Addressing the Bacteria Impairment at Fairview Beach: Monitoring Data Analysis and Justification for a Watershed Plan Approach

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Executive Summary

Fairview Beach is a small beach on the Potomac River in King George County, Virginia. Since 2004, the beach water has been monitored for fecal indicator bacteria on a weekly basis by the Virginia Department of Health (VDH) Rappahannock Health District. Water samples are analyzed for *Enterococci* bacteria to determine if beach water meets Virginia's water quality standards (WQS) for primary contact recreation (swimming). The monitoring shows that the beach frequently does not meet water quality standards. Based on its monitoring, VDH has issued swimming advisories for Fairview Beach an average of four times per year, and the beach has been under a swimming advisory an average of 21 days a year. Based on VDH monitoring data, Fairview Beach is not meeting the water quality standard for bacteria for its Primary Contact (Swimming) Use, and in 2006 the Virginia Department of Environmental Quality (DEQ) placed Fairview Beach on Virginia's List of Impaired Waters.

In addition to the monitoring performed by VDH, additional monitoring, including microbial source tracking (MST) and sampling for optical brighteners, has been performed in cooperation with VDH by Virginia Tech (VT) Department of Crop and Soil Environment under the direction of Professor Charles Hagedorn. The goal of this sampling was to determine the source of bacteria impacting Fairview Beach. VT actively monitored Fairview Beach between 2004 and 2009. Since 2011, the Fairview Beach Resident's Association (FBRA) have been working with the Virginia Department of Environmental Quality (DEQ) to perform bacteria monitoring using Coliscan kits provided by DEQ.

The following conclusions can be drawn from the bacteria monitoring performed by VDH, VT, and FBRA:

1. Bacteria concentrations are elevated when river conditions are turbulent, muddy, choppy, or otherwise rough;
2. Bacteria concentrations under turbid or rough conditions tend to decrease moving away from the shoreline, indicating the direct source of bacteria under rough conditions is not the Potomac River;
3. Elevated bacteria concentrations under turbid or rough conditions may not be a problem confined to Fairview Beach;
4. Bacteria concentrations in the Potomac River outside the vicinity of Fairview Beach are generally lower than the concentrations observed at Fairview Beach;
5. Elevated concentrations of bacteria are observed in local stormwater draining Fairview Beach;
6. Although several human sources of bacteria have been identified and rectified, local human sources continue to contribute to the bacteria observed at Fairview Beach; and
7. Eliminating bacteria just from human sources and pets may not be sufficient to fully resolve the bacteria impairment at Fairview Beach.

The primary pathways for the transport of local sources are most likely stormwater runoff, erosion of beach sand, and resuspension of sediment, though there may be contributions from bacteria in groundwater in preferential flow paths.

Under the Clean Water Act, Total Maximum Daily Loads (TMDLs) must be developed for pollutants for waterbodies not supporting their designated uses. TMDLs represent the total pollutant load that a waterbody can assimilate and still meet its designated uses. EPA regulations and guidance, however, recognize that an impaired water not may need a TMDL if there are other pollution control requirements that are sufficient to meet water quality standards within a reasonable period of time. "Other pollution control requirements (e.g., best management practices) required by local, State, or Federal authority" that are stringent enough to implement the appropriate water quality standards (40 CFR 130.7(b)(1)(iii)) can be used as an alternative to developing a TMDL. Waterbodies where an alternative approach can be used instead of a TMDL for addressing an impairment can be classified as Category 4B ("…impaired or threatened for one or more designated uses, but does not require a TMDL because pollution control requirements…are reasonably expected to result in attainment of water quality standards…") in contrast to waterbodies requiring TMDLs, which are classified as Category 5 in Virginia's Water Quality Integrated Report.

Fairview Beach is a candidate for a Category 4B listing, for the following reasons:

1. The impairment is very small (0.012 sq. mi). Elevated bacteria levels extend no more than 25 yards into the Potomac River. The local drainage area contributing to the impaired area is of the order of one to two square miles. The control measures and restoration measures needed to address the bacteria impairment are highly specific, and TMDL allocations won't provide any guidance on implementing them.

2. Some control measures, such as pet waste stations, are already in place. The implementation of other control measures, such as structural measures to control beach erosion, are already underway.

3. The highest priority should be given to the identification and elimination of the contribution of human sources (septic systems, faulty sewer connections) to the bacteria impairment. Since there is no legal discharge of these sources, they would receive no allocation under a hypothetical TMDL.

The best vehicle for justifying a Category 4B Listing for Fairview Beach is a Watershed Plan (WP). A WP for Fairview Beach would document those measures already put in place to address impairment (such as pet waste stations) as well as specify the additional measures required to meet WQS. These would include planned improvements to the beach and the measures required to eliminate human sources of bacteria. It can also include additional measures, such as stormwater controls, that could reduce bacteria inputs to the beach.

1.0 Introduction

Fairview Beach is a small beach on the Potomac River in King George County, Virginia. It lies in the Primary Settlement Area (PSA) of Fairview Beach. PSAs are unincorporated areas of King George County where the county provides water and sewer services. Figure 1 shows the location of the PSA of Fairview Beach.

There are approximately 3,000 feet of shoreline in Fairview Beach, including a designated swimming area about 75 to 100 yards long. All of the shoreline is privately owned, but property owners have access to the shoreline by covenant. The Fairview Beach Resident's Association (FBRA), a voluntary organization of residents and property owners, maintains the shoreline and the designated swimming area. Although the shoreline and beach are private property, the public can access them by boat or from the limited commercial property within Fairview Beach.

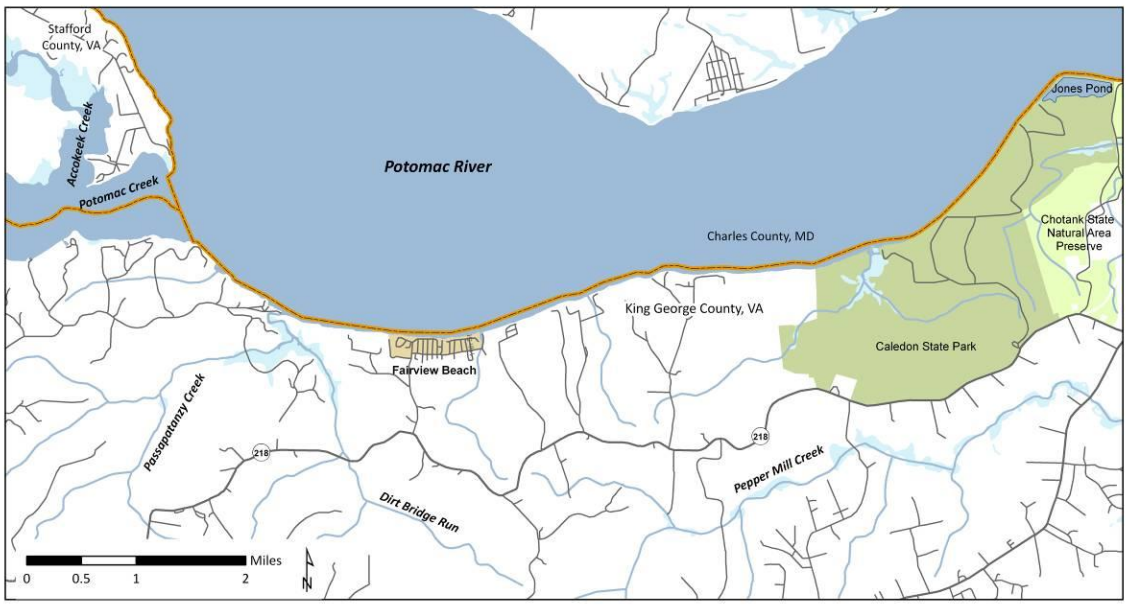

Figure 1: Location of Fairview Beach

Since 2004, the beach water has been monitored for fecal indicator bacteria on a weekly basis by the Virginia Department of Health (VDH) Rappahannock Health District. Water samples are analyzed for *Enterococci* bacteria to determine if beach water meets Virginia's water quality standards (WQS) for primary contact recreation (swimming). The monitoring shows that the beach frequently does not meet water quality standards. Based on its monitoring, VDH has issued swimming advisories for Fairview Beach an average of four times per year, and the beach has been under a swimming advisory an average of 21 days a year. Table 1 shows the number of advisories and the number of days per year the beach has been under advisory from 2004 through 2012.

Based on VDH monitoring data, Fairview Beach is not meeting the water quality standard for bacteria for its Primary Contact (Swimming) Use, and in 2006 the Virginia Department of Environmental Quality (DEQ) placed Fairview Beach on Virginia's List of Impaired Waters. Under the Clean Water Act, Total Maximum Daily Loads (TMDLs) must be developed for pollutants for waterbodies not supporting their designated uses. TMDLs represent the total pollutant load that a waterbody can assimilate and still meet its designated uses.

Table 2 gives the specification of the impairment.

Table 1: Fairview Beach Closures, 2004 -2012

Year	Number of Advisories	Days Under Advisory
2004	4	13
2005	2	8
2006	3	33
2007	6	32
2008	5	24
2009	5	16
2010	4	18
2011	4	22
2012	5	10
Average	4.1	20.9

Table 2: Fairview Beach Bacteria Impairment

Name	Cause Group Code	Description	Size	Initial Listing
Fairview Beach (Potomac River)	A29E-02-BAC	Includes all of Fairview Beach on the Potomac River	0.012 $mi.^2$	2006

In addition to the monitoring performed by VDH, additional monitoring, including microbial source tracking (MST) and sampling for optical brighteners, has been performed in cooperation with VDH by Virginia Tech (VT) Department of Crop and Soil Environment under the direction of Professor Charles Hagedorn. The goal of this sampling was to determine the source of bacteria impacting Fairview Beach. VT actively monitored Fairview Beach between 2004 and 2009. Since 2011, the Fairview Beach Resident's Association (FBRA) have been working with the Virginia Department of Environmental Quality (DEQ) to perform bacteria monitoring using Coliscan kits provided by DEQ.

1.1 Description of Drainage Area

The area draining to the impairment is about one and a half square miles. It includes both the original subdivisions of Fairview Beach within the PSA and bluffs overlooking the Potomac River.

According to the King George County Comprehensive Plan (2012), the subdivisions of Fairview Beach were surveyed in the 1920's. The original subdivisions cover only about 100 acres. Most of the homes were constructed in the 1950's as second homes, but even in the 1970's they were already being converted to primary residences (Dewberry, Nealon, and Davis, 1974). In 2011 the resident population was 930. Average lot size is small, 5,000 to 8,000 square feet, and it is estimated that impervious cover accounts for 50-70% of the average lot (King George County, 2012).

Fairview Beach is served by the King George County Service Authority, which provides water and sewer to the settlement area. The original wastewater treatment plant began operation in 1982, and is currently operating with a 0.2 million gallons per day (MDG) treatment capacity. The settlement area currently includes not only the original subdivisions of Fairview Beach but the recently developed subdivision of Potomac Landing to the east, where the new plant is located. The Service Authority estimates that no more than two or three homes within the PSA may still be using septic systems (C. Thomas and S. Sweeney, 2013, personal communication).

Fairview Beach is in the Coastal Plain. The original subdivisions are set in a marine terrace. According to the 2010 King George County soil survey (NRCS, 2013), Woodstown fine sandy loam is the dominant soil in the subdivisions, though the soil survey cautions that it may not be accurate at that small a scale. The use of the soils in the original subdivisions for septic fields is severely limited because the water table can be within 1.5 feet of the surface.

Overlooking the PSA are bluffs rising to an elevation of 100 feet with 15 to 30% slopes. The dominant soils on the bluffs are of the Galestown-Sassafras complex. There are about a dozen homes on large lots in the bluffs outside the PSA; these homes are served by onsite wastewater systems.

1.2 Applicable Water Quality Standards

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)." According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be*

reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

Effective February 1, 2010, VADEQ specified a new bacteria standard in 9 VAC 25-260-170 A. Fairview Beach is in the transitional zone of the Potomac River, between tidal freshwater and saltwater (9 VAC 25-260-140 C). For a non-shellfish, transitional or saltwater waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"Enterococci bacteria shall not exceed a monthly geometric mean of 35 CFU/100 ml in transition and saltwater...Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples… If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed 104 CFU/100 ml."*

Enterococci are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

2.0 Analysis of Monitoring Data

2.1 Virginia Department of Health Monitoring Data

Starting in 2004, VDH has monitored *Enterococci* concentrations on approximately a weekly basis, May through September, in the vicinity of Fairview Beach. In 2004 and 2005, VDH monitored at four sites, shown in Figure 2. The designated swimming area of the beach is between monitoring stations B and C, and is only about 75 to 100 yards long (VT, 2006). The location of site D was approximated from a description of its location by VT (2004). Monitoring at Site D was discontinued in 2006. VDH issues a swimming advisory if the arithmetic average *Enterococci* count exceeds the assessment threshold of 104 cfu/100 ml. VDH reports its results by Site number (Site #1, Site #2, etc.). The site numbers have changed from year to year. Based on reports and communications, Table 3 reconstructs the location of VDH site numbers over the 2004-2012 monitoring period.

Table 4 summarizes VDH *Enterococci* monitoring results by the locations shown in Figure 2. In calculating the summary statistics for Table 4, concentrations below the detection limit were set at the detection limit. Values labeled "Too Numerous to Count" (TNTC) were set at 24,191 cfu/100 ml, which is the maximum value used by VDH when calculating the daily average concentration across sites. These rules will be used in all summary calculations throughout this report.

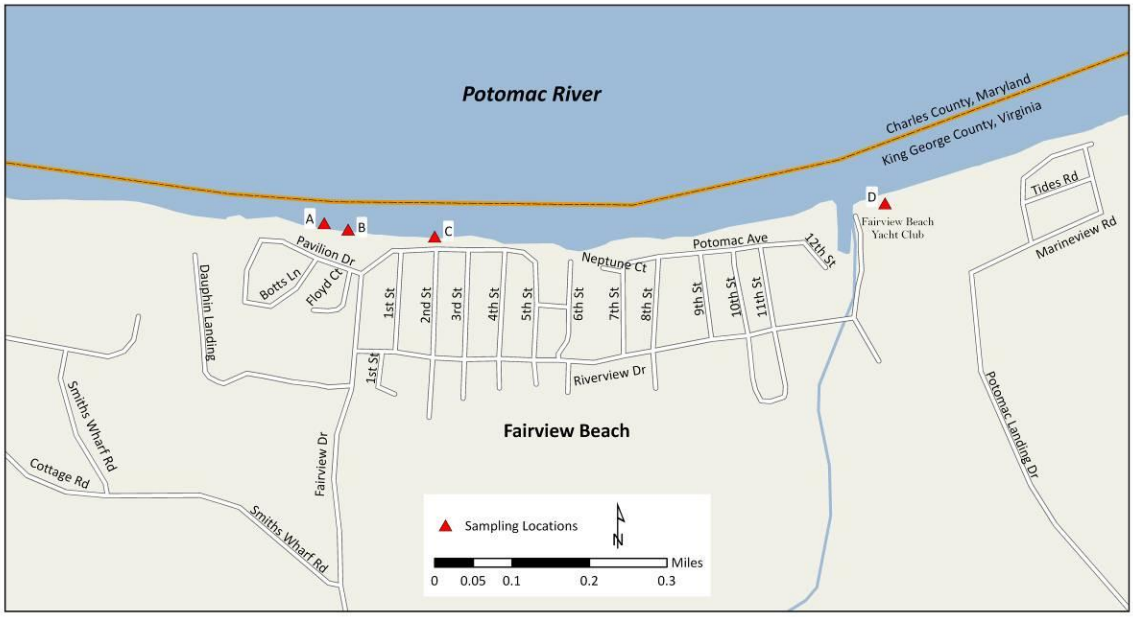

Figure 2: VDH Monitoring Station Locations (location of Site D is estimated from VT (2004))

Table 3: Location of VDH Monitoring Sites as Shown in Figure 2[1]

Year	A	B	C	D
2004	4	1	3	2
2005	4	1	3	2
2006	4	1	3	
2007	3	1	2	
2008	3	1	2	
2009	3	1	2	
2010	3	1	2	
2011	3	1	2	
2012	1	2	3	

[1] Based on Thompson (2011) personal communication; Cover et al. (2011); VT (2004)

Approximately 30% of the average values are above 104 cfu/100 ml. There does not appear to be statically significant differences among the locations. A Kruskal-Wallis test failed to detect a difference in the median concentration among the stations. Figure 3 shows boxplots of the distribution of observed *Enterococci* concentrations at the VDH sampling locations. This does not take into account the fact that since 2004 two sources of bacteria have been identified and mitigated, as will be discussed in the subsequent section.

Table 4: VDH *Enterococci* Monitoring Results (cfu/100 ml) by Location

Statistic	A	B	C	D	Average
Count	185	188	187	40	188
Minimum	1	1	1	1	2.7
10th Percentile	10	9.4	9.2	5.5	11.2
25th Percentile	20	16	12	10	16.7
Median	50	53	34	51	56.8
75th percentile	120	132.5	107	115.75	126.0
90th Percentile	276.8	320	261.6	214	281.2
Maximum	24,191	24,191	24,191	730	24,191.0
Average	744.4	503.8	479.0	98.2	570.6
Std. Deviation	3,920.6	3,044.5	3,042.2	140.0	3021.3
Geometric Mean	54.1	49.2	40.3	34.8	57.2

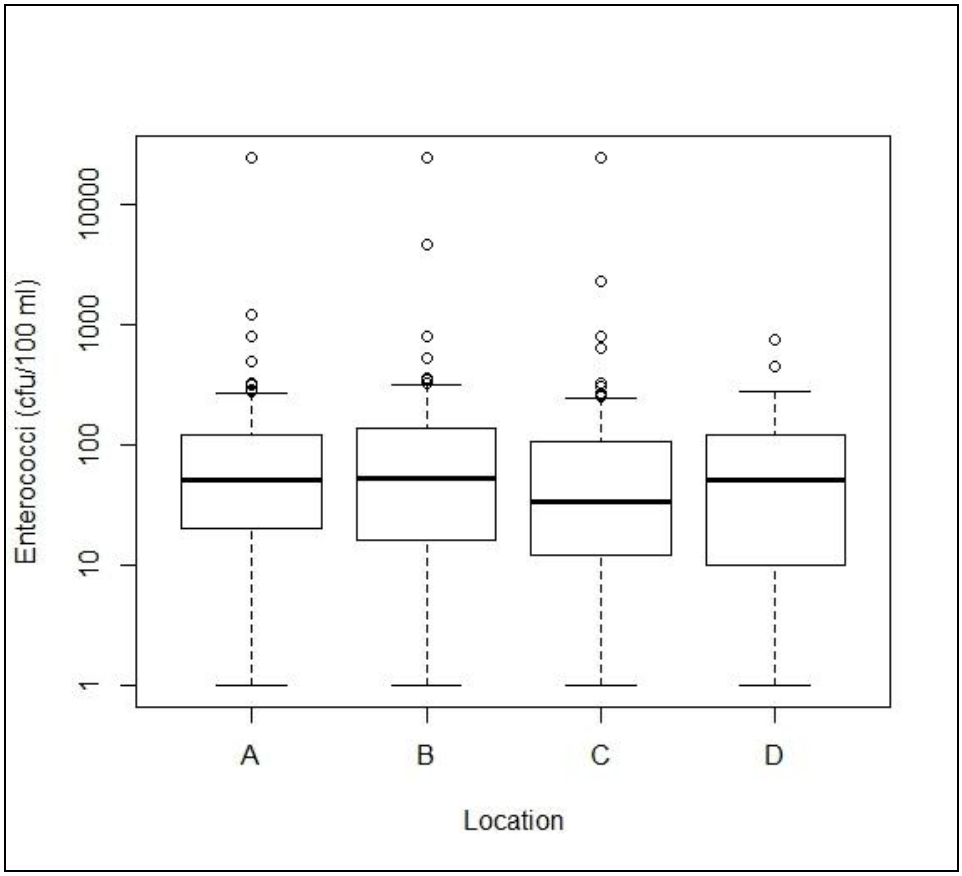

Figure 3: *Enterococci* Concentrations (cfu/100 ml) Observed at VDH Sampling Locations, 2004 -2012

VDH swimming advisories are based on a single day's observations. There are sufficient observations in VDH monitoring results to compare them to Virginia's monthly geometric mean *Enterococci* criterion. Table 5 gives the monthly geometric mean concentrations for months in which there are at least four weekly values. The monthly geometric mean is calculated using the arithmetic mean of the daily observations. Geometric mean values exceeding the 35 cfu/100 ml criterion are shown in red. About two-thirds of the months have mean values above the criterion. There was no year in which four samples were taken in the month of May, so a geometric mean was not calculated for May samples.

Table 5: Monthly Geometric Mean *Enterococci* Concentrations (cfu/100 ml)), Fairview Beach (based on daily arithmetical average concentration)

Year	June	July	August	September
2004	46	6	17	112
2005		84	64	
2006	149	27	7	
2007	136	43	69	52
2008	60	80	24	216
2009	84	31	39	88
2010	28	32	42	
2011	177	15	75	
2012	44	56	31	

Monthly concentrations above the 35 cfu/100 ml criterion are shown in red

2.2 Virginia Tech Monitoring Results

VT staff sampled *Enterococci* concentrations, measured optical brighteners (OB) and performed microbial source tracking (MST) at Fairview Beach during the swimming season during 2004 to 2009. The monitoring was performed at the VDH sampling locations but also at other sites to test specific hypotheses about the source of bacteria at Fairview Beach. These other sites included:

- Sinkhole at 8th Street
- Drain pipe at Pavilion Drive
- Potomac River and neighboring embayments
- Caledon Natural Area State Park
- Fairview Beach Yacht Club marina and boating events

MST and OB measurements were not performed at every site. Table 6 shows the analyses performed for each site type.

The MST methodology used at Fairview Beach was Antibiotic Resistance Analysis (ARA). In ARA, the responses of bacteria to a battery of antibiotics are tested. Isolates

are classified according to the similarity in response when compared to known sources. For Fairview Beach the sources of bacteria were classified as (1) birds, (2) wildlife, (3) human, or (4) dogs or pets (the VT reports refer to pets and dogs interchangeably).

Table 6: VT Analyses Performed (2004-2009) By Site Type

Site Type	*Enterococci*	MST	OB
VDH sites	X	X	X
8th Street Sinkhole	X[1]	X	X
Drainpipe	X	X	X
Potomac River	X		
Caledon State Park	X		
Boating and Marina	X	(marina only)	

[1] 2004 samples were not analyzed for *Enterococci* concentrations.

Optical Brighteners (OBs), also known as fluorescent whitening agents (FWAs), are chemical additives put in laundry detergents to brighten clothing (Hagedorn *et al*., 2005a, b). They are also added to hand soap and toilet paper. OBs are discharged with wastewater and can therefore be used as an indicator of the presence of wastewater. The presence of OBs is detected using an instrument called a fluorometer, whose measurements must be calibrated against known sources. OBs are reported in fluorescence units. In a study of septic system pollution in the Coan River, Hagedorn *et al*., 2005b found that MST detected a strong human signature whenever OB measurements were 89-90 and greater; in their studies of Fairview Beach, VT (2005, 2006 and 2007) considered OB measurements over 100 as positive tests for the presence of wastewater.

2.2.1 VT Sampling Results at VDH Sampling Sites

The most significant result of VT MST is the detection of a strong human signature at Fairview Beach at the VDH sampling sites. In 70% of the samples analyzed at these sites, at least one isolate from human sources was identified.

The relative contribution of sources over multiple samples can be calculated by assuming that the sources of observed bacteria are proportional to the fraction of isolates in a sample from those sources. In other words, the bacteria attributable to a source can be defined to be:

Bacteria attributable to source in sample =
Sample bacteria concentration * number of isolates from source/total number of isolates

Using this formula and summing over all samples, about 25% of the observed bacteria can be attributed to human sources. Figure 4 shows the breakdown by source. Based on the observed data, about half the bacteria observed at Fairview Beach can be attributed to human sources or pets (primarily dogs).

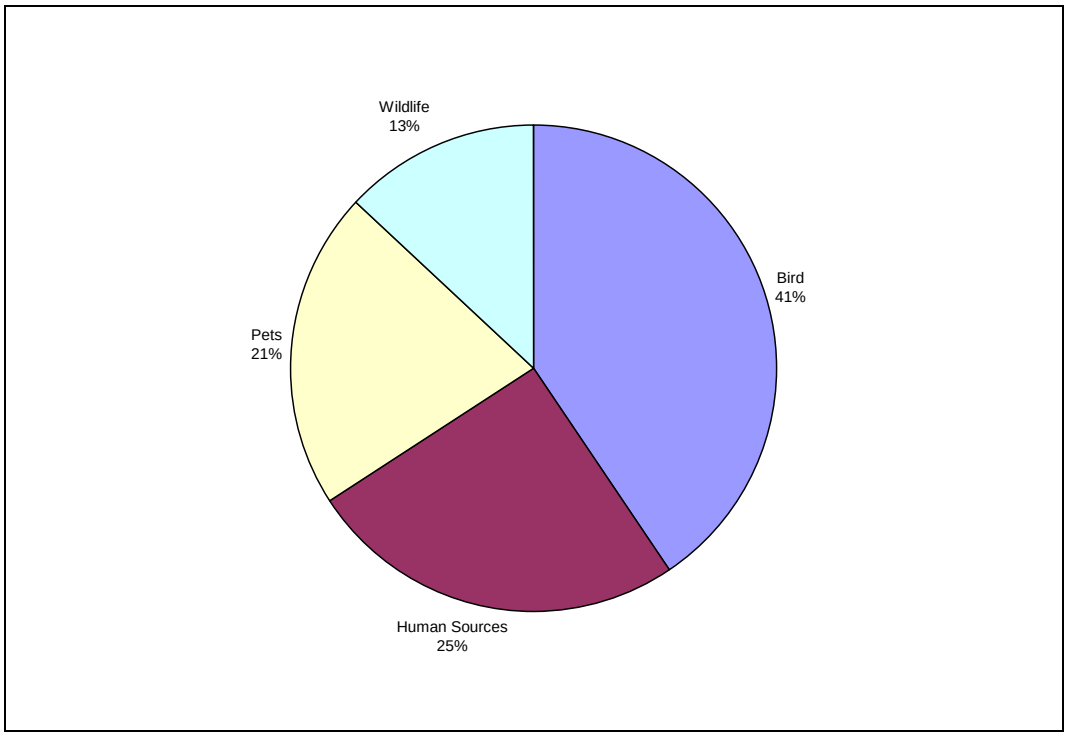

Figure 4: Observed Bacteria Attributable to Sources, Fairview Beach, 2004-2007

The fraction attributable to anthropogenic sources (human and pets) is slightly larger if only samples with bacteria concentrations larger than 104 cfu/100 ml are included in the analysis. For these samples, 26% of the observed bacteria can be attributed to human sources and 22% to dogs. There are positive trends between observed concentrations and percent bacteria attributable to human or anthropogenic sources. Figure 5 shows the correlation between observed concentrations and the percent of those concentrations attributable to human sources; Figure 6 shows the correlation between concentrations and percent attributable to anthropogenic sources. Higher percentages attributable to these sources tend to be associated with higher observed concentrations. High bacteria concentrations, however, are also observed when the percent of the bacteria attributable to anthropogenic sources are relatively low. If the fraction of bacteria attributable to anthropogenic sources is subtracted from observed bacteria concentrations, about 30% of the average daily *Enterococci* concentrations would still be above 104 cfu/100 ml.

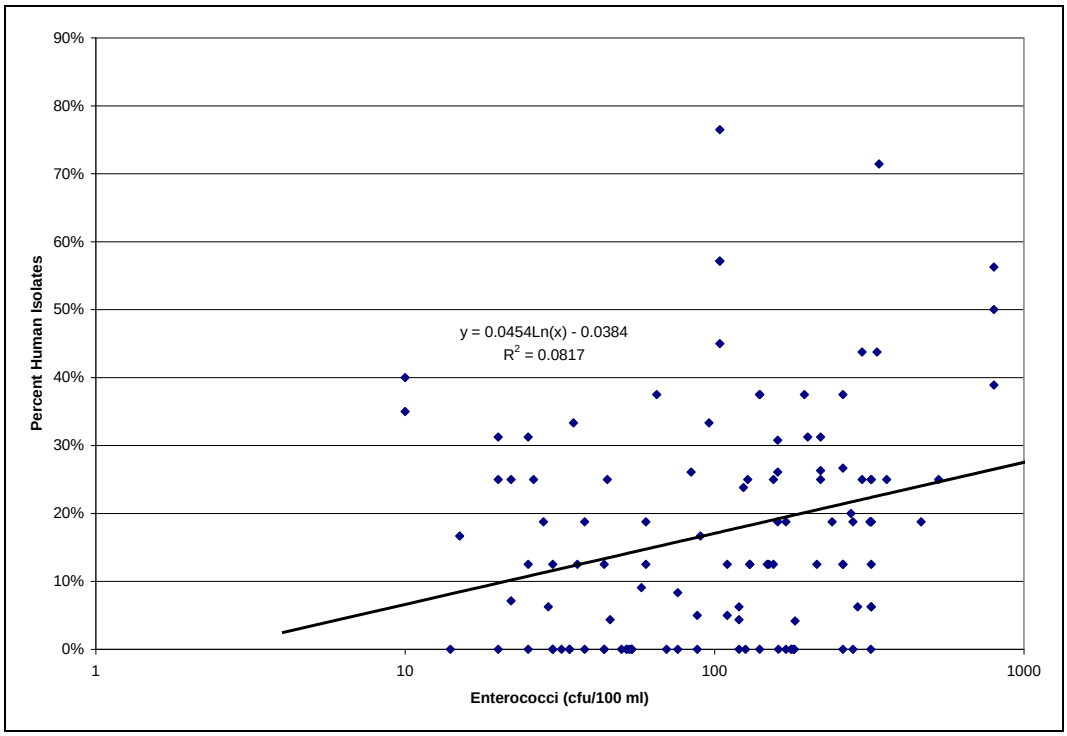

Figure 5: Percent Isolates Attributable to Human Sources vs. Observed *Enterococci* Concentration (cfu/100 ml), Fairview Beach, 2004-2007

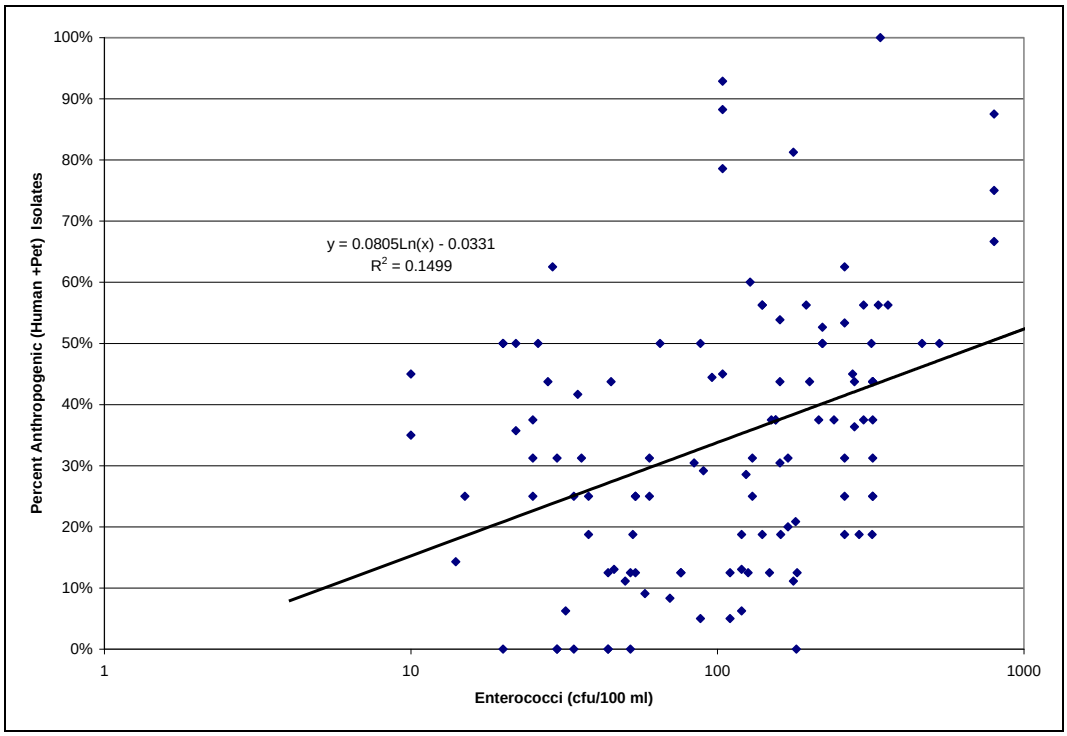

Figure 6: Percent Isolates Attributable to Anthropogenic Sources vs. Observed *Enterococci* Concentration (cfu/100 ml), Fairview Beach, 2004-2007

To further evaluate the human signature detected in the bacteria observed at Fairview Beach, VT staff conducted several studies in 2007 and 2008 to attempt to identify potential human sources of bacteria at Fairview Beach. To test whether the Potomac River is the source of human signature at Fairview Beach, VT took three paired samples, one at the VDH sampling location, and one 25 meters out into the Potomac River. No OB measurement was greater than 100 and, although human isolates were found, generally birds were responsible for the greatest number of isolates. Nevertheless, in all paired samples, (1) the concentration of *Enterococci*; (2) OB fluorescence measurements; and (3) the number of isolates attributable to human sources were less in the samples taken 25 meters out into the Potomac River than in the samples taken closer to shore. Table 7 shows the results of the paired sampling events.

Table 7: Paired Sampling Monitoring Results (VDH Sampling Locations vs. 25 Meters Out into Potomac River), Fairview Beach

Date	Station	Position	*Enterococci* (cfu/100 ml)	Optical Brighteners	Isolates				
					Bird	Human	Pet	Wildlife	Total
6/23/2006	A	Shore	318	70	7	3	5	1	16
		25 m	140	46	11	1	2	2	16
	B	Shore	214	64	8	2	4	2	16
		25 m	90	54	13	0	1	2	16
	C	Shore	465	95	5	3	5	3	16
		25 m	175	67	12	1	2	1	16
7/13/2006	A	Shore	220	70	6	5	3	2	16
		25 m	50	47	13	1	1	1	16
	B	Shore	195	68	6	6	3	1	16
		25 m	65	53	10	2	2	2	16
	C	Shore	155	66	8	2	4	2	16
		25 m	73	45	13	0	2	1	16
5/30/2007	A	Shore	38	60	10	3	1	2	16
		25 m	14	36	10	0	1	1	12
	B	Shore	36	46	9	2	3	2	16
		25 m	21	34	9	0	3	0	12
	C	Shore	45	77	7	4	3	2	16
		25 m	17	47	11	1	0	0	12

2.2.2 8th Street Sinkhole

In 2004, VT staff performed MST analysis and measured OBs at a sinkhole at 8th Street, as well as a storm drain at 8th Street. A strong human signal was detected at the 8th Street sinkhole. OBs also measured 171 on 6/24/04. The sinkhole was filled in with concrete at the end of the summer. Samples were taken the following year on 6/15/05 inside and at the end of the 8th Street storm drain, as well as at the end of the pier on 8th Street. No human isolates were detected at any of these locations, and OB measurements were below 40, suggesting that filling in the sinkhole had prevented human signal found in the sinkhole from reaching the river. No explanation of the source of the human signal was

ever determined. Table 8 shows the sampling results taken in the vicinity of the 8th Street sinkhole.

Table 8: VT Sampling Results in Vicinity of 8th Street, Fairview Beach

Date	Location	*Enterococci* (cfu/100 ml)	Optical Brighteners	Isolates				
				Bird	Human	Pet	Wildlife	Total
6/15/2004	Storm drain	*	40	7	3	4	10	24
6/15/2004	Sinkhole	*	78.7	3	9	6	6	24
6/24/2004	Sinkhole	*	171	2	10	3	9	24
6/15/2005	Storm drain	220	32.4	8	0	2	6	16
6/15/2005	Storm drain (inside)	670	37.8	18	0	0	2	20

* Sample not analyzed for bacteria.

Because the sample taken at the end of the pier adjacent to the storm drain on 8th Street on 6/15/2005 had an *Enterococci* concentration less than 10 cfu/100 ml, no MST analysis was performed on the sample.

2.2.3 Pavilion Drive Storm Drain

A storm drain, which starts at Pavilion Drive and discharges to the Potomac River just upstream of the bathing area, became the focus of investigation starting in 2006. VT sampled the storm drain and the sand at the mouth of the drain in 2006 and 2007 and found elevated *Enterococci* concentrations and isolates attributable to human sources. The drain, but not the sand, was sampled for OBs and levels were about 100, indicating the presence of human sources. Table 9 shows the monitoring results from the storm drain, and Table 10 shows the results from the sand.

Additional samples were also collected from the water beneath the sand to the right and left of the drain. Observed *Enterococci* concentrations were 540 and 195 cfu/100 ml at the right and left, respectively. Nine of sixteen isolates were attributed to human sources at the right of the pipe and eight of sixteen isolates were attributed to human sources at the left. OB measurements were 113 and 121, respectively, confirming the presence of bacteria from human sources.

An intermittent creek flows into the storm drain above Pavilion Drive. The creek was sampled once on 7/13/2006. The observed *Enterococci* concentration was 1780 cfu/100 ml. Seven of 16 isolates could be attributed to human sources, and the OB measurement was 149, corroborating the presence of wastewater.

Table 9: VT Monitoring Results from Pavilion Avenue Drainpipe, 2006-2007

Date	*Enterococci* (cfu/100 ml)	Optical Brighteners	Isolates				
			Bird	Human	Pet	Wildlife	Total
6/23/2006	158	112	6	5	4	1	16
7/13/2006	560	119	7	6	3	0	16
5/30/2007	317	121	7	6	3	0	16
7/17/2007	380	57	8	7	1	0	16
9/2/2007	1440	213	6	8	2	0	16
9/3/2007	4220	127	5	8	3	0	16
9/4/2007	4460	188	5	9	2	0	16

Table 10: VT Monitoring Results from Sand below Pavilion Avenue Drainpipe Outfall, 2006-2007

Date	*Enterococci* (cfu/100 ml)	Isolates				
		Bird	Human	Pet	Wildlife	Total
6/23/2006	180	5	6	4	1	16
5/30/2007	680	6	7	2	1	16
7/17/2007	1175	3	8	3	2	16
9/2/2007	460	5	9	2	0	16
9/3/2007	600	5	9	2	0	16
9/4/2007	2300	4	8	3	1	16

At the end of the bathing season in 2007, the King George County Health Department investigated the sewage disposal systems in a trailer park and apartment building adjacent to the storm drain (Burkett, 2007). The trailer park occupies the area along Botts Lane, Floyd Court, and Pavilion Drive west of Botts Lane (See Figure 2). The investigation was done with the full cooperation of the owners of trailer park. Some of the trailer homes are served by septic systems, and some are connected to public sewer lines. One drain field which lies between trailer homes on Pavilion Drive and the Potomac River was found to functioning properly, but two other septic systems were replaced with connections to the public sewer system. Dye tests, with subsequent investigation with transducer and camera, uncovered two breaks in the sewer lines connecting trailer homes with the public sewer system. Effluent from these breaks had entered the Pavilion Avenue drain pipe and discharged to the river. The breaks were repaired. VT staff sampled the drainage pipe for *Enterococci* in 2009. Table 11 shows the monitoring results. VT (2009) characterized the bacteria counts observed in 2009 as “lower overall” than previous years, but as Table 11 shows, observed *Enterococci* concentrations were frequently above the 104 cfu/100 ml assessment criteria. At the close of the bathing season in 2011, another sewer line break in the trailer park was discovered and repaired. Sampling performed by FBRA in the vicinity of the drainage pipe will be discussed below.

Table 11: Observed *Enterococci* Concentrations (cfu/100 ml) at Pavilion Avenue Drainpipe, 2009

Date	*Enterococci* (cfu/100 ml)		Date	*Enterococci* (cfu/100 ml)		Date	*Enterococci* (cfu/100 ml)
5/21/2009	190		7/13/2009	350		8/17/2009	20
6/2/2009	860		7/21/2009	120		8/24/2009	60
6/22/2009	100		7/27/2009	140		8/25/2009	230
6/25/2009	670		8/3/2009	790		9/1/2009	830
6/27/2009	210		8/5/2009	170		9/2/2009	120
6/29/2009	90		8/6/2009	30		9/6/2009	580
7/6/2009	380		8/10/2009	10		9/9/2009	240

2.2.4 Potomac River

To investigate the source of high bacteria concentrations at Fairview Beach, VT staff sampled the Potomac River and several Virginia embayments for *Enterococci* and OBs in 2007 and 2008. MST was not performed on the samples.

Sixteen sites in the Potomac River, two in Aquia Creek, and two in Potomac Creek were monitored on 7/17/07. Figure 7 shows the *Enterococci* concentrations observed at these locations. Only four of the 16 concentrations were above 104 cfu/100 ml, and three of these were in close proximity to Fairview Beach. A fourth sample, collected in the Potomac River near the mouth of Passapatanzy Creek had a concentration of 360 cfu/100 ml. The possible significance of that sample is discussed below in Section 3.3. The maximum OB measurement observed in the Potomac River samples was 68. Concentrations sampled on the same day at VDH sites A, B, and C were 155, 355, and 24 cfu/100 ml, respectively.

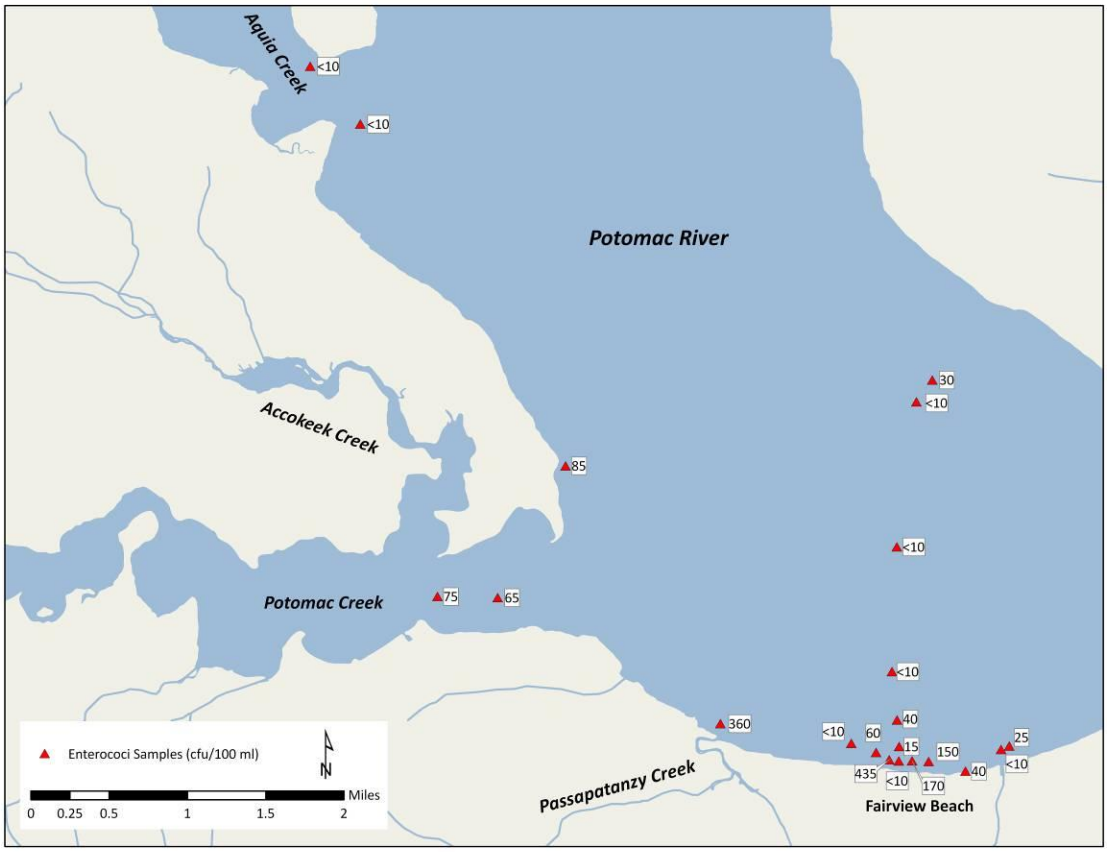

Figure 7: Observed *Enterococci* Concentrations (cfu/100 ml) in Potomac River and Embayments, 2007

Quantitative data from 2008 is unavailable. VT (2008) states that sampling in 2008 "discounted the river as the source of problems at Fairview."

2.2.5 Caledon Natural Area State Park

To test whether wildlife may be the source of high bacteria concentrations at Fairview Beach, VT staff sampled the waters off the Caledon Natural Area State Park (see Figure 1) for *Enterococci* and OBs in 2007 and 2008. MST was not performed on the samples.

Two dates were sampled in 2007. Figure 8 shows the location of the sampling locations. Table 12 shows the results. No observed *Enterococci* concentration was above 104 cfu/100 ml, and no OB measurement was above 70.

Quantitative data from 2008 is unavailable. VT (2008) states that "...there were no major sources of wildlife in the preserve that appeared to be capable of impacting water quality at the beach."

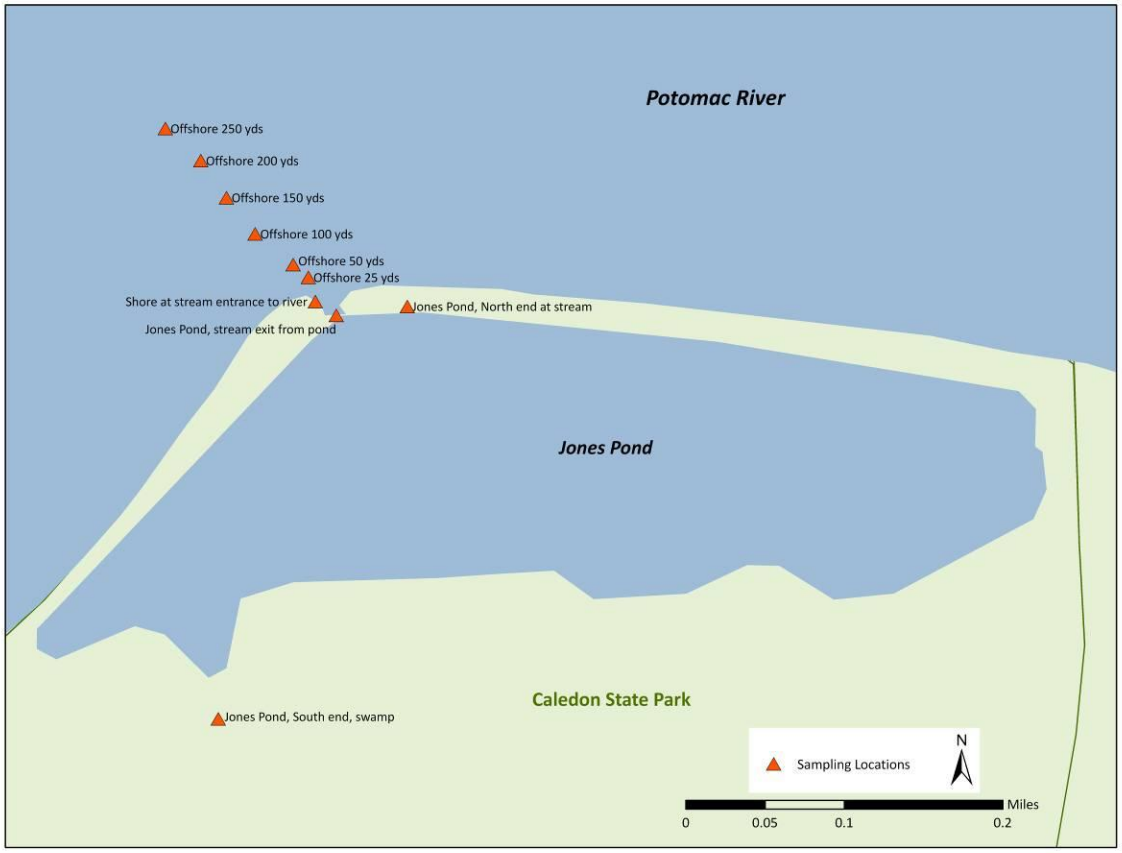

Figure 8: Sampling Locations near Caledon State Park, 2007

Table 12: VT Sample Results in Caledon Natural Area State Park (2007)

	7/17/2007		9/3/2007	
Location	***Enterococci* (cfu/100 ml)**	**Optical Brighteners**	***Enterococci* (cfu/100 ml)**	**Optical Brighteners**
Offshore 250 yds	<10	41	34	36
Offshore 200 yds	45	40	83	21
Offshore 150 yds	52	26	<10	37
Offshore 100 yds	68	42	48	40
Offshore 50 yds.	<10	22	<10	21
Offshore 25 yds	53	35	73	31
Shore at stream entrance to river	<10	24	56	46
Jones Pond, stream exit from pond	45	39	68	25
Jones Pond, South end, swamp	74	20	102	17
Jones Pond, North end at stream	58	70	73	33

2.2.6 Marina and Boating Events

VT staff took samples 50 yards north and south of the marina of the Fairview Beach Yacht Club in 2004. A single isolate was attributed to human sources at the south sampling location, while no isolate was attributed to human sources at the north sampling location. OB measurements were 41.1 and 41.5 at the north and south sites, respectively. The samples were not analyzed for bacteria concentrations.

In 2007 and 2008, VT staff sampled for bacteria and OBs in and around an event at Fairview Beach that attracted a large number of boaters. The 2007 event occurred on Labor Day weekend. Table 13 shows that despite the presence of as many as 70 boats over the weekend, *Enterococci* concentrations and OB measurements remained low. Over the same weekend at one VDH sampling site on 9/2/2007, a concentration of 135 cfu/100 ml was observed but the average value of all three VDH sites was below 104 cfu/100 ml.

In 2008, an even larger event, attended by hundreds of boats, occurred. No quantitative results from VT sampling of this event are available, but VT (2008) reports that "[t]he impact of weekend crowds and boaters was not a problem."

Table 13: VT Monitoring Results of Labor Day Weekend (2007) Boating Event at Fairview Beach

	9/2/2007 (20-30 boats)		**9/3/2007 (50-70 boats)**		**9/4/2007 (no boats)**	
Location	***Enterococci* (cfu/100 ml)**	**Optical Brighteners**	***Enterococci* (cfu/100 ml)**	**Optical Brighteners**	***Enterococci* (cfu/100 ml)**	**Optical Brighteners**
Down river - below boats	43	22	85	20	20	19
Beyond boats in main channel	<10	20	<10	21	<10	20
Up river - beyond boats	35	40	30	38	15	30
In front of stage	54	35	102	43	38	37

2.3 Fairview Beach Resident's Association Monitoring Results

Starting in 2011, the Fairview Beach Resident's Association (FBRA) worked with the Virginia Department of Environmental Quality (DEQ) to perform bacteria monitoring using Coliscan kits provided by DEQ. Coliscan kits provide an inexpensive way of testing for *E. coli* bacteria. This testing method sufficiently indicates the presence and concentration of *E. coli* bacteria that may be present; however the data may have variations in quality assurance and is not used quantitatively to list/delist waterbodies on the impaired waters list. The *E. coli* freshwater assessment threshold of 235 cfu/100 ml, which is used for assessing waterbodies when there are not enough samples to calculate a geometric mean, is roughly equivalent to the 104 cfu/100 ml for *Enterococci*. *E. coli* die off more rapidly in salt water, so the Coliscan results may underestimate the equivalent *Enterococci* concentration. FBRA has kept DEQ informed of the results of their monitoring; DEQ provided training in the use of the Coliscan kits and continue to provide advice to the FBRA volunteers.

FBRA monitoring has primarily focused on three issues: (1) the level of bacteria in local runoff; (2) elevation of bacteria concentrations under agitated conditions; and (3) potential sources of bacteria in the vicinity of the Pavilion Street drain pipe.

2.3.1 Bacteria in Local Runoff

FBRA collected samples at multiple locations along eleven streams, drain pipes, and ditches where stormwater runoff could potentially impact the beach. Figure 9 shows the location of the monitoring locations. Table 14 shows the *E. coli* concentrations observed using the Coliscan kits. As FBRA reported (Cover *et al*., 2011), there were practically no bacteria in these locations if there had been no rainfall, but there were significant concentrations of bacteria after rainfall events. Nineteen samples were taken at these locations after 1.3 inches of rain fell on July 8, and only one of the samples had a concentration less than 900 cfu/100 ml.

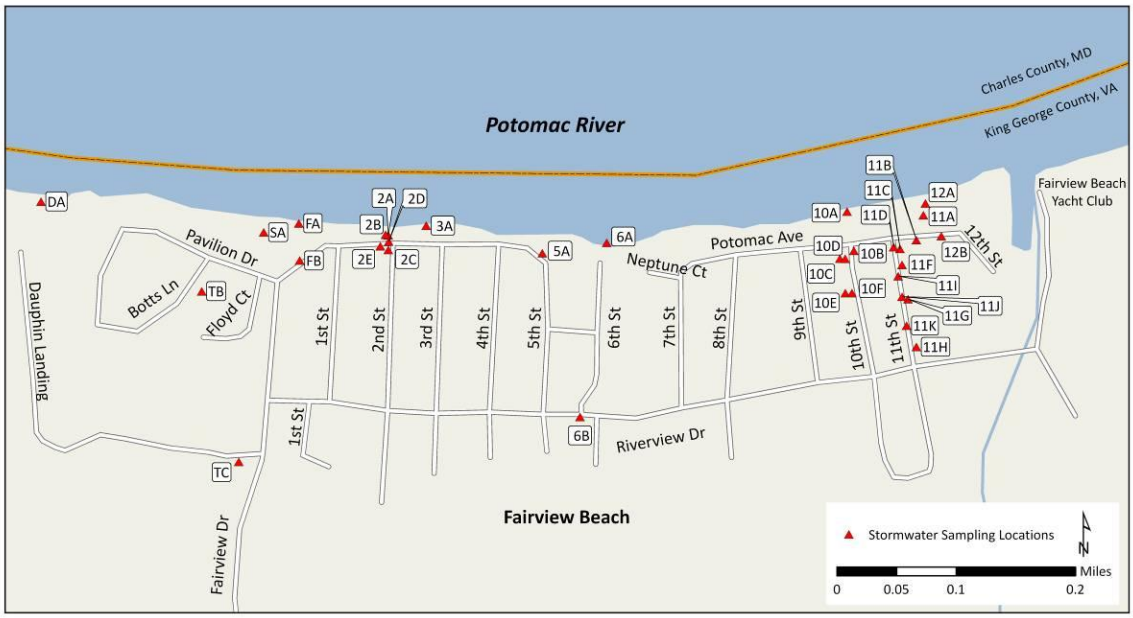

Figure 9: FBRA Stormwater Sampling Locations

Table 14: Observed *E. coli* Concentrations (cfu/100 ml) FBRA Storm Sampling

Date	6/20/2011	6/25/2011	6/28/2011	6/29/2011	7/3/2011	7/8/2011	7/13/2011
Rain (inches)	**1.0**	**0.0**	**0.0**	**0.75**	**0.25**	**1.3**	**0.51**
2A		<100		<100	5,900	1,450	
2B							
2C						1,200	
2D						1,300	
2E						900	
3A		<100		<100			
5A		400	250	100		4,000	
6A		100		1,050			
6B					600		
10A		<100		<100			
10B						3,900	
10C						4,000	
10D						1,650	
10E							TNTC
10F							TNTC
11A				TNTC		3,200	>5000
11B					TNTC	2,600	
11C						TNTC	
11D						2,650	
11E						3,150	
11F							6,250
11G							>5000
11H							1,250
11I							TNTC
11J							>5000
11K							1,100
12A						2,800	
12B							4,350
DA		150		100		1,300	
FA		<100				4,000	
FB		<100					
SA				<100		9,200	
TB	100			<100	3,600		
TC	150					1,600	

2.3.2 Elevated Bacteria Concentrations under Rough or Muddy Conditions

VT (2005, 2006) observed that precipitation events often triggered elevated bacteria concentrations and (2007) entertained the hypothesis that bacteria resuspension under the action of wind waves or tides could contribute to high bacteria concentrations. Cover *et al*. report that "[a] former VDH employee once told us that he could almost forecast high

bacteria readings based on the sight of the river (p.4).” If the river was muddy or turbulent, the bacteria concentrations could be expected to be high.

FBRA sampled on several occasions to test the hypothesis that elevated bacteria concentrations occurred primarily under rough or muddy conditions. Table 15 summarizes the mean *E. coli* concentrations observed in the Potomac River under calm and rough conditions. Bacteria concentrations were low, either at or below the detection limit, in samples taken from the Potomac River under calm conditions. Although elevated concentrations were not always observed when conditions were rough, concentrations exceeding the 235 cfu/100 ml assessment threshold occurred only under rough or muddy conditions.

On the other hand, when FBRA monitors collected a sediment sample and placed it in distilled water, they were not able to observed high bacteria concentrations when they agitated the sediment.

Table 15: Average *E. coli* Concentrations (cfu/100 ml) in Calm vs. Rough Conditions

Date	Conditions	Number of Samples	Arithmetic Mean	Geometric Mean
7/18/2011	Calm	7	100	100
8/4/2011	right after rain	5	100	100
9/10/2011	muddy 100-140 feet, wavy	12	163	153
9/15/2011	muddy, whitecaps	11	177	139
9/18/2011	muddy, wavy, trash	3	483	479
12/18/2011	rough, choppy	3	100	100
3/23/2012	Calm	3	100	100
3/28/2012	Calm	3	100	100
4/3/2012	Calm	3	100	100
5/10/2012	12" cap muddy	3	100	100
5/25/2012	Calm	3	100	100
5/26/2012	low tide, very rough water	6	1,267	1150
8/18/2012	Pounding waves	5	2,540	2320
9/10/2012	white caps, 1 ft waves	5	170	155
9/15/2012	1 foot caps	6	308	299
9/22/2012	Calm	3	100	100
9/30/2012	Calm	2	100	100
10/6/2012	river had been rough	5	220	206

In 2011, FBRA volunteers took paired samples from five locations (1) waste-deep and (2) shoulder-deep in the Potomac under choppy conditions. Table 16 shows the results. The waste-deep samples had *E. coli* concentrations between 200 and 250 cfu/100 ml, while samples taken farther out (shoulder deep) generally had no detectable concentrations. This confirms the results of VT’s paired sampling, which also found bacteria concentrations to be higher near shore.

Table 16: *E. coli* Concentrations (cfu/100 ml) at Paired Sampling Sites in the Potomac River, FBRA Sampling 2011

	9/10/2011		9/15/2011	
Location	**waste deep**	**farther out**	**waste deep**	**farther out**
VDH-C	250	150	600	<100
5th Street	250	100	100	<100
8th Street	150	150	400	<100
11th Street	200	100	<100	150
DA (see Figure 9)	200	<100		<100
VDH-B	200	<100	<100	<100

FBRA volunteers also sampled for *E. coli* near shore at five locations over a half a mile upriver from Fairview Beach under rough conditions. As shown in Figure 10, observed concentrations ranged from 750 to 1450 cfu/100 ml. The observation of elevated concentrations under rough conditions up to a half of a mile upriver from Fairview Beach may indicate that a more general mechanism may be responsible for the elevated bacteria concentrations observed at the beach.

Figure 10: *E. coli* Concentrations Observed under Rough Conditions Upriver From Fairview Beach, 5/26/2012

2.3.3 Parking Lot Drainage and Subsurface Sampling

In 2012, the parking lot off Pavilion Drive at the foot of Botts Lane was embanked, and a twelve inch black corrugated pipe was installed to carry runoff approximately forty feet to the Potomac River, adjacent to the bathing area. Prior to the installation of the pipe, runoff from the parking lot would frequently erode the beach (Cover *et a*l., personal communication, 8/22/12).

FBRA volunteers sampled standing water in the parking lot after a small amount of rain. The *E. coli* concentration was estimated to be greater than 5000 cfu/100 ml. The *E. coli* concentration detected in subsequent sampling from the water found about 15 inches below the sand surface near the pipe outlet was also greater than 5000 cfu/100 ml, while a subsurface sample taken in the vicinity of VDH Site A detected no *E. coli* bacteria.

FBRA volunteers took six additional samples from runoff in the parking lot during a 20 minute storm in which 0.75 inches of rain fell. Two samples from runoff at the periphery of the parking lot had elevated concentrations, 900 cfu/100 ml and TNTC, but at the point where the runoff entered the black corrugated pipe the *E. coli* concentration was 150 cfu/100 ml. This suggested that parking lot runoff was not the source of the elevated bacteria concentrations observed in the subsurface sample at the end of the pipe.

About a dozen additional subsurface samples were taken in the vicinity of the end of the black corrugated pipe, on the theory that there was a sewer leak somewhere near where the pipe discharged to the Potomac River. Elevated concentrations, ranging from 700 to greater than 5000 cfu/100 ml, were measured within four feet of the outfall, but at greater distances, the concentrations tended to be below the detection limit. At this point in time no sewage leak has been confirmed at this location.

2.4 Summary of Monitoring Results

The following conclusions can be drawn from the bacteria monitoring performed by VDH, VT, and FBRA:

1. Bacteria concentrations are elevated when river conditions are turbulent, muddy, choppy, or otherwise rough;
2. Bacteria concentrations under turbid or rough conditions tend to decrease moving away from the shoreline, indicating the direct source of bacteria under rough conditions is not the Potomac River;
3. Elevated bacteria concentrations under turbid or rough conditions may not be a problem confined to Fairview Beach;
4. Bacteria concentrations in the Potomac River outside the vicinity of Fairview Beach are generally lower than the concentrations observed at Fairview Beach;
5. Elevated concentrations of bacteria are observed in local stormwater draining Fairview Beach;
6. Although several human sources of bacteria have been identified and rectified, local human sources continue to contribute to the bacteria observed at Fairview Beach; and
7. Eliminating bacteria just from human sources and pets may not be sufficient to fully resolve the bacteria impairment at Fairview Beach.

These conclusions are discussed in more detail in connection with potential sources and transport mechanisms in the next section.

3.0 Source and Transport Mechanisms for Bacteria

3.1 Human Sources

MST analysis and OB monitoring have indicated that human sources are contributing to the bacteria impairment at Fairview Beach. Although several leaking sewer pipes have been fixed and failing septic drain fields have been circumvented in the vicinity of the Pavilion Avenue drain pipe, not all human sources of bacteria have been addressed. As discussed in Section 2.2.3, both MST and OB monitoring show a strong human signal from the intermittent creek draining to the upper end of the drain pipe near Pavilion Drive. The human sources contributing bacteria to the creek have not been identified. MST and OB monitoring also indicated that human sources contributed to the bacteria found in the sinkhole on 8th Street. Although levels of bacteria and isolates attributed to human sources fell after the sink hole was filled in, the human source contributing to the sinkhole was also never identified.

Potential human sources of bacteria include (1) failing septic systems; (2) septic systems with drain fields located too close to waterbodies; (3) faulty connections between residences and sewer lines; and (4) leaks and/or overflows from sewer lines. Examples of some of these sources have been found in the trailer park, and may be present in other parts of Fairview Beach that have not been subject to the same scrutiny. Although Fairview Beach is served by public sewer, there still may be homes on septic systems outside of the trailer park. The soils in Fairview Beach are inappropriate for septic systems, because the water table is close to the surface. Failing septic systems were the primary cause of the construction of the wastewater treatment plant at Fairview Beach in the 1980's. In a study for King George County at that time, Dewberry, Nealon, and Davis (1974) report that in Fairview Beach "during wet periods sewage is leeching through the surface of the ground" (p.5). Systems that do not exhibit ponding effluent may also be providing insufficient treatment if the bacteria are transported to the water table and ground water discharges to surface water nearby. The drainfields between Pavilion Drive and the Potomac River are likely to be too close to the river to provide adequate treatment. If the trailer homes along Botts Lane are served by septic systems, they may also be the source of bacteria observed in the creek above the Pavilion Avenue drainpipe. Preferential ground water flow paths, caused by installing pipe, may exacerbate the problem. If, for example, the Pavilion Avenue drainpipe was laid in a gravel bed, the bed may be serving as a conduit for groundwater flow, contributing to the high bacteria concentrations observed near the drainpipe outfall.

Home owners themselves are responsible for the connections between their homes and the public sewer lines. Whether these connections have been made correctly, and are functioning correctly without leaking or otherwise discharging effluent, is not known (comment by unidentified resident, Fairview Beach Monitoring Meeting, 9/20/2012). In this regard, it may be helpful to determine through MST or OB monitoring whether

human sources can be detected in the stormwater flows in Fairview Beach. That may give some indication of how extensive the contribution of human sources is to the impairment.

3.2 Dogs

VT staff (2007) reported that dogs are not restricted from the beach and dog waste was observed near the beach in every year they sampled there.

3.3 Birds and Wildlife

VT staff (2005) reported that "trash was not a problem" at Fairview Beach, so it can be inferred that there are not a large number of gulls in the vicinity of the beach. Observed bacteria concentrations are low in the vicinity of Caledon State Park, about one and a half miles downstream of Fairview Beach.

Cover *et al*. (2011) determined that there were a "significant number" of geese on a beach a mile upstream of Fairview Beach and a large flock of swans in Passapatanzy Creek which joins the Potomac River a mile upstream from Fairview Beach. Presumably these are the closest points to Fairview Beach at which a large number of birds have been seen. As discussed in Section 2.2.4, a sample taken in the Potomac River near the mouth of Passapatanzy Creek had an *Enterococci* concentration of 360 cfu/100 ml. In contrast, when FBRA analyzed samples collected in Passapatanzy Creek and in the Potomac River near the geese, the samples had *E. coli* concentrations of 100 and < 100 cfu/100 ml, respectively. In any case, since there is no barrier, like an island or deep channel, to prevent the flow from Passapatanzy Creek from mixing laterally into the mainstem Potomac River, it is unlikely that bacteria concentrations a mile away from Fairview Beach are transported close to shore and contribute significantly to bacteria concentrations at the beach.

VT (2007) suggests raccoons are the most likely source of bacteria from wildlife. Based on the MST, as shown in Figure 4, 13% of the bacteria observed at Fairview Beach could be attributed to wildlife. It is interesting to note that most of the isolates attributed to wildlife were identified in the first two years of the VT MST study. While overall 13% of the bacteria were attributable to wildlife, 31% of the bacteria were attributable to wildlife in 2004 and 2005, in contrast to 2006 and 2007, when only 7% and 12%, respectively, were attributable to wildlife. The explanation for these differences is not clear, though it may be a function of meteorological or hydrological conditions.

3.4 Potomac River

Background bacteria concentrations at Fairview Beach stem from the Potomac River. VT's recent monitoring of *Enterococci* show that generally bacteria concentrations in the Potomac River are low. Paired monitoring of near shore and sites farther out in the river

by both VT and FBRA show that bacteria concentrations tend to drop moving from the shore out into the river.

Potential human sources of bacteria occur upstream in the Washington DC metropolitan area. Both the District of Columbia and the City of Alexandria have combined sewer systems (CSSs). The former is subject to a Long-Term Control Plan (LTCP) which will reduce the number and quantity of combined sewer overflows (CSOs) in the future; the LTCP for the City of Alexandria will be revised to achieve water quality improvements.

The impact of the Potomac River as a background source can be gaged by an analysis of fecal coliform monitoring data collected by the Maryland Department of Natural Resources. Table 17 summarizes the observed fecal coliform concentrations in the Potomac River over the period 1986-1998. Monitoring stopped in 1998. The detection limit was 2 cfu/100 ml. Figure 11 shows the location of the sampling stations. The stations closest to Fairview Beach are in the salinity transition zone: RET2.1, RET2.2, RET2.3, and RET2.4.

Table 17: Potomac River Fecal Coliform Concentrations (cfu/100 ml), Maryland DNR, 1986-1998 [1]

Station	Number of Samples	Arithmetical Mean	Geometrical Mean	Percent > 200 cfu/100 ml	Percent > 400 cfu/100 ml	Maximum
TF2.1	136	624	93	41%	28%	9300
TF2.2	135	307	56	30%	21%	4300
TF2.3	137	208	38	22%	12%	3300
TF2.4	138	117	18	12%	8%	5000
RET2.1	139	155	9	6%	4%	9300
RET2.2	138	63	7	3%	3%	4900
RET2.3	52	7	5	0%	0%	43
RET2.4	136	13	4	2%	1%	490

[1] Source: Chesapeake Bay Program Data Hub
http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present

As Table 17 shows, there is a strong gradient in bacteria concentrations with elevated concentrations upstream in the Washington metropolitan area and diminishing concentrations in the salinity transition zone. Before a sufficient number of *E. coli* or *Enterococci* samples had been taken, a fecal coliform concentration of 400 cfu/100 ml was used by Virginia as an assessment threshold equivalent to the *E. coli* assessment threshold of 235 cfu/100 ml or the *Enterococci* threshold of 104 cfu/100 ml. As many as 28% of the samples had fecal coliform concentrations above 400 cfu/100 ml upstream of the transition zone, but in the transition zone less than 5% of the samples exceed the 400 cfu/100 ml threshold. Elevated bacteria concentrations occur far less frequently in the main channel of the Potomac River in the transition zone than at Fairview Beach, indicating that the Potomac River is not generally the source of the elevated bacteria concentrations observed at Fairview Beach or the large fraction of the bacteria attributable to human sources when concentrations are elevated.

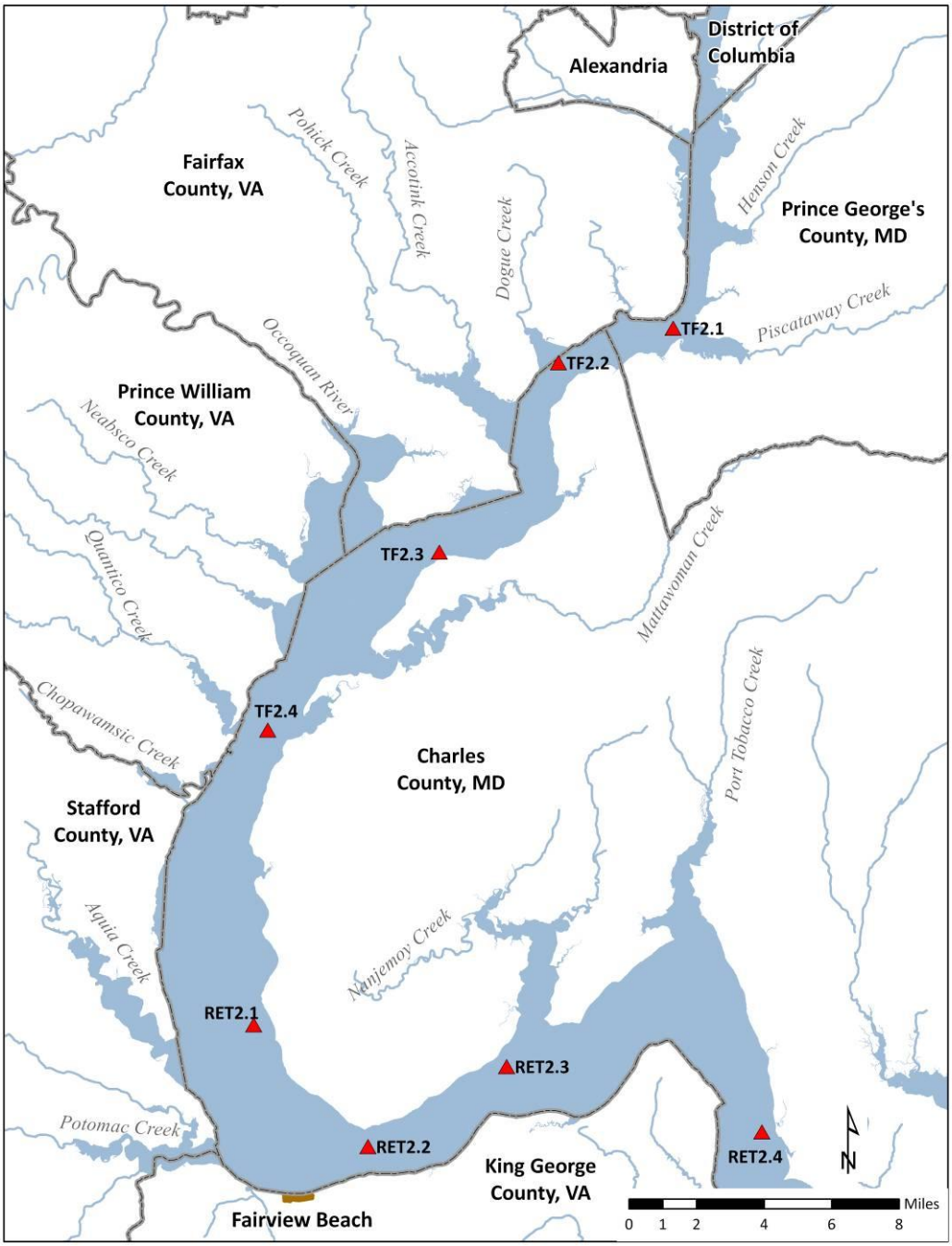

Figure 11: Maryland DNR Fecal Coliform Monitoring Stations

3.5 Resuspended Sediment and Beach Sand

Because elevated bacteria concentrations frequently occur under rough or muddy conditions, resuspended sediment is a possible source of bacteria at Fairview Beach. The source of the bacteria in sediment is discussed in part below.

Recently, scientists have identified beach sand as a reservoir of fecal indicator bacteria, including *Enterococci* (Halliday and Gast, 2011). Observed concentrations can be an order of magnitude more or greater in beach sand than tidal water, if the concentration in sand is measured as cfu/100g or cfu/100 ml volume. *Enterococci* find a hospitable environment in the biofilms surrounding sand particles, which provide sufficient moisture and nutrients while sheltering the bacteria from sunlight. Some researchers assert that *Enterococci* and other indicator bacteria are able to regenerate in sand, and that sand supports natural strains not directly derivable from any animal species (Whitman and Nevers, 2003).

The beaches dynamically exchange sediments with the tidal water at their margins. In their review article, Halliday and Gast report that "[d]ata from nearly all environments suggest erosional flow conditions generated by storms or tides may flush bacteria out of sediments or sands, resulting in some level of contamination of the water column" (p.9). Whitman and Nevers (2003), in their detailed study of an urban beach in Chicago, studied correlations between sand and water column bacteria concentrations and concluded that sand and water "were correlated, indicating a continued flux between sand and water…this flux has bidirectional components, but the net movement of *E. coli* is presumably from foreshore lakeward, driven by swash and resuspension" (p.5559). E. Halliday (2012), in a study of beaches at Providencetown, MA, found similar results for *Enterococci*: the flood tide transfers bacteria from sand to the water column, and the stronger the waves, the greater the transfer. Yamahara *et al*. (2007) in a study of a beach in Monterrey, CA found that even in the absence of erosion, *Enterococci* in beach sand can be mobilized or eluted by flood tide. The bacteria lost from the sand were roughly equivalent to the bacteria gained by the water column.

VT (2006, 2007) found elevated concentrations of bacteria in sand in the vicinity of the outfall of the Pavilion Avenue drainpipe. It is not known how widespread elevated concentrations are in sand or whether high concentrations are confined to a few hotspots. The presence of bacteria in beach sand may also explain why FBRA observed elevated bacteria concentrations upstream of Fairview Beach under rough conditions, as shown in Figure 10.

The presence of *Enterococci* in beach sand may also explain the large fraction of bacteria attributable to birds at Fairview Beach. Since bacteria survive better in sand than in the water column, a small number of birds defecating in the sand can have a magnified impact. Bacteria from birds can be spread by beach traffic (Whitman and Nevers, 2003), enhancing the opportunity for their transport to beach waters. If natural strains of *Enterococci* are present, they may confound the identification of isolates attributable to birds and wildlife, since they are likely not to have extensive exposure to antibiotics.

3.6 Stormwater

Stormwater has already been identified as a source of elevated bacteria concentrations. Stormwater also carries suspended sediment in elevated concentrations and bacteria are likely transported in this sediment. This sediment may be deposited near shore and contribute to the bacteria resuspended under rough or muddy conditions. In a study of the Neuse River Estuary, Fries et al. (2006) found 38% of the indicator bacteria attached to particulate matter and noted that this fraction was similar to fraction of bacteria attached to particulate matter in stormwater.

3.7 Groundwater

As stated earlier, the water table is relatively close to the surface in the soils underlying Fairview Beach, making them unsuitable for septic drain fields. Even well-functioning systems can transport bacteria to surface water. Groundwater may also be a conduit for bacteria from leaking or faulty sewer connections. On the other hand, the relatively few samples collected from groundwater have not verified that groundwater is a major conduit for bacteria. Significant bacteria concentrations have been observed at the water table by FBRA volunteers only immediately in the vicinity of the recently-installed drain from the parking lot, discussed in Section 2.3.3. Moreover, the fact that bacteria concentrations dropped and the detection of isolates from human sources ceased after the 8th Street sinkhole was filled in may indicate that subsurface flow is not a significant transport path for bacteria. This may also be indicated by the fact that bacteria concentrations are relatively low under calm conditions, when the influence of groundwater may be more significant. A broader survey of bacteria in groundwater may prove helpful in determining to what extent groundwater is a conduit for bacteria transport.

3.8 Recommendations for Additional Monitoring

Based on the available data, the following is a set of working hypotheses on the sources of bacteria at Fairview Beach:

- Anthropogenic sources (failing septic systems, faulty sewer connections, dogs) make a substantial contribution to the bacteria observed at Fairview Beach;
- The primary pathways for the transport of bacteria are stormwater runoff, resuspension of sediment, and erosion of beach sand; and
- The contribution of non-anthropogenic sources, such as birds and wildlife, are exacerbated by anthropogenic modifications of the environment.

Additional monitoring can confirm or contravene these hypotheses. The highest priority should be given to performing MST and OB measurements on stormwater runoff in Fairview Beach to determine if human sources are contributing to elevated bacteria concentrations. The detection of human sources can help identify the location of these sources, and can serve as a prelude to a sanitary survey of residences in Fairview Beach,

to determine if (1) they are connected to the public sewer system, and (2) if the connection is installed properly and is not leaking wastewater. Sediment concentrations should also be measured in stormwater.

Second, the concentrations of *Enterococci* in beach sand should be measured, to better characterize beach sand as a potential source of bacteria in the water column. The physical characteristics (grain size) and bacteria concentrations of sediment near shore and farther out in the Potomac River should be measured, and similar observations made on resuspended sediment at these locations. In the absence of offshore sources of pollution, a decreasing gradient of bacteria concentrations can be expected moving away from the shore into deeper water. Two possible reasons for this gradient are (1) there is a near shore source of bacteria, such as beach sand, and (2) shallow water has less volume for dilution and is more vulnerable to impacts from suspended sediment (Wymer *et al*., 2005). The latter suggests an alternative hypothesis on the sources of bacteria at Fairview Beach: the sediments and/or sand in the vicinity of Fairview Beach do not have higher bacteria concentrations than sands or sediment found elsewhere in the Potomac River, but bacteria concentrations are elevated at the margins of the river because of less dilution or greater resuspension per water volume. Sampling to better characterize the sand and sediment at Fairview Beach can help resolve uncertainty in the sources of bacteria observed there. If sediments in the vicinity of Fairview Beach have a higher concentration than elsewhere in the Potomac River, the source of the bacteria should be determined through MST.

4.0 Actions Undertaken or Planned to Address Bacteria Impairment at Fairview Beach

Since 2003, Fairview Beach has suffered significant damage in major storms, including Hurricane Isabel (2003) and Tropical Storm Ernesto (2006), which destroyed the bulkheads protecting the beach (VT, 2006). VT staff (2006, 2007) asserted without structural improvements the swimming advisories could be expected to continue. They recommended (1) repairing breakwater structures to control beach erosion, (2) improving drainage control so that runoff does not flow into swimming areas, and (3) increasing the width of the beach by a minimum of ten to fifteen yards. They also recommended controls on dog waste.

FBRA is engaged in several projects to improve the physical structure of the beach and reduce beach erosion. Their website (http://mysite.verizon.net/vzet7zqu/fbra2/id20.html) documents their efforts. The efforts include (1) repairing the bulkheads and enhancing them with native vegetation to hold them in place; and (2) repairing or replacing groins controlling erosion from the beach. The latter should reduce wave energy and control beach erosion, therefore reducing the potential impacts of beach sand as a source of bacteria at Fairview Beach.

In addition, the Tri-County/City Soil Water Conservation District installed ten pet waste stations. FBRA volunteers are maintaining these stations.

As discussed in Section 1.1, the original portion of the Fairview Beach settlement area is characterized by small lot sizes with a high degree of impervious surface. The King George County Plan (2012) calls for implementation strategies to encourage low density development in or adjacent to Fairview Beach. New development should minimize impervious area while maximizing native vegetation. Redevelopment should reduce nonpoint source loads by 10% or impervious cover by 20%. In this regard, it can be noted that the trailer park in which the leaking sewer lines were discovered has been rezoned for the construction of multi-unit dwellings, so the opportunity may exist in the future for significant water quality improvement through redevelopment.

Whatever the source of bacteria in runoff, the amount of bacteria delivered to the beach could be reduced by reducing runoff volume through using rain barrels, redirecting downspouts onto grassy areas, installing porous pavement, etc. FBRA may be willing to encourage its members to adopt such runoff reduction practices.

5.0 Development of a Watershed Plan and Category 4B Listing

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. EPA regulations and guidance, however, recognize that an impaired water not may not need a TMDL if there are other pollution control requirements that are sufficient to meet water quality standards within a reasonable period of time. "Other pollution control requirements (e.g., best management practices) required by local, State, or Federal authority" that are stringent enough to implement the appropriate water quality standards (40 CFR 130.7(b)(1)(iii)) can be used as an alternative to developing a TMDL. Waterbodies where an alternative approach can be used instead of a TMDL for addressing an impairment can be classified as Category 4B ("…impaired or threatened for one or more designated uses, but does not require a TMDL because pollution control requirements…are reasonably expected to result in attainment of water quality standards…") in contrast to water bodies requiring TMDLs, which are classified as Category 5 in Virginia's Water Quality Integrated Report.

Fairview Beach is a candidate for a Category 4B listing, for the following reasons:

1. The impaired area is very small (0.012 sq. mi.). Elevated bacteria levels extend no more than 25 yards into the Potomac River. The local drainage area contributing to the swimming area is of the order of one to two square miles. The control measures and restoration measures needed to address the bacteria impairment are highly specific, and TMDL allocations won't provide any guidance on implementing them.

2. Some control measures, such as pet waste stations, are already in place. The implementation of other control measures, such as structural measures to control beach erosion, are already underway.

3. The highest priority should be given to the identification and elimination of the contribution of human sources (septic systems, faulty sewer connections) to the bacteria impairment. Since there is no legal discharge of these sources, they would receive no allocation under a hypothetical TMDL.

Formally, the justification of a Category 4B listing requires the following six elements (Regis, 2006):

1. Identification of segment and statement of the problem causing the impairment;
2. Description of pollution controls and how they will achieve water quality standards;
3. An estimate or projection of the time when WQS will be met;
4. Schedule for implementing pollution controls;
5. Monitoring plan to track effectiveness of pollution controls; and
6. Commitment to revise pollution controls, as necessary.

According to Regis (2006), pollution control requirements are not required to have a statutory or regulatory basis, as long as it can be demonstrated that the controls implemented will lead to the attainment of WQS in "within a reasonable period of time." Monschein and Reems (2009) document the wide variety of regulatory and non-regulatory types of pollution controls that have successfully been used to justify a Category 4B listing. These include (1) remediation; (2) point source controls required under permits; (3) CSO consent orders and LTCPs; and (4) nonpoint source controls specified in watershed restoration or implementation plans (watershed plans or watershed-based plans).

The best vehicle for justifying a Category 4B Listing for Fairview Beach is a Watershed Plan (WP). A WP for Fairview Beach would document those measures already put in place to address impairment (such as pet waste stations) as well as specify the additional measures required to meet WQS. These would include planned improvements to the beach and the measures required to eliminate human sources of bacteria. It can also include additional measures, such as stormwater controls, that could reduce bacteria inputs to the beach. One additional advantage of a WP is that it could make some of these efforts eligible for funding under Section 319 of the Clean Water Act. In order to be eligible for funding, the WP must include the following nine elements (EPA 2008):

1. Identification of causes and sources of pollution;
2. Estimate of load reductions expected from management measures;
3. Description of management measures to achieve load reductions and of the critical areas in which these need to be implemented;
4. Estimate of the technical and financial assistance needed to implement plan;

5. An information and education component used to enhance public understanding of the project;
6. Schedule for implementing management measures;
7. Description of interim measureable milestones to determine whether management measures are being implemented;
8. Criteria for determining progress towards meeting WQS; and
9. Monitoring component to evaluate effectiveness of implementation efforts over time.

Because of the small geographical size of the impaired waterbody and the local drainage basin, it would not be difficult to specifically enumerate the management measures required to address the bacteria impairment. The schedule for implementation can double as the list of interim milestones for implementation. Similarly, the best measure of the effectiveness of management measures is a reduction in swimming advisories, beach closures, and bacteria concentrations in VDH monitoring. FBRA can provide an active stakeholder group for implementing the information and educational component of the WP. Regis (2006) explicitly recognizes that "incentive-based actions by private parties" can contribute to pollution control efforts, so FBRA activities, such as beach restoration, can be included in the WP.

The nine elements of the WP cover the first five elements of the 4B Listing justification and include some additional elements, like a public information component and interim milestones, which are not essential elements of the justification. The only element of the justification not explicitly address by the WP is the commitment to adaptive management, which either could be incorporated into the WP or addressed separately in the justification.

5.1 Summary of Recommendations for Addressing Bacteria Impairment at Fairview Beach

Based on the available monitoring data, *Enterococci* bacteria concentrations exceeding the 104 cfu/100 ml threshold triggering swimming advisories are due to local sources. The primary pathways for the transport of local sources are stormwater runoff, erosion of beach sand, and resuspension of sediment, though there may be contributions from bacteria in groundwater in preferential flow paths. Human sources, such as septic systems and faulty sewer connections, and pets (primarily dogs) make a significant contribution to bacteria concentrations observed in Fairview Beach, although it is not clear whether the elimination of only the anthropogenic sources will fully mitigate the bacteria impairment.

The first step in addressing the bacteria impairment is to better categorize bacteria concentrations in storm runoff and beach sand. Additional concentration measurements should be made to determine the extent of the problem and some form of bacteria source tracking performed to determine the source of the bacteria; measurement of optical brighteners can be substituted for source tracking for stormwater runoff.

The second step is to draft a Watershed Plan to enumerate the management actions and control measures that are (1) currently being performed as well as (2) additional actions that need to be performed to address the bacteria impairment at Fairview Beach.

The third step is to use the WP to justify classifying Fairview Beach as Category 4B ("…impaired or threatened for one or more designated uses, but does not require a TMDL because pollution control requirements…are reasonably expected to result in attainment of water quality standards…") instead of as Category 5, requiring a TMDL, in Virginia's Water Quality Integrated Report.

6.0 References

Burkett, J. 2007. Septic System Overview of Fairview Beach Mobile Home Park. King George County Health Department.

Cover, H., J. Hancharick, J. Harrover, and G. Meadows. 2011. FBRA Contamination Study Summer 2011. Fairview Beach Resident's Association.

Dewberry, Nealon, and Davis. 1974. King George County, Virginia Water and Sewerage Study. Fairfax, VA.

Fries, J. S., G. W. Characklis, and R. T. Noble. 2006. Attachment of Fecal Indicator Bacteria to Particles in the Neuse River Estuary, NC. Journal of Environmental Engineering 132:1338-1334. ?

Hagedorn, C., M. Saluta, A. Hassall, and J. Dickerson. (2005a). Fluorometric Detection of Optical Brighteners and an Indicator of Human Sources of Water Pollution. Part I. Description and Dectection of Optical Brighteners. Crop and Science Environmental News. http://www.sites.ext.vt.edu/newsletter-archive/cses/2005-11/part1.html

_____. (2005b). Fluorometric Detection of Optical Brighteners and an Indicator of Human Sources of Water Pollution. Part II. Development as a Source Tracking Methodology in Open Waters. Crop and Science Environmental News. http://www.sites.ext.vt.edu/newsletter-archive/cses/2005-11/part2.html

Halliday, E. 2012. Digging into Dry Weather Bacteria Violations at Recreational Beaches. www.epa.gov/region1/neaeb2012/pdfs/1130_BR3_ElizabethHalliday.pdf

Halliday, E. and R. J. Gast. 2011. Bacteria in Beach Sands: An Emerging Challenge in Protecting Coastal Water Quality and Bather Health. Environmental Science and Technology 45(2):370-379.

King George County. 2012. Draft King George County Comprehensive Plan.

Monschein, E. and S. Reems. 2009. Category 4b—Current National Status and Trends. U. S. Environmental Protection Agency. Washington, DC.

Natural Resource Conservation Service (NRCS).2013. Custom Soil Resource Report for Charles County, Maryland, and Stafford and King George Counties, Virginia. (generated at http://websoilsurvey.nrcs.usda.gov).

Regis, D. 2006. Memorandum: Information Concerning the 2008 Clean Water Act Sections 303(d), 305(b), and 314 Integrated Reporting and Listing Decisions. U. S. Environmental Protection Agency. Washington, DC. http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2006_10_27_tmdl_2008_ir_memorandum.pdf

Virginia Polytechnic Institute and State University, Department of Crop and Soil Environmental Science (Virginia Tech). 2004. 2004 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2005. 2005 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2006. 2006 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2007. 2007 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2008. 2008 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2009. 2009 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.

_____. 2011. 2011 Final Project Report, Microbial Source Tracking and Virginia's Beach Monitoring Program. Blacksburg, VA.
U. S. Environmental Protection Agency. 2005.

U. S. Environmental Protection Agency. 2008. Handbook for Developing Watershed Plans to Restore and Protect our Waters. Washington, DC. EPA 841-B-08-002.

Whitman, R. L. and M. B. Nevers. 2003. Foreshore Sand as a Source of *Escherichia coli* in Nearshore Water of a Lake Michigan Beach. Applied and Environmental Microbiology 69(9): 5555-5562.

Wymer, L. J, K. P. Brenner, J. W. Martinson, W. R. Stutts, S. A. Schaub, and A. P. Dufour. The EMPACT Beaches Project: Results from a Study on Microbial Monitoring in Recreational Waters. U. S. Environmental Protection Agency Office of Research and Development, National Exposure Research Laboratory. Cincinnati, OH. EPA 600/R-04/023.

Yamahara, K. M., B. A. Layton, A. E. Santoro, and A. B. Boehm. 2007. Beach Sands along the California Coast are Diffuse Sources of Fecal bacteria to Coastal Waters. Environmental Science and Technology 41:4515-4521.