



Merrimack River Watershed Council
Water Quality Monitoring Program
2020 Year-End Report



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1. Abstract

This report discusses the water quality program run by the Merrimack River Watershed Council (MRWC). The results presented were collected from July to November of 2020. The data were collected at 10 sites along the Merrimack River. MRWC collected data on dry and wet weather days and following combined sewer overflows (CSOs). The team collected additional data in Methuen to investigate high levels of *E. coli* found in this area. The results collected from this sampling program were used to validate a pilot predictive model developed by Brown and Caldwell for the City of Newburyport.

2. Introduction

a. Background

Bacteria in water bodies present a serious threat to local communities. High bacteria levels make recreational activities, such as swimming or boating, potentially unsafe. Furthermore, research has shown CSOs discharging into water bodies used for recreational use can lead to a higher risk of water-borne illness. [1] High bacteria concentrations can result from several sources, including stormwater, illicit sewer connections and agricultural runoff. Some of the highest peaks of bacterial contamination come from combined sewer overflows (CSOs).

CSOs discharge large volumes of untreated sewage and stormwater into the Merrimack River, drastically impacting valuable downstream water quality and habitat. These effects are expected to be compounded by future climate change-induced increases in rainfall event frequency and severity, as well as increases in surface water temperatures. In light of the staggering 800 million gallons of untreated wastewater released into the Merrimack in 2018, MRWC recognized the need to fill critical data and education gaps with a renewed water monitoring effort in our 303(d) bacteria-impaired Merrimack River. Since the passage of the Clean Water Act in 1972 [2], the dozens of industrial facilities and wastewater treatment plants that still rely on the Merrimack and its tributaries as receiving water bodies for their waste, are required to meet federal regulations for the effluent they discharge. A notable exception to this law is the untreated sewage, stormwater, and industrial waste that drains directly into the Merrimack from CSO events during heavy rainfall, introducing pathogens and other harmful contaminants to surface water bodies where people swim, fish, and boat. This has a marked effect on the shellfish harvest, which saw a 40% decline in 2018, linked in part to the increased CSO releases [3] and degrades habitat for species such as the endangered shortnose sturgeon [4]. Five communities along the mainstem of the Merrimack River—Manchester and Nashua, NH, and Lowell, Lawrence, and Haverhill, MA—are home to a total of more than 50 combined sewer outfalls. The cost to eliminate CSO events by separating the stormwater and sewage inputs is prohibitive for these post-industrial cities—on the order of hundreds of millions to billions of dollars. As it is, the long-term control plans developed to meet the standards of the Clean Water Act will cost hundreds of millions of dollars and are projected to take decades to implement. Climate change projections anticipate more frequent and intense rainfall events in New England—the exact conditions under

which CSO events occur. As long as the problem of CSOs remains a reality, downstream towns and ecological communities are at risk. Any gaps in data, education, and municipal coordination, will only serve to prolong the time to meaningful action and weaken any adaptation efforts.

b. Bacteria Testing

To address the serious threat to human and ecological health posed by CSO events, in 2020 the MRWC renewed its monitoring program in the Merrimack River. With the help of trained volunteers, MWRC monitored the *E. coli* and *Enterococcus* concentrations in the river on dry and wet weather days and following CSOs. Sampling on dry days was used to study the baseline concentrations of bacteria in the river. The sampling days following CSO-triggering rainstorms were selected to collect data to determine the effects of CSOs on the bacteria concentrations in the river. MRWC uses the collected data to better inform citizens about the safety of the Merrimack and develop predictive models that will provide more accurate safety recommendations.

The bacteria tested for were *E. coli* and *Enterococcus*, as these two bacteria serve as reliable indicators of contamination from untreated sewage. The samples were collected by local volunteers. The samples were either collected from bridges using a rope and bucket or from the shore. Once collected, the volunteers brought the samples to a central location, packed them with ice, and transported them to an EPA-approved laboratory for analysis. Due to issues with the COVID19 pandemic, and computer virus issues at one of the laboratories, three different laboratories were used to analyze the samples during 2020 (see Table 1 below). The resulting data were then reviewed for reasonableness to expected range and completeness, before being analyzed and presented in this report. It should be noted that the laboratories used different EPA-approved methods for determining the bacteria concentrations. Due to this fact, results from Alpha Analytical are reported as most probable number per 100 milliliters (MPN/100mL) and the results from the other laboratories are reported as colony forming units per 100 milliliters (CFU/100mL). These two units are equivalent and only indicate how the result was calculated. The results were compared to the limits specified in the MA Surface Water Quality Standards that were put in place to satisfy the Clean Water Act and enforced by the US EPA. For *E. Coli* and *Enterococcus*, the limits for beaches are 235 CFU/100mL and 61 CFU/100mL, respectively. [5]

Table 1: Laboratories and sampling days each laboratory was used to analyze samples.

Laboratory	Location	Method	Sampling Dates
Alpha Analytical	8 Walkup Dr, Westborough, MA 01581	121,9223B 102,ENTEROLER	7/16/2020
Analytical Balance Corporation	422 W Grove St, Middleborough, MA 02346	EPA 1604 EPA 1600	7/23/2020 - 7/27/2020
Nashoba Analytical LLC	31 Willow Rd, Ayer, MA 01432	EPA 1603 EPA 1600	8/5/2020 - 12/31/2020

c. Other Water Quality Parameters

In addition to collecting water samples for bacteria analysis, onsite water quality measures were taken using handheld meters. Each volunteer was provided with a Pocket Pro+ Multi 2 Tester to measure 5 parameters: 1) pH, 2) conductivity, 3) total dissolved solids (TDS), 4) salinity, and 5) temperature. Prior to testing, the meters were calibrated to ensure accuracy. At each site, 3 samples were collected, to ensure precision of the measurements. At saltwater sites, the volunteers were trained to properly dilute samples and accordingly adjust measurement calculations, since the probes do not operate with high levels of salt. The volunteers recorded data on datasheets provided by MRWC and results were transcribed into Excel for analysis.

3. Sampling Sites

During 2020, 10 sites were identified for sampling. The sites were distributed along the Merrimack River from Lowell down to the river’s mouth, at Plum Island (Newburyport) and Salisbury Beach State Reservation (Salisbury). The sites were selected to be easily accessible by volunteers while providing a representative picture of the water quality along the length of the lower river. All 10 sites were tested for *E. coli*. Furthermore, the 4 sites closest to the ocean were tested for *Enterococcus*, as this bacterium has been shown to be a more effective indicator of bacteria in salt water. A full list of the sites and their locations is provided in Figure 1 and Table 2. At two of the sites, 285 Lincoln Ave (Haverhill) and Bridge Road (Newburyport), sampling was performed both from bridges and from nearby docks. This was done to determine if there was a significant difference between sampling from the center and edge of the river. In the tables in the next section, the bacteria measurements from these sites are denoted with “Bridge” or “Dock” to specify where the samples were collected.

Table 2: Summary of sampling locations and abbreviations, GPS coordinates, and bacteria of interest

Site	Site Abbreviation	GPS Coordinates	Bacteria
Lowell - Pawtucket Boulevard	LPB	42.6411911, -71.3460007	E. Coli
Dracut - Heav’nly Donuts	DHD	42.6585413, -71.2625371	E. Coli
Lawrence – Bashara Boathouse	LBB	42.69238, -71.17673	E. Coli
Methuen - 81 Riverview Blvd	MRB	42.7273583, -71.1290352	E. Coli
Haverhill - 285 Lincoln Ave, Bridge	HLAB	42.7642673, -71.0345758	E. Coli
Haverhill - 285 Lincoln Ave, Dock	HLAD	42.768307, -71.032042	E. Coli
West Newbury – Ferry Park	WNFP	42.8101931, -70.9963550	E. Coli

Amesbury - Deer Island	ADI	42.8348062, -70.9068175	E. Coli Enterococcus
Newburyport - Bridge Road, Bridge	NBRB	42.816901, -70.871739	E. Coli Enterococcus
Newburyport - Bridge Road, Dock	NBRD	42.816008, -70.871260	E. Coli Enterococcus
Newburyport - Plum Island Lighthouse	NPIL	42.81681, -70.8199290	E. Coli Enterococcus
Salisbury - Salisbury Beach State Reservation	SBSR	42.8218847, -70.8212684	E. Coli Enterococcus

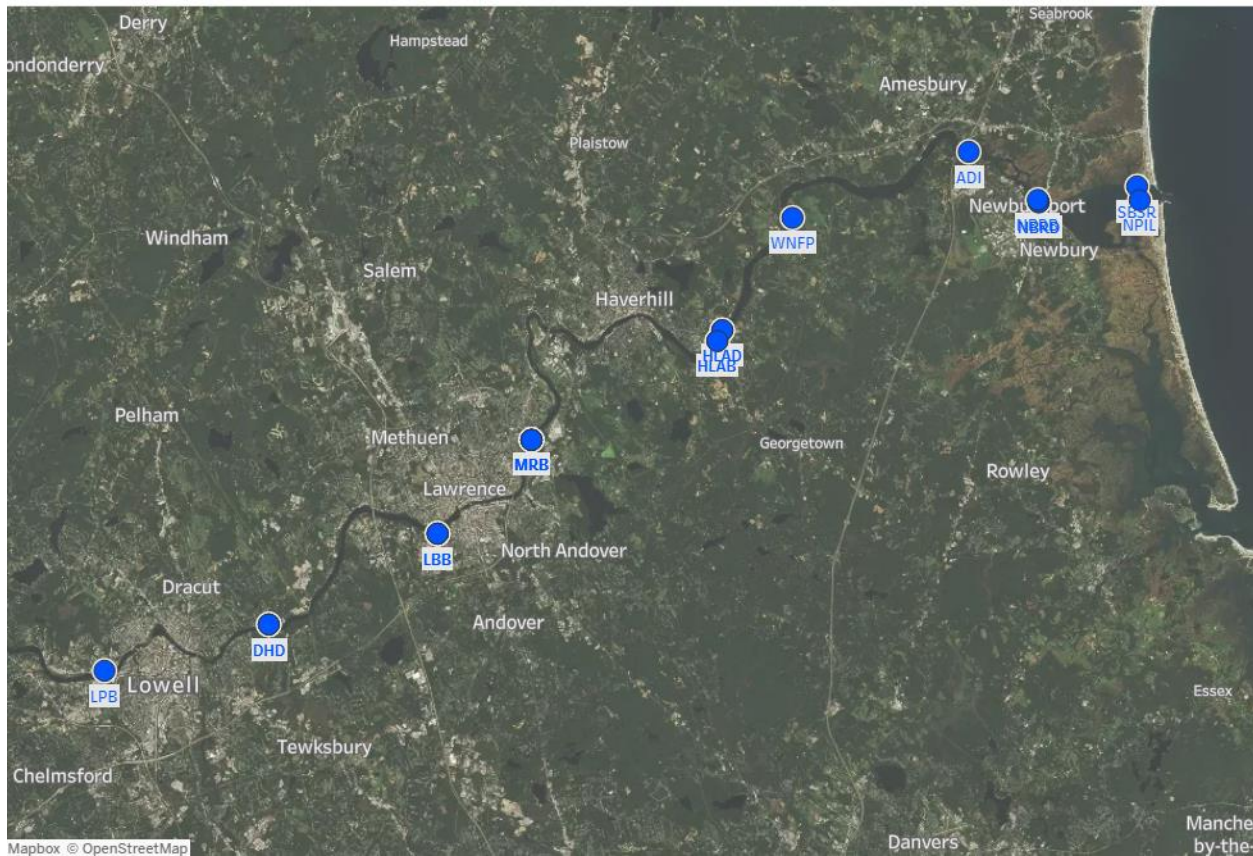


Figure 1: Map of sampling sites.

4. Results and Data

a. Onsite Water Quality Data

Plots of the 5 measured water quality parameters (temp, pH, TDS, specific conductivity, salinity) are provided below. The data shows a relatively constant temperature along the length of the river, with a slight decrease towards the mouth of the river. The pH was also relatively constant, ranging from 6.65 to 9.27. Slightly more acidic conditions were observed from river mile 16 to 26

(Methuen to Haverhill). The other three parameters, TDS, specific conductance, and salinity did show dramatic increases towards the mouth of the river. This was expected due to salt water from the ocean. Interestingly, there is a significant increase in the range of values of TDS, specific conductance, and salinity observed at Deer Island in Amesbury and Bridge Road in Newburyport. This is believed to be the result of changes in the salt content caused by the cycles of the tides.

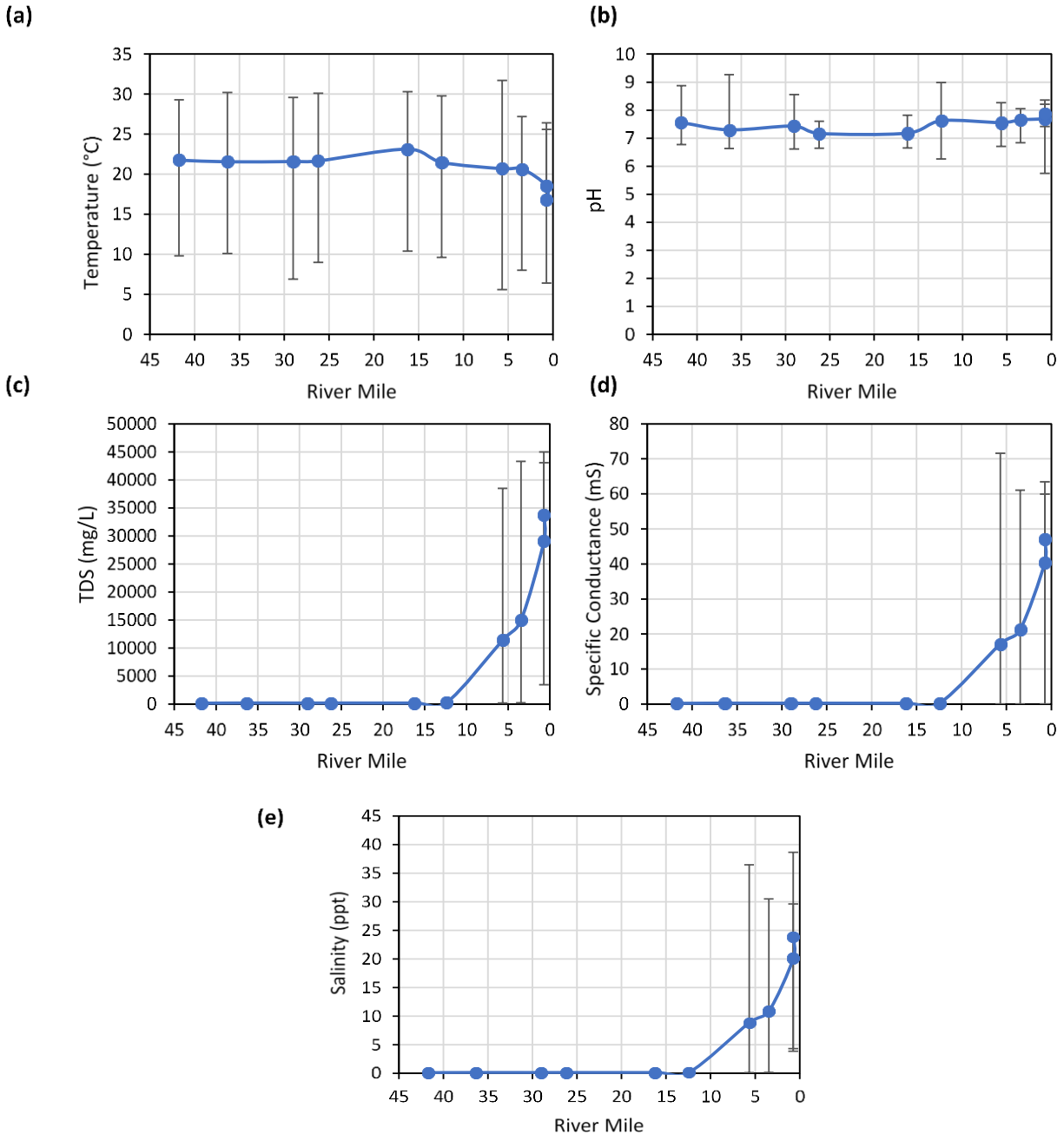


Figure 2: Plots of the average values of (a) temperature, (b) pH, (c) TDS, (d) specific conductivity, and (e) salinity collected from 7/16/2020 to 11/13/2020. Error bars represent the range between the maximum and minimum values recorded at each site.

b. CSO Bacteria Data

During this year, sampling was performed during 4 CSO events. CSO 1 and CSO 3 were relatively large rain events which triggered releases in at least 3 municipalities. The storms that triggered CSO 2 and CSO 4 had less rainfall in the areas surrounding the Merrimack, resulting in only Haverhill releasing untreated sewage. It should be noted that CSO 1 was the result of several thunderstorms, that triggered multiple releases over two days. See Table 3 below for a summary of each CSO event.

Table 3: List of CSO events that occurred after the start of the sampling program. Included is the date and what towns discharged.

CSO Number	Date	Did Discharge Occur?				
		Manchester	Nashua	Lowell	Lawrence	Haverhill
1	7/22/2020 to 7/23/2020	No	Yes	Yes	Yes	Yes
2	8/4/2020	No	Not Yet Reported	No	No	Yes
3	9/10/2020	No	Not Yet Reported	Yes	Yes	Yes
4	10/13/2020	No	Not Yet Reported	No	No	Yes

From the CSO data collected, several trends were observed. For CSO 1, high concentrations of bacteria were observed during three days of sampling, though a significant decrease in concentration was observed by 7/27/20, three days after the end of the CSO. During CSO 1, there were multiple releases of untreated sewage from several wastewater treatment plants, which made it difficult to directly track the movement of the untreated sewage down the river.

In comparison, CSO 2 was relatively simple, with only Haverhill releasing untreated sewage. Interestingly, on the first sampling day for this CSO (8/5/20), the highest concentration, 4150 CFU/100mL, was detected at 81 Riverview Blvd, Methuen, which is upstream of the only reported discharging municipality- Haverhill. The following day (8/6/20) an elevated concentration, 1048 CFU/100mL, was observed at Ferry Park in West Newbury, suggesting the bacteria observed in Methuen the previous day and/or the bacteria from the Haverhill plant had moved down the river to West Newbury. By the third sampling day (8/7/20), the bacteria observed in West Newbury had moved through the river to the ocean or had decayed down to levels not significantly higher than the bacteria concentrations found elsewhere in the river.

Due to limitations in laboratory availability for testing (all are closed on weekends), following CSO 3, the team had to wait until the fourth and fifth day following the CSO to collect samples. The team was expecting to see elevated bacteria levels towards the mouth of the river, due to the sewage from the CSO having travelled downstream over time. Surprisingly, the locations close to the mouth of the river (Newburyport, Salisbury, and Amesbury) had low levels of bacteria, suggesting the bacteria from the CSO had decayed or moved out into the ocean. Due to the extremely low flow in the river at the time, the bacteria concentrations decaying away is considered more likely. Interestingly, concentrations exceeding the Massachusetts Surface Water Quality Standards [5] for *E. coli* (235 CFU/100mL) were found in Methuen on both days and in Lawrence on the first sampling day (9/14/2020). While these elevated levels may have been the result of residual bacteria from CSO 3, it is more likely there is a non-CSO source for these unsafe levels of bacteria.

Similar to CSO 2, during CSO 4 only Haverhill released untreated sewage. The CSO occurred on 10/13/2020 and samples were collected the following three days. On the first day of sampling (10/14/2020) high concentrations were observed in Dracut, Amesbury, and Newburyport with 480 to 490 CFU/100mL. These high levels were attributed to factors other than the CSO, as Dracut is significantly upstream from the CSO and Amesbury and Newburyport are far enough downstream that the bacteria from the CSO had likely not reached these areas yet. On the second day (10/15/2020) a spike in *E. coli* concentration was observed at Ferry Park in West Newbury. Since there was no additional rain or CSO events, this spike was attributed to the bacteria from Haverhill arriving in West Newbury. By the third sampling day (9/16/2020), the bacteria from the Haverhill CSO was not observed. There were slightly elevated levels of bacteria in Methuen (420 CFU/100 mL) and Haverhill (300 CFU/100mL). These levels were attributed to the rain (0.43 in) that occurred on that day which may have introduced bacteria from other non CSO sources into the river.

Table 4: Bacteria Data from the first CSO event. Values exceeding the EPA limits for Surface Water Quality Standards are highlighted in red.

Site	CSO#1: (discharged 7/22/2020 to 7/23/2020)					
	E. coli			Enterococcus		
	7/23/2020: (day of)	7/24/2020: (+1 day)	7/27/2020: (+3 days)	7/23/2020: (day of)	7/24/2020: (+1 day)	7/27/2020: (+3 days)
Lowell - Pawtucket Boulevard	60	30	60	-	-	-
Dracut - Heav'nly Donuts	>2000	500	50	-	-	-
Lawrence – Bashara Boathouse	30	300	<10	-	-	-
Methuen - 81 Riverview Blvd	800	>2000	800	-	-	-
Haverhill - 285 Lincoln Ave, Bridge	400	>2000	1100	-	-	-
Haverhill - 285 Lincoln Ave, Dock	500	>2000	140	-	-	-
West Newbury – Ferry Park	100	60	110	-	-	-
Amesbury - Deer Island	-	130	30	-	40	<10
Newburyport - Bridge Road Bridge	-	70	30	-	10	30
Newburyport - Bridge Road Dock	-	-	-	-	-	-
Salisbury - Salisbury Beach State Reservation	-	-	-	-	-	-
Newburyport - Plum Island Lighthouse	-	-	-	-	-	-

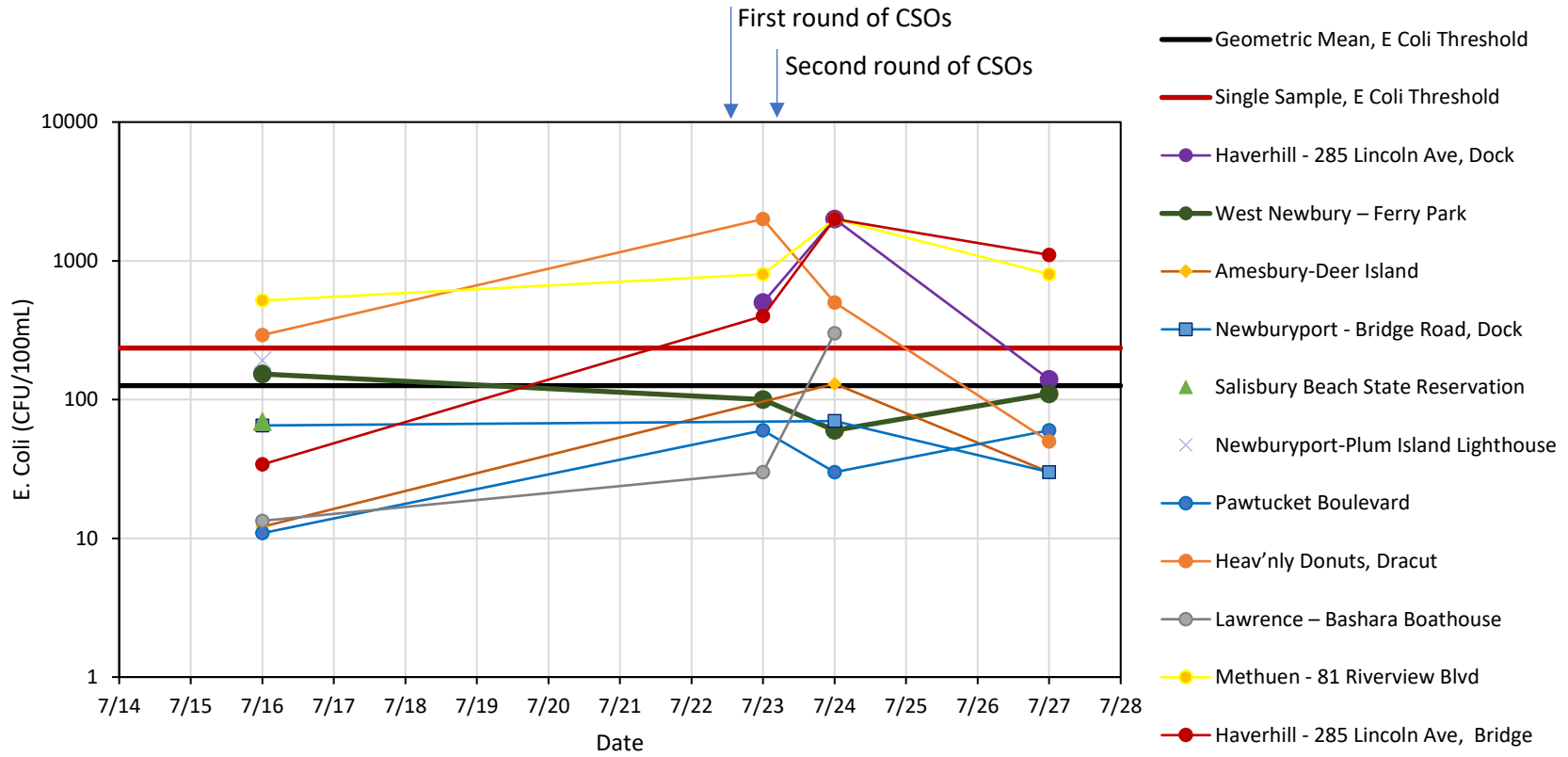


Figure 3: Time series of *E. coli* counts during the first CSO event.

Table 5: Bacteria Data from the second CSO event. Values exceeding the EPA limits for Surface Water Quality Standards are highlighted in red.

Site	CSO#2: (discharged 8/4/2020)					
	E. coli			Enterococcus		
	8/5/2020: (+1 day)	8/6/2020: (+2 days)	8/7/2020: (+3 days)	8/5/2020: (+1 day)	8/6/2020: (+2 days)	8/7/2020: (+3 days)
Lowell - Pawtucket Boulevard	32	8	12	-	-	-
Dracut - Heav'nly Donuts	88	104	120	-	-	-
Lawrence – Bashara Boathouse	28	8	28	-	-	-
Methuen - 81 Riverview Blvd	4150	320	50	-	-	-
Haverhill - 285 Lincoln Ave, Bridge	136	136	56	-	-	-
Haverhill - 285 Lincoln Ave, Dock	116	100	56	-	-	-
West Newbury – Ferry Park	68	1048	150	-	-	-
Amesbury - Deer Island	312	16	10	8	8	6
Newburyport - Bridge Road Bridge	48	32	16	18	12	2
Newburyport - Bridge Road Dock	60	24	16	6	6	2
Salisbury - Salisbury Beach State Reservation	-	-	-	-	-	-
Newburyport - Plum Island Lighthouse	-	-	-	-	-	-

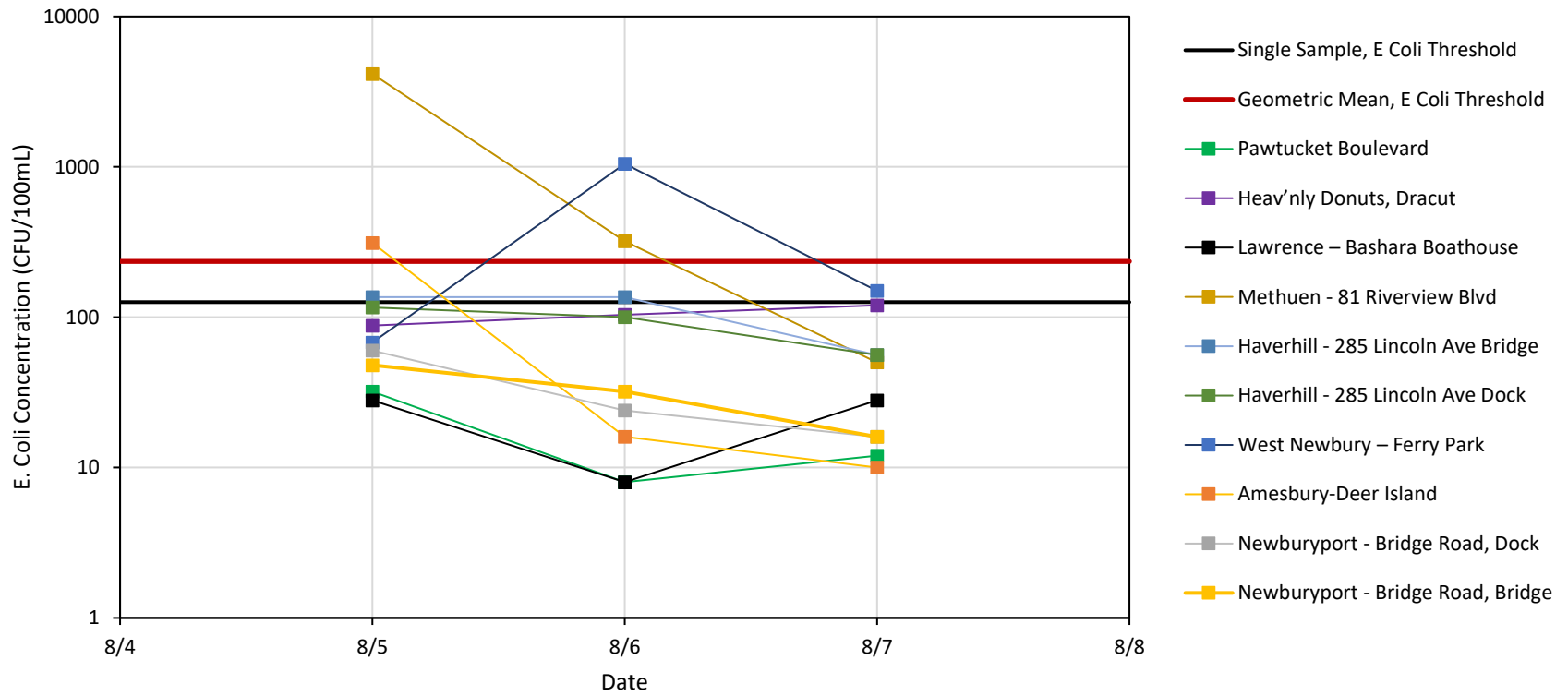


Figure 4: Time series of E. coli counts during the second CSO event.

Table 6: Bacteria Data from the third CSO event. Values exceeding the EPA limits for Surface Water Quality Standards are highlighted in red.

Site	CSO#3: (discharged 9/10/2020)			
	E. coli		Enterococcus	
	9/14/2020: (+4 days)	9/15/2020: (+5 days)	9/14/2020: (+4 days)	9/15/2020: (+5 days)
Lowell - Pawtucket Boulevard	4	4	-	-
Dracut - Heav'nly Donuts	112	100	-	-
Lawrence – Bashara Boathouse	324	132	-	-
Methuen - 81 Riverview Blvd	256	280	-	-
Haverhill - 285 Lincoln Ave, Bridge	-	-	-	-
Haverhill - 285 Lincoln Ave, Dock	32	16	-	-
West Newbury – Ferry Park	12	8	-	-
Amesbury - Deer Island	20	60	8	<2
Newburyport - Bridge Road Bridge	-	-	-	12
Newburyport - Bridge Road Dock	12	52	2	-
Salisbury - Salisbury Beach State Reservation	<4	<4	<2	<2
Newburyport - Plum Island Lighthouse	<4	<4	-	<2

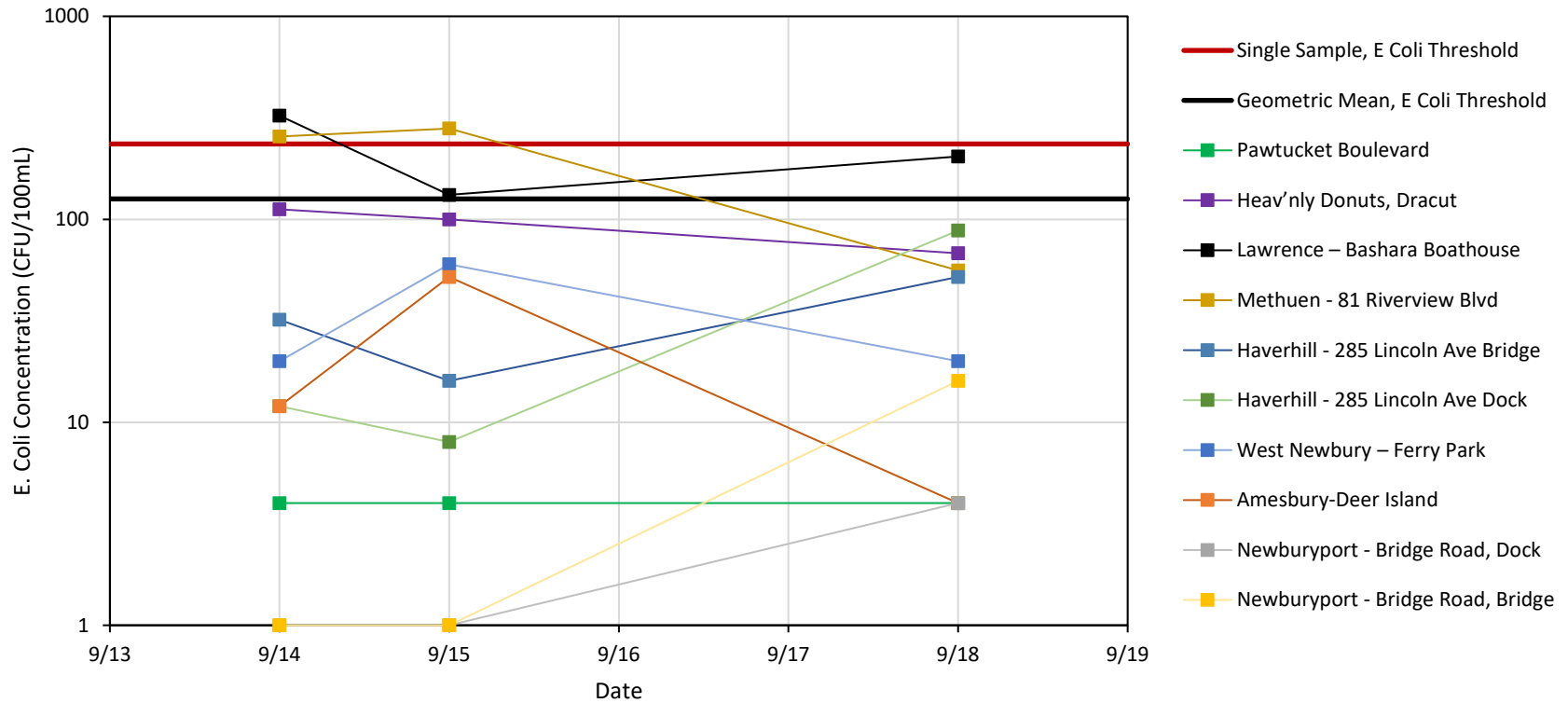


Figure 5: Time series of E. coli counts during the third CSO event.

Table 7: Bacteria Data from the fourth CSO event. Values exceeding the EPA limits for Surface Water Quality Standards are highlighted in red.

Site	CSO#4: (discharged 10/13/2020)					
	E. coli			Enterococcus		
	10/14/2020: (+1 day)	10/15/2020: (+2 days)	10/16/2020: (+3 days)	10/14/2020: (+1 day)	10/15/2020: (+2 days)	10/16/2020: (+3 days)
Lowell - Pawtucket Boulevard	50	30	10	-	-	-
Dracut - Heav'nly Donuts	480	20	80	-	-	-
Lawrence – Bashara Boathouse	40	30	140	-	-	-
Methuen - 81 Riverview Blvd	160	170	420	-	-	-
Haverhill - 285 Lincoln Ave, Bridge	-	-	-	-	-	-
Haverhill - 285 Lincoln Ave, Dock	210	60	300	-	-	-
West Newbury – Ferry Park	90	1150	60	-	-	-
Amesbury - Deer Island	490	20	20	62	6	66
Newburyport - Bridge Road Bridge	-	-	-	-	-	-
Newburyport - Bridge Road Dock	490	<10	<10	-	2	2
Salisbury - Salisbury Beach State Reservation	10	<10	<10	-	<2	4
Newburyport - Plum Island Lighthouse	60	10	10	-	<2	2

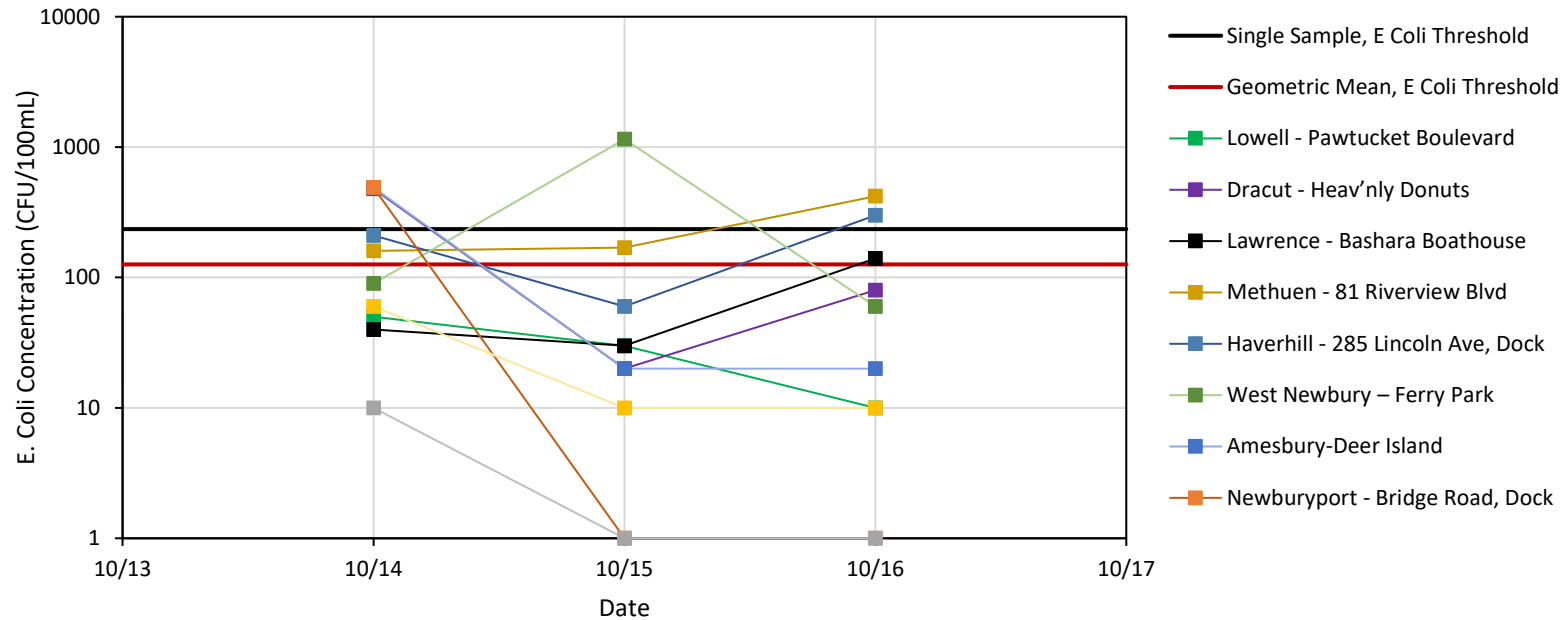


Figure 6: Time series of *E. coli* counts during the fourth CSO event.

c. Non CSO Bacteria Data

Samples were collected on seven days not following CSO events. The concern about the bacteria levels at 81 Riverview Blvd, in Methuen is further supported by the fact that on four out of the seven non-CSO sampling days, the bacteria concentrations at 81 Riverview Blvd Methuen were above the EPA limits. At this location, on 7/16/20, 8/20/20, 10/30/2020, and 11/13/2020 the bacteria concentrations were 517.21 MPN/100mL, 280 CFU/100mL, 520 CFU/100mL, and 500 CFU/100mL, respectively. Four other sites had high *E. coli* concentrations on at least one non CSO sampling day. Of these four sites, the most significant elevated levels were observed at Bashara Boathouse in Lawrence which had an *E. coli* concentration greater than 1200 CFU/100mL on 10/5/2020 and equal to 1070 CFU/100mL on 11/13/2020. Unsafe levels of bacteria were also observed at Heav'nly Donuts in Dracut (290.93 MPN/100mL) Ferry Park in West Newbury (400 CFU/100mL), and Salisbury Beach State Reservation (430 CFU/100mL). Finally, high *Enterococcus*

concentrations were found at Amesbury Dear Island on one day, Salisbury Beach State Reservation on three days, and Newburyport-Plum Island Lighthouse on two days. Both Salisbury Beach State Reservation and Newburyport - Plum Island Lighthouse each saw one day with *Enterococcus* concentrations above 1000 MPN/100mL (or CFU/100mL).

Table 8: *E. coli* data from the non-CSO sampling days. Values exceeding the EPA limits for MA Surface Water Quality Standards highlighted in red.

Site	Non CSO Sampling Days (<i>E. coli</i>)						
	7/16/2020	8/20/2020	9/18/2020	10/5/2020	10/23/2020	10/30/2020	11/13/2020
Lowell - Pawtucket Boulevard	10.89	4	4	20	<10	10	10
Dracut - Heav'nly Donuts	290.93	24	68	24	80	140	10
Lawrence – Bashara Boathouse	13.36	24	204	>1200	90	140	1070
Methuen - 81 Riverview Blvd	517.21	280	56	36	190	520	500
Haverhill - 285 Lincoln Ave, Bridge	34.05	4	-	-	-	-	-
Haverhill - 285 Lincoln Ave, Dock	-	-	52	100	35	150	60
West Newbury – Ferry Park	152.86	400	88	96	60	150	30
Amesbury-Deer Island	12.11	108	20	24	70	20	<10
Newburyport - Bridge Road Bridge	65.04	10	-	-	-	-	-
Newburyport - Bridge Road Dock	-	-	4	12	<10	40	50
Salisbury Beach State Reservation	69.45	<4	16	4	<10	430	<10
Newburyport-Plum Island Lighthouse	191.79	4	4	<4	10	30	30

Table 9: Enterococcus data from the non-CSO sampling days. Values exceeding the EPA limits for Massachusetts Surface Water Quality Standards are highlighted in red.

Site	Non CSO Sampling Days (Enterococci)						
	7/16/2020	8/20/2020	9/18/2020	10/5/2020	10/23/2020	10/30/2020	11/13/2020
Amesbury-Deer Island	8.44	-	12	18	24	32	200
Newburyport - Bridge Road Bridge	44.14	6	-	-	-	-	-
Newburyport - Bridge Road Dock	-	-	<2	6	28	28	20
Salisbury Beach State Reservation	2419.57	2	10	2	6	172	92
Newburyport-Plum Island Lighthouse	755.55	<2	10	<2	6	>1200	32

d. **Bacteria Concentrations at 81 Riverview Blvd, Methuen:**

From the data collected by the sampling program, MRWC noticed high levels of bacteria at one sampling location, 81 Riverview Blvd, Methuen. Samples taken along the shore at this site had a significant number of samples above the limit from Massachusetts Surface Water Quality Standards of 235 CFU/100mL for bathing beaches and non-bathing beaches. Over four months of sampling, 22 samples were collected at this site and 11 had bacteria levels above the limit of 235 CFU/100mL. This included 5 of 6 samples collected following upstream CSOs, as well as 6 out of 16 samples collected not following upstream CSOs. This represented a significantly higher rate of exceedance at this site than the other sites being sampled.

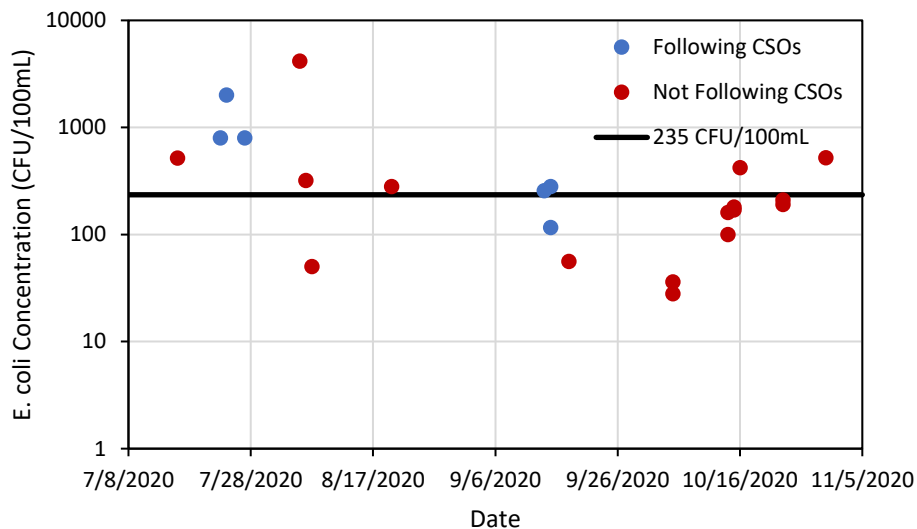


Figure 7: Plot of *E. coli* concentration versus date, from days following and not following CSO events. Note the value of 200 CFU/100mL on 7/24/2020 was reported as >2000 CFU/100mL by the laboratory and the actual value may be significantly higher.

To determine if the high bacteria levels seen 81 Riverview Blvd, Methuen (GPS coordinates: 42.7273583, -71.1290352) were the result of illicit sewer connections, MRWC performed extra sampling in the area immediately upstream. First, the area upstream was surveyed and several outflows were identified as potential sources of the bacteria. The team selected 2 outflows for additional sampling. The outflows were labeled Outflow 1 (GPS coordinates: 42.7226506, -71.1340201) and Outflow 2 (GPS coordinates: 42.718813, -71.136271). Samples were also collected directly from the river at a point upstream (GPS coordinates: 42.716795, -71.135459) to determine if the high bacteria concentrations at the main site were explained by the bacteria coming from the sampled outflows.

The samples showed significant levels of *E. coli* on the three days samples were collected. The highest levels were seen on 10/14/2020, with 580 CFU/100mL at Outflow 1 and 420 CFU/100mL

at Outflow 2. This result is likely due to the rainfall on the previous day (1.29 in). Interestingly, when the bacteria concentrations at the 81 Riverview Blvd, Methuen and the upstream point were considered, the results appear to indicate that there are other sources of bacteria present further upstream. The first set of results on 10/5/2020 suggested the two outflows were the source of the bacteria, with the upstream point having a low level of 8 CFU/100mL, and 81 Riverview Blvd, Methuen, having a slightly higher concentration of 36 CFU/100mL. Due to the relatively low flow on that day, the bacteria from the two outflows could have accounted for the increase in bacteria. However, when the locations were sampled again on 10/14/2020 and 10/23/2020, higher levels were found at the upstream point than at 81 Riverview Blvd, Methuen. These results indicate that while Outflow 1 and 2 are contributing to the high levels seen at 81 Riverview Blvd, Methuen, there are other sources of bacteria further upstream. MRWC plans to continue their sampling activities and plans to identify additional sources of bacteria to the river.

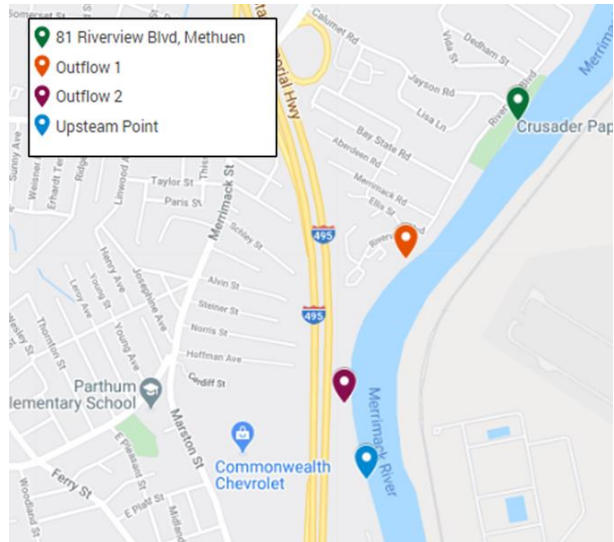


Figure 8: Map of locations sampled in Methuen by MRWC.

Table 10: *E. coli* concentration data collected in Methuen by MRWC- October, 2020.

Date	<i>E. coli</i> Concentration (CFU/100mL)			
	Upstream Point	Outflow 1	Outflow 2	81 Riverview Blvd, Methuen
10/5/2020	8	236	72	36
10/14/2020	420	580	420	160
10/23/2020	630	110	120	190

e. Comparison with Brown and Caldwell’s Predictive Model

Brown and Caldwell has worked with the City of Newburyport to develop a model that predicts the movement of bacteria concentration down the Merrimack River following CSO events. Using data on the amount of untreated sewage released and the flow rate of the river, the model predicts the *E. coli* concentrations in Newburyport. To validate this model, MRWC has shared our sampling data from the CSO events that occurred in summer/fall 2020. Brown and Caldwell’s model predicted low bacteria levels arriving in Newburyport several days after the CSOs. MRWC’s results were in general agreement with Brown and Caldwell’s model, finding the *E. coli* concentrations in Newburyport were not significantly higher following CSO event than the *E. coli*

levels on a typical dry sampling day. The model and the field data predicted safe levels following the three CSO events. The only exception was a sample collected on 10/14/2020, but the team believes these high levels were from stormwater runoff. The sample on 10/14/2020 was collected 18 hours after a CSO in Haverhill started. Brown and Caldwell’s model predicted the bacteria from this CSO would take 3 and a half days to reach Newburyport, given the flow rate in the river at that time. Therefore, the team is confident the issue is not the result of a mistake in calculating the travel time of the bacteria and instead the bacteria concentrations are the result of another bacteria source.

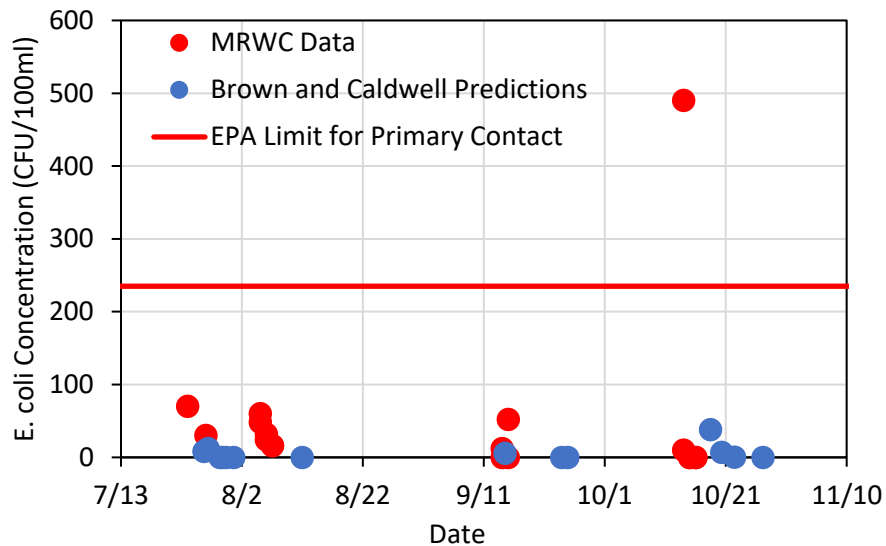


Figure 9: Plot of E. coli concentration measured by MRWC and the concentrations predicted by Brown and Caldwell’s predictive models.

5. Conclusions

This report covered the data collected by the MRWC’s water quality monitoring program in 2020. The main events and takeaways from the collected data included:

- General water quality parameters (temperature, pH, TDS, specific conductivity, and salinity) were collected at each site using Pocket Pro+ Multi 2 Testers
- Bacteria data was collected during 4 CSO events
- Following the CSOs the team was able to track the movement of bacteria down the river
- The results showed the bacteria concentration decrease down to background levels by the time they reached Newburyport
- These results were confirmed by Brown and Caldwell’s model, which showed the bacteria concentration decay/dilute to nearly non-detectable levels, further exaggerated by the extremely low flow in the river in 2020

- Regularly high *E. coli* concentrations were found frequently at 81 Riverview Blvd, Methuen, both on days following and not following CSO events. MRWC collected samples from two outflow upstream of the main sampling site and found high *E. coli* concentrations, suggesting that an unknown source was releasing untreated sewage into the river.
- High *E. coli* concentrations were found at four other sites on at least one non-CSO sampling day; Bashara Boathouse in Lawrence (>1200 CFU/100mL on 10/5/2020 and 1070 CFU/100mL on 11/13/2020), Heav'nly Donuts in Dracut (290.93 MPN/100mL on 7/16/2020) Ferry Park in West Newbury (400 CFU/100mL on 8/20/2020), and Salisbury Beach State Reservation (430 CFU/100mL on 10/30/2020).

6. Plans for Future Work

To expand on the success of this year's sampling activities, the team is planning a number of measures for the upcoming months and years, including:

- The sampling will continue year-round to monitor the seasonal variations in water quality.
- The team will expand the number of sampling sites, to provide a more detailed picture of the bacteria concentrations in the river.
- The team will collect data from additional CSO events. The CSOs that occurred this year took place during a Phase 2 drought, when the flow in the river was very low. The team is interested in monitoring the bacteria levels when flow is higher to see the effect on the movement of bacteria down the river.
- The team will work with the EPA, to arrange for the US EPA Region 1 Lab in Chelmsford to perform analysis of our samples.
- The list of analytes may be expanded to include nutrients such as nitrite, nitrate, ammonia, and phosphate.
- Several municipalities do not release full CSO data until the end of the year. The team plans to collect and review any additional CSO information released by the municipalities, to provide better information for predictive models.
- MRWC will work with EPA and MassDEP to identify sources of elevated bacteria in Methuen and any other hot spots identified.

7. References

[1] Jyotsna S. Jagai, Quanlin Li, Shiliang Wang, Kyle P. Messier, Timothy J. Wade, and Elizabeth D. Hilborn, Extreme Precipitation and Emergency Room Visits for Gastrointestinal Illness in Areas with and without Combined Sewer Systems: An Analysis of Massachusetts Data, 2003–2007. *Environmental Health Perspectives*, 123(9), September 2015. 873-879.

[2] US Congress. Federal Water Pollution Control Act (Amended). US Congress; 2002. <https://www.epa.gov/sites/production/files/2017-08/documents/federal-water-pollution-control-act-508full.pdf>.

[3] MassDMF 2019 Annual Report. Department of Fish and Game.

[4] Shortnose Sturgeon Status Review Team. 2010. A Biological Assessment of shortnose sturgeon (*Acipenser brevirostrum*). Report to National Marine Fisheries Service, Northeast Regional Office. November 1, 2010. 417 pp.

[5] US Environmental Protection Agency. 2006. Massachusetts Surface Water Quality Standards. December 1, 2010. 10 pp.

8. Appendix A: Maps and Box and Whisker Plots of the Data

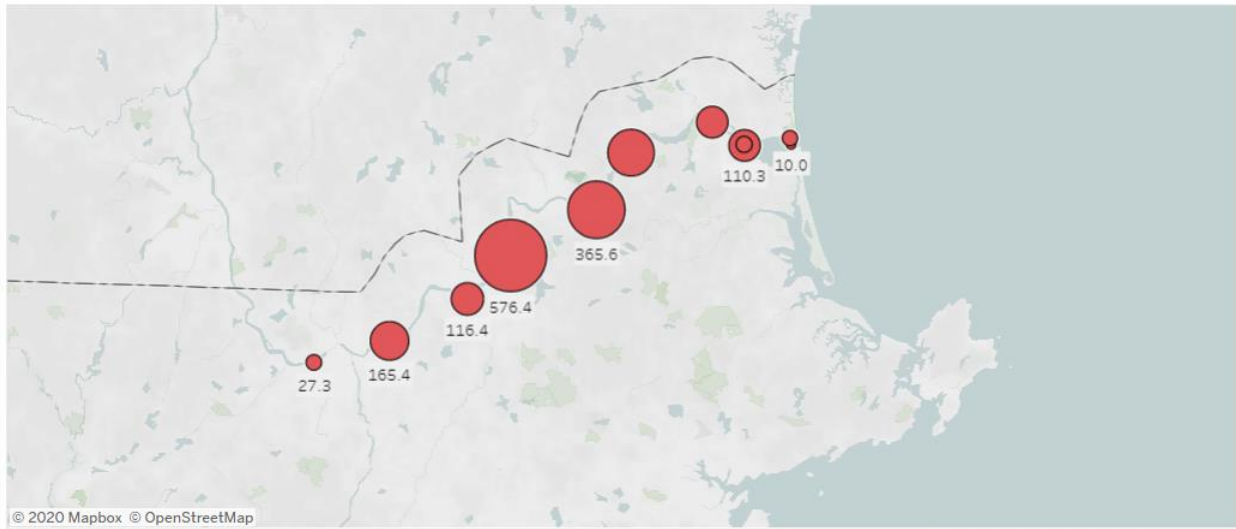


Figure 10: Map displaying the averaged E. coli concentrations at each site following 4 CSO events.

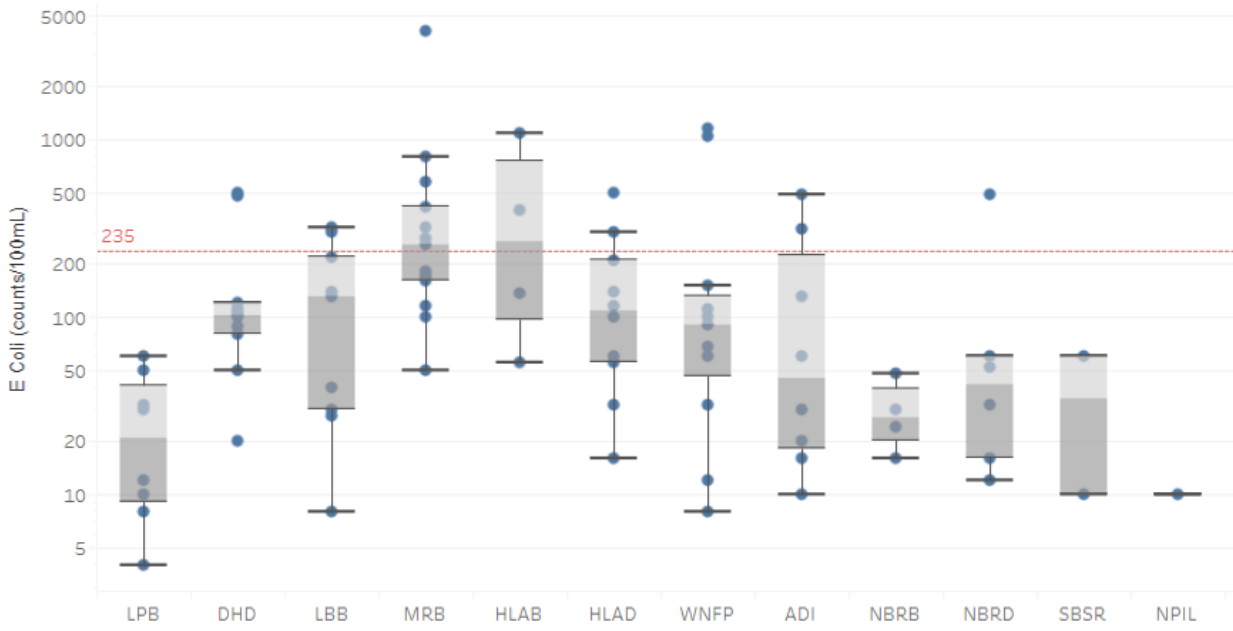


Figure 12: Box and whisker plot of E. coli concentration on the 4 CSO sampling days.



Figure 13: Map displaying the enterococcus concentrations at each site following 4 CSO events.

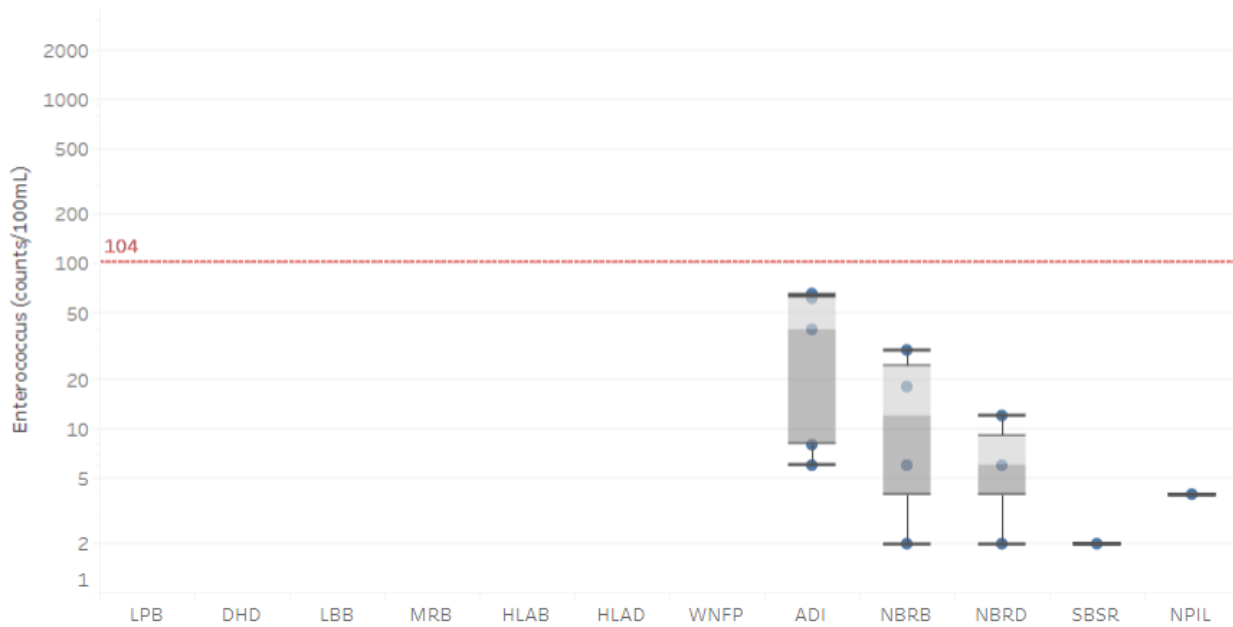


Figure 19: Box and whisker plot of *enterococcus* concentration on the 4 CSO sampling days.

9. Appendix B: Sampling Site Location Information

Lowell- Pawtucket Boulevard:

GPS Coordinates: 42.6411911, -71.3460007

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B038'28.3%22N+71%C2%B020'45.6%22W/@42.6411911,-71.3460007,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.6411911!4d-71.3460007>

Parking: Along street



Dracut- Heav'nly Donuts:

GPS Coordinates: 42.6585413, -71.2625371

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B039'30.8%22N+71%C2%B015'45.1%22W/@42.6585413,-71.2625371,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.6585413!4d-71.2625371>

Parking: in the Heav'nly Donuts parking lot or on a dirt patch by the side of the road



Lawrence – Bashara Boathouse:

GPS Coordinates: 42.69238, -71.17673

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B041'32.6%22N+71%C2%B010'36.2%22W/@42.69238,-71.17673,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.69238!4d-71.17673>

Parking: In boathouse parking lot (shown in first picture)



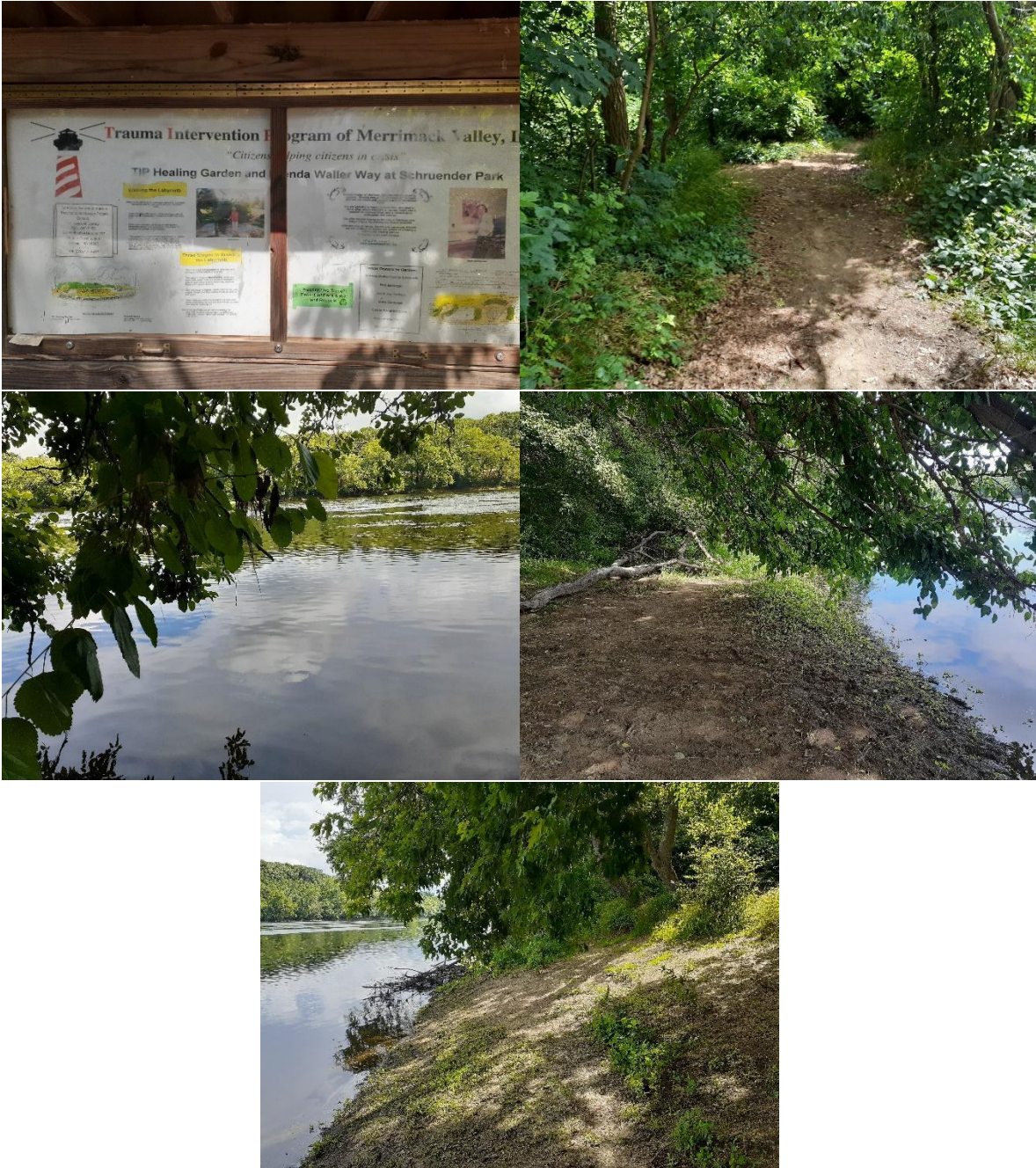
Methuen - 81 Riverview Blvd:

GPS Coordinates: 42.7273583, -71.1290352

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B043'38.5%22N+71%C2%B007'44.5%22W/@42.7273583,-71.1290352,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.7273583!4d-71.1290352>

Parking: Dirt patch on the side of the road



Haverhill - 285 Lincoln Ave:

GPS Coordinates: 42.7642673, -71.0345758

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B045'51.4%22N+71%C2%B002'04.5%22W/@42.7642673,-71.0345758,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.7642673!4d-71.0345758>

Parking: Market Basket parking lot across the street



West Newbury – Ferry Park:

GPS Coordinates: 42.8101931, -70.9963550

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B048'36.7%22N+70%C2%B059'46.9%22W/@42.8101931,-70.996355,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.8101931!4d-70.996355>

Parking: dirt patch along the site of the road



Amesbury-Deer Island:

GPS Coordinates: 42.8348062, -70.9068175

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B050'05.3%22N+70%C2%B054'24.5%22W/@42.8348062,-70.9068175,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.8348062!4d-70.9068175>

Parking: Parking lot for hiking on Deer Island



Newburyport - Bridge Road:

GPS Coordinates: 42.816901, -70.871739

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B049'00.8%22N+70%C2%B052'18.3%22W/@42.816901,-70.871739,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.816901!4d-70.871739>

Parking: Public parking for a dollar at 72 Merrimac St, some business may allow us to park for free



Salisbury- Salisbury Beach State Reservation:

GPS Coordinates: 42.8218847, -70.8212684

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B049'18.8%22N+70%C2%B049'16.6%22W/@42.8218847,-70.8212684,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.8218847!4d-70.8212684>

Parking: The reservation charges \$14 for parking but there is plenty of room. Non-Massachusetts license plate cost \$40.



Newburyport-Plum Island Lighthouse:

GPS Coordinates: 42.81681, -70.8199290

Google Maps Location:

<https://www.google.com/maps/place/42%C2%B049'00.5%22N+70%C2%B049'11.7%22W/@42.81681,-70.819929,17z/data=!3m1!4b1!4m5!3m4!1s0x0:0x0!8m2!3d42.81681!4d-70.819929>

Parking: Parking lots are available, we made should check about parking permits. Park at “Captain’s Fishing Parties and Cruises” and walk behind it to the pier.

