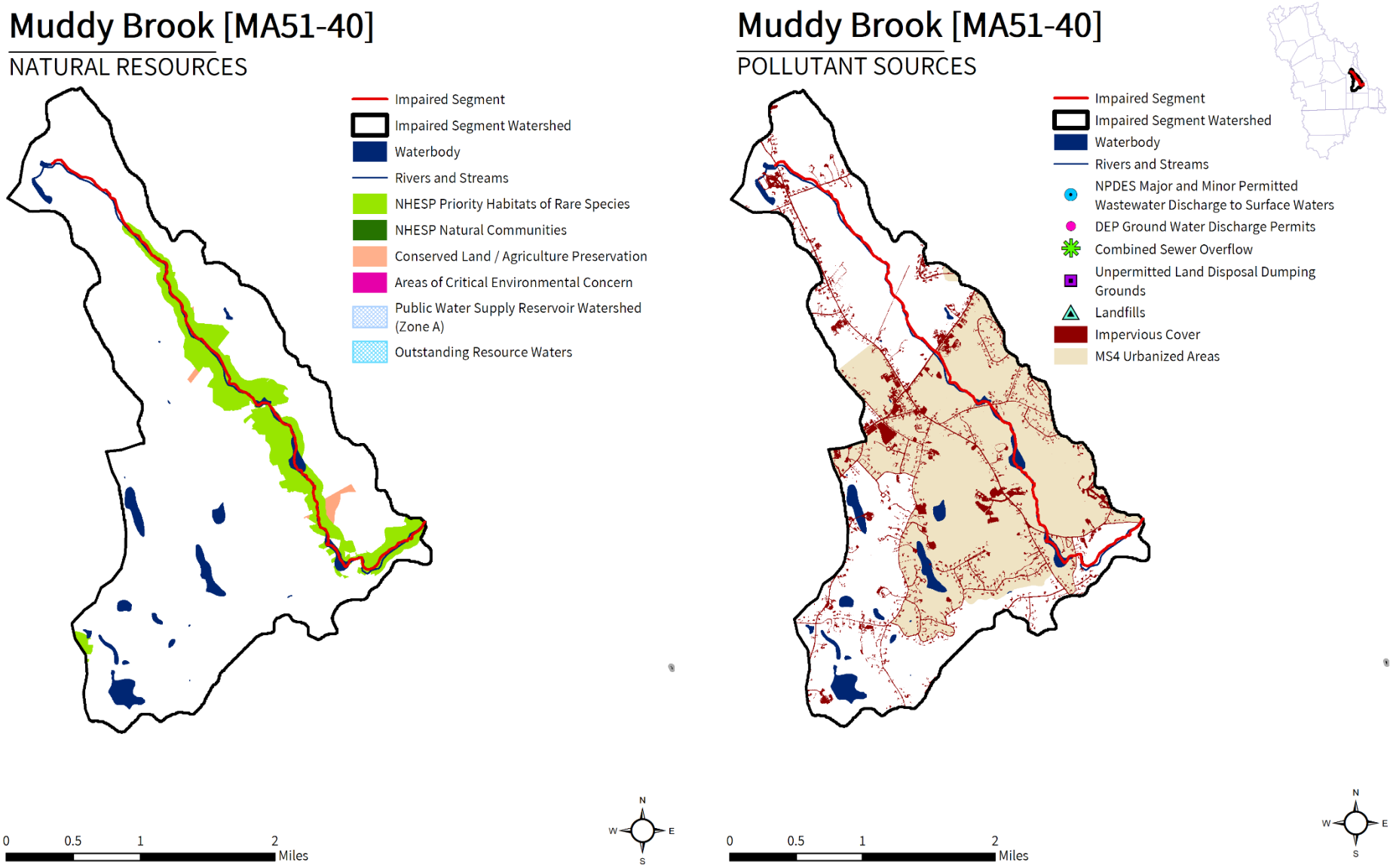


Figure 20-1. Natural resources and potential pollution sources draining to the Muddy Brook segment MA51-40. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

20.2. Waterbody Impairment Characterization

Muddy Brook (MA51-40) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 20-1, 20-2; Figure 20-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1760, resulting in three days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during both wet and dry weather.

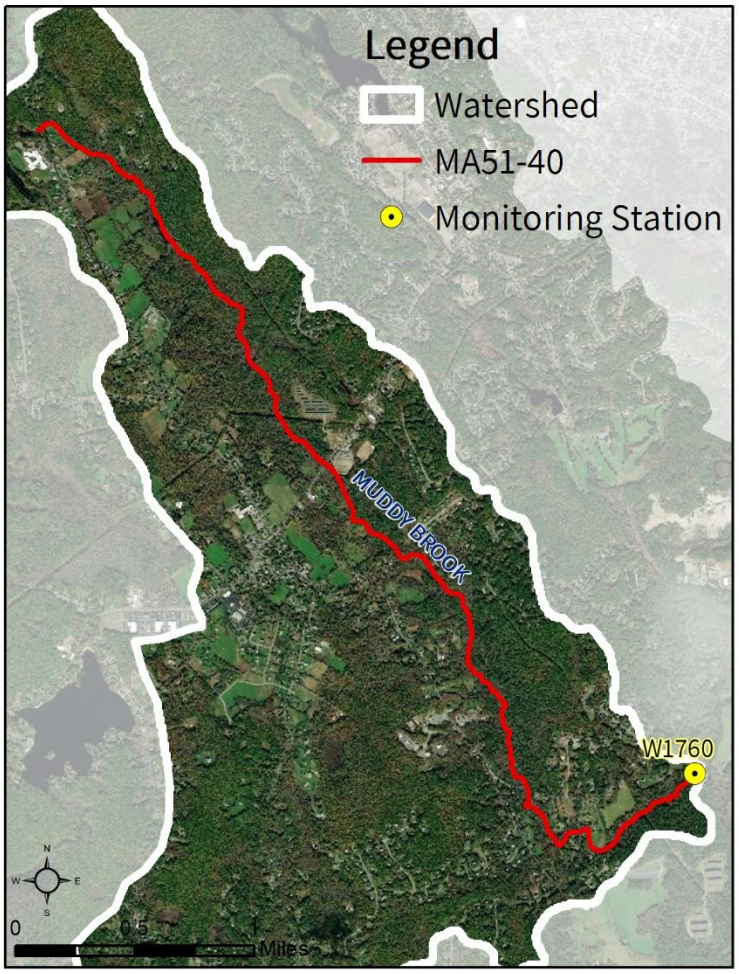


Figure 20-2. Location of monitoring station(s) along the impaired river segment.

Table 20-1. Summary of indicator bacteria sampling results by station for Muddy Brook (MA51-40). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1760	5/1/2008	8/28/2008	6	368	3	2

Table 20-2. Indicator bacteria data by station, indicator, and date for Muddy Brook (MA51-40). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1760	*E. coli*	5/1/08	WET	19	19	
W1760	*E. coli*	5/29/08	DRY	55	32	
W1760	*E. coli*	6/26/08	WET	190	58	
W1760	*E. coli*	7/10/08	DRY	2400	148	
W1760	*E. coli*	8/7/08	WET	600	350	
W1760	*E. coli*	8/28/08	DRY	67	368	

20.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels in Muddy Brook (MA51-40) were elevated during both wet and dry weather. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Elevated results during dry weather suggest that baseflow sources, such as leaking pipes, illegal cross connections, other illicit discharges, and failing septic systems, are likely to be major sources of pathogens. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The watershed is moderately developed (although residential neighborhoods and other development are generally not adjacent to the segment), with 46% of the land area in MS4 and 5% as DCIA. Stormwater runoff from urban areas is likely a source of pathogens.

Illicit Sewage Discharges: With the downstream half of the watershed as MS4 area and elevated indicator bacteria levels during dry weather, illicit discharges may be a source of pathogens. The watershed is not served by public sewer; thus, most probable type of illicit discharge is from septic systems to stormwater drains or direct discharges to the environment.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater disposal. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to the environment.

Agriculture: Agriculture accounts for 7% of watershed land area and includes mostly fields, with small areas of row crops and garden plots. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: Muddy Brook flows mostly through a wooded landscape, though the downstream section flows through residential neighborhoods around Providence Street and Hartford Avenue. In addition, 4% of the watershed area is Protected and Recreational Open Space. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: There are many open fields in the watershed visible on recent aerial photos, though very few are directly adjacent to water. Nonetheless, conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

20.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Mendon

Most of Mendon is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (Permit ID #MAR041133) and has an EPA-approved Notice of Intent (NOI). Mendon has a Stormwater Management Plan available online at http://www.mendonma.gov/swmp (Town of Mendon, 2020a), has mapped all of its MS4 stormwater system, and has submitted the map as an attachment with the NOI. It adopted illicit discharge detection and elimination (IDDE), erosion and sedimentation control (ESC), and post-construction stormwater management in 2019; this is available at https://www.mendonma.gov/sites/g/files/vyhlif881/f/file/file/2019_mendon_ma.pdf (Tighe & Bond 2019). According to the NOI, there are 78 stormwater outfalls into Muddy Brook (MA51-40) and 10 outfalls to Ohio Brook upstream of the impaired segment.

Mendon has the following ordinances and bylaws:

- Stormwater Management Bylaw, Town Bylaws page 56: https://www.mendonma.gov/sites/g/files/vyhlif881/f/uploads/3.12.20_-_mendon_bylaws_3.12.2020_update_1.pdf (Town of Mendon, 2020b)
- Title 5 Regulations, Town Bylaws, Section 2.02, page 8: https://www.mendonma.gov/sites/g/files/vyhlif881/f/uploads/3.12.20_-_mendon_bylaws_3.12.2020_update_1.pdf (Town of Mendon, 2020b)
- Wetland Protection Bylaw: https://www.mendonma.gov/sites/g/files/vyhlif881/f/uploads/3.12.20_-_mendon_bylaws_3.12.2020_update_1.pdf (Town of Mendon, 2020b)
- Pet Waste: None found.
- Stormwater Utility (or similar): None found.

Mendon does not currently have a Master plan but is actively pursuing the development of one (Town of Mendon, 2020c).

The Mendon Open Space and Recreation Plan for 2013-2020 has an extensive section on water resources, surface waters, aquifer recharge areas, flood hazard areas, and wetlands. The plan provides information on water quality monitoring programs and area lake associations as well.

Open Space and Recreation Plan:
https://www.mendonma.gov/sites/g/files/vyhlif881/f/file/file/open_space_and_recreation_plan_text_2013-2020_12.28.14.pdf (Town of Mendon, 2014)

Mendon has a stormwater task force which assists the Town in developing Mendon's Stormwater Management Plan. Mendon stormwater page: https://www.mendonma.gov/storm-water-task-force (Town of Mendon, 2020d)

21. MA51-45 Cronin Brook

21.1. Waterbody Overview

Cronin Brook segment MA51-45 is 2.6 miles long and begins at its perennial headwaters west of Potter Hill Road in Grafton and flowing generally south and southeast, crossing briefly into Millbury, to end at its confluence with the pathogen-impaired Blackstone River (MA51-03) in Grafton.

Tributaries include only unnamed streams draining small ponds and wetlands. There are no other named streams, lakes, or ponds within this segment watershed.

Major landmarks in the watershed include the Millbury Street Elementary School and a small part of the large solar installation named Blackstone River Park at the southern end of the watershed. Road crossings include Millbury Street, Fitzpatrick Road (twice), Follette Street, and the access road to the solar installation.

Cronin Brook (MA51-45) drains an area of 2.9 square miles, of which 0.2 mi^2 (7%) is impervious and 0.2 mi^2 (6%) is directly connected impervious area (DCIA). The watershed is not served by public sewer[58] but the entire watershed is subject to stormwater regulations under the NPDES General MS4 Stormwater Permit (USEPA, 2020). There are no NPDES permits on file governing point source discharges of pollutants to surface waters, and no additional NPDES permits for wastewater treatment facilities. There are no groundwater discharge permits for on-site wastewater discharge, no combined sewer overflows, no landfills, and no unpermitted land disposal dumping grounds. See Figure 21-1.

Segment MA51-45 flows through a watershed of predominantly forest (64%) and wetlands (12%), in its upstream half, then sparse, low-density residential development downstream, with some agriculture (3%). There is a large agricultural parcel (MassGIS, 2016) through which the stream flows, although recent aerial photos seem to show a meadow or lawn with a thin naturalized riparian buffer a few meters wide.

Reduction from Highest Calculated Geomean: 77%

Segment Watershed Area (Acres): 1,838

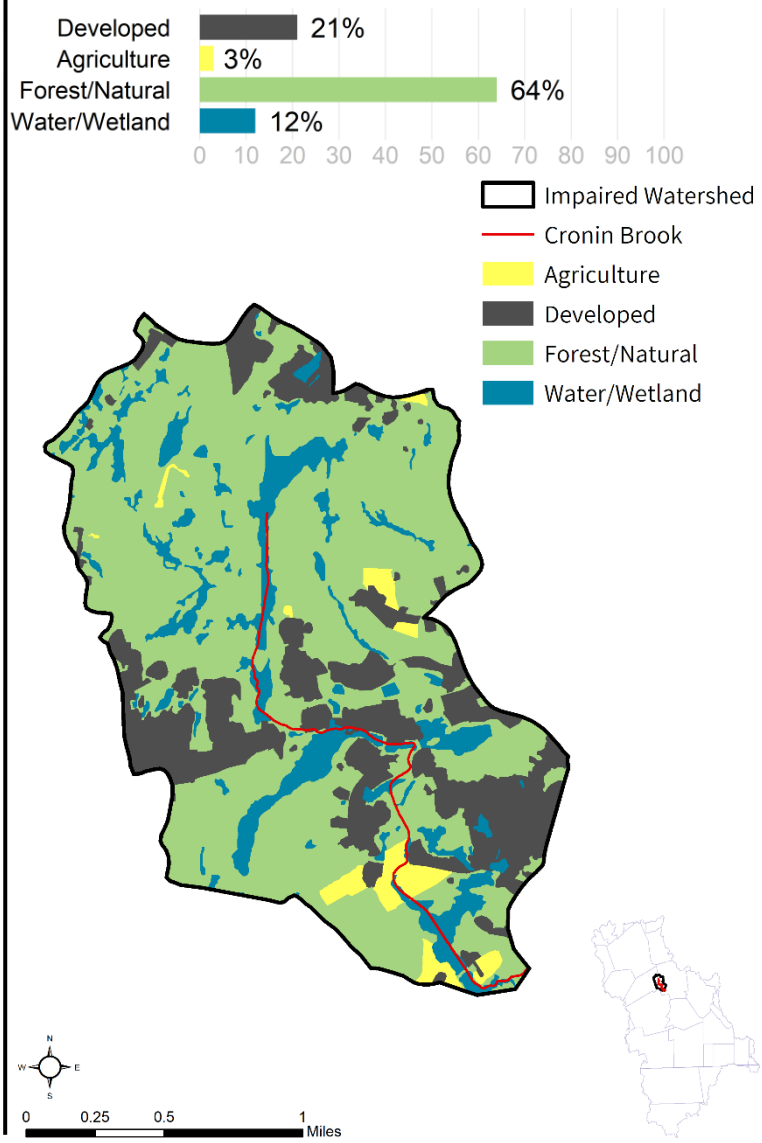
Segment Length (Miles): 2.6

Impairment(s): *E. coli* (Primary Contact Recreation)

Class (Qualifiers): B

Impervious Area (Acres, %): 137 (7%)

DCIA Area (Acres, %): 104 (6%)



[58] Estimated percentage of developed areas with wastewater infrastructure in the watershed was based on available information: MWRA service areas, MassDEP's Water Utility Infrastructure Mapping Project https://www.mass.gov/guides/water-utility-resilience-program (MassDEP 2020), MS4 reports, and local knowledge.

In the watershed of Cronin Brook (MA51-45), under the Natural Heritage and Endangered Species Program, there are 196 acres (11%) of Priority Habitats of Rare Species. There are no Areas of Critical Environmental Concern, no areas under Public Water Supply protection, and no areas identified as Outstanding Resource Waters. Over 141 (8%) of land protected in perpetuity[59] exist within the segment watershed, which is part of a total of 542 acres (29%) of Protected and Recreational Open Space[60]. See Figure 21-1.

[59] Land protected in perpetuity include several interests such as conservation restriction, agricultural preservation, private deed restrictions, wetland restrictions, aquifer protection, historic preservation, etc. Refer to Mass GIS metadata for the Protected and Recreational Open Space data layer.

[60] Only land protected in perpetuity is shown on the natural resources map. Protected and Recreational Open Space estimates reflect areas in the State of Massachusetts only (and thus reflect only a portion of the total open space for watersheds that extend outside the State of Massachusetts).

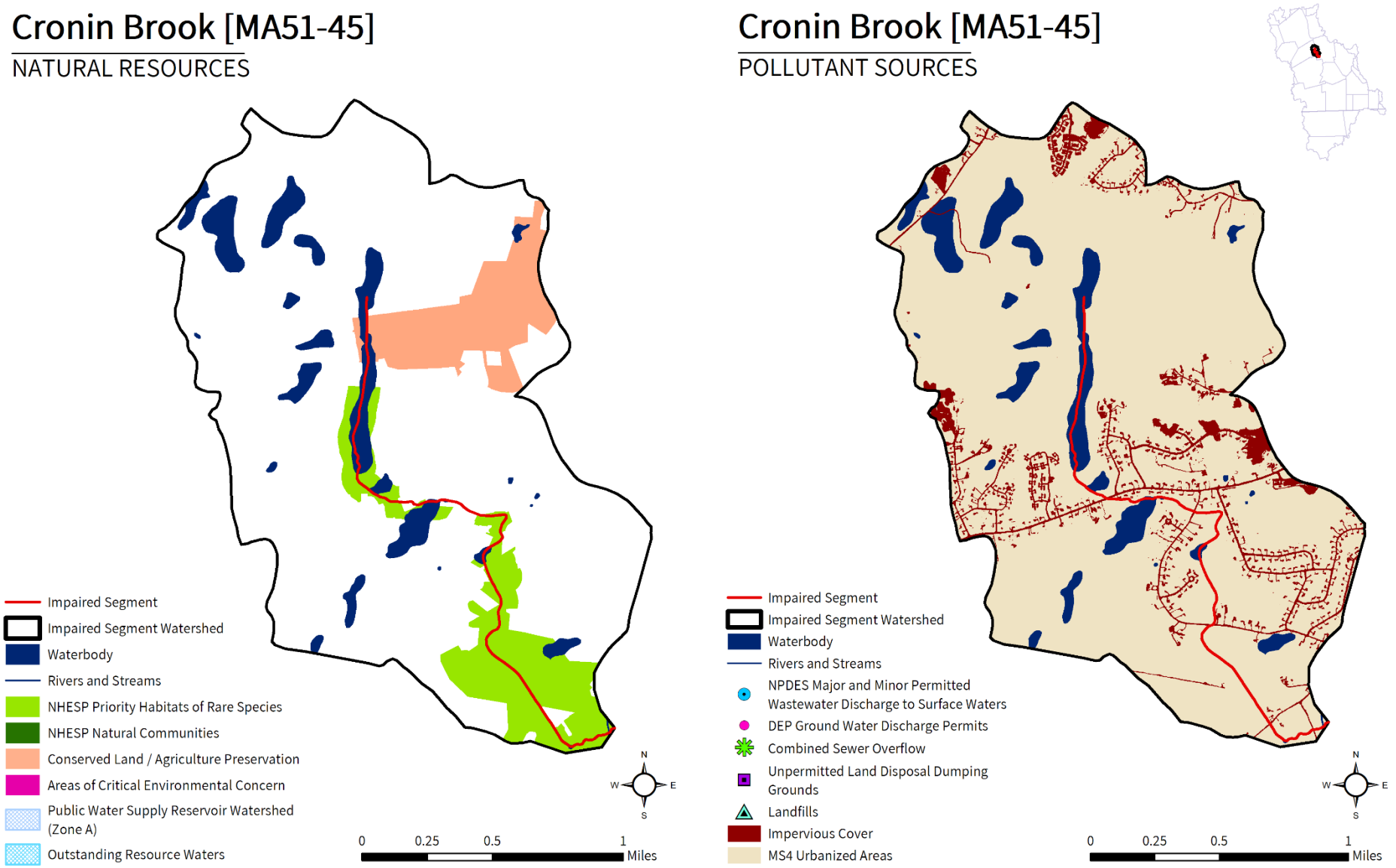


Figure 21-1. Natural resources and potential pollution sources draining to the Cronin Brook segment MA51-45. The map on the left shows critical habitat, water features, and conserved land. The map on the right indicates potential and known pollution sources, including impervious cover, MS4 areas, and permitted facilities.

21.2. Waterbody Impairment Characterization

Cronin Brook (MA51-45) is a Class B Water (MassDEP, 2021).

The Primary Contact Recreation use was assessed for attainment of SWQS using the indicator bacteria *E. coli* at the station listed below (refer to Tables 21-1, 21-2; Figure 21-2). Data were evaluated against the SWQS geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria and the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli.* The geomean and STV criteria for the impaired segment apply to data on a year-round, 90-day rolling basis.

- In 2008, six samples were collected at W1769, resulting in six days when the 90-day rolling geomean exceeded the criterion. Since there were no stations and years with more than 10 samples, the STV criterion was applied to single sample results. Out of six samples, two exceeded the STV criterion during wet weather only.

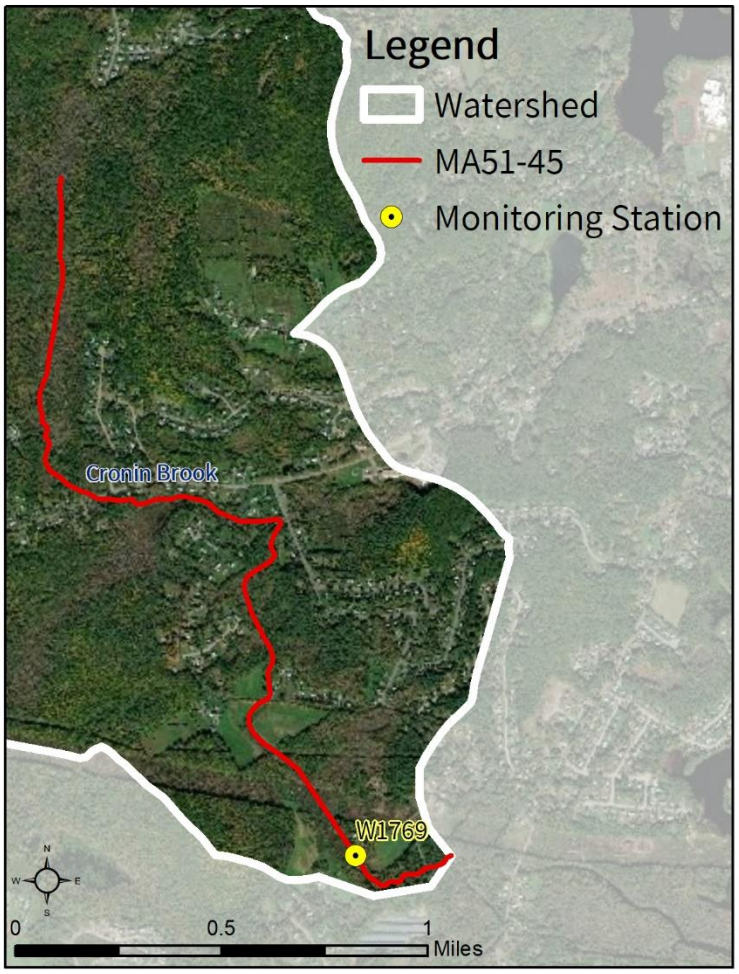


Figure 21-2. Location of monitoring station(s) along the impaired river segment.

Table 21-1. Summary of indicator bacteria sampling results by station for Cronin Brook (MA51-45). The maximum 90-day rolling geometric mean (geomean), the number of days exceeding the geomean criterion of 126 CFU/100 mL for *E. coli* indicator bacteria, and the number of single samples exceeding the Statistical Threshold Value (STV) criterion of 410 CFU/100 mL for *E. coli* indicator bacteria are shown. The STV criterion is applied to the single sample results if less than 10 samples were collected within a calendar year at a site. The highest maximum 90-day rolling geomean of the sites is used to calculate the percent load reduction required to meet SWQS.

Unique Station ID	First Sample	Last Sample	Count	Maximum 90-Day Rolling Geomean (CFU/100mL)	Number Geomean Exceedances	Number STV Exceedances
W1769	4/29/2008	8/26/2008	6	550	6	2

Table 21-2. Indicator bacteria data by station, indicator, and date for Cronin Brook (MA51-45). Each sample date was designated as representing wet or dry weather conditions with wet weather defined as more than 0.5 inches of precipitation in the previous 72 hours. Red text highlights criteria exceedances of 410 CFU/100 mL (applied to single-sample "Result" since there were no more than 10 samples in a year to calculate the Statistical Threshold Value or STV) and 126 CFU/100 mL (applied to rolling 90-day geomean) for *E. coli* indicator bacteria.

Unique Station ID	Indicator	Date	Wet/Dry	Result (CFU/100mL)	90-Day Rolling Geomean (CFU/100mL)	90-Day Rolling STV (CFU/100mL)
W1769	*E. coli*	4/29/08	WET	550	550	
W1769	*E. coli*	5/27/08	DRY	93	226	
W1769	*E. coli*	6/24/08	WET	2100	475	
W1769	*E. coli*	7/8/08	DRY	120	337	
W1769	*E. coli*	8/5/08	DRY	120	230	
W1769	*E. coli*	8/26/08	DRY	240	292	

21.3. Potential Pathogen Sources

Comparing data collected during wet weather versus dry weather conditions provides an indication of the types of sources present and information that can be used to focus pollutant reduction activities. Pathogen levels (as estimated by indicator bacteria) are usually higher in wet weather conditions as storm sewer systems overflow and/or stormwater runoff carries fecal matter that has accumulated on the landscape to the river via overland flow and stormwater conduits. Wet weather sources include wildlife and domesticated animal waste (including pets), urban stormwater runoff (including MS4 areas), CSOs, and SSOs. In other cases, dry weather pathogen and associated indicator bacteria concentrations can be high when there is a constant flow of pollutants, which then becomes diluted during periods of precipitation. Dry weather sources include leaking sewer pipes, illicit connections of sanitary sewers to storm drains, failing septic systems, recreational use (such as swimmers), and direct wildlife and domesticated animal waste (including pets).

Indicator bacteria levels for Cronin Brook (MA51-45) were elevated during wet weather. Elevated results during wet weather is consistent with urban stormwater, pet waste, and wildlife pathogen sources. Certain types of septic system malfunctions, such as rainwater infiltration or saturated disposal fields which overflow during precipitation, may also result in elevated wet weather indicator bacteria levels. Given the relatively small sample set, additional sampling under both wet and dry conditions, ideally at more than one location, would likely help in identifying pollutant sources.

Each potential pathogen source relevant to this segment is described in further detail below.

Urban Stormwater: The watershed is moderately developed, with all land area in MS4 and 6% as DCIA. The impaired segment flows through several residential neighborhoods. Stormwater runoff from urban areas is likely the most significant source of pathogens.

Illicit Sewage Discharges: With the entire watershed designated as MS4 area and served by septic systems, illicit discharges from septic systems to stormwater drains or directly to the environment are possible.

On-Site Wastewater Disposal Systems: The watershed relies on septic systems for wastewater disposal. It is likely that a portion of septic systems are not being properly maintained and are discharging untreated effluent to the environment.

Agriculture: Agriculture accounts for 3% of watershed land area, although areas adjacent to the stream do not appear to be actively farmed in recent aerial photos. Agricultural activities related to manure storage and spreading, if not well managed, are a possible source of pathogens to waterbodies.

Pet Waste: Protected and Recreational Open Space makes up a large portion (29%) of the watershed. Conservation lands, parks, and ballfields popular for dog-walking, especially where paths are adjacent to rivers, ponds, or wetlands, represent a possible source of pathogens.

Wildlife Waste: Conservation and recreational lands with large open mowed areas with a clear sightline to a waterbody may attract large congregations of waterfowl and elevate indicator bacteria counts in the water.

21.4. Existing Local Management

This section identifies the municipalities immediately surrounding the impaired segment and its sub-basin, the portion of the impaired segment watershed not shared with upstream impaired segments. For a complete view of upstream municipalities and waterbodies, see the map in Figure 2-1.

Town of Grafton. See Section 5.4.

Town of Millbury. See Section 5.4.

22. References

Aqualis. (2020) [online]. *The Town of Auburn. Excerpts from the Town of Auburn, MA Bylaws. Chapter XVII Stormwater Management.* Accessed on 12/8/2020. Available at https://www.aqualisco.com/compliance_item/town-of-auburn-2/

Canal District of Worcester. (2019) [online]. *The History. The long and storied history of the Canal District of Worcester MA*. Accessed on 12/8/2020. https://thecanaldistrict.com/the-history/

City of Worcester. (2006) [online]. *City of Worcester Open Space & Recreation Plan. 2006.* Available at http://www.worcesterma.gov/uploads/b2/cf/b2cf512db5d833bbf34e564180a42b07/open-space-plan.pdf

City of Worcester. (2019a) [online]. *City of Worcester Wetlands Protection Ordinance and Wetlands Protection Regulations.* Last amended June 24, 2019. Available at http://www.worcesterma.gov/uploads/46/04/46040c720fab869be6e1f8acb6c7ab5b/wetland-ordinance.pdf

City of Worcester. (2019b) [online]. *Integrated Water Resources Management Plan.* Department of Public Works & Parks. Worcester, MA. October 2019. Available at http://www.worcesterma.gov/cww/integrated-plan.pdf

City of Worcester. (2020) [online]. *Document Center. Parks, Recreation & Cemetery*. Available at http://www.worcesterma.gov/parks/document-center

CMRPC. (2019) [online]. *Holden Master Plan. 2019 Update.* Central Massachusetts Regional Planning Commission. For Holden, Massachusetts. Available at https://www.dropbox.com/s/j2hss4juo5t2f56/Holden%20Master%20Plan%202019.pdf?dl=0

CMRPC. (2020) [online]. *Central Massachusetts Regional Planning Commission.* Accessed on 12/8/2020. Available at http://www.cmrpc.org/

Environmental Partners. (2019) [online]. *Stormwater Management Plan.* Prepared for Milford, MA. June 2019. Available at https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/town_of_milford_stormwater_management_plan_for_comments.pdf

Geosyntec. (2019). *Watershed-Based Plan – Blackstone River watershed within the Town of Millbury.* Prepared by Millbury Department of Planning & Development and Geosyntec Consultants, Inc. March 4, 2019. Available at https://prj.geosyntec.com/MassDEPWBP/Content/ShowAcceptedPlan?pid=1399

Horsley & Witten Group, Inc. (2016) [online]. *Town of Shrewsbury Master Plan. March 3, 2016.* Prepared for Town of Shrewsbury, Massachusetts by Horsley Witten Group, Inc., RKG Associates, Inc. and McMahon Associates, Inc. Available at https://horsleywitten.com/shrewsbury/pdf/Shrewsbury%20Master%20Plan_Mar%203%202016.pdf

ILWA. (2020) [online]. *Indian Lake Watershed Association.* Available at https://www.ilwa.org/

MAPC. (2014) [online]. *Stormwater Financing/Utility Starter Kit*. Metropolitan Area Planning Council. March 23, 2014. Accessed on 12/8/2020. Available at https://www.mapc.org/resource-library/stormwater-financing-utility-starter-kit/

MAPC. (2018) [online]. *MS4 Outfall Catchment Calculator*. Metropolitan Area Planning Council. May 22, 2018. Accessed on 12/8/2020. Available at https://www.mapc.org/resource-library/ms4-outfall-catchment-calculator/

MAPC. (2020) [online]. *Metropolitan Area Planning Council*. Accessed on 12/8/2020. Available at https://www.mapc.org/

MassDEP. (2010) [online]. *Blackstone River Watershed 2003-2007 Water Quality Assessment Report*. March 2010. Report Number 51-AC-3. CN 240.0. Accessed on 12/8/2020. Available at https://www.mass.gov/doc/blackstone-river-watershed-2003-2007-water-quality-assessment-report/download

MassDEP. (2016) [online]. *Blackstone River Watershed SMART Monitoring Program 2011-2013. Technical Memorandum CN 418.0*. Accessed on 12/8/2020. Available at https://www.mass.gov/doc/Blackstone-river-watershed-smart-monitoring-program-2011-2013

MassDEP. (2020) [online]. *Water Utility Resilience Program.* Massachusetts Department of Environmental Protection. Available at https://www.mass.gov/guides/water-utility-resilience-program

MassDEP. (2021). *314 CMR 4.00: Massachusetts Surface Water Quality Standards.* Massachusetts Department of Environmental Protection. Boston, MA. Available at https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards#current-regulations

MassDEP. (2022). *Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle.* CN 505.1. Massachusetts Department of Environmental Protection, Bureau of Water Resources, Division of Watershed Management, Watershed Planning Program. Worcester, MA. Available at https://www.mass.gov/doc/final-massachusetts-integrated-list-of-waters-for-the-clean-water-act-20182020-reporting-cycle/download

MassGIS. (2016) [online]. *MassGIS Data: 2016 Land Cover/Land Use.* Massachusetts Bureau of Geographical Information. Accessed on 12/8/2020. Available at https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use

MassGIS. (2017) [online]. *MassGIS Data: MassDEP Hydrography (1:25,000).* Massachusetts Bureau of Geographical Information. Accessed on 12/8/2020. Available at https://docs.digital.mass.gov/dataset/massgis-data-massdep-hydrography-125000

TBWA. (n.d.) [online]. *Tatnuck Brook Watershed Association.* Available at https://tatnuckbrook.org/

Think Blue Massachusetts. (2019) [online]. *About Think Blue Massachusetts*. Accessed on 12/8/2020. Available at https://www.thinkbluemassachusetts.org/about-us

Tighe & Bond. (2018) [online]. *Stormwater Infrastructure.* Notice of Intent. Bellingham, Massachusetts. September 2018. Available at https://www.bellinghamma.org/sites/g/files/vyhlif2796/f/uploads/noi_drainage_infrastructure_map.pdf

Tighe & Bond. (2019) [online]. *Mendon's Stormwater Management Program.* Prepared for the Town of Mendon, MA. June 2019. Available at https://www.mendonma.gov/sites/g/files/vyhlif881/f/file/file/2019_mendon_ma.pdf

Town of Auburn (1979). *General By-laws of the Town of Auburn, Massachusetts.* Date of Passage August 20, 1979. Accessed on 12/8/2020. Available at https://www.auburnguide.com/DocumentCenter/View/486/General-By-Laws-PDF

Town of Auburn. (2016) [online]. *Town of Auburn 2014 Open Space & Recreation Plan*. Updated June 2016. Available at https://www.auburnguide.com/DocumentCenter/View/583/Approved-2014-Open-Space-Plan-PDF

Town of Auburn. (2020) [online]. *Auburn, Massachusetts.* Available at https://www.auburnguide.com/

Town of Bellingham. (n.d. a) [online]. *Article IX: Environmental Controls. § 240-54 Stormwater management.* Town of Bellingham, MA. The Code. Part I: Bylaws: Zoning. Available at https://www.ecode360.com/15958720

Town of Bellingham. (n.d., b) [online]. *Chapter 235: Wetlands Protection.* Town of Bellingham, MA . The Code. Part I: Bylaws. Available at https://www.ecode360.com/15958364#15958364

PGC Associates, Inc. (2017) [online]. *Open Space and Recreation Plan. 2017. Bellingham, Massachusetts.* Prepared for the Town of Bellingham. Available at https://www.bellinghamma.org/sites/g/files/vyhlif2796/f/uploads/open_space_plan.pdf

Town of Bellingham. (2020a) [online]. *Department of Public Works*. Bellingham, Massachusetts. Available at https://www.bellinghamma.org/department-public-works

Town of Bellingham. (2020b) [online]. *The Draft 2020 Master Plan Update is available for public comment.* Available at https://www.bellinghamma.org/home/news/draft-2020-master-plan-update-available-public-comment

Town of Blackstone. (1986) [online]. *Chapter 119: Wetlands.* Town of Blackstone, MA / Division 2: Town Meeting Enactments / Part II: General Legislation. Adopted April 29, 1976. Available at https://ecode360.com/8904497

Town of Blackstone. (1988) [online]. Chapter 188: Sewage Disposal Systems, Sanitary. Town of Blackstone, MA / Division 2: Town Meeting Enactments / Division 4: Miscellaneous Regulations. Adopted December 7, 1988. Available at https://ecode360.com/8905957

Town of Blackstone. (2011) [online]. *Chapter 110: Stormwater Management and Land Disturbance.* Town of Blackstone, MA / Division 2: Town Meeting Enactments / Part II: General Legislation. Adopted May 31, 2011. Available at https://ecode360.com/15990110

Town of Blackstone. (2018) [online]. *Master Plan. Town of Blackstone, MA. 2018.* Available at https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-master-plan.pdf

Town of Douglas. (1998) [online]. *Douglas Master Plan.* Douglas, Massachusetts. April 1998. Available at http://www.douglasma.org/cdd/mpic/docs/masterplan.pdf

Town of Douglas. (2003) [online]. *Article 8: Wetland Bylaw.* Unofficial Version of the Douglas Wetland Bylaw. Douglas, Massachusetts. August 19, 2003. Available at https://douglas-ma.gov/DocumentCenter/View/421/Wetland-Bylaw-PDF?bidId=

Town of Douglas. (2007) [online]. *Town of Douglas Open Space and Recreation Plan.* Douglas, Massachusetts. November 2007. Available at http://www.douglasma.org/cdd/os/reports/071130-openspaceplan.pdf

Town of Douglas. (2008) [online]. *Town of Douglas General Bylaws*. Adopted: January 1, 1974. Updated May, 2008. Douglas, Massachusetts. Available at http://www.douglasma.org/general/General_Bylaws_May2008.pdf

Town of Grafton. (n.d., a.) [online]. *Pick up the Poop and Protect Grafton's Ponds, Lakes, Rivers, Brooks and Community Health*. Available at https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/pick_up_the_pet_waste_4-17-2012.pdf

Town of Grafton. (n.d., b.) [online]. *Stormwater (NPDES) Phase II Information.* Grafton, Massachusetts. Available at https://www.grafton-ma.gov/department-public-works-engineering/pages/stormwater-npdes-phase-ii-information

Town of Grafton. (2001) [online]. *Town of Grafton Massachusetts 2001 Comprehensive Plan*. Available at https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/2001_master_plan.pdf

Town of Grafton. (2013) [online]. *Stormwater Bylaw*. Town of Grafton. Conservation Commission. Available at https://www.grafton-ma.gov/conservation-commission/pages/stormwater-bylaw

Town of Grafton. (2019) [online]. *Draft Open Space and Recreation Plan Draft Plan – 2019*. Open Space & Recreation Committee. Available at https://www.grafton-ma.gov/open-space-recreation-committee/pages/draft-open-space-and-recreation-plan

Town of Grafton. (2020a) [online]. *Town of Grafton Stormwater Management Program.* EPA NPDES Permit Number MAR041119. Updated June 30, 2020. Available at https://www.grafton-ma.gov/sites/g/files/vyhlif4461/f/uploads/swmp-grafton-2020-final-compiled.pdf

Town of Grafton. (2020b) [online]. *Grafton, Massachusetts.* Available at https://www.grafton-ma.gov/

Town of Holden. 1999 [online]. *Chapter 5.0 Board of Health Title 5.* Board of Health Regulations. Requirements for the Subsurface Disposal of Sanitary Sewage. Holden, Massachusetts. Town Clerk. Available at https://www.holdenma.gov/town-clerk/pages/chapter-50-board-of-health-title-5

Town of Holden. (2020) [online]: *2020 Open Space and Recreation Plan.* Holden, Massachusetts. Open Space and Recreation Committee. Available at https://www.holdenma.gov/open-space-and-recreation-committee

Town of Hopedale. (2014) [online]. *Town of Hopedale Massachusetts. Zoning Bylaws.* Planning Board. August 24, 2014. Available at https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/uploads/hopedale_zoning_by_laws_v2.0.pdf

Town of Hopedale. (2020) [online]. *Master Plan Steering Committee*. Hopedale, Massachusetts. Available at https://www.hopedale-ma.gov/master-plan-steering-committee

Town of Leicester. (2009) [online]. *Leicester Master Plan 2009.* Available at https://www.leicesterma.org/sites/g/files/vyhlif781/f/uploads/2009mp.pdf

Town of Leicester. (2015) [online]. *2015 Open Space & Recreation Plan*. Leicester, MA. February 2015. Available at https://www.leicesterma.org/planning/pages/2015-open-space-recreation-plan

Town of Leicester. (2015) [online]. *Leicester Conservation Commission Rules and Regulations For Administering The Town of Leicester Wetlands Protection Bylaw*. Town of Leicester, MA. Effective May 6, 2009, revised November 18, 2015. Available at https://www.leicesterma.org/sites/g/files/vyhlif781/f/uploads/leicester_wetland_regulations_11-18-2015_-_copy_1.pdf

Town of Leicester. (2020) [online] *Zoning Bylaws & Map*. Leicester, Massachusetts. Planning Department. Available at https://www.leicesterma.org/planning-board/pages/zoning-bylaws-map

Town of Mendon. (2014) [online]. *Open Space and Recreation Plan. Mendon, Massachusetts. 2013-2020.* Updated December 28, 2014. Available at https://www.mendonma.gov/sites/g/files/vyhlif881/f/file/file/open_space_and_recreation_plan_text_2013-2020_12.28.14.pdf

Town of Mendon. (2020a) [online]. *Stormwater Task Force.* Mendon, Massachusetts. Available at https://www.mendonma.gov/storm-water-task-force

Town of Mendon. (2020b) [online]. *General By – laws of the Town of Mendon, Massachusetts*. Updated March 12, 2020. Available at https://www.mendonma.gov/sites/g/files/vyhlif881/f/uploads/3.12.20_-_mendon_bylaws_3.12.2020_update_1.pdf

Town of Mendon. (2020c) [online]. *Master Plan Committee.* Mendon, Massachusetts. Available at https://www.mendonma.gov/master-plan-committee#:~:text=What%20is%20a%20Master%20Plan,and%20development%20of%20the%20community.

Town of Mendon. (2020d) [online]. *Storm Water Task Force.* Mendon, Massachusetts. Available at https://www.mendonma.gov/storm-water-task-force

Town of Milford. (n.d.) [online]. *Article 33: Wetlands Administration Bylaw*. Milford, Massachusetts. Available at https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/wetlands_bylaw.pdf

Town of Milford. (2003) [online]. *Milford Comprehensive Plan 2003.* Milford, Massachusetts. Available at https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/milford_comprehensive_plan_2003.pdf

Town of Milford. (2003) [online]. *Milford Township Comprehensive Park & Recreation Plan 2003.* Milford, Massachusetts. Available at https://milfordtownship.org/wp-content/uploads/2018/08/park_plan.pdf

Town of Milford. (2005) [online]. *Town of Milford, Massachusetts. Stormwater Management General By-law*. Adopted October 24, 2005. Available at https://www.milfordma.gov/sites/g/files/vyhlif3466/f/uploads/stormwater_management_by_law.pdf

Town of Milford. (2018) [online]. *What Is Stormwater?* Milford, Massachusetts. Available at https://www.milfordma.gov/planning-engineering/pages/what-stormwater

Town of Millbury. (n.d.) [online]. *MS4 (Stormwater). Municipal Separate Stormwater Sewer Systems.* Millbury, Massachusetts. Public Works Department. Available at https://www.millbury-ma.org/public-works/pages/ms4-stormwater

Town of Millbury. (2008) [online]. *Open Space & Recreation Plan*. Millbury, Massachusetts. Planning & Development. Available at https://www.millbury-ma.org/public-works/pages/ms4-stormwater

Town of Millbury. (2010) [online]. *Subdivision Rules and Regulations.* Section 6: Design Standards. Subsection 6.17: Stormwater Management. Millbury, Massachusetts. Planning & Development. Updated December 13, 2010. Available at https://www.millbury-ma.org/sites/g/files/vyhlif4706/f/uploads/section6_0.pdf

Town of Millbury. (2019) [online]. *Master Plan Committee.* Millbury, Massachusetts. Available at https://www.millbury-ma.org/master-plan-committee

Town of Millville. (n.d.) [online] *Stormwater.* Douglas, Massachusetts. Highway Department. Available at https://www.millvillema.org/highway-department/pages/%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8B%E2%80%8Bstormwater

Town of Millville. (2009) [online]. *Town of Millville Stormwater Management Regulations*. Millville, Massachusetts. Adopted October 26, 2009. Available at https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/stormwater-management-regulations.pdf

Town of Millville. (2013) [online]. *Chapter 95 Wetlands.* Town of Millville, MA . Part II: General Legislation Adopted by the Town Meeting of the Town of Millville 5-13-2013. Available at https://ecode360.com/15640276

Town of Millville. (2018a) [online]. *Master Plan. Town of Millville, MA. 2018*. Millville, Massachusetts. Available at https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-master-plan.pdf

Town of Millville. (2018b) [online]. *Town of Millville Open Space & Recreation Plan 2018.* Millville, Massachusetts. Available at https://www.millvillema.org/sites/g/files/vyhlif906/f/uploads/millville-open-space-recreation-plan-.pdf

Town of Northbridge. (1994) [online]. *A Master Plan for the Town of Northbridge, Massachusetts.* Adopted by the Northbridge Planning Board April 27, 1994. Available at https://www.northbridgemass.org/sites/g/files/vyhlif981/f/u71/1994_master_plan.pdf

Town of Northbridge. (1999) [online]. *Division 1: Code of Bylaws* Section 10-100: Sewers. Public Works Department. Northbridge, Massachusetts. Available at https://www.ecode360.com/14688505

Town of Northbridge. (2002) [online]. *Open Space & Recreation*, Community Planning & Development. Northbridge, Massachusetts. Available at https://www.northbridgemass.org/community-planning-development/pages/open-space-recreation

Town of Northbridge. (2008a) [online]. *Section 7-800. Stormwater Management Bylaw.* Town of Northbridge, MA. Division 1: Code of Bylaws. Regulations Governing the Use of Private Property. Adopted May 6, 2008. Available at https://ecode360.com/14688329

Town of Northbridge. (2008b) [online]. *Section 7-700. Wetlands Protection Bylaw.* Town of Northbridge, MA. Adopted May 6, 2008. Available at https://www.northbridgemass.org/sites/g/files/vyhlif981/f/file/file/proposed_wetland.pdf

Town of Paxton. (n.d.) [online]. *Dog Waste.* Town of Paxton, Massachusetts. Available at https://www.townofpaxton.net/stormwater-awareness/pages/dog-waste

Town of Paxton. (2008) [online]. *Master Plan.* Town of Paxton, Massachusetts. Master Plan Implementation Committee. September 25, 2008. Available at https://www.townofpaxton.net/sites/g/files/vyhlif4846/f/uploads/paxton_introduction_and_goal_statement_chapter.pdf

Town of Paxton. (2013) [online]. *Open Space Plan.* Town of Paxton, Massachusetts. Available at https://www.townofpaxton.net/open-space-recreation-committee/pages/open-space-plan

Town of Paxton. (2018) [online]. *Town of Paxton Wetlands Protection Bylaw*. Last amended May 7, 2018. Available at https://www.townofpaxton.net/sites/g/files/vyhlif4846/f/uploads/paxtonwetlandsbylaw.pdf

Town of Paxton. (2019) [online]. *Town of Paxton Storm Water Bylaw.* Town of Paxton, Massachusetts. Accepted May 6, 2006 (Amended May 6, 2019. Available at https://www.townofpaxton.net/sites/g/files/vyhlif4846/f/uploads/storm_water_bylaw_amend._5.6.19_read_only_.pdf

Town of Paxton. (2020) [online]. *Storm Water Awareness*. Town of Paxton, Massachusetts. Available at https://www.townofpaxton.net/advanced-search?keywords=storm%20water&f%5B0%5D=og_group_ref%253Atitle%3AStormwater%20Awareness

Town of Shrewsbury. (2012) [online]. Shrewsbury Open Space & Recreation Plan. Shrewsbury, Massachusetts 2012. With assistance from the Central Massachusetts Regional Planning Commission. Available at https://shrewsburyma.gov/DocumentCenter/View/323/2012-Open-Space-and-Recreation-Plan-PDF

Town of Shrewsbury. (2019a) [online]. *Town of Shrewsbury Stormwater Management Rules & Regulations*. Shrewsbury, Massachusetts. Adopted February 19, 2019. Revised February 19, 2019. Available at https://shrewsburyma.gov/DocumentCenter/View/4595/Stormwater-Management-Rules-and-Regulations?bidId=

Town of Shrewsbury. (2019b) [online]. *Town of Shrewsbury Stormwater Utility Rates*. Shrewsbury, Massachusetts. Department of Public Works. Adopted February 19, 2019. Effective July 1, 2019. Available at https://shrewsburyma.gov/DocumentCenter/View/4667/Stormwater-Utility-Rates

Town of Shrewsbury. (2019c) [online]. *General By-Laws of the Town of Shrewsbury*. Shrewsbury, Massachusetts. Amended through Nov. 6, 2019. Available at https://shrewsburyma.gov/DocumentCenter/View/5624/General-Bylaws-Nov-6-2019?bidId=

Town of Shrewsbury. (2020a) [online]. *Entering Shrewsbury Massachusetts.* Available at https://shrewsburyma.gov/

Town of Shrewsbury. (2020b) [online]. *Stormwater Management.* Shrewsbury, Massachusetts. Department of Public Works. Engineering & Conservation Division. Available at https://shrewsburyma.gov/803/Stormwater-Management

Town of Sutton. (2012) [online]. Elements of the Master Plan. Sutton, Massachusetts. Planning Board. Available at https://www.suttonma.org/planning-board/pages/master-plan-2012

Town of Sutton. (2013) [online]. *Town of Sutton Open Space & Recreation Plan: 2013-2020*. Sutton, Massachusetts. Planning Department. Available at https://www.suttonma.org/sites/g/files/vyhlif3901/f/uploads/osrp.pdf

Town of Sutton. (2019) [online]. *General Bylaws. Sutton, Massachusetts.* With Amendments through May 2019. Available at https://www.suttonma.org/sites/g/files/vyhlif3901/f/uploads/general_bylaws_2019_05.pdf

Town of Upton. (n.d.) [online]. *Stormwater Management.* Town of Upton, Massachusetts. Conservation Commission. Available at https://www.uptonma.gov/conservation-commission/pages/stormwater-management

Town of Upton. (2004) [online] *Wetlands Protection Bylaw*. Upton, Massachusetts. Adopted May 1, 2004. Available at https://www.uptonma.gov/sites/g/files/vyhlif5121/f/uploads/upton_wetland_bylaw.pdf

Town of Upton. (2005) [online]. *Upton Master Plan.* Upton, Massachusetts. Adopted July 2005. Upton Master Plan Sub-Committee. Daylor Consulting Group, Inc. Central Massachusetts Regional Planning Commission. Available at https://www.uptonma.gov/sites/g/files/vyhlif5121/f/pages/supp_03_upton_master_plan_adopted_july_2005.pdf

Town of Upton. (2014) [online]. *Stormwater Regulations*. Upton, Massachusetts. Version 7/11/2014. Available at https://www.uptonma.gov/sites/g/files/vyhlif5121/f/uploads/stormwater_regulations.pdf

Town of Upton. (2020a) [online]. *Town of Upton, Massachusetts.* Available at https://www.uptonma.gov/

Town of Upton. (2020b) [online]. *Town of Upton Open Space and Recreation Plan.* June 2020. Upton, Massachusetts. Upton Conservation Commission. Upton Open Space Committee. Available at https://www.uptonma.gov/sites/g/files/vyhlif5121/f/pages/osrp_final_june_2020_wo_fig_app.pdf

Town of Uxbridge. (2019) [online]. *Town of Uxbridge Regulations Governing Stormwater Management.* Uxbridge, Massachusetts. Planning Board. Adopted June 26, 2019. Available at https://www.uxbridge-ma.gov/sites/g/files/vyhlif3971/f/uploads/stormwater_regulations.pdf

Town of Uxbridge. (2020) [online]. *Stormwater Committee.* Uxbridge, Massachusetts. Available at https://www.uxbridge-ma.gov/stormwater-committee

Town of West Boylston. (n.d.) [online]. *Stormwater Management.* West Boylston, Massachusetts. Available at https://www.westboylston-ma.gov/public-works/pages/stormwater-management

Town of West Boylston. (2005) [online]. *Master Plan of the Town of West Boylston.* Available at https://www.westboylston-ma.gov/town-wide-planning/pages/master-plan

Town of West Boylston. (2018a) [online]. *Town of West Boylston. Zoning Bylaws. Amended October 18, 2018.* Available at https://www.westboylston-ma.gov/sites/g/files/vyhlif1421/f/uploads/zoning_bylaws_2018.10.15-_6_14.pdf

Town of West Boylston. (2018b) [online]. *Open Space Implementation Committee.* Available at https://www.westboylston-ma.gov/open-space-implementation-committee

Town of West Boylston. (2020) [online]. *Town of West Boylston General Bylaws.* Oct. 17, 2020. Available at https://www.westboylston-ma.gov/sites/g/files/vyhlif1421/f/uploads/2020.10.17_gen_bylaws_master1.pdf

UMass Amherst. (1992) [online]. *A Bright Future, Rich In History. A Master Plan Update for the Town of Uxbridge, Massachusetts.* University of Massachusetts, Amherst. Department of Landscape Architecture and Regional Planning. Spring 1992. Available at https://www.uxbridge-ma.gov/sites/g/files/vyhlif3971/f/uploads/1992_master_plan_a_bright_future_rich_in_history.pdf

USEPA (2020). General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts, United States Environmental Protection Agency. Region 1. National Pollutant Discharge Elimination System (NPDES). Permit issue date April 4, 2016. Modified December 7, 2020. Available at https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp-mod.pdf

USGS. (2019) [online]. *The National Map.* United States Geological Survey. Accessed on 12/8/2020. Available at https://viewer.nationalmap.gov/advanced-viewer/

Weston & Sampson. (2020) [online]. *Illicit Discharge Detection and Elimination. MS4 General Permit Compliance. Town of Hopedale, Massachusetts.* June 2020. Available at https://www.hopedale-ma.gov/sites/g/files/vyhlif711/f/pages/hopedale_idde_plan_06262020.pdf