TMDL for six creeks in Northumberland County

The six creeks being considered in the final bacterial TMDL in Northumberland County (Cod west, Cod east, Presley, Hull, Cubitt and Hacks Creeks) all discharge northward to the Potomac River between the Coan River and Smith Point. The creeks are close together and all are located on the “coastal fringe” north of the Suffolk Scarp, in a similar environmental setting, yet they have very different degrees of “urbanization.” Thus they present an opportunity to try to understand the causes of bacterial contamination. A map is available on p. 5 of the handout prepared for the 06/24/09 TMDL meeting in Heathsville - www.deq.virginia.gov/tmdl/mtgppt.html.

Data on land use indicate that Hull Creek has, by far, the largest watershed and the largest absolute number of homes, and by extension, septic systems and pets. In contrast, Cod east and Cod west are the smallest bodies of water but have the highest density of homes. Cod west includes one of three old developments in Northumberland County, Pine Point Estates, that is zoned “Residential Restricted” (R-3). This zoning category is no longer allowed, and once permitted “… medium density residential development on [small] non-conforming lots of record … recorded prior to September 1, 1974.” Hacks Creek has few year-round residents. Cod east and Cod west are relatively open for boat traffic to the Potomac, Hull creek is passable with care and local knowledge, but the other three creeks, especially Hacks, are nearly impassible under most circumstances, except for canoes and kayaks. Presley Creek has a history of major changes in tidal exchange with the Potomac. Prior to Ernesto, the creek had almost no tide and an anomalously low salinity, and was evolving into a pond. There are too few salinity data from the six creeks to warrant analysis, especially because a salinity gradient is always present, decreasing from the mouth of the creeks toward the headwaters because of groundwater discharge and runoff. Additionally, salinity stratification is observed in some creeks in summer, resulting in “dead zones” whose lateral extent and duration are undocumented.

Land use

Creek	acres	# homes	homes/acre	% forest	%farm	% other
Cod W	889	89	0.10	48	34	18
Cod E	948	130	0.14	60	23	17
Presley	4066	338	0.083	46	39	15
Hull	6725	511	0.076	55	26	19
Cubitt	2276	195	0.086	66	19	15
Hack	2125	126	0.059	62	25	13

Data provided by Stuart McKenzie, Environmental Planner, NNPDC. Maps are available from him showing the distribution of forest, farmland, and the location of residences.

In contrast to differences in size and degree of habitation between the creeks, bacterial concentrations (MPN/100 ml) are all quite similar and not statistically distinct. The data always document increasing bacterial concentrations toward the headwaters of the creeks. Explanations for this unexcepted phenomenon include runoff from the land and/or decreased organism lethality in lower salinity water. The headwaters of the creeks, with the highest bacterial concentrations, always have the lowest density of homes.

Bacterial concentrations

	12/20/84 to 7/22/08, headwaters			4/14/04 to 7/22/08, near mouth		
Creek	Station	average	median	Station	average	median
Cod W	3	52.6	15	2	25.8	9
Cod E	5	62.5	9	4	16.2	4
Presley				21	28.7	15
Hull	16	64.2	23	11	16.9	4
Cubitt	20A	68.3	23	19	72.1	11
Hack				23	32.1	9

Data on fecal coliform bacterial concentrations collected by VDH's Shellfish Sanitation division are not easily explained in detail. Table 1 presents the available data for all six creeks between 4/14/04 and 07/22/08. The sampling stations chosen are those that most closely correspond to station # 9-23 in Hacks Creek in order to make the comparison between creeks as similar as possible.

Table 1

Cod W 2	Cod E 4	Presley 6	Hull 11	Cubitt 19	Hack 23	date	average	rain	named storms
23	23	21	9	93	23	4/14/04	32.0	2.5	
9	9	9	3	23		5/25/04		0.2	
9	3	43	3	9	4	6/9/04	11.8	0	
3	3	4	15	3	43	7/12/04	11.8	1.1	
4	4	9	9	23	4	8/26/04	8.8	0	Alex, Bonnie, Charlie, Gaston
43	23	23	9	23	43	9/7/04	27.3	0.9	Frances, Ivan, Jeanne
9	93	150	15	43	23	10/25/04	55.5	0.1	
43	43	23	15	93	43	11/16/04	43.3	0	
23	3		9	3	3	2/7/05		0	
3	4	23	3	3	3	3/30/05	6.5	0.9	
4	4	23	4	9	4	4/5/05	8.0	0	
9	3	4	3	23	4	5/18/05	7.7	0	
43	39	43	43	93	23	6/8/05	47.3	0	
3	4	9	3	4	4	7/19/05	4.5	0.2	Cindy
4	9	39	23	4	9	8/30/05	14.7	0	
23	9	15	43		43	9/28/05		0	
460	93	43	240	1100	43	10/25/05	329.8	1.3	
7	15	15	9	240	23	11/8/05	51.5	0.1	

9	23	43	9	240	460	12/7/05	130.7	1.5	
43	23	3	3	43	9	1/23/06	20.7	0	
3	3	3	3	3	3	2/21/06	3.0	0	
3	3	3	3	3	43	3/6/06	9.7	0	
43	4	43	3	7	23	4/19/06	20.5	0.5	
9	4	4	3	23	93	5/4/06	22.7	0	
15	23	23	39	93	43	6/15/06	39.3	1.2	Alberto
7	4	43	4	3	23	7/17/06	14.0	0.1	
9	7	93	9	9	43	8/16/06	28.3	0.5	
43	43	93	75	150	9	9/13/06	68.8	0.6	Ernesto
23	39	23	23	460	43	10/18/06	101.8	0.4	
4	3	4	4	3	4	12/18/06	3.7	0	
3	3	9	15	9	3	1/29/07	7.0	0	
43	4	4	23	93	43	3/26/07	35.0	2.3	
75	43	150	43	7	43	4/26/07	60.2	0.1	
39	4	43	4	23	9	5/14/07	20.3	0.1	
4	4	21	3	9	3	6/13/07	7.3	0.1	Barry
3	3	4	9	9	9	7/10/07	6.2	0	
3	3	3	2	11	13	8/27/07	5.8	0.2	
9	3	4	4	23	3	9/10/07	7.7	0	Gabrielle
3	7	10	1	18	7	10/22/07	7.7	0	
2	1	6	1	7	1	11/8/07	3.0	0	
1			5	2	6	1/10/08		0	
50	81	117	25	173	81	4/29/08	87.8	1.5	
10	1	3	1	23	73	5/15/08	18.5	0.9	unnamed Nor'easter
3	3	5	1	3	6	6/16/08	3.5	1.4	
2	2	7	1	5	6	6/30/08	3.8	0.1	
3	2	1	2	5	1	7/22/08	2.3	0.1	Cristobal

Table 1: Bacterial concentrations for stations near the mouths of all six creeks for the interval 4/14/04 to 7/22/08 (MPN/100 ml.) The number below the name of the creek is the station number. The bacterial concentrations in the six creeks were averaged only when data are available for all six creeks. Rainfall was measured in inches at my pier on Spencers Creek, Little Wicomico River, 2.5 miles southeast of Hacks Creek, and includes the sampling date plus two days before sampling.

Summary statistics (MPN/100ml) for the time interval 12/20/84 to 07/22/08, for stations closest to the headwaters, for the four creeks for which data are available over that longer time interval, also demonstrate no significant differences in bacterial levels.

	Station	Average	median	homes/acre
Cod west	3	52.6	15	0.10
Cod east	5	62.5	9	0.14
Hull	16	64.2	23	0.076
Cubitt	20A	68.3	23	0.086

Simple inspection of Table 1 suggests that high bacterial concentrations are commonly, but not always, observed in all creeks at the same time. Most puzzling are “spikes” that appear for no obvious reason. The single “spike” on 10/25/05 is the reason the average bacterial concentration is higher in Cubitt than in the other creeks. If that single observation is omitted, the average bacterial concentration is reduced to 48.8, much more similar to the other creeks.

Rainfall is the most obvious variable that might explain temporal variations in the data. Indeed, the average bacterial concentration in Hacks Creek was 93 MPN/100ml (8 samples) when rainfall within two days of sampling exceeded one inch at my pier. In contrast, the average bacterial concentration was only 16 MPN/100 ml when rainfall was less than one-half inch (28 samples) within two days of sampling. Sorting the data from Table 1 according to decreasing rainfall shows this relationship (Table 2).

date	Cod W	Cod E	Presley	Hull	Cubitt	Hack	average	in. rain	>14 5	
4/14/04	23	23	21	9	93	23	32.0	2.5	55	XXXXXXXXXX
3/26/07	43	4	4	23	93	43	35.0	2.3	4	XXXXXXXX
12/7/05	9	23	43	9	240	460	130.7	1.5	4	XXXXXXXX
4/29/08	50	81	117	25	173	81	87.8	1.5	6	XXXXXXXXXXXX
6/16/08	3	3	5	1	3	6	3.5	1.4	0	
10/25/05	460	93	43	240	1100	43	329.8	1.3	6	XXXXXXXXXXXX
6/15/06	15	23	23	39	93	43	39.3	1.2	6	XXXXXXXXXXXX
7/12/04	3	3	4	15	3	43	11.8	1.1	2	XXXX
9/7/04	43	23	23	9	23	43	27.3	0.9	5	XXXXXXXXXX
3/30/05	3	4	23	3	3	3	6.5	0.9	1	XX
5/15/08	10	1	3	1	23	73	18.5	0.9	2	XXXX
9/13/06	43	43	93	75	150	9	68.8	0.6	5	XXXXXXXXXX
4/19/06	43	4	43	3	7	23	20.5	0.5	3	XXXXXX
8/16/06	9	7	93	9	9	43	28.3	0.5	2	XXXX
10/18/06	23	39	23	23	460	43	101.8	0.4	6	XXXXXXXXXXXX
7/19/05	3	4	9	3	4	4	4.5	0.2	0	
8/27/07	3	3	3	2	11	13	5.8	0.2	0	
10/25/04	9	93	150	15	43	23	55.5	0.1	5	XXXXXXXXXX
11/8/05	7	15	15	9	240	23	51.5	0.1	4	XXXXXXXX
7/17/06	7	4	43	4	3	23	14.0	0.1	2	XXXX
4/26/07	75	43	150	43	7	43	60.2	0.1	5	XXXXXXXXXX
5/14/07	39	4	43	4	23	9	20.3	0.1	3	XXXXXX
6/13/07	4	4	21	3	9	3	7.3	0.1	1	XX
6/30/08	2	2	7	1	5	6	3.8	0.1	0	
7/22/08	3	2	1	2	5	1	2.3	0.1	0	
6/9/04	9	3	43	3	9	4	11.8	0	1	XXXX
8/26/04	4	4	9	9	23	4	8.8	0	1	XX
11/16/04	43	43	23	15	93	43	43.3	0	6	XXXXXXXXXXXX
4/5/05	4	4	23	4	9	4	8.0	0	1	XX
5/18/05	9	3	4	3	23	4	7.7	0	1	XX
6/8/05	43	39	43	43	93	23	47.3	0	6	XXXXXXXXXXXX
8/30/05	4	9	39	23	4	9	14.7	0	2	XXXX
1/23/06	43	23	3	3	43	9	20.7	0	3	XXXXXX
2/21/06	3	3	3	3	3	3	3.0	0	0	
3/6/06	3	3	3	3	3	43	9.7	0	1	XX
5/4/06	9	4	4	3	23	93	22.7	0	2	XXXX
12/18/06	4	3	4	4	3	4	3.7	0	0	

1/29/07	3	3	9	15	9	3	7.0	0	1	XX
7/10/07	3	3	4	9	9	9	6.2	0	0	
9/10/07	9	3	4	4	23	3	7.7	0	1	XX
10/22/07	3	7	10	1	18	7	7.7	0	1	XX
11/8/07	2	1	6	1	7	1	3.0	0	0	
average	25.8	16.2	28.7	16.9	72.1	32.1				

Table 2 – Data (MPN/100 ml) from Table 1 for the interval 4/14/14 to 7/22/08 sorted according to decreasing rainfall. Sampling dates for which data are unavailable for all six creeks have been omitted. The column "> 14" gives the number of stations for that day that exceeded 14 MPN/100ml, and that number is shown graphically in the far-right column. Of the 41 sampling dates for which data are available for all six creeks, 18 (44%) had at most one sample that exceeded 14 MPN/100 ml. On 7 sample dates, the next most common category, all creeks exceeded the standard.

There were dates (11/16/04 and 6/8/05, for example) when there was little rain, but bacterial concentrations were high, just as there were dates (6/16/08, for example) when there was appreciable rain but bacterial concentrations were low. But the data clearly show a relationship between rainfall and high bacterial concentrations. The column ">14" shows that more creeks exceeded the 14 MPN standard after rain than conversely, but many exceptions exist.

The data certainly prove that variations in bacterial concentrations within creeks are much larger than variations between creeks. Thus it is likely that local land use is a less important variable in controlling bacterial concentrations than is a regional variable like rainfall or strong winds. This conclusion supports the findings of Simmons (1995, Managing Nonpoint Fecal Coliform Sources to Tidal Inlets, Univ. Council on Water Resources, Update, 100: 64-74, www.ucowr.siu.edu/updates/pdf/V100_A10.pdf). In a setting considerably more "urbanized" (31%) than is true of these six creeks, Simmons concluded that "… fecal contamination of tidal inlets, bays and estuaries does have an explanation which, to a large extent, can be attributed to nonhuman origin …."

Bacterial Source Tracking (BST) data are not worth detailed analysis. As I have stated previously, supported by cited peer-reviewed scientific publications, unbiased practitioners of this "art" are highly skeptical of BST results, especially when ARA alone is used. Additionally, DEQ has never provided quality control data (blind duplicate analyses, analysis of standards as unknowns, etc.) despite my request. Recent oral presentations have mentioned large numbers of samples for which no categorization into human, wildlife, pet or livestock origin was possible. Absent rigorous analytical quality control, it is impossible to quantitatively assess the validity of the ARA data. Many data sets suggest large contributions by livestock, between 10 and 46% for 4 of the 6 creeks under consideration here (pages 14 and 15 of the handout prepared for the 06/24/09 TMDL meeting in Heathsville), when livestock are either absent or present in extremely small numbers in the watershed. Cod creek, with the highest density of septic systems, some of them very old, is no more contaminated by bacteria of human origin than Hacks Creek, with far fewer permanent inhabitants. I conclude that the ARA data provide no useful, reliable information.

One of the first TMDLs for Northumberland County, for the Little Wicomico River, approved by EPA 12/18/03, concluded that "… elimination of the human fecal component alone is sufficient to ensure that water quality standards will be well within the acceptable standard." (p. vi). For the Coan River TMDL, approved at the same time, only one arm required reduction in livestock contamination, and human contamination needed to be reduced by between 19 to 100%. More recent TMDLs, e. g. Indian, Tabbs, Dymer and Antipoison Creeks, approved by EPA 04/08/09, recognize that "**The TMDL seeks to eliminate 100% of the human derived fecal component regardless of the allowable load determined through the load allocation process."** Table 5.14B (p. 50) also requires a total load reduction from pets and livestock of 100%.

A sufficient number of scientists have puzzled over the bacterial concentration data without coming to simple verifiable conclusions as to the source(s) of contamination to make further "research" of doubtful value. Despite the scientific uncertainties that remain regarding the causes of bacterial contamination, it is much more cost-effective to try to eliminate all anthropogenic sources rather than to spend time and tax dollars researching a problem that may not be solvable without committing massive resources. This should be DEQ/DCR's strategy – reduce contamination from all known sources of anthropogenic origin, including problematic septic systems, overboard boat discharge, livestock with access to streams, the land application of sewage sludge and poultry litter, concentrations of dogs, and runoff from impervious surfaces. It is likely, in my opinion, that wildlife are the major source of bacterial contamination. Data from the six creeks under consideration in this TMDL do not confirm any correlation between bacterial concentrations and anthropogenic factors. Given that the anoxic bottom sediment is known to contain fecal coliform bacteria, and that a massive bacterial contribution by wildlife certainly exists, reduction of bacterial contamination to meet water quality standards is probably impossible, especially in the headwaters of the creeks. The most cost-effective strategy is to reduce all known anthropogenic sources of contamination as much as practicable, continue the VDH monitoring program, and be prepared to conclude that naturally high bacterial levels are due to uncontrollable (wildlife) sources and that a Use Attainability Analysis is necessary.

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