Water Pollution from Livestock in the Shenandoah Valley

Virginia's System of Manure Management Fails to Protect Waterways and Needs to be Strengthened

ENVIRONMENTAL INTEGRITY PROJECT

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THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

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PHOTO CREDITS

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Executive Summary

Virginia's Shenandoah Valley is famous for its cultural heritage and natural beauty, but also hosts a thriving livestock and poultry industry. Much of that industry lies in Augusta, Page, Rockingham, and Shenandoah counties, which together raise more than 159 million chickens and 16 million turkeys a year, and manage more than 528,000 dairy and beef cows in feedlots and pastures. These animals generate more than 410,000 tons of poultry litter and one billion gallons of liquid manure annually.[1] The runoff from that huge volume of livestock manure ends up in Shenandoah waters, adding to pollution that threatens to disrupt the fishing, swimming, rafting, and other recreational uses that valley residents and visitors alike have long enjoyed. This report reviews Virginia's program to control manure runoff pollution and identifies significant gaps that need to be closed if the state program is to succeed in protecting the Shenandoah and its tributaries.

The Environmental Integrity Project (EIP) analyzed the pollution management plans for 675 factory farms in the Shenandoah Valley's Augusta, Page, Rockingham, and Shenandoah counties, 448 inspection reports from the Virginia Department of Environmental Quality, as well as data from the U.S. Department of Agriculture, and reached the following conclusions:

Tubing and rafting are popular on the Shenandoah River and its tributaries, but high E. coli bacteria levels are common in part because of manure runoff. Virginia fails to warn people to avoid contact with these contaminated waters, even when bacteria levels are more than 100 times the recreational limit.

Manure Has Much More Phosphorus Than Local Farmers Can Use

Livestock manure is used to fertilize fields because it is rich in the nitrogen and phosphorus that crops need to grow. But the huge volume of manure produced in Augusta, Rockingham, Page, and Shenandoah counties contains at least one and a half times more phosphorus than the amount needed by all the crops harvested in those counties in the most recent year for which data are available (2012).[2] Much of that acreage needs no phosphorus at all, because the soil already has more than enough to meet crop needs. Yet, farmers are allowed to apply more manure to fields that are already overloaded.[3]

Manure and Phosphorus Runoff Contaminates the Shenandoah with Algae and Bacteria

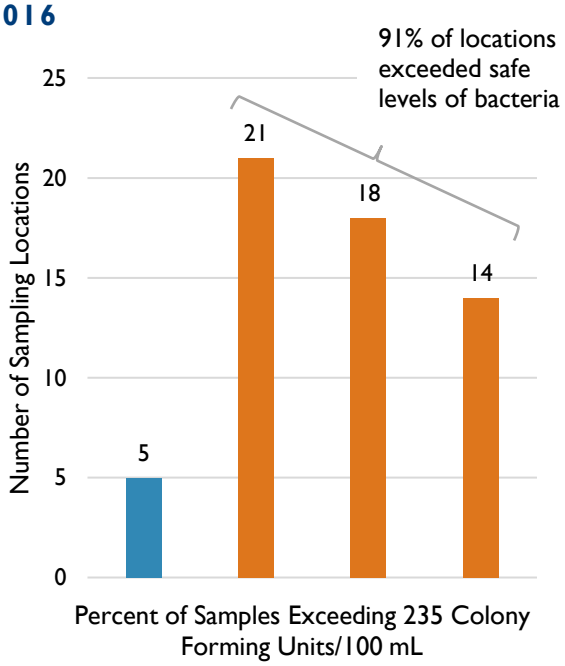
The excess phosphorus washed off fields where manure is spread ends up feeding algae blooms in the Shenandoah and its tributaries and low oxygen "dead zones" in the Chesapeake Bay. Manure runoff also contributes to bacterial contamination of streams and rivers.

- Virginia considers water quality "poor" for phosphorus when concentrations exceed 50 micrograms per liter.[4] Phosphorus levels were higher than that from 2014 through 2016 at nearly half (seven out of 16) of the state's long-term monitoring sites in the Shenandoah Valley, based on the average of measurements over those three years.

- Virginia advises avoiding swimming, fishing, or boating in waters when *Escherichia coli* (*E. coli)* bacteria levels exceed 235 "colony forming units" per 100 milliliters in more than 10 percent of samples. That *E. coli* standard was exceeded at 91 percent of the locations (53 of 58) where bacteria levels are measured in Shenandoah waters. The standard was exceeded more than a half of the time at 33 percent of those monitoring stations (19 of 58).

- Swallowing water with high *E. coli* levels can cause serious gastro-intestinal illness. The state issues public advisories warning beachgoers to stay out of the ocean when bacteria levels do not meet the recreational standard. But the state provides no such notice when the Shenandoah Valley and other rivers and streams are contaminated, even when *E. coli* levels are more than 100 times the recreational limit. (See table and map on pages 14 and 15, and Appendix B).

Figure 1. Number of Sampling Locations that Exceeded the *E. coli* Bacteria Health Standard for Water Contact Recreation, 2014-2016



Virginia advises people to avoid contact with water when samples exceed this level more than 10 percent of the time. Source: Virginia Department of Environmental Quality

Problems with Virginia's Pollution Management System

Virginia's pollution management plans for livestock manure are required for only 12.5 percent of the farmland in these four counties. Virginia requires pollution management plans, called "nutrient management plans," for large livestock operations. The plans' limits on spreading manure-based phosphorus and nitrogen apply only to land owned or leased by these large operators, and not to the vast majority of manure, which is sent off-site to other farms.

Most pollution management plans allow farmers to pile even more phosphorus on soils that already have enough. Over half of the farm acres required to be covered by plans (34,069 of the 67,303 acres in these four counties) do not need *any* more phosphorus for at least three years based on soil tests that show concentrations are already sufficient to support plant growth. The plans advise against the spreading of more manure on 18 percent (6,139) of these acres, but allow its continued application on the remainder, adding yet more phosphorus to cropland and pasture that has no need for this nutrient.

The state counts on crops to absorb the phosphorus in manure, but does not measure the actual results. Virginia officals depend on crop rotations with yields high enough to absorb the phosphorus from added manure. But actual harvests are often smaller than farmers project. This means less phosphorus is taken up by crops and more is left behind to build up in the soil.

Inspections are limited and enforcement is rare. The state's few inspectors work hard, but their inspections are announced in advance, they are becoming less frequent, and they are often limited to file reviews rather than on-site observation of actual field conditions. The fact that the nutrient application rates in nutrient management plans are expressed as "recommendations" rather than requirements makes enforcement even more difficult. State officials usually take no enforcement action beyond the occasional warning letter, even where violations are repeated or when farmers load more manure on their land than their plans supposedly allow.

The runoff of livestock manure feeds algal blooms on the Shenandoah River that damage the ability of people to enjoy the waterway. The problem also hurts businesses that use the river, such as fishing guides and tubing and rafting companies.

Record keeping is sometimes poor. Some farms fail to keep adequate records, and the conclusions of this report are based on the limited available records. For example, soil and manure samples that determine how much phosphorus or nitrogen should be applied to

farm fields are required to be taken only once every three years from poultry operations, and 15 percent of the operations inspected in 2014 or 2015 missed even that deadline.

Recommendations for a Better System:

1) Require pollution control plans for all farms that spread manure, not just a few.

Virginia's current system of requiring nutrient management plans for 12.5 percent farm acreage will have limited impact in counties like those in the Shenandoah Valley that have a large surplus of animal manure. The state should strengthen its program by requiring nutrient management plans for all farms that spread manure, not just large animal operations. The state should also strengthen its requirements for phosphorus applications in order to further limit the amount that can be applied to farm fields that already have enough.

2) Ask farmers to report their actual crop yields to improve the accuracy of the plans.

The state should tally up nitrogen or phosphorus removal rates at the end of each three year nutrient management plan, based on the specific crops planted and their actual (not projected) yield. This will help ensure that each plan more accurately accounts for how much of the nutrients are actually removed by crops, and therefore better targets phosphorus overload.

3) Expand and improve reporting.

Farmers should file annual reports that include manure and nutrient application rates as well as actual crop yields. That would provide more comprehensive information about how well these management practices are implemented, which is not available from inspection reports that only document a fraction of farm records. Where needed, the state should enlist consultants to help farmers compile and submit these reports.

4) Tighten inspections, enforcement, and requirements.

The state should provide adequate funding to support staffing levels sufficient to perform thorough and regular inspections of livestock operations, including actual field observations and not just paperwork checks. All livestock operations should fence their cattle out of streams. When violations are repeated, penalties may be appropriate.

5) Warn the public about high bacteria levels.

Virginia should increase the frequency of sampling for *E. coli*, especially during months when people use the river for recreational activities. Virginia warns visitors to the state's ocean front beaches to stay out of the water when bacteria counts are

too high. But the state provides no such warning to the tens of thousands who swim, fish, raft, or just splash around in the Shenandoah River or its tributaries – even when *E. coli* samples are more than 100 times higher than state standards. That needs to change. People have a right to know when waters in the Shenandoah Valley and elsewhere are not clean enough for recreation.

6) List the Shenandoah as impaired by algae.

Virginia should list the Shenandoah river segments that have too much algae as officially "impaired" under the federal Clean Water Act so that the state can start taking more meaningful steps to curb pollution and accelerate its cleanup.

Collecting and Managing Surplus Manure: Who Should Pay?

Even these improvements may not be enough to significantly improve water quality in the Shenandoah, given the huge manure surplus in the valley and elsewhere in the region. In the long run, we need more sustainable agricultural practices that reduce our dependence on a large, intensive livestock sector that produces much more manure than local farms can use. In the meantime, if Virginia wants to sustain this sector while protecting the Shenandoah's waterways, it will need to establish a system for collecting and disposing of the surplus manure, or recycling it for shipment to regions with low levels of phosphorus in the soil. That will take money and political leaders with the courage to either raise it from Cargill, Pilgrim's Pride, and other large meat companies that contract with farmers, or to use public funds to collect and manage livestock waste.

Without actions to further reduce phosphorus and bacteria runoff from livestock operations and poultry manure, the phosphorus overload is likely to increase and high bacteria counts will continue to make the Shenandoah's rivers and streams – home to an important fishing, rafting, paddling, and tourism industry – unhealthy for local residents and visitors alike. Without action, Virginia will have no choice but to warn the public to stay out of the water.

The Shenandoah Valley's Imbalance: Too Many Animals, Not Enough Cropland

Poultry farms in Augusta, Rockingham, Page, and Shenandoah counties raised more than 159 million chickens and 16 million turkeys in the most recent year for which U.S. Department of Agriculture's Census of Agriculture data are available (2012).[5] That accounts for nearly 65.5 percent of the chickens (broilers, layer hens, and pullets) and 90 percent of the turkeys raised in Virginia that year. The poultry output from the four counties is enough to generate an estimated 410,198 tons of poultry litter per year containing nearly 8.2 million pounds of phosphorus.[6] A billion gallons of liquid waste from more than half a million cows add another 5 million pounds, bringing the phosphorus load from poultry and livestock to over 13.3 million pounds a year.[7] (Table A).

Table A. 2012 Estimated Phosphorus Output from Poultry and Cows, Augusta, Page, Rockingham, and Shenandoah Counties

Type	Number of Animals	Manure Output	Phosphorus (pounds)
Chickens			
Broilers	157,380,630	196,726 tons	4,485,348
Pullets	1,286,348	32,101 tons	251,545
Layers	939,008	32,560 tons	250,715
Turkeys	16,534,511	148,811 tons	3,258,961
Cows	528,943	1.28 billion gallons	5,056,038
Total	**176,669,440 animals**	**410,198 tons and 1.28 billion gallons**	**13,302,607**

Note: Manure generation and phosphorus content shown on a recoverable or as-is basis. Sources: USDA 2012 Agricultural Census, Virginia Department of Conservation and Recreation 2014 Nutrient Management Standards and Criteria, and the Chesapeake Bay Program. See Appendix A for methods.

Manure can be used to fertilize crops, but plants will not take in more nutrients than they need for growth. Animal operations in Augusta, Page, Rockingham, and Shenandoah counties generate more phosphorus from manure than local crops can use. The 2012 Census of Agriculture counted 539,955 acres of crop and pastureland in the four-county area. About half of that acreage was used to grow harvestable grains like wheat, soybeans, and field corn, and silage crops like corn and sorghum.[8] The rest was in permanent pasture. Based on the phosphorus removal rates that Virginia Department of Conservation and Recreation (DCR) has assigned for these crops and pastureland, this farmland could absorb only about 8.1 million pounds of phosphorus in 2012, which amounts to only 61 percent of the estimated 13.3 million pounds in the manure produced by livestock that year. (Table B). (See Appendix A for methods).

Table B. Estimated Phosphorus Output v. Potential Crop Removal (pounds), Augusta, Page, Rockingham, and Shenandoah Counties

Phosphorus Output (lbs)	Potential Phosphorus Removal by Crops (lbs)		Excess Phosphorus (lbs)
Livestock and Poultry Manure	Grain and Silage Crops	Pasture	Output - Removal
13,302,607	-5,160,453	-2,935,194	5,206,960

Based on 2012 Livestock Production and Harvest

But the imbalance is greater than suggested by Table B, because much of the counties' farmland already has enough phosphorus to grow crops without adding more by spreading manure. Virginia has determined that crops do not need additional phosphorus once soil concentrations exceed 55 parts per million. According to the most recent nutrient management plans from the 316 large livestock and poultry operations in the four-county area that spread manure on land they own or lease, 51 percent of the land (34,069 acres out of 67,303) covered by factory farm NMPs did not need additional phosphorus to support crop growth. Exporting poultry litter to other regions with low soil phosphorus levels could help restore the balance, but the data suggest that "exported" manure rarely leaves the Shenandoah watershed. (See page 20).

Damaged Waterways: Phosphorus, Algae, and Bacteria

Manure overload increases phosphorus levels in local Shenandoah Valley waters and the Chesapeake Bay. While Virginia does not have a water quality criteria threshold for phosphorus, the state uses a screening threshold of 50 parts per billion to determine if phosphorus levels are suboptimal for sustaining bottom-dwelling (benthic) organisms.[9] Elevated levels of phosphorus, along with nitrogen, fuel algae blooms and excessive algae growth.

The Virginia Department of Environmental Quality samples water at sixteen long-term monitoring sites in the Shenandoah Valley, and seven of these have exceeded the 50 ppb threshold for phosphorus, based on a three-year average of sampling results from 2014 through 2016. Based on a review of the state's most recent water quality assessment report, many of the areas with high phosphorus levels also have benthic impiarments, meaning that healthy populations of bottom-dwelling organisms like worms, crayfish, clams, snails and other organisms cannot thrive.[10] (Table C, Figure 3).

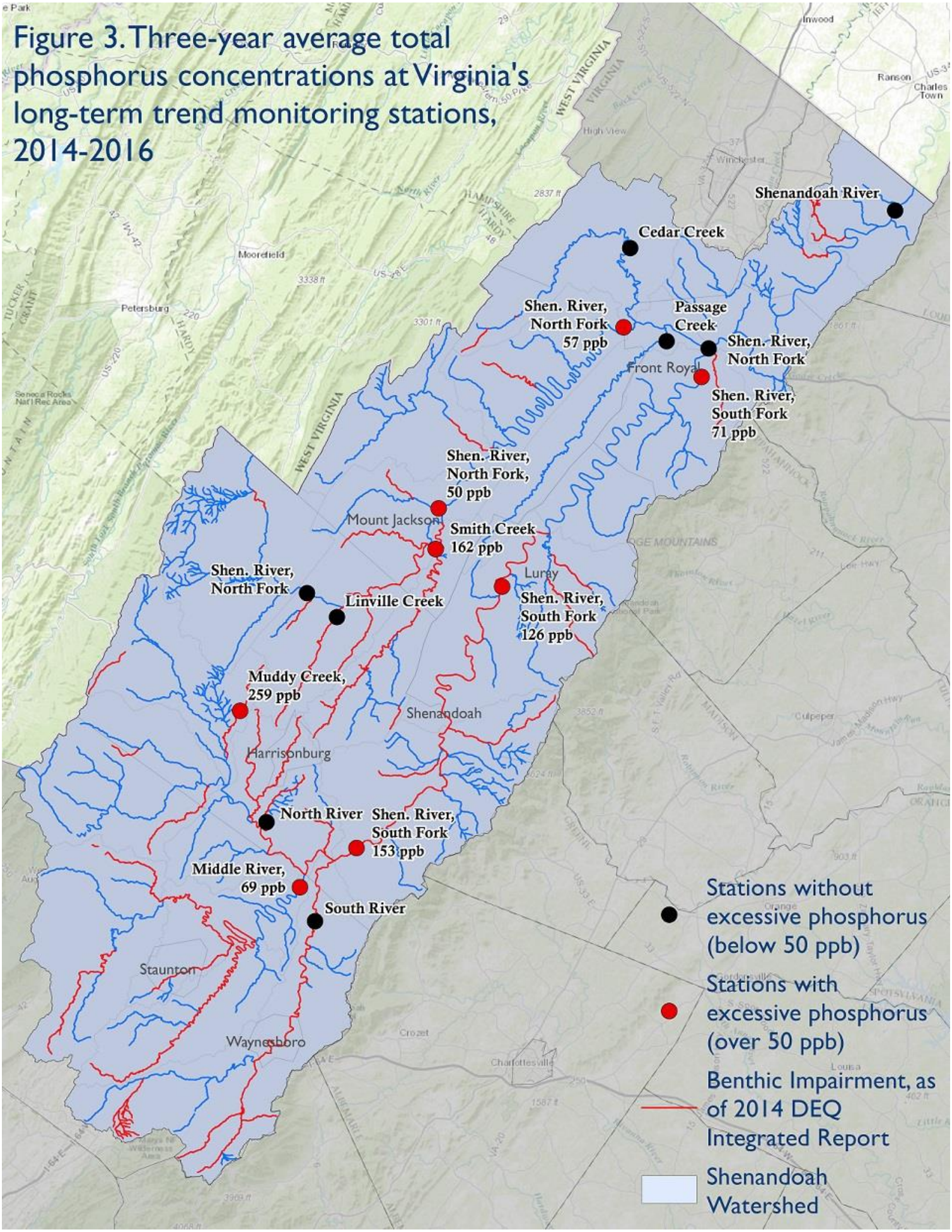
In Rockingham County, about 80 percent of farms with cattle fail to fence the animals out of streams, allowing them to defecate into the waterways. This contributes to high fecal bacteria levels in rivers where children swim.

Table C. Average Total Phosphorus Concentrations at Virginia's Long-Term Trend Monitoring Stations in the Shenandoah Valley

Stream Name (ID)	2014 Benthic Impairment	2014	2015	2016	3-year Average
Cedar Creek (1BCDR013.29)	No	13.3	11.7	10.0	11.7
Linville Creek (1BLNV001.22)	Yes	45.0	40.0	45	43.3
Muddy Creek (1BMDD005.81)	Yes	409.5	168.2	198.4	258.7
Middle River (1BMDL001.83)	No	34.0	103.3	NA	68.7
North Fork (1BNFS000.57)	No	30.0	20.0	21.7	23.9
North Fork (1BNFS010.34)	No	44.0	63.2	65.0	57.4
North Fork (1BNFS070.67)	No	46.7	63.3	40.0	50.0
North Fork (1BNFS093.53)	No	10.0	10.3	10.6	10.3
North River (1BNTH014.08)	Yes	38.3	51.7	50.0	46.7
Passage Creek (1BPSG001.36)	No	16.7	15.0	18.6	16.8
Shenandoah River (1BSHN022.63)	No	21.7	23.3	30.0	25.0
Smith Creek (1BSMT004.60)	Yes	191.1	145.7	148.9	161.9
South Fork (1BSSF003.56)	No	59.5	61.7	92.9	71.4
South Fork (1BSSF054.20)	Yes	145.0	71.7	160.0	125.6
South Fork (1BSSF100.10)	Yes	128.3	133.6	197.5	153.1
South River (1BSTH007.80)	Yes	23.3	35.0	40.0	32.8

Concentrations are in parts per billion (ppb). Phosphorus levels over 50 ppb, VDEQ's "suboptimal" screening level, are highlighted orange. Streams with "benthic impairments" have low levels of life on the bottom. Source: Virginia Department of Environmental Quality monitoring data and Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report.

Figure 3. Three-year average total phosphorus concentrations at Virginia's long-term trend monitoring stations, 2014-2016



Complaints About Excessive Algal Blooms

In January 2015, the nonprofit group Shenandoah Riverkeeper and its parent organization, the Potomac Riverkeeper Network, sent a report to Virginia authorities complaining about excessive algal blooms on the Shenandoah and its tributaries. The groups informed the Virginia Department of Environmental Quality that rafts of reeking algae in the valley's waterways often prevented people from using the waters for rafting, swimming, fishing, and other recreation.[11] The groups requested that Virginia officially identify the waterways as "impaired" by algae under the federal Clean Water Act – a designation that would require stronger efforts to control pollution.

Large and frequent algae blooms on the river make it hard to fish and swim.

As part of the Riverkeepers' report to the state, the organizations included the written testimony of 126 people who use the river. Many of them testified that the algal blooms had become worse over the last decade or two. The written testimony was backed up by more than 1000 photographs and videos of algal blooms, some of which showed unnatural-looking, neon-green blankets of slime covering waterways, often in the hot months of summer and early fall.[12]

One fisherman, Rodney Miner, submitted this statement to state officials: "My friend and I saw lots of algae and the fishing was absolutely terrible. We saw dead fish lying on the bottom of the river and caught very few fish which is very unusual on this stretch of river. ...I had planned to float the river numerous times this summer but, when one sees these conditions you have to wonder how healthy it is to be in water when you see high levels of algae and dead fish."[13]

A turtle climbs on a floating mattress of alage in the Shenandoah.

A professional fishing guide, Brian Trow, wrote: "Half of the beauty of floating the rivers of our state is underwater. Looking into a river and seeing nothing but green water, brown and green rocks, and smelling the awful smells of rotting algae is very discouraging. We already have to deal with poor water quality that takes trophy bass from us every year, and now we can't even enjoy the beauty of looking into the river. . . . I guide and fish on many other rivers in the state including the James in

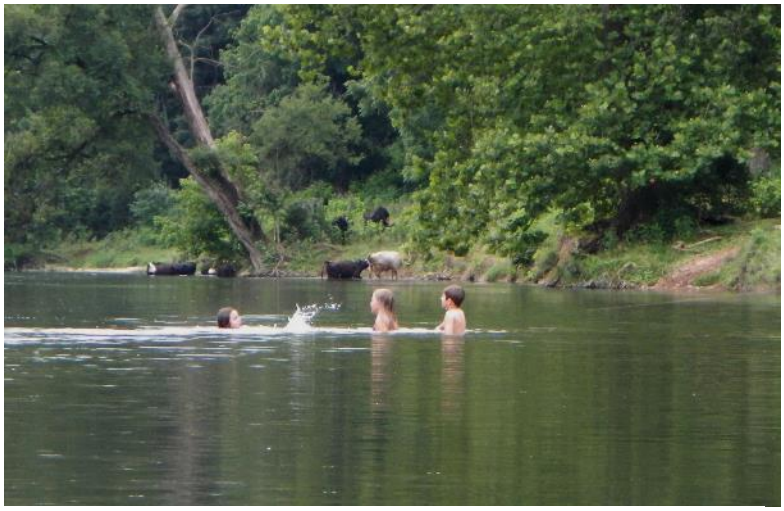
central Virginia, the Rappahannok, the Cowpasture, and the New River. All of these drainages have algae, but not nearly to the degree that the Shenandoah does."[14]

Phosphorus can be trapped in algae and cycle back into the water column after algae die. Algae can also be flushed out of waterways during storms and certain other conditions involving high river flow, transporting phosphorus downstream. Unlike other states, Virginia does not consistently measure chlorophyll levels in Shenandoah waters to keep track of algae formation.

Officials with the Virginia Department of Environmental Quality say they are working on a method of assessing algae growth in the waterways in the valley and elsewhere, but have not designated the Shenandoah and its tributaries as impaired. Because of the state's inaction, on April 4, 2016, Shenandoah Riverkeeper and the Potomac Riverkeeper Network filed a notice of intent to sue the U.S. Environmental Protection Agency (which approves state "impairment" decisions for waterways) for the failure to list the Shenandoah as impaired for excessive algae growth.

Shenandoah Waters Fail Recreational Standards for E. coli Bacteria

Many stretches of the valley's rivers and creeks are also contaminated with *Escherichia coli* (*E. coli*), a bacterium found in animal manure.[15] Ingesting water with high *E. coli* levels can cause severe gastrointestinal distress that requires hospitalization and may even lead to death in very extreme cases. Virginia advises avoiding *any* recreational contact – including rafting, swimming, fishing, and boating – in waters where more than 10 percent of samples in an assessment period exceed 235 "colony forming units" of *E.coli* per 100 milliliters of water (235 CFU/100 mL).[16] While Virginia DEQ typically monitors *E. coli* only once or twice a month in Shenandoah Valley waterways, 53 out of 58 (91 percent) of the regularly monitored stations exceeded the recreational standard 10 percent of the time, and 19 stations (33 percent) exceeded that threshold at least half of the time (Table D, Figure 4, Appendix B).



Children often swim in the Shenandoah River and its tributaries, despite the high levels of fecal bacteria often detected in the waterways.

Some of the reported *E. coli* levels are astronomically high, even in prized trout streams like Mossy Creek, where *E. coli* levels reached 5,172 CFU/100 mL on April 15, 2015. Not surprisingly, Mossy Creek and many other stream segments have been listed as "impaired" by *E. coli* (Figure 5), which means that contamination is serious enough to interfere with the public's ability to swim, fish, boat, or otherwise enjoy these waters. Virginia has listed

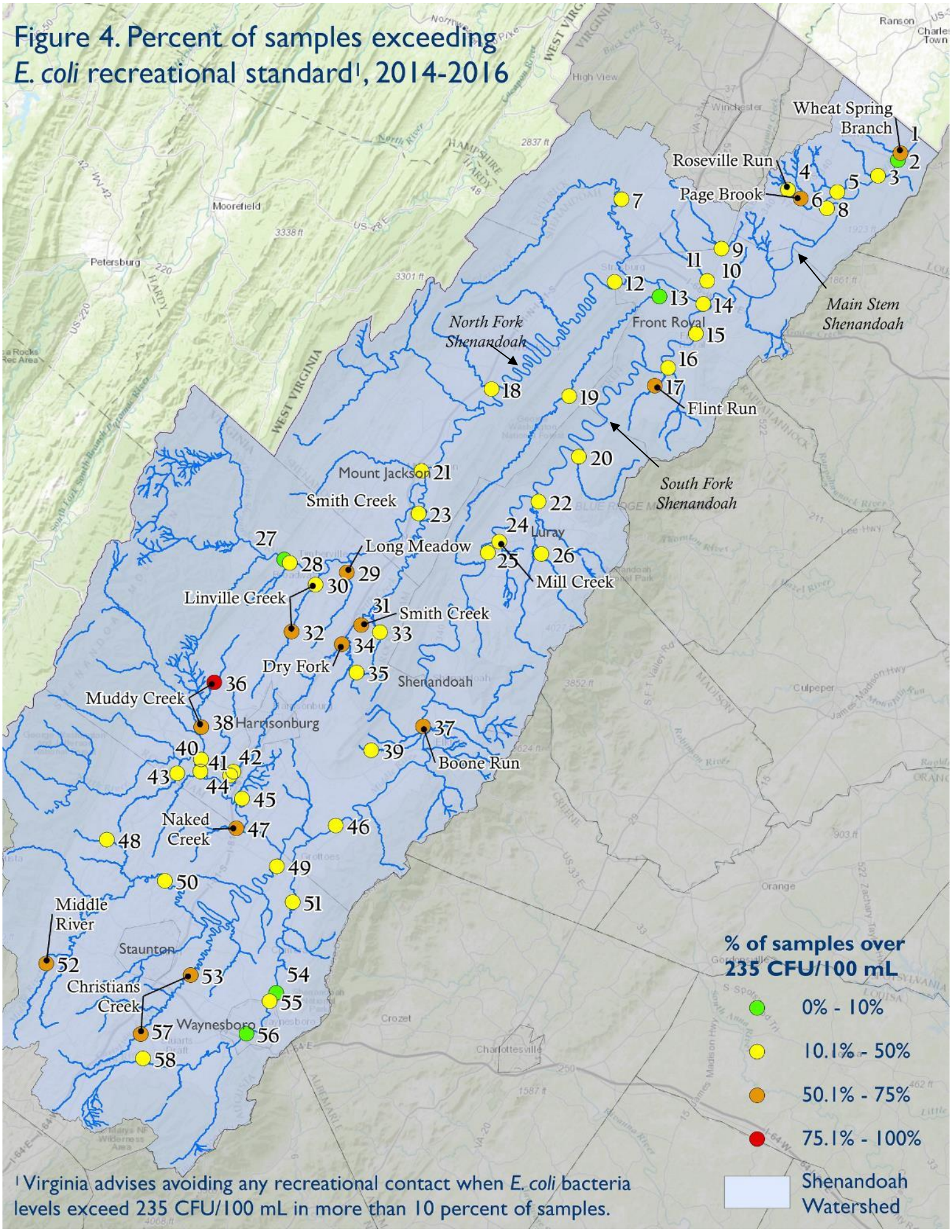
agricultural sources as among those contributing to bacterial contamination of many streams and rivers in the Shenandoah Valley watershed.

Table D. Shenandoah Waters Exceeding Virginia's *E. coli* Bacteria Recreational Standard in Half or More Samples, 2014-2016

Station ID	Map Key	Stream Name	Total Number of Samples	Number of Samples Over Standard	Percent of Samples Over Standard	Highest Value Measured (CFU/100 mL)
1BMDD005.81	36	Muddy Creek	60	49	82%	> 24,196
1BLNV006.49	32	Linville Creek	36	27	75%	24,196
1BWSB000.22	1	Wheat Spring Branch	18	13	72%	3,130
1BCST012.32	53	Christians Creek	24	17	71%	1,670
1BBON000.60	37	Boone Run	18	12	67%	3,654
1BLOM001.45	29	Long Meadow	12	8	67%	12,033
1BMDL060.48	52	Middle River	36	24	67%	8,664
1BNKD000.80	47	Naked Creek	24	16	67%	7,701
1BDFK000.76	34	Dry Fork	36	23	64%	> 24,196
1BFNT002.16	17	Flint Run	36	23	64%	6,867
1BSMT023.18	31	Smith Creek	36	23	64%	3,255
1BCST021.76	57	Christians Creek	24	15	63%	1,354
1BMDD000.40	38	Muddy Creek	18	10	56%	15,531
1BPGE000.09	6	Page Brook	35	18	51%	1,860
1BLNV001.22	30	Linville Creek	36	18	50%	11,199
1BMLC000.40	24	Mill Creek	24	12	50%	1,723
1BNPC000.02	18	Narrow Passage Creek	18	9	50%	4,884
1BSTH041.68	58	South River	36	18	50%	11,199
1BWAR003.88	33	War Branch	36	18	50%	2,755

Note: A waterway exceeds Virginia's recreational water quality standard for E. coli *when more than 10 percent of samples in an assessment period exceed 235 "colony forming units" of E.coli per 100 milliliters of water (235 CFU/100 mL). The sampling stations listed in this table exceeded that standard more frequently, with 50 percent of samples or more containing at least 235 CFU/100 ml. Use the map key to find locations on the next page (Figure 4).*

Figure 4. Percent of samples exceeding *E. coli* recreational standard[1], 2014-2016



[1] Virginia advises avoiding any recreational contact when *E. coli* bacteria levels exceed 235 CFU/100 mL in more than 10 percent of samples.

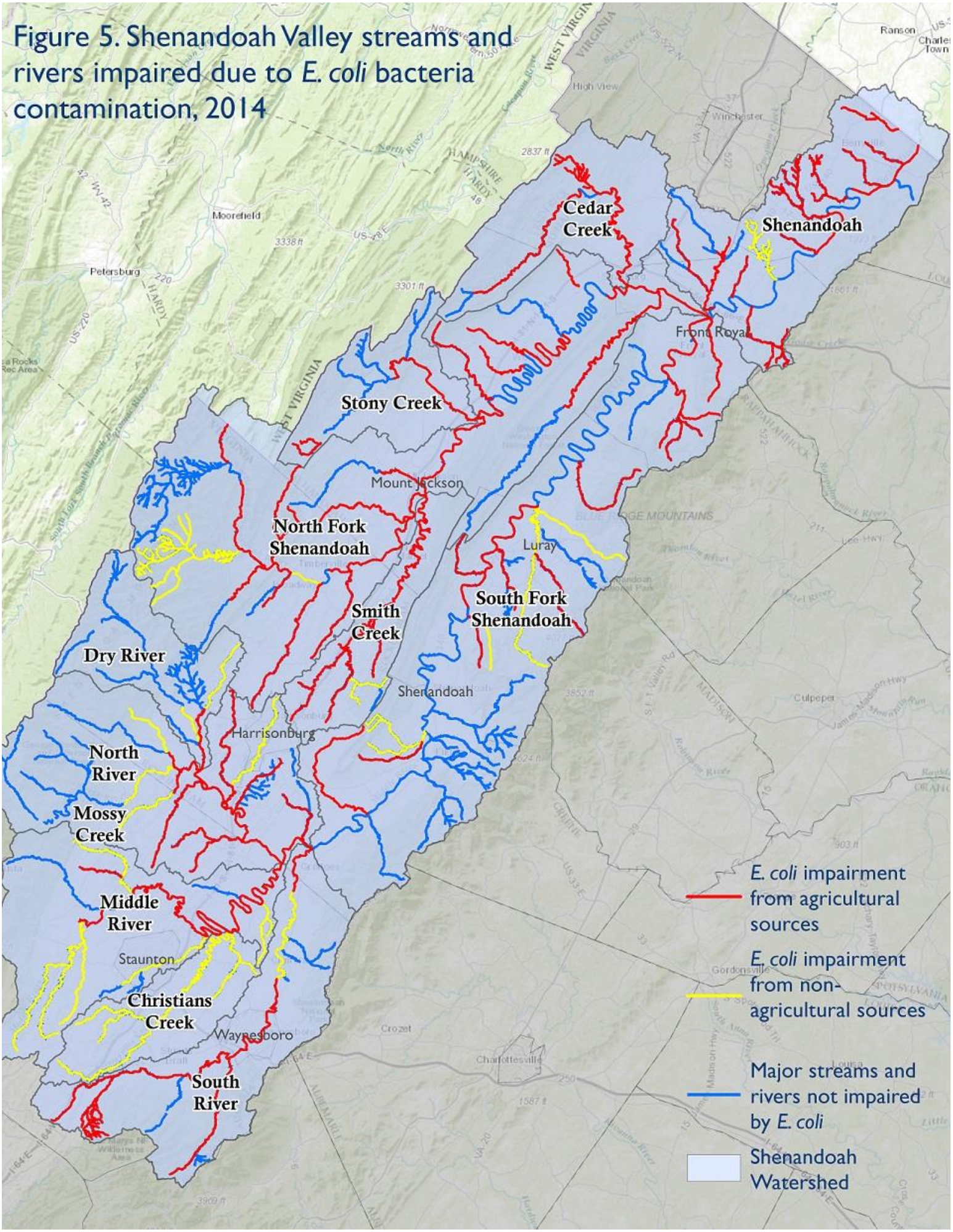


Figure 5. Shenandoah Valley streams and rivers impaired due to E. coli bacteria contamination, 2014
Cedar Creek
Shenandoah
Stony Creek
North Fork Shenandoah
South Fork Shenandoah
Smith Creek
Dry River
North River
Mossy Creek
Middle River
Christians Creek
South River
Front Royal
Mount Jackson
Luray
Harrisonburg
Staunton
Waynesboro
Moorefield
Petersburg
Winchester
Culpeper
Charlottesville
Crozet
E. coli impairment from agricultural sources
E. coli impairment from non-agricultural sources
Major streams and rivers not impaired by E. coli
Shenandoah Watershed

Fencing Cattle Out of Streams

In some cases, the bacterial contamination of waterways by livestock farms is likely happening because rain washes excess manure off of farm fields. In other cases, cows wade directly into streams, trampling the banks, stirring up sediment, and defecating into the waterway. Because this is a significant source of water pollution, Virginia's official plan for cleaning up its waterways to meet EPA pollution limits and restore the Chesapeake Bay directs the state to fence cattle out of streams on 95 percent of the commonwealth's farms.[17] The state made some progress in encouraging streamside fencing by offering farmers reimbursement for up to 100 percent of the cost. But then, funding for the program ran short, and a large backlog of farmers seeking the money developed – and the result is that Virginia remains far behind its goal.[18]

Cattle wading into streams and defecating is often a problem in the Shenanoah Valley, creating unhealthy levels of fecal bacteria for people who swim and boat. Virginia has a goal of convincing 95 percent of farmers who own cattle to fence them out of streams. But in Rockingham County, only 20 percent have these streamside fences, according to a survey by Shenandoah Riverkeeper.

Statewide figures on what percentage of farms fence their cattle out of streams are not available. But in the Shenandoah Valley's biggest agricultural county, Rockingham County, the Shenandoah Riverkeeper organization performed a survey in late 2016 that found only about 20 percent of the 841 farms with livestock and streams or rivers fence their cows out of the waterways.[19] That meant about 80 percent (or 675) of the county's cattle farms allowed the animals to have unfettered access to wade into streams – providing one possible source of fecal bacteria in waterways.

Virginia's Flexible Manure Application Options

Another major source of pollution is the runoff of manure and fertilizer from farm fields. Virginia requires large livestock operations to obtain nutrient management plans (NMPs), and if those operations have land, their NMPs are supposed to limit the over-application and runoff of phosphorus and nitrogen. NMPs for operations that also grow crops are supposed to be reviewed and updated at least once every three years, and under other circumstances like when crop rotations change or manure or soil samples change significantly. The plans include recommended manure application rates based on the nitrogen or phosphorus needs of crops, soil and manure test results, and crop rotations.

It is important to distinguish crop "removal rates" from a crop's "need" for additional phosphorus in the discussion below. Crops take up phosphorus and other nutrients through their root systems from the soils in which they are planted. These removal rates generally reflect the total amount of phosphorus required to support plant growth. "Crop need" for

phosphorus represents the difference between the existing soil concentration and the amount a crop will remove. This is the amount that a farmer needs to add through manure or other fertilizer. The state's nutrient management plans estimate total crop need over a three year cycle, to allow for enough flexibility.

Whether a farmer is allowed to apply manure to meet the nitrogen or phosphorus needs of a crop is based on soil test phosphorus results. If a farmer has a field with a phosphorus soil test value below 55 ppm – the threshold the state has said is enough to achieve expected crop yields – they can apply manure to meet nitrogen needs of their crop.[20] That often results in phosphorus over-application because most manures (especially poultry litter) contain more phosphorus than nitrogen.

If soil contains more than 55 ppm phosphorus, farmers can no longer apply inorganic phosphorus (fertilizer), but they have two options that allow them to continue applying manure, even though the soil already has enough: the Environmental Threshold Method and the Phosphorus Index. These options are discussed in more detail below.

In the Shenandoah Valley, once soil test levels show concentrations higher than 525 ppm phosphorus, the farmer is not allowed to apply any more phosphorus.[21] Soil tests from large animal operation NMPs taken after 2013 suggest that these extremely high levels are found on only half of one percent of the cropland in Augusta, Page, Rockingham, and Shenandoah Counties.[22]

The environmental threshold method: This method relies on field-specific soil test results. In the Shenandoah Valley, this method prohibits phosphorus applications to fields that have soil test values over 162 ppm phosphorus, and it limits application rates to the rate at which crops or a crop cycle can remove the nutrient.

The phosphorus index method: This method uses a site-specific, risk-based algorithm to determine application rates based on the likelihood of phosphorus leaving a a farm field. It combines an erosion risk factor, a runoff risk factor, and a subsurface risk factor to derive a phosphorus index value. Higher scores mean there is a higher risk of phosphorus leaving the field. Phosphorus cannot be applied if the phosphorus index exceeds 100, is limited to the crop removal rate for index values between 61 and 100, and is limited to 1.5 times the crop removal rate for index values between 31 and 60. A farmer can apply manure to meet nitrogen needs of crops if the phosphorus index value is below 30.

To summarize, most crops do not need additional phosphorus if the soil phosphorus level is greater than 55 ppm. Any phosphorus added to such fields will tend to build up in soil and could potentially migrate to local waterways. Yet the rules provide two options for applying phosphorus to these fields. In the Shenandoah Valley, Virginia only prohibits phosphorus application on soils with concentrations greater than 525 ppm – nearly 10 times higher than the maximum needs of most crops. As described in more detail below, farmers are allowed to routinely apply far more phosphorus than crops need and some farmers apply even more than their NMPs allow.

Analysis of Nutrient Management Plans and Inspection Reports

The Environmental Integrity Project (EIP) requested nutrient management plans (NMPs) and inspection reports from Virginia Department of Environmental Quality (VDEQ) in the Spring of 2016. These plans are required for permitted poultry and livestock operations throughout the state as part of the state's water pollution abatement permit programs. In general, large animal operations that do not raise crops are required to renew and update their NMPs every five years, while operations that raise crops must update their plans every three years. DEQ routinely inspected these operations and their on-site records every one or two years during 2014 and 2015. (Some smaller animal operations and crop farms in the valley have NMPs even though they are not required by a permit program. We did not analyze the plans for these farms because their plans are not enforceable.)

Below, we analyze the most recent NMPs for 675 permitted poultry, dairy, and cattle operations, as well as inspection reports for 448 operations inspected in 2014 or 2015, to evaluate how the state's nutrient management regulations work to reduce phosphorus loads to farm fields. Only 316 of the 675 operations had nutrient management plans that covered crop and pastureland. (More information about our methods can be found in Appendix A.)

In total, the 675 nutrient management plans showed that permitted poultry, cattle, and dairy operations in the four-county area could raise up to 196.7 million chickens, 20.2 million turkeys, and 19.7 thousand cows, based on capacities and flock numbers listed in NMPs. Many cattle operations seem to be unpermitted when comparing to the total number of cattle at operations with NMPs to the population estimates in the 2012 Census of Agriculture (see p. 8). The NMPs also show that more turkeys and chickens are raised in the four-county area than the Census counted in 2012. This could be due to several reasons, including different time frames, but it is important to note that the estimate from NMPs is based on maximum output (capacity x flocks per year), while the Census is based on actual sales and the layer chicken inventory at the end of 2012. We relied on the Census estimates in our earlier analysis because they were more conservative.

The chicken and turkey operations in the four-county area can produce up to 369,417 tons of poultry litter each year, according to their NMPs. This volume of litter is smaller than the volume we estimated earlier (see pg. 8) because NMPs used a variety of litter production factors which were, on average, lower than the ones we relied on from the Virginia DCR's Nutrient Management Standards and Criteria document and the Chesapeake Bay Program. However, it is unclear whether or not the difference actually affects land application rates.

Based on the manure estimates from NMPs, poultry operations sell or export 86 percent of that litter to other farms and apply about 11 percent of the litter to crop or pastureland under their control each year. A small percentage of the litter – 2 percent – goes unused and is likely stored.

Farmers "Export" 86 Percent of Their Poultry Litter to Other Farms, but End Users Get Little Oversight

In addition to reviewing export totals from NMPs, we also reviewed poultry waste transfer records from Virginia Department of Environmental Quality inspection reports that document where a subset of permitted poultry operations sent their "exported" litter. These transfer records documented 8.6 million pounds of phosphorus exported from operations in Augusta, Page, Rockingham, and Shenandoah counties over a three year period from 2013 to 2015. This accounts for about a third of the manure transferred on an annual basis, compared to the total documented in NMPs. Despite the fact that this analysis provides only a snapshot of the volume of phosphorus exported, it provides valuable insight into where poultry litter ends up. The transfer records show that 56 percent of exported manure stayed within the four-county area, while 35 percent went to brokers or other unknown or untracked destinations (Table E). Only a small fraction of poultry waste left the Shenandoah watershed (7.9 percent). Figure 6 illustrates where poultry litter transferred from operations in Augusta, Page, Rockingham, and Shenandoah counties went within the Shenandoah Valley, by subwatershed.

Table E. Poultry Waste Transferred Off-Site from Operations in Augusta, Page, Rockingham, and Shenandoah Counties, 2013-2015

Waste Transfer Destination	Pounds of Phosphorus Transferred Off-Site	Percent of Total Transferred
Within the four-county area	4,570,885	56.2%
Other counties in the Shenandoah watershed	59,218	0.7%
Outside of Shenandoah Watershed but within Virginia	566,865	7.0%
Out of state (West Virginia, Ohio, Kentucky)	73,899	0.9%
To brokers or unknown destinations	2,857,021	35.2%
Total Phosphorus from Poultry Litter Transferred	**8,127,887**	

Farmers who import manure are supposed to follow regulations that limit the amount and location of manure applied to farm fields. Under these rules, poultry waste "end users" have to abide by certain manure storage and application setback requirements, and can apply manure only under certain conditions (e.g. during specific months and not to fields with steep slopes when the ground is frozen).[23] These end users can elect to spread according to a NMP if they have one. If they have no NMP but have recent soil tests, they can spread according to the soil test method or environmental threshold methods described earlier. If soil tests are not available, and if farmers have not applied organic nutrients (such as manure or biosolids) to a particular field over the past three years, he or she can apply poultry litter to that field at a standard rate of 1.5 tons per acre. Not all end users are required to obtain NMPs or submit them to the Virginia Department of Environmental Quality, making it difficult to determine which (if any) of these approaches are selected.

And even if they had NMPs, it would be difficult to determine whether they follow their recommendations without sufficient oversight or enforcement.

Unfortunately, Virginia does not inspect farms that accept the manure that livestock operators ship offsite unless they receive a third party complaint.[24] Records from VDEQ show that the state does get and responds to complaints about uncovered litter piles, odors, or manure spreading too close to a stream or a neighbor's property. But those violations normally are visible to the naked eye only from the road or property line. Citizens cannot see or recognize when too much manure or phosphorus is being spread on crops, except perhaps in the most extreme cases. Little public documentation exists to demonstrate that exported poultry litter is being applied in a manner that protects waterways or according to Virginia's regulations. The cropland that receives exported manure may or may not be able to absorb the additional phosphorus in poultry litter. At present, there is no way to know. Until Virginia collects this information and enforces its end user requirements, it cannot demonstrate that its nutrient management program will achieve Chesapeake Bay phosphorus reduction targets and clean up the pervasive *E. coli* contamination and algae-related impairments of the valley's rivers and streams.

The Virginia Department of Conservation and Recreation (DCR) has an incentive program that is supposed to promote poultry litter transport outside of Page and Rockingham Counties to points outside of the Chesapeake Bay watershed.[25] Based on data from 2010, this program subsidized the transport of only 8,045 tons of poultry litter between late 2007 when the program began, and June 2009, which is only a fraction of what is transported off of poultry farms each year.[26] The program is funded by both the state and the Virginia Poultry Federation (a trade group representing several poultry companies). The incentive program sets strong standards for poultry waste end users who wish to apply poultry litter to their crops, such as the requirement to have a nutrient management plan that does not rely on the phosphorus site index, lower soil test phosphorus caps than those set by other nutrient management regulations, and specific requirements for the poultry litter transferred (moisture content, etc). This program also seems to have more paperwork requirements, and DCR spot checks compliance. However, in order for it to work better, it needs to be expanded to more source counties in the valley, not just Page and Rockingham, and it needs to offer a higher subsidy (more than $15 per ton) to compete with the local, informal poultry litter markets that are not currently doing a good enough job to protect water quality.

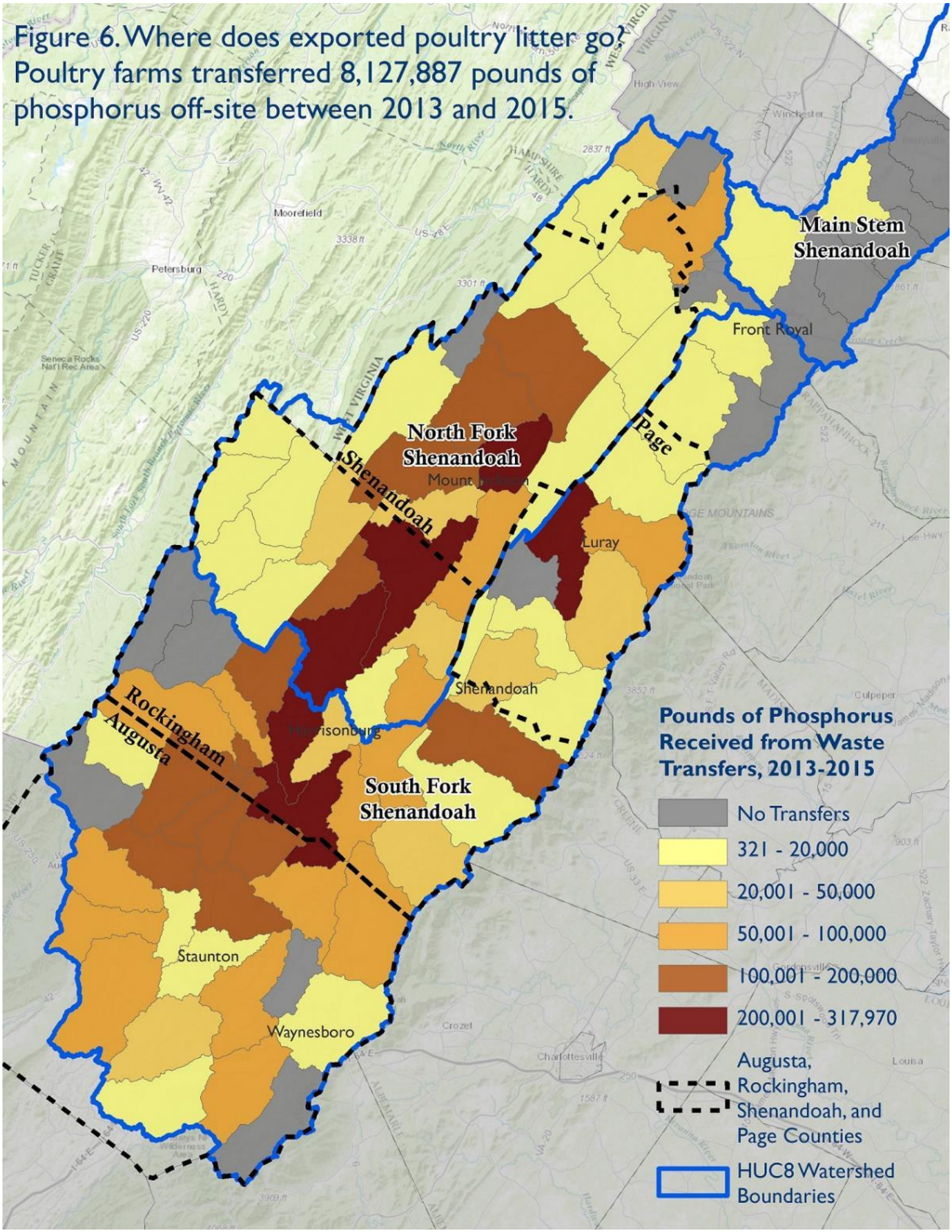


Figure 6. Where does exported poultry litter go? Poultry farms transferred 8,127,887 pounds of phosphorus off-site between 2013 and 2015.
Main Stem Shenandoah
North Fork Shenandoah
South Fork Shenandoah
Shenandoah
Page
Rockingham
Augusta
Front Royal
Luray
Shenandoah
Harrisonburg
Staunton
Waynesboro
Moorefield
Petersburg
Seneca Rocks Nat'l Rec Area
Crozet
Charlottesville
Culpeper
Louisa
Pounds of Phosphorus Received from Waste Transfers, 2013-2015
No Transfers
321 - 20,000
20,001 - 50,000
50,001 - 100,000
100,001 - 200,000
200,001 - 317,970
Augusta, Rockingham, Shenandoah, and Page Counties
HUC8 Watershed Boundaries

Factory Farm Nutrient Management Plans Cover Only 12.5 percent of Augusta, Page, Rockingham, and Shenandoah County Farmland

Table F shows that NMPs for factory farms cover only 12.5 percent of the total crop and pastureland in Augusta, Page, Rockingham, and Shenandoah counties, and that the plans limit phosphorus applications to an even smaller fraction of farmland (3.6 percent). County-level cropland and pastureland acreage were obtained from the 2012 Census of Agriculture, while the acreage covered by factory farm nutrient management plans was compiled from the most recent NMPs for 316 large livestock operations that grew crops in the four-county area.

Table F. NMP Phosphorus Limits By Crop Acreage

County	Total Crop and Pastureland (2012)	Acres Covered by Permitted Factory Farm NMPs	Permitted Acres with Phosphorus Limits	Percent of Crop and Pastureland with Phosphorus Limits
Augusta	207,605	25,700.8	3,726	1.8%
Page	55,795	6,904.1	1,425	2.6%
Rockingham	176,917	28,436.9	12,707	7.2%
Shenandoah	99,638	6,260.7	1,437	1.4%
Total	**539,955**	**67,302.5**	**19,295**	**3.6%**

Source: Acres of crop and pastureland are from table 8 of the 2012 USDA Census of Agriculture. Acres with phosphorus limits are from a review of 316 nutrient management plans from large livestock operations.

Virginia's Nutrient Management Plans May Not Help Reduce Manure and Phosphorus Surplus

With limited exceptions, Virginia's NMPs allow the continued spreading of manure on cropland already overloaded with phosphorus. The state justifies this by assuming that any phosphorus added to fields that already have enough will be more than offset by the amount that crops remove from the soil. This approach promises more than it can deliver, because:

- NMPs are based on optimistic assessments about crop yields that over-estimate actual harvests and the amount of phosphorus crops will remove from soil;
- Farmers do not always follow recommended crop rotations, e.g., skipping one or two of the planting cycles specified in the NMPs that were designed to remove additional phosphorus from the soil;
- State inspections do not evaluate whether farms achieve their projected crop yields and phosphorus removal rates spelled out in NMPs;
- Infrequent sampling may not accurately measure the amount of phosphorus (and nitrogen) in manure at the time its applied to farm fields;

- NMPs expire and are not always updated in a timely way, and some operators apply nutrients over the recommended limits; and

- Because of understaffing, inspectors are often limited to file reviews and document manure applications to one or two fields at a farm that applies manure to many more fields.

Each of these findings is explained further below. The observations that follow are limited to the subset of large poultry and livestock operations that have NMPs that cover cropland.

Added Phosphorus Assumed to be Offset by Crop Removal

Virginia's NMPs recommend manure application rates based on the phosphorus or nitrogen content of manure and soil and the capacity of specific crops to remove these nutrients from the soil. The balance between projected application and removal rates is critical, since that determines whether excess nutrients are left behind where they are more likely to pollute public waterways.

A review of the most recent NMPs available from large animal operations confirms that where phosphorus "limits" apply, most plans allow continued manure application while counting on crops to remove enough phosphorus to offset the added load. (We refer to the recommended nutrient application rates in NMPs as "limits" in the discussion below, although it is unclear whether they can actually be enforced.)

To illustrate, NMPs from large livestock operations cover 67,303 acres of cropland, hayfields, or pasture owned or leased by large livestock operations in Augusta, Page, Rockingham, and Shenandoah counties. The balance sheets in these plans indicate that nearly 34,069 acres already have more than enough phosphorus in the soil to meet crop needs without adding more. In response, the NMPs for this phosphorus-rich soil:

- Advise against spreading manure on 6,139 acres.[27]

- Balance manure application and crop removal rates for phosphorus on 15,344 acres. Overall, these plans anticipate that the planned crops will remove an average of 109 pounds of phosphorus per acre over three years (1,710,778 pounds total), more than enough to offset the average 84 pounds per acre (1,293,700 pounds) recommended through manure spreading.

- Allow farmers to apply manure to 12,586 acres based on crop nitrogen needs, even though these fields need no additional phosphorus.

Nitrogen-based recommendations do little to reduce the potential for runoff and spol phosphorus overload. Where NMPs do target phosphorus, they depend heavily on high crop removal rates. The balance sheet below, for an 18-acre field in Rockingham County,

provides a more detailed example of the state's approach in most of the NMPs that limit phosphorus (Table G).

Table G. NMP Balance Sheet for an 18 Acre Field in Rockingham County (2012-2014)

Crop (silage)	Year	Target Crop Yield (tons/acre)	Poultry Litter Recommended (tons/acre)	P Application Recommended (lbs/acre)	Expected P Removal by Crops (lbs/acre)	Net P (lbs/acre)
Corn	2012	22.6	2.1	37.1	-41.5	-4.4
Barley	2012	12	1.1	18.8	-26.6	-7.9
Corn	2013	22.6	2.1	37.1	-41.5	-4.4
Barley	2013	12	1.1	18.8	-26.6	-7.9
Corn	2014	22.6	2.1	37.1	-41.5	-4.4
Barley	2014	12	1.1	18.8	-26.6	-7.9
Total			**9.6**	**167.6**	**-204.2**	**-36.7**

Note: "P" means phosphorus.

The NMP estimates a net reduction in phosphorus of 36.7 pounds per acre over a three-year period, assuming that a six-crop rotation of corn and barley silage (used to feed animals) will remove more phosphorus than the amount added in manure. Corn and barley silage remove about 1.8 and 2.2 pounds of phosphorus, respectively, for each ton harvested, according to Virginia's Nutrient Management Standards and Criteria document.[28] The crop yields in the table above reflect the output needed to achieve the phosphorus removal rates in the NMP. For example, a harvest of 22.6 tons of corn silage per acre that absorbs 1.8 pounds of phosphorus per ton will remove 37.1 pounds of phosphorus per acre. However, there are several reasons why these phosphorus balance sheets may fall short.

Actual Crop Yields Are Often Lower Than Projected, Which Reduces Phosphorus Removal

Farmers understandably want to maximize production from their fields, and that encourages optimistic predictions about their expected output. Also, soils that have more than enough phosphorus will often still need additional nitrogen to support crop growth. Nitrogen needs for each crop are usually calculated based on the highest crop yields possible for specific soil types to ensure that harvests aren't limited by nitrogen shortages.

Virginia has established phosphorus removal rates on a per-bushel basis for grain crops and by the harvested ton for silage, hay and other forage crops. But the amount removed per acre will depend on the actual harvest, which is often lower than forecast due to a number of reasons that can and cannot be controlled by farmers, like soil pH or weather. Lower crop yields will remove less phosphorus than anticipated in a NMP.

For example, corn silage is grown throughout the Shenandoah Valley to feed the region's livestock. Virginia DEQ's inspection reports for Rockingham County in 2014 and 2015 included seventeen operations that spread manure on more than 1,000 acres of corn silage.

The NMP balance sheets for that cropland assumed an average yield of 22 tons of corn silage, removing about 93 pounds of phosphorus per acre. But actual corn silage yields in Rockingham averaged 18.5 tons per acre in 2012 and just over 16 tons in 2007, according to the Census of Agriculture.

The NMP described in Table G (page 22) assumed that alternating crops of barley and corn silage would remove more phosphorus than added manure would supply. Table H shows that actual results can be quite different, increasing rather than decreasing the phosphorus in soil.

Table H. Changing the Phosphorus Balance for an 18 Acre Field in Rockingham County, NMP Projections vs. Actual Results

		NMP Projections (per acre)				Actual Results (per acre)			
Crop	Year	Yield	P Added	P Removed	Net Change in P	Yield	P Added	P Removed	Net Change in P
Corn	2012	22.6 t	37.1	-41.5	-4.4	9 t	35.3	-16.6	18.8
Barley	2012	12 t	18.8	-26.6	-7.9	85 bu	20.5	-14.8	5.7
Corn	2013	22.6 t	37.1	-41.5	-4.4	No crop	0	0	0
Barley	2013	12 t	18.8	-26.6	-7.9	No crop	0	0	0
Soybeans	2013	Not in NMP	n/a	n/a	n/a	55 bu	0	-21.4	-21.4
Corn	2014	22.6 t	37.1	-41.5	-4.4	12 t	51.9	-21.8	30.1
Barley	2014	12 t	18.8	-26.6	-7.9	No crop	0	0	0
Total			**167.6**	**-204.2**	**-36.7**		**107.8**	**-74.6**	**33.2**

Note: "t" = tons, "bu" = bushels, "P" = phosphorus. Actual results from a farmer's records attached to a VDEQ inspection report.

Based on records attached to a 2015 inspection report, this farm applied less manure than the NMP allowed, but the manure had more phosphorus than anticipated. The farmer also planted fewer crops, and generally had lower yields, so the crops absorbed much less phosphorus than the NMP assumed. The NMP estimated that high crop removal rates would ultimately reduce the phosphorus load by 36.7 pounds per acre by the end of 2014. Instead, the available records suggest that load increased by about 33.2 pounds per acre.

Of course, some farms in some years may achieve higher yields than expected, thereby removing more phosphorus than their NMPs anticipate. Also, NMPs do attempt to adjust yields downward where soil quality is poor and they take a farmer's historical yield records into account when they are available. While it seems more likely that crop yields will more often fall short of projections, for the reasons explained earlier, Virginia cannot be sure that NMP targets are met without reviewing actual results and their impact on phosphorus removal.

Similarly, NMPs typically assume that an acre of orchard grass hay will remove 24.4 pounds of phosphorus at an expected yield of about 3.5 tons per acre. The Census of

Agriculture for 2002, 2007, and 2012 show that actual hay yields range between 1.75 tons (Augusta County, 2002) to to a high of 2.6 tons per acre (Rockingham County, 2012).

Farmers May Skip a Planting Season or Substitute Crops with a Lower Potential for Phosphorus Removal.

Nutrient management plans estimate phosphorus removal based on the frequency and type of crop that is planted. Farmers may choose to skip a fall or spring planting or substitute another crop, e.g., grain corn for corn silage that removes less phosphorus on a per acre basis. These decisions may make good economic sense from the farmer's perspective, but such actions mean lower phosphorus removal rates. Table H (page 26) also shows an example of a farmer that did not follow their planned crop rotation.

Actual Manure Phosphorus Concentrations Can be Higher than Assumed in Nutrient Management Plans

Virginia requires livestock operators to test the nutrient concentrations in poultry litter and other dry or semisolid livestock manure at least once every three years.[29] Under the current rules, growers can average test results within the past three years or select the most recent one to estimate phosphorus loading rates. Actual lab results for the same farm can vary widely, so infrequent sampling is a shaky basis for managing phosphorus application rates. For example, poultry litter samples taken at one operation went from 18.2 pounds of phosphorus per ton in 2011 to 24.4 pounds per ton in 2014, a 35 percent increase. Additionally, inspection reports from 2014 and 2015 show that sample results were more than three years old for 10 percent (16 of 162) of the inspected growers that also farmed cropland, which means nutrient loading rates were estimated on outdated and possibly inaccurate information.

Site Inspections and Compliance

Are Virginia's nutrient management plans actually reducing manure and phosphorus overload, at least on the limited acreage covered by NMPs? To answer those questions, Virginia and the U.S. EPA need to find out what is happening in the field, not just on paper. And that requires reviewing a number of factors to determine whether operators are hitting their planned targets, including:

- Manure application rates and nutrient concentrations, based on up-to-date sampling;
- Actual crop rotations and crop yields and their impact on phosphorus removal; and
- Whether NMPs have been updated to reflect current soil test results.

According to the Environmental Protection Agency's (EPA) 2015 assessment of Virginia's animal feeding operation programs, the state's pollution abatement program is understaffed, relying on 9 or 10 employees statewide to track compliance with storage and other waste management requirements for 1,037 permitted livestock and poultry operations.[30] Virginia

inspects these facilities about once every two to three years and has recently informed operators they plan to reduce inspection frequency. Many of these inspections are actually just offsite file reviews, in part due to biosecurity concerns, e.g., about spreading avian flu or other diseases.

EIP took a closer look by reviewing inspection reports from 2014 and 2015 for 162 livestock and poultry operators in Augusta, Page, Rockingham, and Shenandoah counties that are required to follow NMPs when applying nitrogen and phosphorus to farmland they own or lease. Given limited resources, inspectors were only able to document manure and fertilizer application rates for just over 4,802 acres, or 7 percent of the 67,303 acres covered by NMPs.[31] Despite these constraints, inspection reports document several major problems.

Out of Date Nutrient Management Plans and Manure and Soil Samples

NMPs for factory farms that also grow crops are supposed to be revised and updated every three years to reflect changing crops, nutrient levels in manure, soil, and other variables. Virginia inspections in 2014 and 2015 found that only 5 out of 162 operations had not updated their NMPs at the time of inspection.

Virginia NMPs generally require poultry operations to sample poultry waste and soil at least once every three years, and dairy and beef farms to do so annually. Updating test results is important, as nutrient levels in manure may vary over shorter periods of time. Yet manure test results were more than three years old for 16 of the 162 poultry, dairy, and beef operators that had land and were inspected in 2014 or 2015. Thirteen out of the 162 operations also had expired soil samples for at least one field covered by a NMP (Table I). These lapses undermine confidence in NMPs, which make recommendations based on current test results.

Table I. Operations with Expired NMPs, Manure Samples, or Soil Samples According to 2014-2015 Inspection Reports

	Number of Operations	Percent of Total Operations (out of 162)
Expired or Lapsed NMP	5	3%
Expired Manure Sample(s)	16	10%
Expired Soil Sample(s)	13	8%

Note: Limited to 162 animal operations that farmed crop or pasture land.

Phosphorus Recommendations Exceeded

Inspection reports identified 14 operations that applied more phosporus from manure to their fields than their NMPs allowed, resulting in an over-application of 9,375 pounds of phosphorus on 172 acres, or about 3.6 percent of the total acreage inspected. This tally does not include fields where farmers exceeded nitrogen limits.

Inspections Do Not Examine Whether Livestock Operators Meet Phosphorus Removal Targets

Virginia's NMPs recognize that more than half the 67,303 acres of crop and pastureland required to be covered by nutrient management plans in Augusta, Page, Rockingham, and Shenandoah counties already have more than enough phosphorus to meet crop needs. But for the 18,805 acres where NMPs provide phosphorus-based recommendations for fields that have no need for the nutrient, NMPs are much more likely to authorize the continued spreading of phosphorus-rich manure (15,344 acres) than not (3,461 acres). In most cases, the NMPs assume that crops will remove more phosphorus over three years than manure would add. In theory, this would gradually lead to lower phosphorus concentrations in soil.

These calculations are based on very specific assumptions about which crops will be planted and how often, and about the expected size of each harvest. Inspectors conscientiously review manure application records to determine phosphorus loading rates. But they do not review or quantify the amount of phosphorus removed based on the type, frequency, and yield of the specific crops that are planted, or compare those to the removal rates anticipated by the NMP. This failure to consider whether crops are taking out more phosphorus than is being added to soils that already have a surplus is a fundamental weakness of Virginia's program.

Are Virginia's Nutrient Managent Plans Voluntary?

A 2015 peer-reviewed study of nutrient management regulations and their effectiveness on the Delmarva peninsula of Virginia, Maryland, and Delaware examined whether farmers complied with their NMPs. The author of the study interviewed 55 regulated farmers between 2005 and 2006. When asked whether they complied with their NMP, 61 percent suggested that they did not or might not.[32]

Some examples of comments indicating non-compliance included complaints about the feasibility of spreading manure at low application rates, little faith in recommendations from the state (and university farmer extension services), and preferences for using recommended rates from fertilizer dealers and test results. Some farmers said they disregard restrictions on winter manure spreading when manure storage reached capacity.

According to the study, some farmers also blatantly evade the law.

> *Several interviewed farmers, private planners, and fertilizer dealers stated they were actively evading the spirit and letter of the law because they (i) kept double books (one plan to show an inspector and one plan to use to farm), (ii) applied higher manure rates than they knew they should be using, (iii) set higher-than-average yield goals to justify higher nutrient application rates.*[33]

The study concludes that in practice, compliance with NMPs is voluntary, even when NMPs are "required." This is because NMPs are difficult for farmers to accept and implement, and they are also difficult for state regulators to enforce in meaningful ways. Perhaps some of the difficulty is due to the fact that NMPs are

complicated "plans" and that nutrient application rates are presented as "recommendations" rather than requirements.

Our review of NMPs and inspection reports from large animal operations found that Virginia's inspectors do a reasonably good job of identifying manure and soil tests that are outdated, NMPs that have expired and need renewal, and fields that have received more nutrients that their plans allow. In many cases, inspectors took samples to expedite testing, and warned operators in advance when manure, soil samples, or NMPs would lapse and need to be updated. Where phosphorus or nitrogen loads were exceeded on certain fields, operators were generally advised to stop applying manure.

However, likely due to staffing and time constraints, inspectors only documented manure application on a small fraction of the fields covered by NMPs. We also identified no cases in which the state had assessed or collected a penalty for the failure to follow nutrient management plans. This may be because the state believes that serious enforcement would reduce the level of cooperation from farmers needed to improve management practices and reduce nutrient runoff.

Whatever approach it chooses, Virginia must be able to show that it has an effective program that is making measureable progress in reducing manure and phosphorus overload in the Shenandoah Valley. Based on our review, the state will need to make significant changes to its program before it can demonstrate that it is working.

Conclusion and Recommendations

The Shenandoah Valley is a place of incomparable beauty and cultural value, but its continued health is at risk. Its livestock industry is producing a vast quantity of manure – about 410,000 tons of poultry litter and a billion gallons of liquid manure annually – that is being applied (and in many places over-applied) to farm fields, where it canrunoff into the valley's streams and rivers. Phosphrous, algal blooms, and fecal bacteria are polluting waterways and destroying the natural beauty that local residents cherish and that the valley's tourism-related industries – including rafting and fishing – require.

Virginia has a system in place that is supposed to prevent this problem by limiting the application of manure to fields. But the commonwealth's system of nutrient management plans for farms is limited and needs an overhaul to protect not only the Shenandoah's waterways but also the Chesapeake Bay and waterways throughout the state.

More importantly, improving the nutrient management program would only be a stop-gap solution. The manure surplus in the Shenandoah Valley is simply too large to be absorbed by local cropland, and it will ultimately need to be collected and disposed of in landfills or recycled and shipped to regions with low phosphorus soils.

This report makes the following recommendations to address the water pollution from livestock and poultry in the Shenandoah Valley:

1) The state should require nutrient management plans for all farms that spread manure, not only for large livestock and poultry operations. Phosphorus and

nitrogen concentrations in manure and soil should be sampled every year (instead of once every three years at poultry farms) to ensure that nutrient application rates are based on accurate and current information. The state should also strengthen its phosphorus application requirements to further limit the amount of manure that can be applied to fields that do not need any more of the nutrient, or where runoff is likely to occur.

2) State inspectors should verify actual yields to ensure that plans take into account realistic phosphorus and nitrogen removal rates. Future manure spreading should be based on the most recent 3 year average yields and if necessary, reduced where low crop removal rates leave excess phosphorus on the field.

3) Farmers should assume more responsibility for tracking their performance by filing annual reports that include manure and nutrient application rates as well as actual crop yields needed to determine how much of those nutrients were removed. Maryland livestock and poultry operations have filed annual implementation reports for the past five years. This reporting is critical if state inspectors have such limited resources.

4) Virginia needs to strengthen its system for collecting, recycling, or disposing of surplus manure, or shipping it to regions with phosphorus-depleted soils. It also needs to provide oversight of farms that "import" poultry litter and enforce its poultry waste end user regulations.

5) Virginia Department of Conservation and Recreation should expand its existing poultry litter transport incentive program to move poultry litter out of the Shenandoah and Chesapeake Bay watersheds. Improving this system will require money, and a large share of that funding should continue to be provided by companies profiting from the livestock and poultry operations.

6) Virginia should require that all cattle operations fence their livestock out of streams, and the livestock industry and state should provide enough money to reimburse farmers for the cost.

7) The state needs to increase the frequency of bacteria and algae monitoring, especially in warm weather months when so many residents and visitors enjoy wading, swimming, fishing, or boating in the valley's rivers and streams. Where bacteria levels are too high, the state needs to warn the public to stay out of the water, as it does on Virginia's beaches.

8) Virginia should list the Shenandoah river segments that have too much algae as officially "impaired" under the federal Clean Water Act to accelerate efforts to reduce nutrient pollution.

Until the manure overload problem in the Shenandoah Valley is addressed, the algal blooms and high bacteria counts will continue. While health warnings for the public are important, the bigger picture is that the Shenandoah watershed is more than a drainage system for the

livestock industry. With more effective limits on agricultural pollution, Virginia can keep its waterways clean enough for all citizens to enjoy.

Appendix A. Methods

Phosphorus Imbalance

EIP estimated manure production and phosphorus content of manure using estimation factors from Virginia Department of Conservation and Recreation's Nutrient Management Standards and Criteria document, Virginia Cooperative Extension, and the Chesapeake Bay Program. All animal number estimates are from the 2012 U.S. Department of Agriculture's Census of Agriculture.

- We assumed that broiler chickens generated 1.25 tons of litter per 1,000 birds, according to DCR's Nutrient Management Standards and Criteria. We also assumed that broiler litter contained an average of 52.18 pounds of phosphate per ton of litter (22.8 lbs phosphorus/ton) on an as-is basis, according to estimates from the Virginia Cooperative Extension.

- We assumed that turkeys generated 9 tons of litter per 1,000 birds, according to DCR's Nutrient Management Standards and Criteria. We also assumed that turkey litter contained 50.23 pounds of phosphate per ton of litter (21.9 lbs phosphorus/ton) on an as-is basis, according to estimates from the Virginia Cooperative Extension.

- We estimated manure and phosphorus generation from pullets and egg-laying chickens using factors developed by the Chesapeake Bay Program's Agricultural Modeling Subcommittee to the Poultry Litter Subcommittee and Agriculture Workgroup. The Bay Program assumed that pullets generate 49.1 pounds of recoverable manure and 0.19555 pounds of phosphorus per bird, and that layers generate 69.35 pounds of recoverable manure and 0.267 pounds of phosphorus per bird. The number of pullets are based on the total number of pullets sold in 2012, and the number of layers was assumed to be the number in inventory at the end of the year according to the 2012 Census of Agriculture.

- The number of cows in the four-county area were assumed to be the total of cattle and calves, cows and heifers that calved, and other cattle according to the 2012 Census of Agriculture. We calculated liquid manure production from each type of cow using formulas, production factors (gallons per year), and typical animal weights provided in table 8-6 in DCR's Nutrient Management Standards and Criteria. We assumed that all liquid cow manure contained 9.08 lbs of phosphate per 1,000 gallons (3.96 lbs phosphorus/1,000 gallons), according to estimates in DCR's Nutrient Management Standards and Criteria. We assumed all cows were confined 100 percent of the time, based on the assumption that cows at pasture and confined cows likely generate manure at similar rates. In order to estimate manure output using the coarse categories provided by the Census of Agriculture, we also had to make assumptions about the weight of each category of cows. We assumed that "cattle and calves" had an average weight of 700 pounds (the average weight of a beef cow, adjusted lower to account for calves). We also assumed that dairy "cows

and heifers that calved" had an average weight of 1,200 pounds, and that "other cattle" had an average weight of 680 pounds (the average weight of a 9-16 month-old heifer). For example, to arrive at the manure and phosphorus output for only dairy cows and heifers that calved, we used the following equation: (109,859 dairy cows and heifers that calved (from the 2012 Census of Agriculture) x 1,200 lbs per cow x 3.65 gallons of manure per year x 100% confined)/1,000 gallons) x 3.96 lbs of phosphorus = 1,905,482 pounds of phosphorus from dairy cows and heifers that calved.

- Our estimates for cows exclude additional nutrients from washwater and process water from dairy and beef operations, runoff from feedlots, and dry or solid manure generated by cows either in confinement or while grazing outdoors.

Crop and pastureland acres are from the 2012 Census of Agriculture's tables 8, 25, and 26. Phosphorus removal rates are from the Virginia DCR's Nutrient Management Standards and Criteria, and we adjusted them from phosphate to phosphorus using a factor of 0.4364 (elemental phosphorus accounts for 43.64% of the molecular weight of phosphate). We assumed that permanent pastureland absorbed 10.91 pounds of phosphorus per acre, which is the average of the State's various removal rates for pasture depending on soil productivity. We included the following crops in our analysis: barley for grain, corn for grain, oats for grain, rye for grain, sorghum for grain, soybeans for beans, triticale, wheat for grain (all), corn for silage or greenchop, sorghum for silage or greenchop, alfalfa hay, small grain hay, other tame hay, wild hay, haylage or greenchop, other haylage, grass silage, or greenchop.

Water Quality and Impairments

EIP requested monitoring data for all stations in the Shenandoah Valley from 2010 to 2016 from the Virginia Department of Environmental Quality (DEQ).

Our analysis of total phosphorus concentrations was limited to the sixteen monitoring stations in DEQ's Ambient Long Term Trend Program to ensure stations measured phosphorus regularly and to avoid calculating averages from stations with few data points. We calculated annual averages using each sample of total phosphorus for a given year. The three-year average is an average of each year's average concentration. For values measured below the detection limit (i.e., less than 0.01 mg/L), we assumed the concentration was equal to the detection limit.

Our analysis of *E. coli* data was limited to the 58 stations that measured *E. coli* relatively regularly (at least every other month) in 2014 and 2015. Because the stations do not monitor frequently enough to calculate a monthly geometric mean, we used Virginia's criteria of no more than ten percent of samples exceeding 235 CFU/100 mL as a benchmark. We calculated the percentage of samples exceeding the Virginia recreational water quality standard by identifying the number of samples over 235 CFU/100 mL and the number of total samples from 2014 to 2016.

We downloaded the impairment status and GIS shapefiles for streams in the Shenandoah Watershed from the DEQ's 2014 305(b)/303(d) Water Quality Assessment Integrated

Report.[34] Using the geospatial data from DEQ, we were able to identify streams impaired by *E. coli* from agricultural sources. Streams identified as being impaired with *E. coli* from agriculture may also be impaired by other parameters or from other sources. We also used this shapefile to identify streams with benthic impairments.

Nutrient Management Plans

EIP submitted Freedom of Information Act requests to the Virginia Department of Environmental Quality's (VDEQ) Valley Regional Office in Spring 2016 for nutrient management plans from permitted poultry and animal operations and related inspection reports, poultry waste transfer records, and enforcement records for both permitted operations and poultry waste end users. We tabulated the following information from nutrient management plans:

- Cover sheet data, which includes summary information such as farm county, number of animals, cropland covered by the plan in acres, and the annual amount of manure produced, exported, imported, and used.

- If a NMP included cropland, we tabulated the most recent soil test results for each field covered by the NMP. We standardized results given as Mehlich III and lb/acre Mehlich 1 to ppm P Mehlich 1 using conversion formulas published by the DCR's Nutrient Management Standards and Criteria document (pp. 41-42). We identified fields where soil tests exceeded 55 ppm phosphorus, which is the point where Virginia's soil test method stops recommending phosphorus applications based on soil tests and crop yield goals, except for tobacco crops. We also identified fields where soil phosphorus exceeded 525 ppm phosphorus, which DEQ has established as the 65% saturation threshold for the Ridge and Valley region of the state. We narrowed our analysis to the most recent plans with soil samples dated after January 1, 2013.

- If an NMP included cropland, we tabulated summary information from each plan's balance sheets, which outline nutrient recommendations for each crop in the crop rotation covered by the plan. Our summary information included tract, field name, acres used, whether the nutrient recommendations were based on nitrogen or phosphorus needs, total phosphorus needed over the life of the plan, total phosphorus recommended from manure over the life of the plan, and where applicable, the final phosphorus removal credit by the end of the crop rotation covered by the plan. We used this information to determine how many acres needed phosphorus based on soil tests and yield goals, how many acres had phosphorus-based nutrient recommendations, the number of acres where NMPs recommended manure application, and the total amount of phosphorus recommended, and the total expected phosphorus removal (if available). Our analysis was limited to the most recent plans for each operation that we had on file, covering a time period from 2010 through 2022.

Waste Transfer Records

EIP requested a spreadsheet from VDEQ containing poultry waste transfer records from 2010 through early 2016, based on inspection reports. This spreadsheet documented shipments of poultry litter from poultry operations to manure brokers and other end users. It also documented the destinations of manure by watershed. We narrowed this list to the transfers from 2013 through 2015 that originated in Augusta, Page, Rockingham, and Shenandoah counties by reviewing the towns, cities, and watersheds listed in the spreadsheet. Not every record in this spreadsheet was complete, i.e. some were missing transfer amounts, some listed brokers instead of watershed destinations, and some did not provide any export destination. Three entries from our narrowed list did not list the amount transferred, and were excluded from the analysis. Using town or city names, and in some cases watershed names, where available, to determine county destinations, we mapped the destinations of manure transfers and calculated the amount of poultry litter that did not leave the four-county area, went to other counties, or went to other states (West Virginia, Kentucky, and Ohio). Eight entries (documenting 2,505 tons of poultry litter transferred, or 92,034 pounds of phosphorus) went to unknown destinations and were included in the "brokers or other unknown destination" category.

Inspection Reports

We requested inspection reports for permitted factory farms covering the time period between 2011 and 2016 from the Virginia DEQ. We analyzed the reports for 162 operations that had crop or pastureland during the most recent complete two years, 2014 and 2015. In a limited number of instances, operations applied to land that wasn't covered by their NMP. EIP tabulated how many operations had expired NMPs, how many operations had expired or missing manure and soil samples, and how many operations over-applied phosphorus from manure.

Appendix B. All Shenandoah Waters that Fail Recreational Health Standards for *E. coli*: 2014-2016

Station ID	Stream Name	Total Samples	Samples Over Standard	Percent of Samples Over Standard	Highest Value Measured	Map Key
1BMDD005.81	Muddy Creek	60	49	82%	> 24,196	36
1BLNV006.49	Linville Creek	36	27	75%	24,196	32
1BWSB000.22	Wheat Spring Branch	18	13	72%	3,130	1
1BCST012.32	Christians Creek	24	17	71%	1,670	53
1BLOM001.45	Long Meadow	12	8	67%	12,033	29
1BBON000.60	Boone Run	18	12	67%	3,654	37
1BNKD000.80	Naked Creek	24	16	67%	7,701	47
1BMDL060.48	Middle River	36	24	67%	8664	52
1BFNT002.16	Flint Run	36	23	64%	6,867	17
1BSMT023.18	Smith Creek	36	23	64%	3,255	31
1BDFK000.76	Dry Fork	36	23	64%	> 24,196	34
1BCST021.76	Christians Creek	24	15	63%	1,354	57
1BMDD000.40	Muddy Creek	18	10	56%	15,531	38
1BPGE000.09	Page Brook	35	18	51%	1,860	6
1BNPC000.02	Narrow Passage Creek	18	9	50%	4884	18
1BMLC000.40	Mill Creek	24	12	50%	1,723	24
1BLNV001.22	Linville Creek	36	18	50%	11,199	30
1BWAR003.88	War Branch	36	18	50%	2,755	33
1BSTH041.68	South River	36	18	50%	11,199	58
1BRSC001.42	Roseville Run	36	17	47%	9,208	4
1BSMT004.60	Smith Creek	58	27	47%	> 24,196	23
1BHKS000.96	Hawksbill Creek	24	11	46%	6,131	22
1BMSS001.35	Mossy Creek	24	11	46%	5,172	43
1BCKS003.10	Cooks Creek	18	8	44%	1,793	44
1BEHC001.18	East Hawksbill Creek	24	10	42%	3255	26
1BTRL000.02	Turley Creek	12	5	42%	> 2,000	28
1BLGC000.96	Long Glade Creek	24	10	42%	24,196	41
1BDGR000.23	Dog Run	18	7	39%	909	3
1BJER000.62	Jeremys Run	36	14	39%	2,382	20
1BNFS070.67	Shenandoah River, North Fork	18	7	39%	7701	21
1BMTR000.93	Mountain Run	36	14	39%	4,106	35
1BMFT006.20	Moffett Creek	31	12	39%	7,270	48
1BDUR000.02	Dry River	24	8	33%	10,462	40
1BBLK000.38	Blacks Run	18	6	33%	14,136	42
1BPSG018.13	Passage Creek	36	9	25%	1,153	19
1BQAL005.29	Quail Run	18	4	22%	1,050	39
1BNFS010.34	Shenandoah River, North Fork	56	11	20%	12,033	12
1BCRO002.75	Crooked Run	36	7	19%	4,106	11
1BSSF003.56	Shenandoah River, South Fork	57	11	19%	11,199	15
1BSTV000.20	Stephens Run	34	6	18%	3448	9
1BWST000.20	West Run	35	6	17%	8,164	10
1BCDR013.29	Cedar Creek	18	3	17%	512	7
1BSPR000.40	Spout Run	36	6	17%	670	8
1BSSF100.10	Shenandoah River, South Fork	36	6	17%	24,196	46
1BMDL001.83	Middle River	24	3	13%	10,462	49
1BCPL000.95	Chapel Run	18	2	11%	379	5
1BNFS000.57	Shenandoah River, North Fork	18	2	11%	1175	14
1BGNY000.04	Gooney Run	36	4	11%	703	16
1BSSF054.20	Shenandoah River, South Fork	18	2	11%	5794	25
1BNTH014.08	North River	18	2	11%	5,475	45
1BMDL036.08	Middle River	36	4	11%	8,164	50
1BSTH007.80	South River	18	2	11%	563	51
1BSTH020.85	South River	36	4	11%	697	55

Note: Virginia's health standard for water contact recreation is that water testing stations should not measure more than 235 colony forming units of E coli bacteria per 100 ML in over 10 percent of samples. Map key can be used to identify station locations on Figure 4.

Notes

[1] Animal numbers are from 2012, the most recent date for which county-level data were available from the U.S.Department of Agriculture. See Appendix A for manure calculations.
[2] Based on harvest and animal output estimates from the USDA Census of Agriculture and manure generation rates from Virginia Department of Conservation and Recreation and Chesapeake Bay Program.
[3] This is according to the limited state data that is available.
[4] This is a screening level that the Virginia Department of Environmental Quality uses to identify potential souces of benthic impairments. The state agency is currently working on a water quality standard for phosphrous.
[5] 159 million chickens includes broiler and pullet sales, and the number of layers in inventory at the end of 2012 according to the USDA Census of Agriculture. Available at: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/, accessed September, 2016.
[6] US Department of Agriculture Census of Agriculture, 2012, county-level data available at: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/, accessed September, 2016. Maguire, Rory O. (2014) "Importance of Farm Phosphorus Mass Balance and Management Options" Virginia Cooperative Extension Publication CSES-98P, available at: https://pubs.ext.vt.edu/CSES/CSES-98/CSES-98-pdf.pdf, accessed October 2016.
[7] Chesapeake Bay Program's Agricultural Modeling Subcommittee to the Poultry Litter Subcommittee and Agriculture Workgroup (March 2015) "Recommendations to Estimate Poultry Nutrient Production in the Phase 6 Watershed Model" available at: http://www.chesapeakebay.net/channel_files/22429/recommendations_to_estimate_poultry_nutrients_for_phase_6_model_03062015.pdf , accessed October 2016 (used to estimate manure generation and nutrient content of manure from pullets and laying hens). Beef and dairy manure production content were calculated based on phosphorus content provided by the Virginia Cooperative Extension (see note 2) and the Virginia Department of Conservation and Recreation, Virginia Nutrient Management Standards and Criteria, Revised July 2014, available at http://www.dcr.virginia.gov/document/standardsandcriteria.pdf. The cow total includes heifers, dairy, and beef cows as counted by the 2012 USDA Census of Agriculture.
[8] USDA 2012 Census of Agriculture, table 1, County Summary Highlights, 2012. Available at: https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_2_County_Level/Virginia/st51_2_001_001.pdf
[9] Virginia Department of Environmental Quality. Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report, Chapter 4.4, Freshwater Probabilistic Monitoring Results, available at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityAssessments/IntegratedReport/2014/ir14_Ch4.4_FPM_Assessment.pdf.
[10] Virginia Department of Environmental Quality. Final 2014 305(b)/303(d) Water Quality Assessment Integrated Report, available at http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2014305(b)303(d)IntegratedReport.aspx. For more information about benthic impairments, see Virginia Cooperative Extension, "TMDLs (Total Maximum Dail Loads) for Benthic Impairments," available at: http://www.pubs.ext.vt.edu/442/442-556/442-556.html, accessed 4/17/2017.
[11] Shenandoah Riverkeeper and Potomac Riverkeeper, "Technical Review of Evidence to Determine the Presence, Extent, and Consequences of Excessive Algal Growths in the Shenandoah River and its Tributaries," submitted to the Virginia Department of Environmental Quality on January 30, 2015.
[12] *Ibid*.
[13] *Ibid*.
[14] *Ibid*.
[15] *E. Coli* is also found in human waste.
[16] 9VAC25-260-170. Bacteria Other Recreational Waters. http://law.lis.virginia.gov/admincode/title9/agency25/chapter260/section170/
[17] Virginia Department of Environmental Quality, Watershed Implementation Plan for Chesapeake Bay Total Maximum Daily Load, available at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/TMDL/Baywip/wipsection5.pdf

[18] Tamara Dietrich, "Gov. Terry McAuliffe's Budget Would Help Chesapeake Bay, Farmers," Hampton Roads Daily Press, January 10, 2016. Link: http://www.dailypress.com/news/science/dp-nws-governor-budget-environment-20160106-story.html
[19] Numbers on cattle fencing survey from Mark Frondorf, Shenandoah Riverkeeper, on April 10, 2017.
[20] Soil test phosphorus thresholds are measured as parts per million Mehlich 1 phosphorus. Mehlich 1 refers to the specific soil testing method used by the lab. Soil test labs can use a variety of testing methods that give different results.
[21] Virginia's soil phosphorus thresholds are based on soil samples analyzed using the Mehlich 1 soil test method. The threshold at which farmers can no longer apply phosphorus varies across the state and is based on where soils reach a 65 percent saturation point, according to Virginia DCR's Nutrient Management Standards and Criteria. Virginia Department of Conservation and Recreation (2014) "Virginia Nutrient Management Standards and Criteria, Revised July 2014," available at: http://www.dcr.virginia.gov/document/standardsandcriteria.pdf, accessed 4/4/2017.
[22] Based on EIP's analysis of soil test results from 316 AFO NMPs..
[23] Virginia Department of Environmental Quality, Requirements for Poultry Litter Use and Storage Fact Sheet, Revised 4/2014. Available at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/VirginiaPollutionAbatement/AFOdocuments/AmendedGP/VPA_AFO_GP_Animal_Waste_Fact_Sheet%20rev%20_04_2014.pdf, accessed October 2016.
[24] Email response to a Freedom of Information Act request to Virginia Department of Environmental Quality, 9/6/2016, from Diana Adams, VFOIA Coordinator, to Courtney Bernhardt, EIP Senior Analyst. "DEQ does not perform routine inspections of poultry waste end users. The only information we would have would be inspection reports related to complaints regarding poultry waste end users."
[25] Virginia Department of Conservation and Recreation (2017) Virginia Poultry Litter Transport Incentive Program," available at http://www.dcr.virginia.gov/soil-and-water/nmlitter, accessed 4/25/2017.
[26] Virginia Department of Conservation and Recreation (2010) "Virginia Water Quality Improvement Fund and The Cooperative Nonpoint Source Pollution Program," p. 17, available at http://leg2.state.va.us/dls/h&sdocs.nsf/By+Year/RD3222010/$file/RD322.pdf, accessed 4/25/2017.
[27] Fifty-six percent of this land had phosphorus limits, while the remainder had nitrogen limits.
[28] Virginia Department of Conservation and Recreation, Virginia Nutrient Management Standards and Criteria, Revised July 2014, available at http://www.dcr.virginia.gov/document/standardsandcriteria.pdf. Phosphate (P_2O_5) removal rates converted to phosphorus.
[29] 4VAC50-85-140(D)(5)
[30] US Environmental Protection Agency (2015) Virginia Animal Agriculture Program Assessment, pg. 47, available at: https://www.epa.gov/sites/production/files/2015-07/documents/virginia_animal_agriculture_program_assessment_final_2.pdf, accessed October 2016.
[31] We did not include acres documented on inspection reports if we did not also have a corresponding NMP or if an operation applied manure between NMP periods. If we were to include these additional acres, the total number of operations inspected would be 192 instead of 163.
[32] Perez, Michelle R. (2015) "Regulating Farmer Nutrient Management: A Three-State Case Study on the Delmarva Peninsula" *J. Environ. Qual.* 44:402-414, doi:10.2134/jeq2014.07.0304, p. 410. Available at: https://dl.sciencesocieties.org/publications/jeq/abstracts/44/2/402, accessed 10/2016.
[33] *Ibid.*
[34] See note 9.