West Virginia Department of Agriculture
Gus R. Douglass, Commissioner
Regulatory and Environmental Affairs Division

West Virginia's
Potomac Headwaters Water Quality Report

July 1998 - June 2008

Chesapeake Bay Program
A Watershed Partenership

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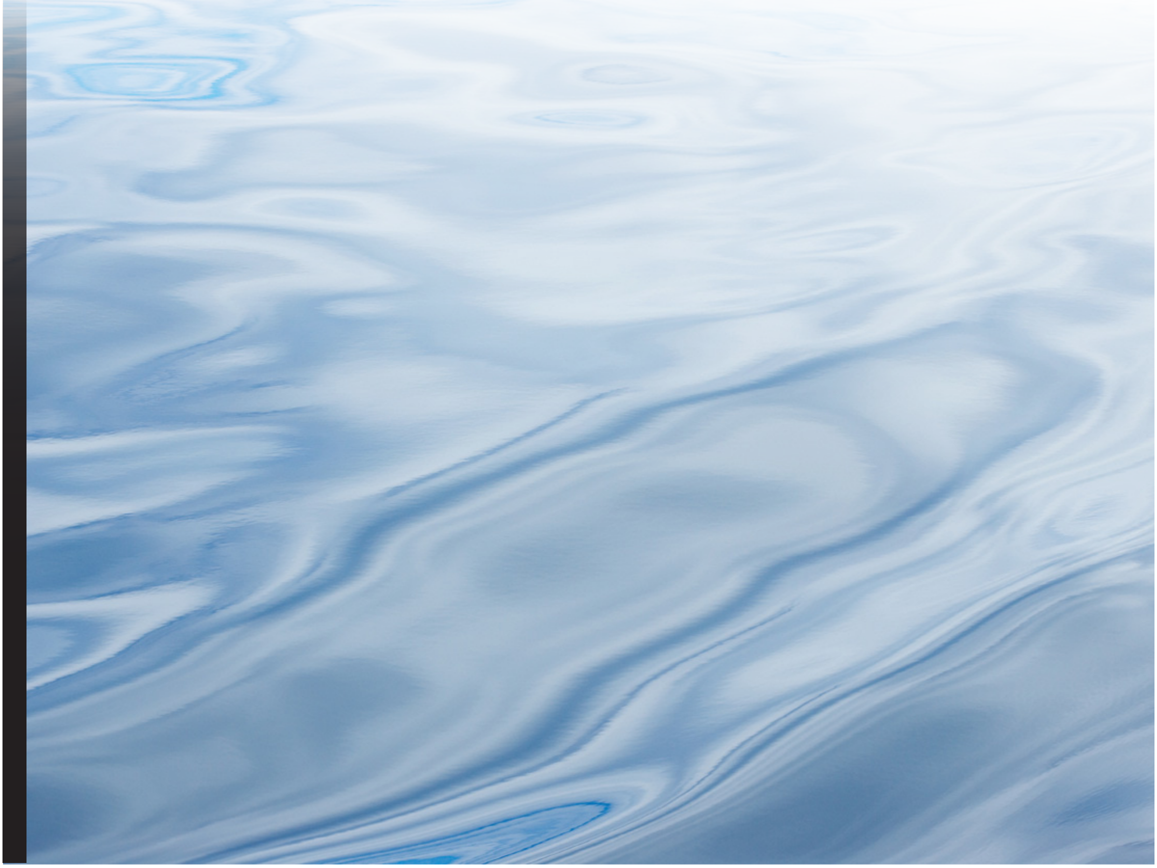


MISSION STATEMENT

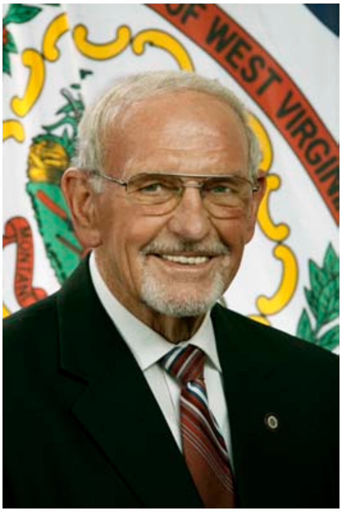
The mission of the West Virginia Department of Agriculture is to protect plant, animal and human health and the state's food supply through a variety of scientific and regulatory programs; to provide vision, strategic planning and emergency response for agricultural and other civil emergencies; to promote industrial safety and protect consumers through educational and regulatory programs; and to foster economic growth by promoting West Virginia agriculture and agribusinesses throughout the state and abroad.

Table of Contents

Abbreviations

BMP	Best Management Practices
CFU	Colony Forming Units
DC	The District of Columbia
DO	Dissolved Oxygen
HPU	Hydraulic Protection Unit
HUC	Hydrologic Unit Code
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
NPDES	National Pollution Discharge Elimination System Program
pH	Hydrogen Ion Present
QAQC	Quality Assurance, Quality Control
RCRA	Resource Conservation and Recovery Act
RM	River Mile
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
USGS	United States Geological Service
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
WV	West Virginia
WVCA	West Virginia Conservation Agency
WVDA	West Virginia Department of Agriculture
WVDEP	West Virginia Department of Environmental Protection

FORWARD



West Virginia's water resources are one of its most important commodities. Clean water is critical not only to human populations, but to farmers and their livestock as well. As the planet's original environmentalists, farmers know all too well that inferior inputs result in poor farm productivity - and a more meager bottom line.

The West Virginia Department of Agriculture (WVDA) realizes the importance of water quality to everyone. This year marks the tenth anniversary of the Department's stream sampling and water quality program. The research conducted by WVDA staff demonstrates that agriculture is not the only source impacting water quality, and that tens of millions of dollars worth of agricultural best management practices (BMPs) are having a substantial positive effect. We cannot let up in our efforts to protect our state's valuable water resources.

My hope is that this report will help to focus attention on what can be done to protect water quality in our state and in the states of our downstream neighbors. I applaud you for your interest in this subject and encourage you to contact my office with any comments or questions at 304/558-3200, or by e-mail at douglass@ag.state.wv.us.

Sincerely,

Gus R. Douglass

Gus R. Douglass
West Virginia Commissioner of Agriculture

Introduction

“West Virginia (WV) is known for its high quality rivers and streams. These waters generate income for the State, provide recreational opportunities for residents and tourists, and water for drinking, irrigation and industries. In order to protect this vital resource, state and federal agencies and other organizations conduct water quality studies to determine the characteristics of the water and identify waters in need of improvement. The quality of every stream’s water is affected by natural factors such as geology, soils and forest type. They can also be impacted by the activities of people, and human effects that are, in excess, described as pollution.

In 1996, segments of seven rivers within West Virginia’s Potomac watershed, generally

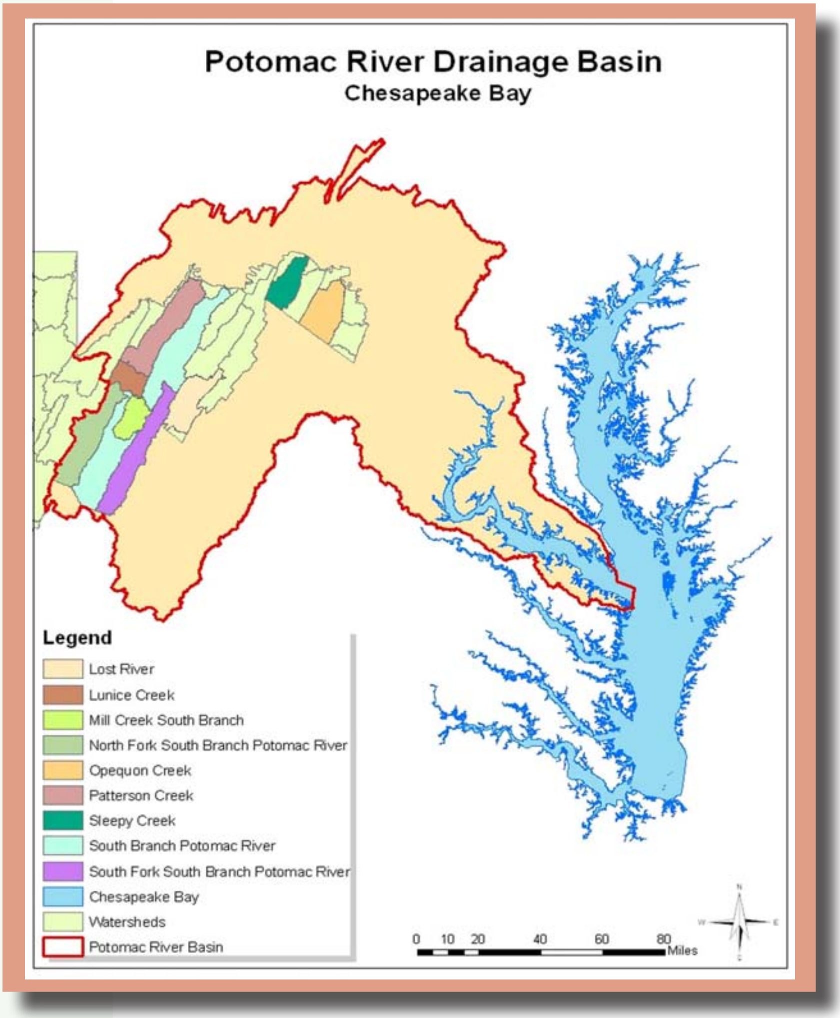


Figure 1: Potomac River drainage basin.

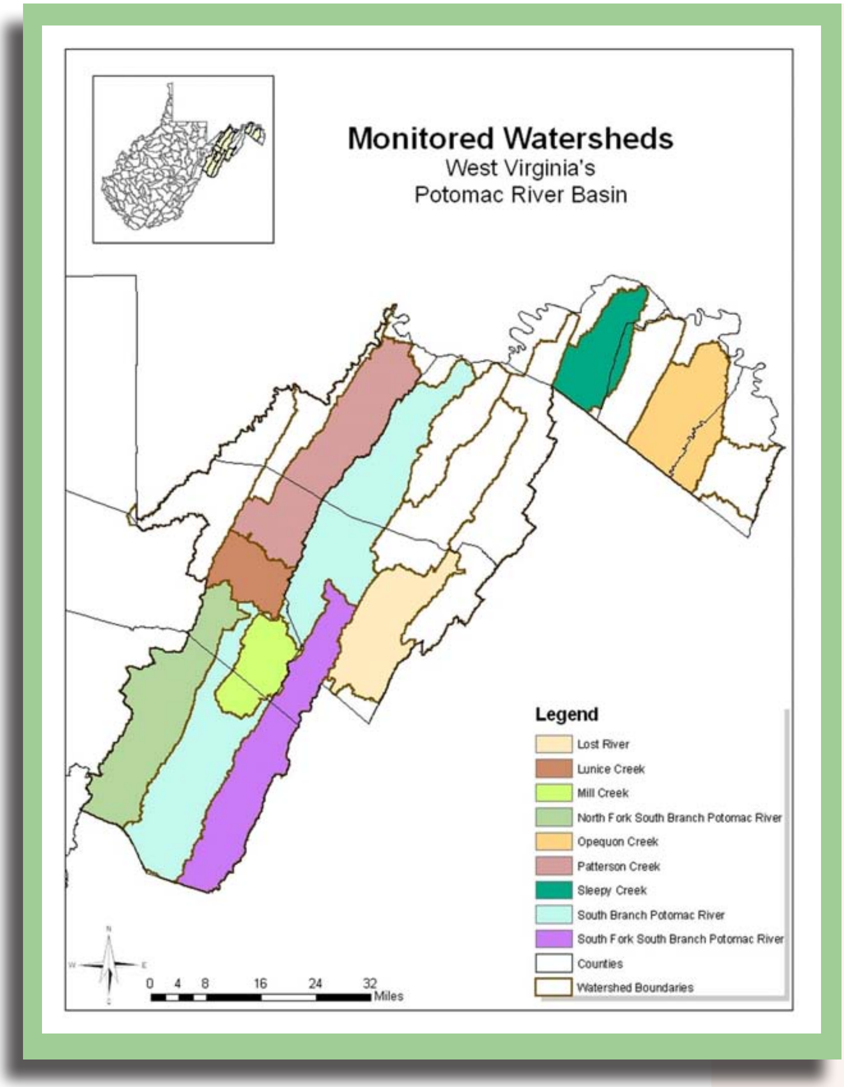


Figure 2: Monitored watersheds of the Potomac River drainage basin.

refered to as the "eastern panhandle", (Lost River, South Branch Potomac River, North Fork South Branch Potomac River, South Fork South Branch Potomac River, Mill Creek, Lunice Creek and Anderson Run) were placed on West Virginia's 303(d) list of impaired water bodies due to fecal coliform bacteria. Out of concern that the listing of these waters was based on insufficient data, in 1998 the WVDA began a water quality sampling program in these watersheds to collect additional data that would more accurately establish the condition of these streams. The WVDA upgraded their water quality laboratory to allow research into the origin of pollutants and to study unanswered water quality questions that arose because of the expansion of agricultural activity in West Virginia's Potomac Basin" *(Figure 1)* (WVDA 2006).

This comprehensive report presents the

WVDA's Water Quality Program findings for various parameters, including temperature, dissolved oxygen (DO), pH, turbidity, conductivity, total phosphorus, ammonia-nitrogen, nitrate-nitrogen and fecal coliform. From July 1998 to June 2008, 25,479 samples were collected from 114 sampling locations throughout the ten watersheds analyzed: Anderson Run, Lost River, Mill Creek, North Fork South Branch Potomac River, Opequon Creek, Patterson Creek, Sleepy Creek, South Branch Potomac River, South Fork South Branch Potomac River and the North Fork South Branch Potomac River *(Figure 2)*.

The watersheds are located within two conservation districts: Potomac Valley Conservation District (Grant, Hampshire, Hardy, Mineral and Pendleton Counties) and Eastern Panhandle Conservation District (Berkeley, Jefferson, and Morgan Counties) *(Figure 3, Table 1)*. All samples were collected on a predetermined schedule regardless of weather conditions, with the exception of extremely hazardous circumstances.

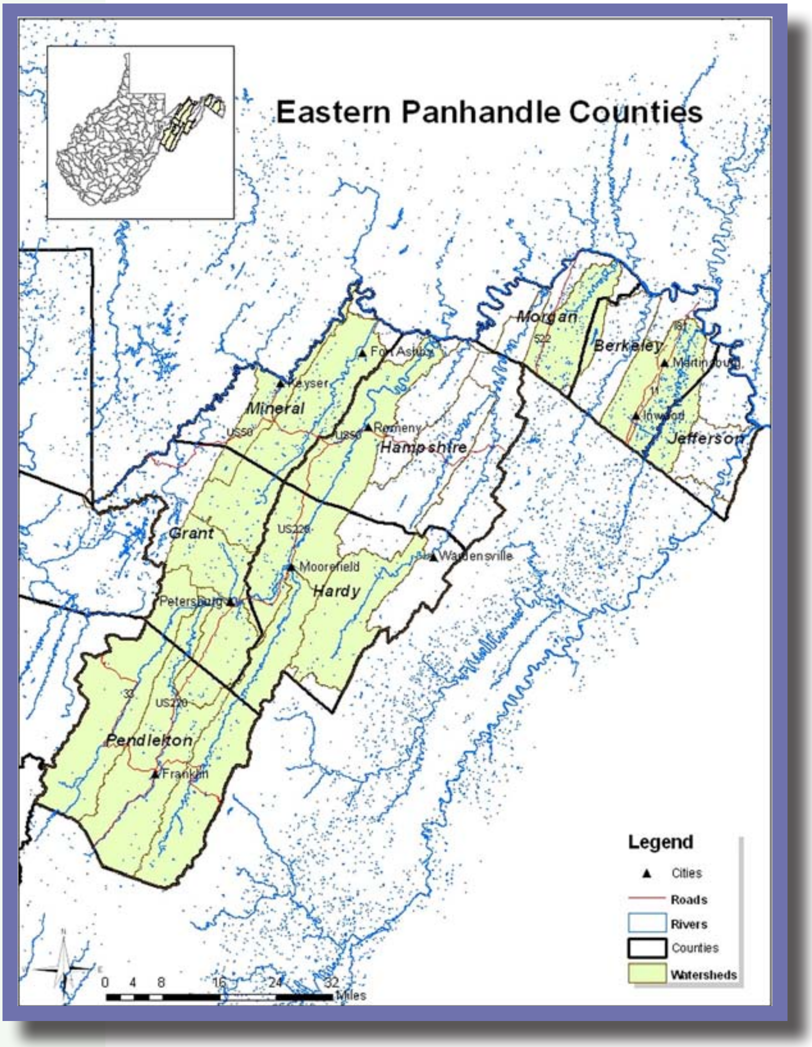


Figure 3: Counties located throughout the eastern panhandle.

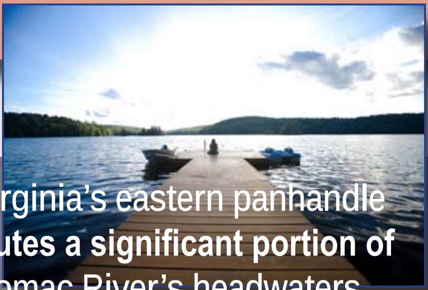



Table 1: United States Census Bureau, 2000 and 2007 populations per selected counties.

County	2000 Population	2007 Population	% Growth 2000-2007
Berkeley	75,905	99,734	31.4%
Grant	11,299	11,925	5.5%
Hampshire	20,202	22,577	11.8%
Hardy	12,669	13,661	7.8%
Jefferson	42,190	50,832	20.5%
Mineral	27,078	26,722	-1.3%
Morgan	14,943	16,351	9.4%
Pendleton	8,196	7,650	-6.7%

Source: US Census Bureau (2008) State and county quick facts. Available online at: http://quickfacts.census.gov/qfd/maps/west_virginia_map.html. Retrieved: April 28, 2009.

The Chesapeake Bay ....



West Virginia's eastern panhandle **contributes a significant portion of** the Potomac River's headwaters, which is the second largest tributary to the Chesapeake Bay.

West Virginia' is one of six states located within the Chesapeake Bay watershed, including Delaware, Maryland, New York, Pennsylvania and Virginia. The District of Columbia (DC) is also included *(Figure 4)*. The first Chesapeake Bay Agreement was signed in 1983, with the goal to decrease nutrients to the Bay. On June 18, 2002, the WVDA, West Virginia Department of Environmental Protection (WVDEP) and West Virginia Conservation Agency (WVCA) officially partnered on the Chesapeake Bay Program Water Quality Initiative. As a headwater state, West Virginia was charged with decreasing nutrients and sediment loads. On August 23, 2005, the West Virginia Potomac Tributary Strategy was submitted to the Chesapeake Bay Program. The strategy called for reductions of 33% of nitrogen, 35% of phosphorus and 6% of sediment (WVTSSWG 2005). Soon after that time the WVDA expanded the water quality sampling schedule to include "priority streams."

The Potomac River is the 2nd largest tributary of the Chesapeake Bay. The drainage area of the basin is 14,670 square miles. West Virginia is one of four states, as well as DC, within the Potomac River basin, containing 3,490 square miles. Of the 5.8 millions citizens living within the watershed, 240,478 reside in West Virginia. This is a population density of 69 persons per square mile; the lowest density within the basin (USCB 2009).

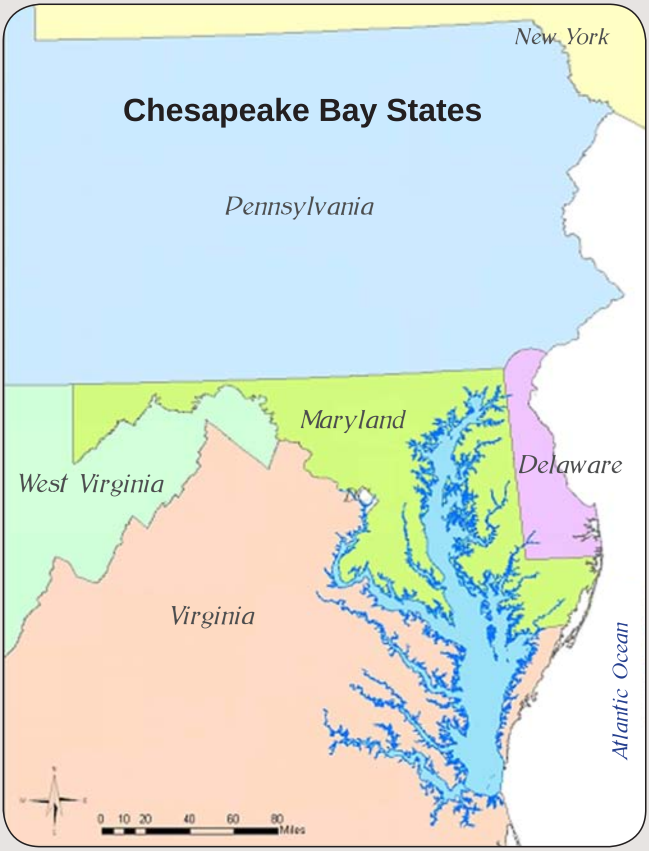
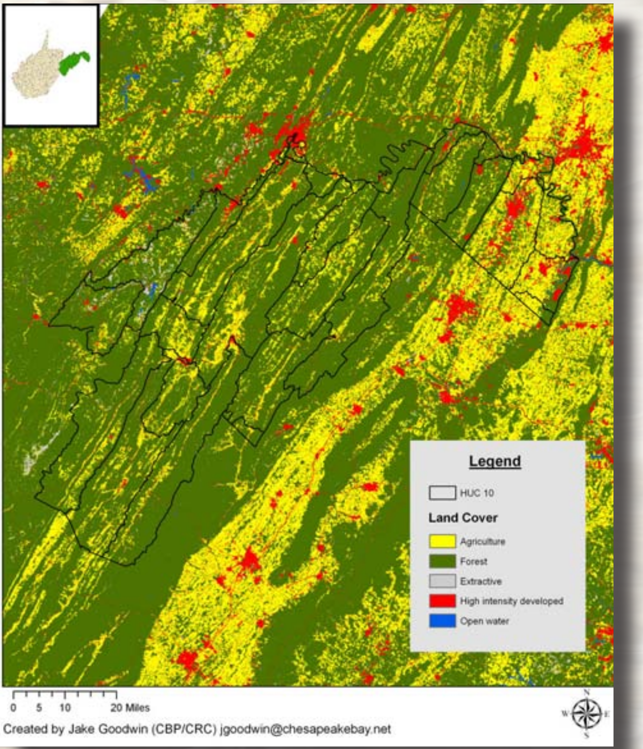


Figure 4: States within the Chesapeake Bay drainage basin.

West Virginia Eastern Panhandle



Created by Jake Goodwin (CBP/CRC) jgoodwin@chesapeakebay.net

Figure 5: Land cover throughout West Virginia's eastern panhandle.

Table 2: Percent of Land use by watershed area.

HUC_10	Watershed	Open Water	Urban	Forested	Agriculture	Other*
0207000101	North Fork South Branch Potomac River	0.09%	1.70%	86.05%	11.64%	0.52%
0207000102	Lunice Creek	0.06%	2.93%	67.92%	28.73%	0.36%
0207000103	Headwaters South Branch Potomac River	0.12%	2.60%	79.62%	17.55%	0.10%
0207000106	Outlet South Branch Potomac River	0.33%	2.54%	78.10%	18.62%	0.42%
	Total South Branch	*0.24%*	*2.57%*	*78.79%*	*18.14%*	*0.27%*
0207000104	Mill Creek South Branch	0.06%	2.95%	77.00%	19.84%	0.14%
0207000105	South Fork South Branch Potomac River	0.13%	2.05%	88.27%	9.31%	0.24%
0207000207	Patterson Creek	0.12%	3.32%	76.90%	19.51%	0.14%
0207000303	Lost River	0.06%	1.86%	86.04%	11.90%	0.14%
0207000402	Sleepy Creek	0.29%	2.30%	85.31%	12.09%	0.01%
0207000409	Opequon Creek	0.12%	16.25%	37.59%	41.35%	4.68%

* Includes Extractive and barren land and nurseries/orchards.

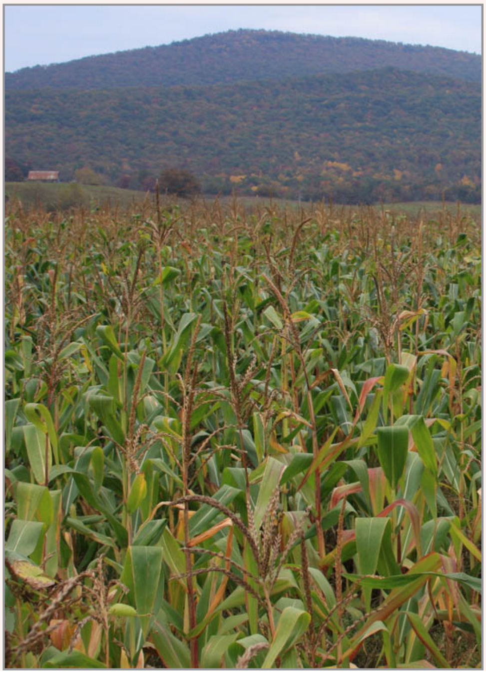
Source: Phase V Chesapeake Bay Watershed model LU/LC dataset. Anderson Run, a sub-watershed of the South Branch Potomac River, was not analyzed. Note: In report only various percentages are listed.

Agriculture

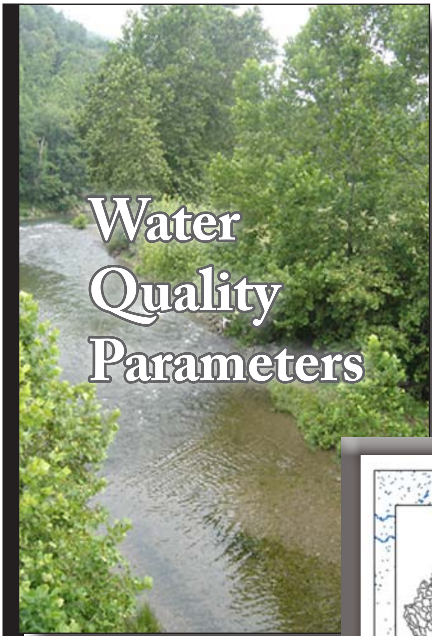
Around 1996, the poultry industry completed an expansion that tripled production in WV's Potomac Headwaters region, leading to specific concerns that increased amounts of poultry litter (a mixture of poultry manure and bedding materials) might impact water quality *(Figure 5, Table 2)*. To address those concerns, the Potomac Headwater Land Treatment Program was initiated in the mid-1990's. This ten year government cost share project focused on accelerated development of nutrient management plans and installation of agriculture waste storage structures, mortality composters and livestock confinement areas. Eighty-five percent of poultry growers in the five county (Pendleton, Grant, Hardy, Mineral and Hampshire) area of the Potomac Valley Conservation District participated in this program.

> Over the last ten years the poultry industry has remained steady.

The number of poultry houses has stayed constant as new structures have replaced out of production houses. Federal and state monies through the United States Department of Agriculture's (USDA) Farm Bill, United States Fish and Wildlife (USFW) and Trout Unlimited's Potomac Headwaters Home River Program for fencing and buffering, and WVCA Section 319 program are just a few of the resources available for nutrient management projects. The most important parameters analyzed in this study are nutrients (total phosphorus, ammonia-nitrogen, nitrate-nitrogen) and fecal coliform bacteria. Among other variables, they provide a good overview of the health of a stream. As the various parameter levels are evaluated, a clearer snapshot of the health and quality of the water can be better established. This knowledge and understanding provides the valuable framework needed to restore, maintain and protect our precious streams.



Water Quality Parameters



Various parameters are used to identify the health of a stream. Determinants can vary from chemicals (atrazine), particulates (total suspended solids, turbidity), elements (magnesium, calcium), compounds (ammonia-nitrate, nitrate-nitrogen), bacteria (fecal coliform, E. coli) and physical features (temperature, conductivity). The body of water or the reason for the analysis usually determines the sampled parameters.

In this analysis, eight parameters were *(Figure 6)* evaluated over each of the ten watersheds including: temperature, dissolved oxygen, pH, conductivity, total phosphorus, ammonia-nitrogen, nitrate-nitrogen and fecal coliform. Water samples collected in the Sleepy Creek and Opequon Creek watersheds were not analyzed for fecal coliform bacteria.

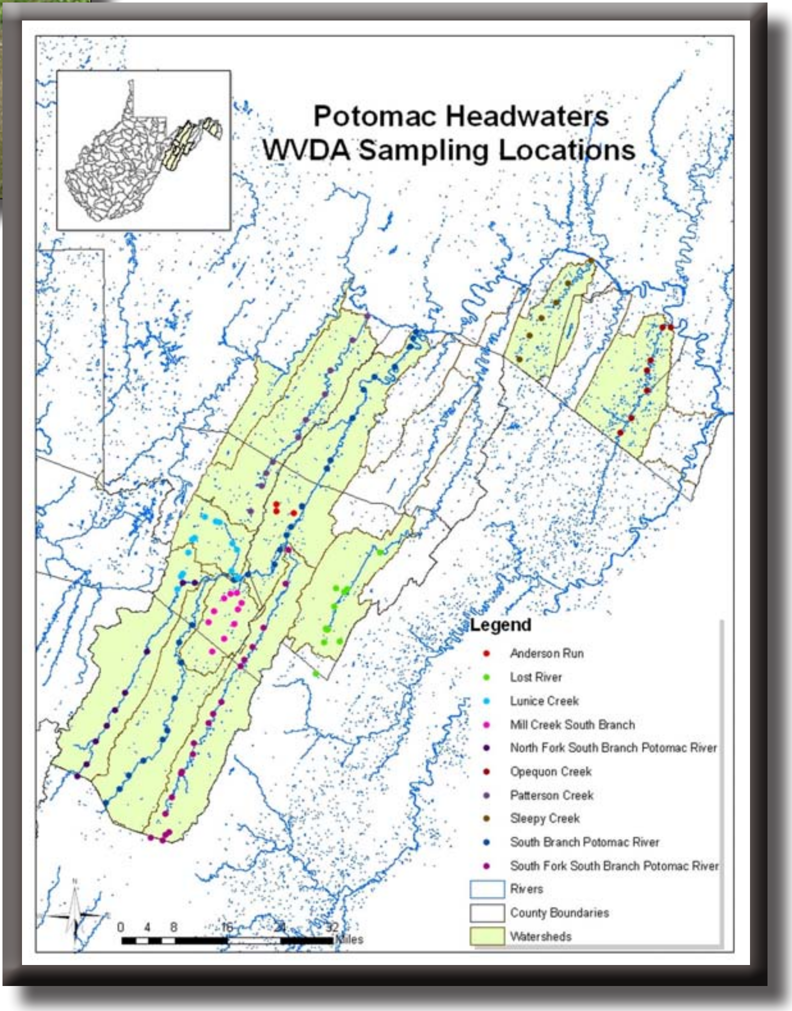
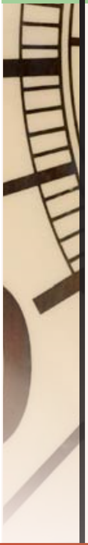


Figure 6: Potomac headwater sampling distributions.

Temperature



"The rates of biological and chemical processes depend on temperature. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Aquatic insects are sensitive to temperature and will move in a stream to find their optimal temperature. Temperature is also critical for fish spawning and embryo development. If stream temperature are outside of optimal levels for prolonged periods of time organism become stressed and may die or be unable to reproduce.

Temperature affects the oxygen content of water (oxygen levels become lower as temperature increases); the rage of photosynthesis by aquatic plants; the metabolic rates of aquatic organism; and the sensitivity of organisms to toxic materials, parasites, and diseases. Increased temperature increases the rate of organism decomposition, which depletes dissolved oxygen.

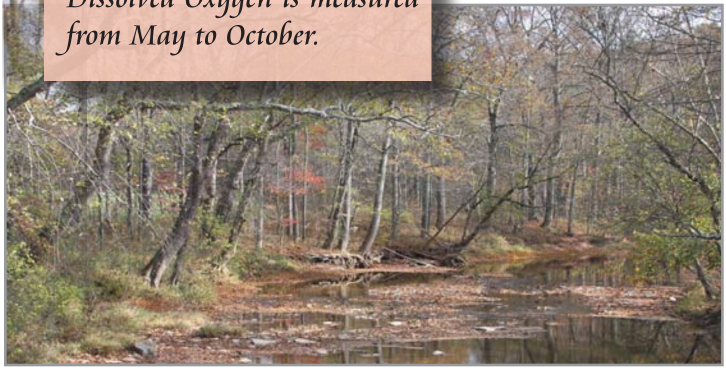
Causes of water temperature change include weather, removal of shading stream bank vegetation, discharge of cooling water and run-off from urban areas. Urban runoff from parking lots and buildings is often much warmer than run off from grassy and woodland areas (UNC 2008)."

Dissolved Oxygen

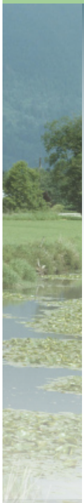
Dissolved Oxygen is defined as the concentration of oxygen dissolved in water. It is measured in milligrams of oxygen per liter of water (mg/L). DO enters a system via a multitude of various processes, such as the diffusion of surrounding air, aeration of water that has tumbled over falls or rapids, and plant and algae photosynthesis. However, DO is also depleted or consumed by the respiration of aquatic animals, decomposition by microorganisms and during the process of chemical reactions. If dissolved oxygen is consumed or depleted more than it is being released then an unbalance is created leading to the relocation, weakening, or death of aquatic life. In some circumstances a hypoxic or "dead" zone might be created. Most often this process is a direct result of eutrophication, a build up of an abundance of nutrients and ultimately a depletion of DO.

Dissolved oxygen levels not only fluctuate seasonally, but over a 24 hour period. DO is highest in a water body before sunrise and is lowest during the afternoon. Understandably, colder water can hold more oxygen then warmer water. Even so the amount of DO an organism needs depends on its species, physical state, water temperature, type of water system, and pollutants present. For example, trout need 10mg/L and bass ~7/8mg/L (Penn State 2009) of dissolved oxygen.

Dissolved Oxygen is measured from May to October.



pH



pH: A Measure of the Concentration of Hydrogen Ions,

is highly variable depending on the time of day, year and location of the measurement. Nevertheless, it is a very important factor in an aquatic system. It affects numerous biological and chemical processes, and is related to stream diversity, metal solubility and fluctuation in toxicity of certain chemicals. For example, heavy metals tend to be more toxic at lower pH of the increased solubility, making them more bioavailable. Alterations of pH can be caused by atmospheric deposition, rocks and municipal and industrial effluents.

The majority of aquatic life flourishes with a pH range of 6.5 to 8.0. Water with pH less than 5 or greater than 9 will support little aquatic life. When pH is outside the optimal zone, the diversity of the stream decreases because it stresses the physiological systems of most organisms. For instance, low pH can allow toxic elements and compounds to become available for the uptake by aquatic plants and animals, in turn hurting sensitive animals like rainbow trout (USEPA 2008).

Conductivity

Conductivity, or specific conductance, is a measure of the ability of water to pass an electrical current (USEPA 2008). Conductivity, calculated in microsiemens per centimeter (uS/cm), is directly proportional to the concentrations and types of positively and negatively charged ions present. For example, the greater the ions present, the more electricity can be conducted by the water. Conductivity is affected by the presence of inorganic dissolved solids like calcium and magnesium. Organic inputs, such as oil and alcohol provide very low electrical currents, therefore very low conductivity. Ionic sources are both naturally occurring and anthropogenic in origin, including soil, bedrock, human and animal waste, fertilizers, pesticides, herbicides and road salt. The conductivity of rivers in the United States generally ranges from 50 to 1500μS/cm (USEPA 2008).

Conductivity: A measure of the ability of water to pass an electric current.

Nutrients

Nutrients: Chemical elements that are *essential* for life. . .

are found naturally in soil, water and the atmosphere. Nonetheless, excess amounts of nutrients can severely harm not only the aquatic life within the water body, but the surrounding terrestrial life. High levels can cause nuisance algae blooms; create hypoxic or "dead" zones; generate an abundance of potentially toxic algae essentially killing aquatic life, helpful algae, aquatic plants, insects, and fish; increase levels of pollution tolerant or undesirable species; and prematurely age a water body. Unstable increase of nutrients can also lead to eutrophication.

The nutrients of most concern to a stream are phosphorus and nitrogen. Not only does the form they feature, but the concentration of the nutrients changes continually. Depending on the season, organic inputs, land applications and type of water body nutrient inputs regularly fluctuate.

Total Phosphorus

Total phosphorus is the sum of all forms of phosphorus including organic and inorganic, suspended, and dissolved. Phosphates naturally are generated from human and animal waste, phosphate-rich rocks, laundry detergent, cleaning and industrial processes, fertilizers and pesticides (HACH 2006). Phosphorus may be dissolved in runoff water or bound to soil and organic matter. The transport of phosphorus to a system most readily occurs during erosion and runoff events. A study conducted by the USGS (2003) concluded that 90% of annual sediment and phosphorus losses occur during storm events.

When phosphorus-bound sediments enters a stream, it quickly falls out of the water column to the stream bottom. Forms of dissolved phosphorus are quickly taken up by microbes and plants, or is chemically absorbed to sediment. Also, during high flow events, benthic phosphorus bound sediment is potentially rereleased into the stream, compounding the issue. Phosphorus is a limiting factor, confining the growth, abundance, or distribution of a population of organisms in an ecosystem. Phosphorus inputs downstream of a point source, such as a waste water treatment plants, are exceptionally high. Non-point source inputs can also be highly phosphorus rich; however, the nutrient can be elusive making it harder to measure exact abundance. Even at low concentrations phosphorus can have a profound biological affect.

In April 2008 a new method detection limit (MDL; 0.007mg/L) was established by WVDA's water quality laboratory for total phosphorus. The MDL is a term used to represent when analytical methods used are not sensitive enough to detect the phosphorus in the water column, not that it was not present.

Ammonia-nitrogen

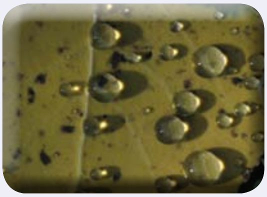
Ammonia-n is a form of reduced inorganic nitrogen. It can occur in two states: un-ionized (free) and ionized. Free ammonia-n is characterized as a gaseous chemical that is potentially toxic in high concentrations to aquatic life, specifically fish then to freshwater invertebrates. These effects are greater during the earlier stages of life. Iodized (ammonium) forms of reduced nitrogen remain soluble in water and are not as harmful as un-iodized ammonia-n. Both forms exist in equilibrium which are dependent upon the concentration of pH and temperature of the water.

Naturally, sources of ammonia-n include decomposing organic animal and plant tissue, and human and animal waste. Small amounts of ammonia-n are generally utilized as an important source of nitrogen for plants. However, large inputs into a system can be fatal for aquatic life. Higher concentrations are most often found in raw sewage, industrial effluent, and fertilizer runoff. West Virginia follows the Environmental Protection Agencies' (EPA) Ambient Water Quality Criteria.

"West Virginia has a water quality standard for ammonia due to its toxic effects on aquatic life. However, the standard is not a simple number that represents the ammonia concentrations that causes harm. The relative percentages of total ammonia present in the form of unionized ammonia and ammonium vary greatly with water temperature and pH. For example, in 15ºC water with a pH of 8, only 2.7% of total ammonia is unionized; at 25ºC and a pH of 9, the share rises to 36%; at 25ºC and a pH of 9.5, the share rises to 64%. Both temperature and pH tend to rise during the day and fall during the night. Daily pH changes due to the effects of photosynthesis and respiration by aquatic plants and algae on water chemistry. The more algae and plants present in a stream and the greater the amount of sunlight that reaches the stream, the larger the effect will be" (WVDA 2006).

"Violations of the acute and chronic aquatic life criteria for ammonia are determined in WV using the tables, formulae, and procedures detailed in the USEPA's Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014)" (WVDA 2006).

In 2004 the Department began using the Lachat Quik Chem 8000 Flow Injection System to measure ammonia, among other parameters. The combination of the usage of a more sensitive meter and decrease of the MDL, ammonia-n values noticeably decreased, skewing the data set. In April 2008 a new MDL (0.006mg/L) was established by WVDA's water quality laboratory for ammonia-n.



Nitrate-nitrogen

Nitrate-n, expressed in milligrams per liter of water, is a bioavailable form of nitrogen that occurs naturally from the decomposition of terrestrial and aquatic plants and animal wastes. Forms of nitrogen include nitrates (NO3), nitrites (NO2), and ammonia (NH3). In this report nitrate-nitrogen (NO3-N) and ammonia-nitrogen (NH-N) will be discussed. Nitrate-n is the main form of nitrogen taken up by plants; it is vital for growth. It is formed when nitrogen combines with oxygen in the soil. Nitrate-n readily dissolves in water; is chemically stable over a broad range of environmental conditions; and moves easily through ground and surface waters (Muller et al 1995). It is the principle structure of all combined nitrogen found in natural waters and is much more persistent in the water column than either phosphorus or ammonia. Various microbial processes that occur at the stream bed transform nitrate in a number of ways, including removal from the stream via conversion to elemental (gaseous) nitrogen (Peterson et al 2001). Excluding anthropogenic inputs, most natural surface waters have less than 0.3 mg/L of nitrate (RIC 1998). However, nitrate levels increase due to wastewater treatment plants, failing septic systems, manure storage areas, runoff from fertilized urban, suburban, and agricultural lands, and industrial and agricultural emissions.

In 1974 the Safe Drinking Water Act was enacted. This law requires USEPA to establish safe drinking water levels in chemicals that may lead to health problems. This “maximum contaminant level goal” (MCLG) for nitrate is 10mg/L (USEPA 2009).

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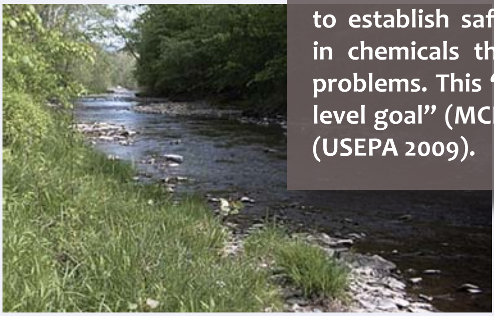


Fecal Coliform Bacteria

Fecal coliform bacteria thrives in the intestines of warmblooded animals and enters the environment with the excretion of feces.

While fecals themselves are usually not harmful, they are often associated with other human pathogens carried in excrement. They are used as markers to indicate that water is contaminated with fecal matter. The bacteria can enter waters through direct deposition by animals, straight pipes, failing septic tanks, runoff, sewage treatment plants, and other point and nonpoint sources. Eight of the ten watersheds analyzed are currently on the 303d list of impaired waters. In 1998, Anderson Run, Lost River, Lunice Creek, Mill Creek and the South Branch (will be revisted in 2014) had a total maximum daily load (TMDL) established for fecal coliform, followed by the South Fork in 2002. In 2008 Opequon Creek and in 2010 Patterson Creek will also have TMDLs set.

Fecal coliform is most commonly used to determine if a river is suitable for water contact recreation. WV has a water quality standard for fecal coliform, which is stated in two parts. If the water quality values do not meet any part of the standard, the stream will be in violation. First, the standard states that a violation occurs if the geometric mean of five or more samples collected within thirty days exceeds 200 colony forming units (cfu) in 100 milliliters of water. Second, a violation occurs if 10% or more of samples collected at a site exceed 400 cfu/100ml. This standard is often very difficult to apply as it requires a high density of samples to be collected within a short period of time. Part two of the standard often applies to a single concentration above 400cfu/100ml for point source discharges, but its use for other purposes is contentious. For this reason, the WVDA collected five samples per month at most sites during the first several years of the program, and at selected sites in later years (WVDA 2006).

Analysis

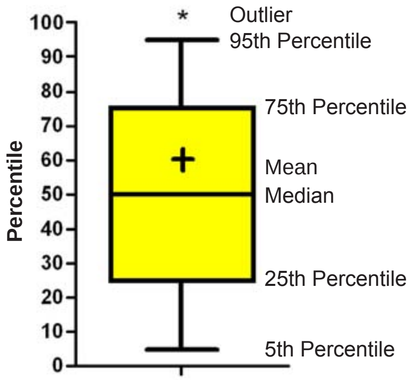
Eight parameters were analyzed throughout ten watersheds within the Potomac Headwaters.

Parameters included are: temperature, dissolved oxygen, pH, conductivity, total phosphorus, nitrate-nitrogen, ammonia-nitrogen and fecal coliform. These particular parameters were chosen to gain an overall snapshot, or understanding, of the water quality throughout the region. Special analytical attention was given to nutrients (total phosphorus, nitrate-nitrogen and ammonia-nitrogen) and fecal coliform bacteria.

In order to reduce sampling bias, all samples were collected based upon a preset schedule and were collected regardless or weather conditions, including both high and low flows, and during periods of normal, high and low precipitation. Samples were not pulled during extreme hazardous conditions, to ensure environmental technicians' safety. For "quality assurance, quality control", (QAQC) duplicate samples were collected usually at the last site in the sampling sequence. In 2004, the WVDA began using the Lachat Quik Chem 8000 Flow Injection System. This in-house system measures various water quality parameters, such as nitrate, nitrite and ammonia. It should be noted that as a result of the heightened sensitivity of the equipment and decrease in the MDL, ammonia-n measurements saw a rather large drop in values and thus, with the exception of Opequon Creek, measurements were noticeably less.

Statistical Methods

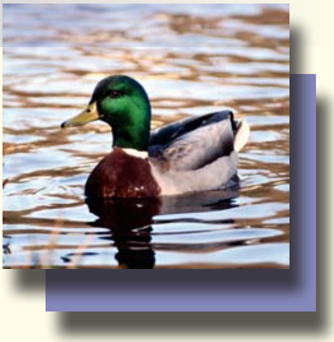
The analysis of water quality parameters from nonpoint source data are exceptionally challenging because the data are so variable. For example, it is not usual to have several low parameter values, then a few extremely larger values during or after flow events. The Grubbs outlier test (1969) was used to check for outliers throughout the WVDA data set. Prism Graph Pad 5.01 and Microsoft Office Excel 2003 were utilized for the statistical analysis. Box and whisker plots *(Drawing 1)* and regression graphs, including a trend line, were utilized to illustrate values. Two types of plots were created using "years" and "sampling sites" as the dependent variables. The regression graphs illustrate each parameter per site, per month throughout the sampling years.



Drawing 1: Example of box and whisker plot.

Nutrient Results

Total Phosphorus



Of the 23,407 total phosphorus samples analyzed, 3,943 (16.8%) were below the MDL of 0.0070mg/L. Of the 114 sampling sites, nine (7.8%) saw median total phosphorus concentrations below the MDL. The lowest of these concentrations was 0.0020mg/L located in the North Fork South Branch River (North Fork) at NF03 (Big Run). The highest median recorded was 0.2410mg/L located in the Opequon Creek at OP06 (bridge at County Route 12). High values were found within the South Branch Potomac River (South Branch) and Opequon Creek. At SB15 (below Moorefield, South Branch) median total phosphorus values were 0.2410mg/L. Values continued to be high throughout the remaining sites. All throughout Opequon Creek, medians were elevated, with the greatest value occurring at OP06. (Note: Phosphorus stored in reservoirs of plants and minerals do not show up in water samples.)

Ammonia-n

In total, 25,479 ammonia-n samples were collected throughout the ten watersheds. Site medians ranged from a low of 0.003mg/L at SB13 (Potomac Valley View, South Branch) to a high of 0.418mg/L at MC02 (South Mill Creek below the dam, Mill Creek). In all, 29.3% of the samples were below the MDL, set at 0.006mg/L. The lowest of the values recorded throughout the ten years was 0.000mg/L at NF08 (Smoke Hole Cavens, North Fork). The highest value analyzed was 10.542mg/L sampled at MC07 (North Mill Creek at Route 220 bridge, Mill Creek). Eight values (0.03%) out of the entire ammonia-n data set were above the water quality standard. Mill Creek, which had the highest concentration of ammonia-n found throughout its waters, had seven (0.19%) of the 3,676 samples above the standard.

Nitrate-n

SC05 (Route 9/3, Sleepy Creek) had the lowest median calculation of 0.148mg/L. The highest median (M = 2.152mg/L) occurred at OP02 (Bridge on State Route 51, Opequon Creek). Site median values were chronically high throughout Opequon Creek's entire watershed, ranging from 1.874mg/L at OP05 (Stone Bridge) to 2.152mg/L at OP02. The minimum nitrate-n value recorded was 0.000mg/L at SB02 (Brushy Fork, South Branch) and the maximum values recorded were 6.500mg/L at LC10 (Route 42, Lunice Creek) and 7.300mg/L at LR01 (Cullers Run, Lost River). The highest acute values occurred most readily throughout the Lost River, especially at LR01 (M = 1.495mg/L). None of the 24,670 nitrate-n samples analyzed were above the drinking water standard of 10mg/L.

Fecal Coliform Results ……

Of the 22,434 fecal coliform samples analyzed throughout the sampling sites, 17,632 (78.5%) were below 200cfu/100ml and 2,801 (12.4%) were above the critical threshold of 400cfu/100ml. Medians were as low as 4.0cfu/100ml at SF05 (Route 9/3, South Branch) and as high as 460.0cfu/100 at MC01 (South Mill Creek Church, Mill Creek). Numerous samples had counts of 1cfu/100ml. The highest values recorded throughout the 10 years were 208,000 and 692,000 cfu/100ml. Both occurred at MC01. Lost River and Mill Creek watershed experienced the highest fecal counts. In total 2,971 (77.1%) was below 200cfu/100ml and 479 (12.4%) were above the critical threshold. Throughout the Mill Creek, 3,800 samples were taken. In total, 2,436 (64.1%) were below 200cfu/100ml and 833 (21.9%) were above 400cfu/100ml. Water samples collected in the Sleepy Creek and Opequon Creek watersheds were not analyzed for fecal coliform bacteria.

Watershed Comparisons ……

All ten watersheds were evaluated in this section: Anderson Run, Lost River, Lunice Creek, Mill Creek South Branch, North Fork South Branch Potomac River, Opequon Creek, Patterson Creek, Sleepy Creek, South Branch Potomac River and South Fork South Branch Potomac River *(Figure 2)*.

A majority of the watersheds are similar; sparsely populated areas settled in highly forested land. However, Opequon Creek watershed is the exception, with highly populated urbanized areas set in very industrialized and agricultural land with low forested areas *(Table 2)*.

A total of 26,252 samples were analyzed. Realizing the scale of this data set, it was necessary to demonstrate where parameters fell in relation to other watersheds. Watershed samples per parameter were averaged for mean or median then plotted onto a concentration map. Complete watershed samples per parameter were used to create the box and whisker plots. Note: As a result of the large data set “whiskers” on the box and whisker plots were set at 1% and 99%.

Sleepy Creek watershed had the least amount of samples, totaling 274 collected from 2002 to 2008. South Branch Potomac River, on the other hand, had the most samples, totaling 6,542 collected from 1998 to 2008. DO had the least amount of samples, while nitrate-n had the highest sampling frequency *(Table 3)*.

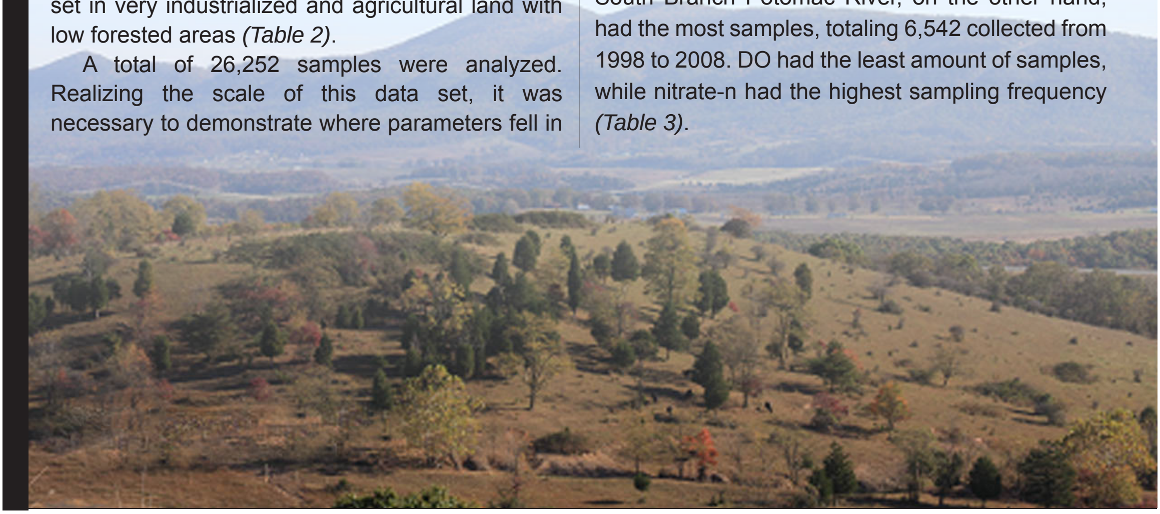


Table 3: Sampling frequency per parameter for watersheds throughout West Virginia's eastern panhandle

Parameters								
Sampling Site	**Samples**	**DO**	**pH**	**Conductivity**	**Total Phosphorus**	**Nitrate-N**	**Ammonia-N**	**Fecal Coliform**
Anderson Run	1551	80	1392	1423	1248	1488	1335	1511
Lost River	3963	320	3730	3781	3476	3879	3670	3851
Lunice Creek	3730	210	3373	3394	2946	3605	3412	3654
Mill Creek South Branch	3850	264	3632	3621	3247	3673	3676	3799
North Fork South Branch Potomac River	1227	263	1074	1064	1044	1146	948	633
Opequon Creek	355	256	354	354	355	355	352	-
Patterson Creek	1838	179	1817	1816	1830	1829	1833	1766
Sleepy Creek	274	199	273	273	271	269	273	-
South Branch Potomac River	6542	872	6369	6362	6331	6379	6064	6166
South Fork South Branch Potomac River	2160	495	1964	1951	1885	2025	1864	1083

Dissolved Oxygen

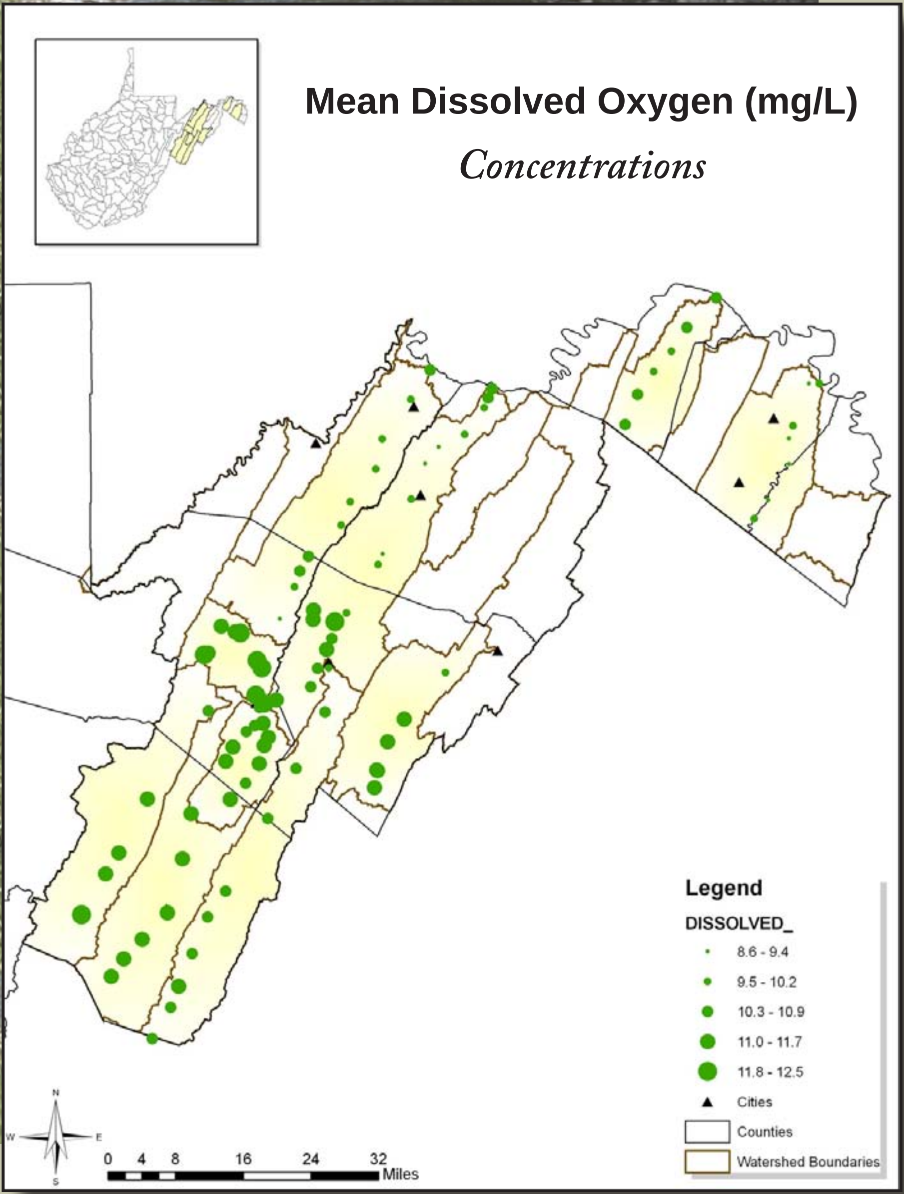


Figure 7: Mean dissolved oxygen distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

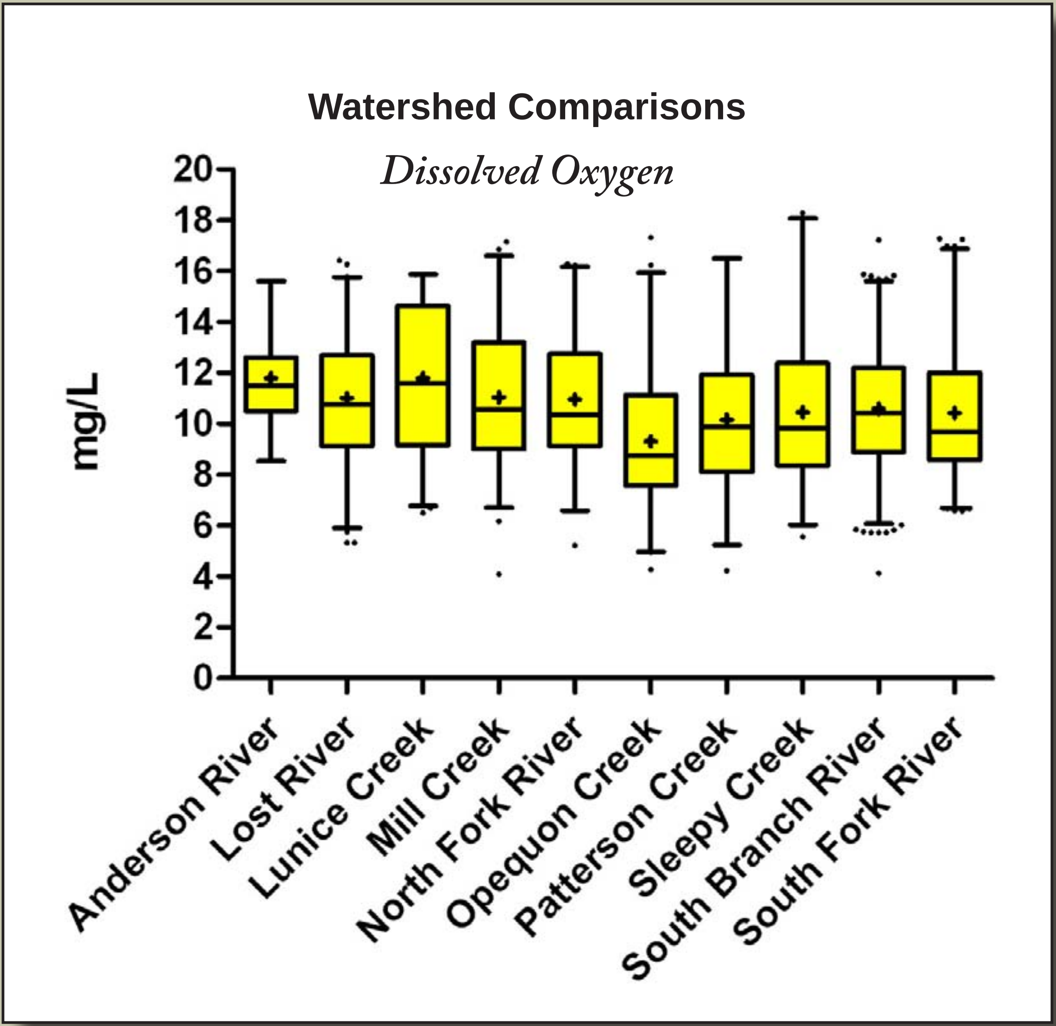


Figure 8: Mean dissolved oxygen for watersheds found throughout the eastern panhandle from 1998 to 2008.

Mean dissolved oxygen values were somewhat steady across the region, ranging from 9.30mg/L throughout Mill Creek to 11.79mg/L within Anderson Run and Lunice Creek watersheds **(Figure 7)**. The lowest measurements of dissolved oxygen were seen within the Mill Creek and South Branch watersheds. From the 3,138 samples collected, interquartiles ranged from 7.57mg/L to 14.65mg/L. Lunice Creek values varied the greatest with interquartiles ranging from 9.16mg/l to 14.65mg/L **(Figure 8)**.

pH

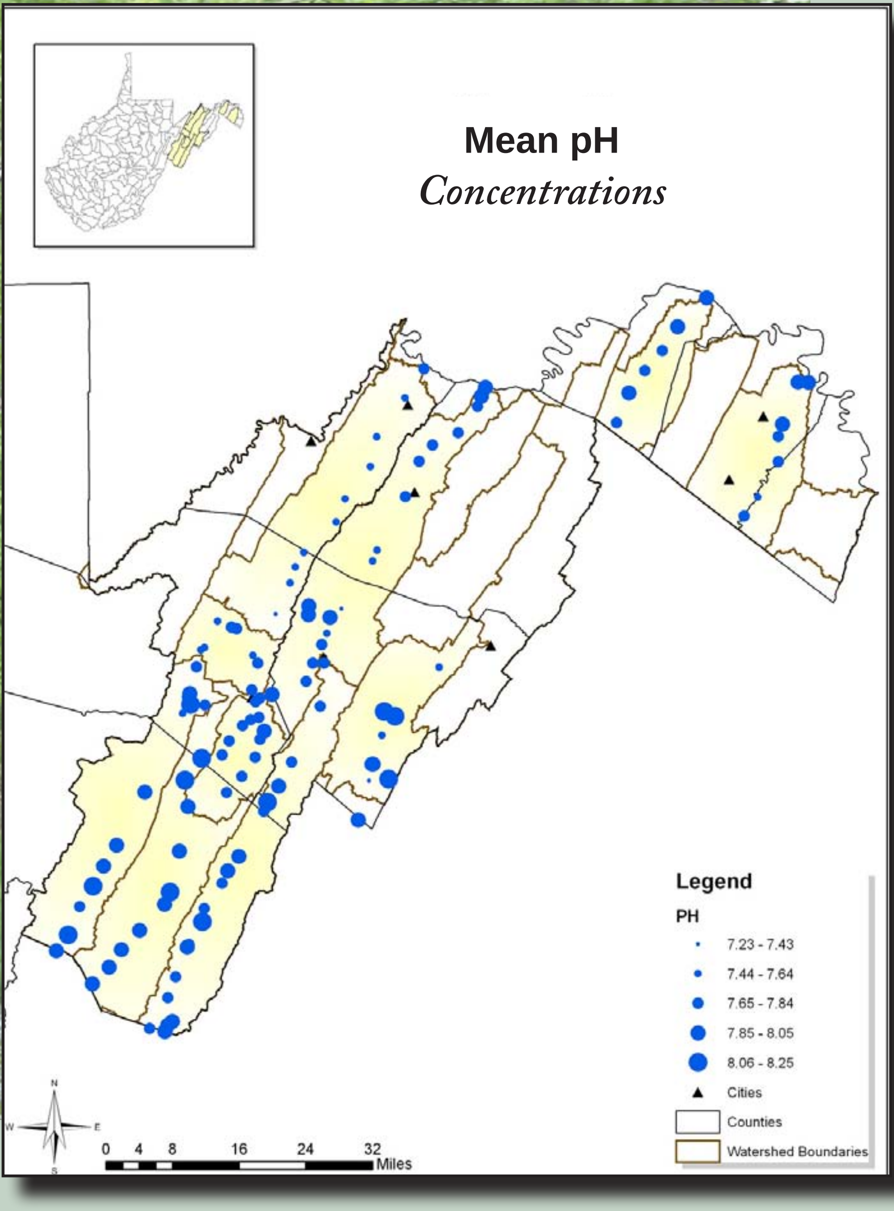


Figure 9: Mean pH distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

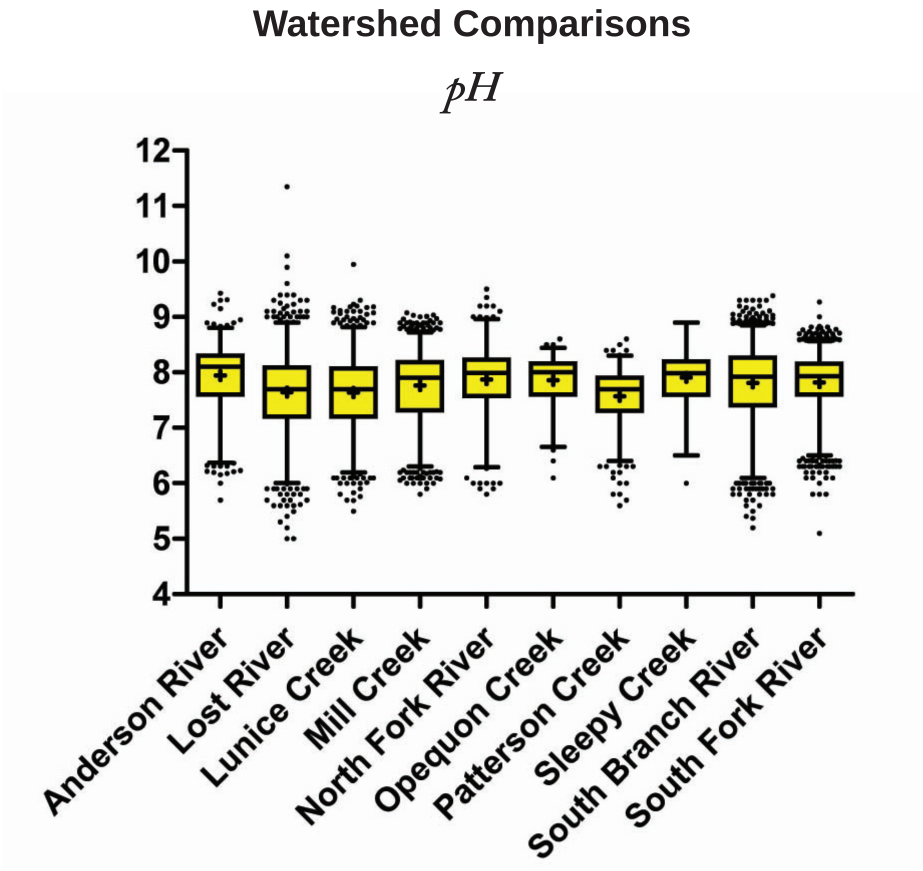


Figure10: Mean pH for watersheds found throughout the eastern panhandle from 1998 to 2008.

pH remained fairly consistent throughout the watersheds. The means varied only 0.38, from 7.56 at Patterson Creek to 7.94 throughout the Anderson Run watershed (Figure 9). Interquartiles ranged from 7.20 throughout the Lost River to 8.30 throughout Anderson Run. pH measured within Lost River and Lunice Creek saw the greatest amount of variability ranging from 6.00 at the 1st percentile to 8.90 at the 99th percentile (Figure 10).

Conductivity

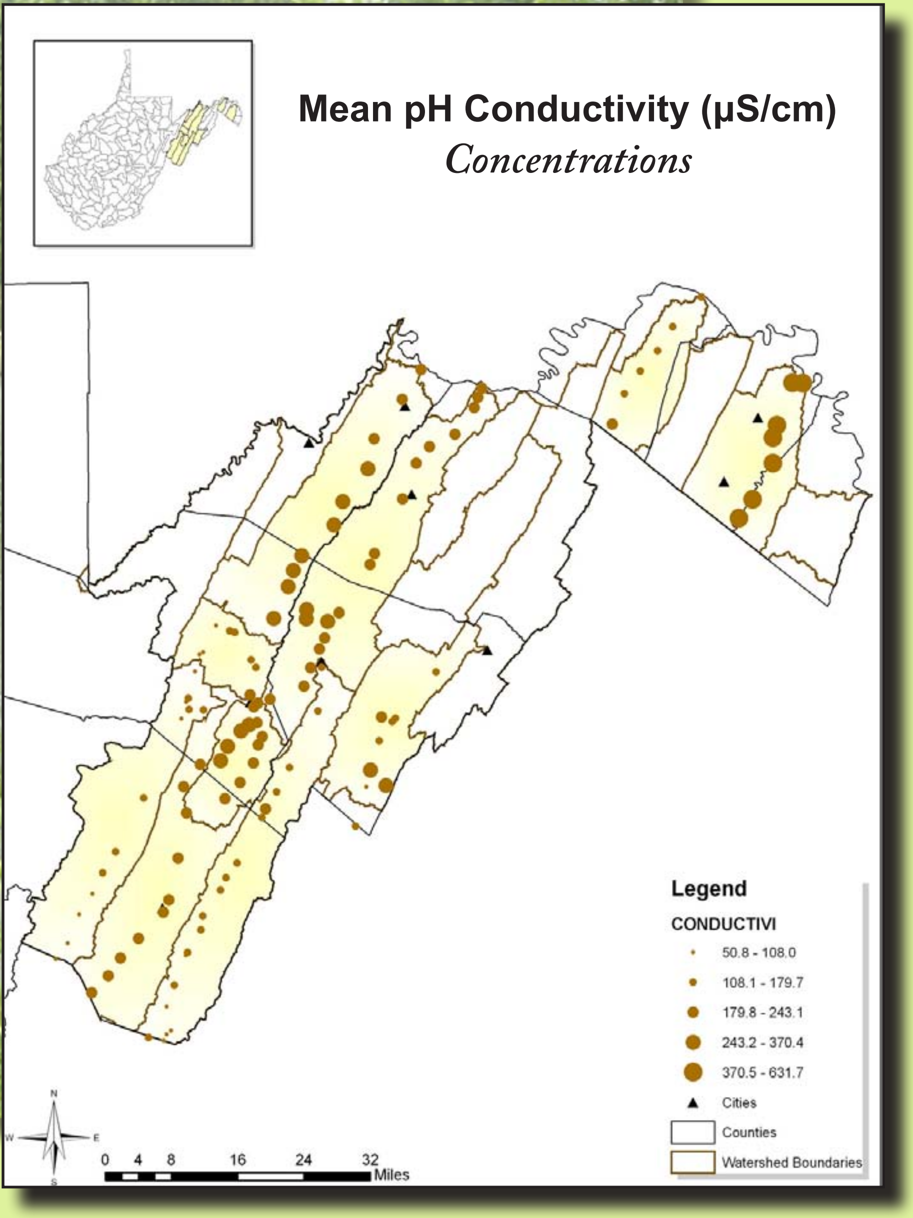


Figure 11: Mean conductivity distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

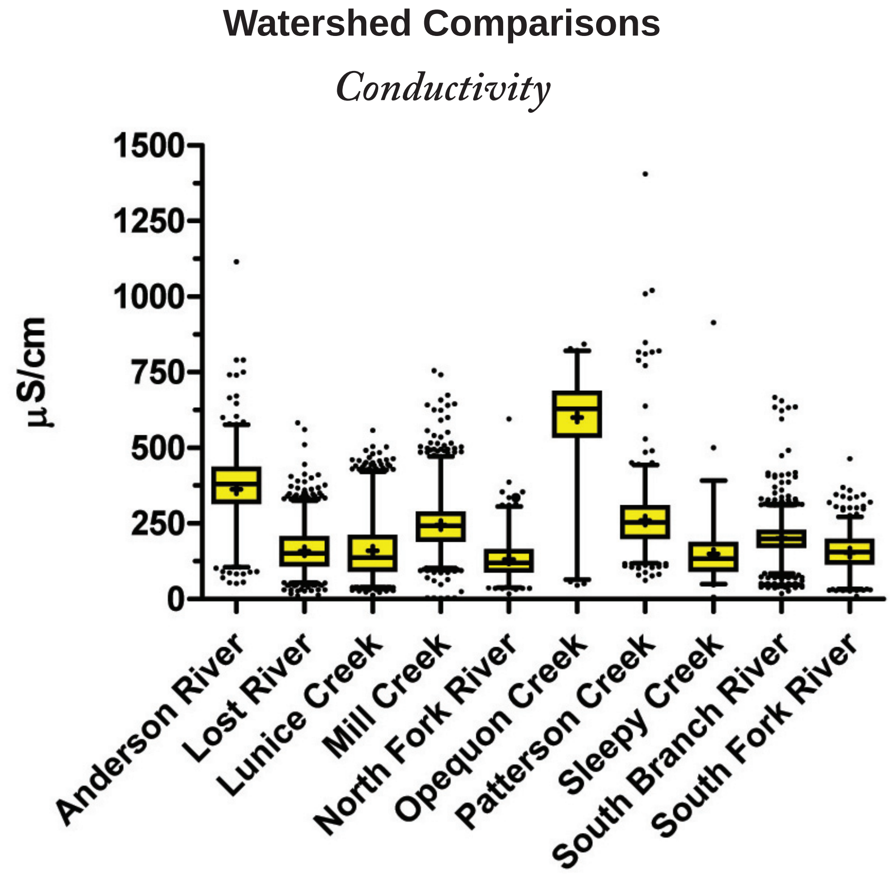


Figure 12: Mean conductivity for watersheds found throughout the eastern panhandle from 1998 to 2008.

Conductivity measurements were diverse throughout the region. Mean values ranged from a low of 130.5µS/cm within North Fork River to a high of 600.6µS/cm within Opequon Creek. Opequon Creek site mean values were fairly steady throughout all sampling locations ranging from 567.7µS/cm at OP05 (Stone Bridge) to 631.7µS/cm at OP06 (Bridge at County Route 12) (Figure 11). Interquartile ranges were smallest within the South Branch River, ranging from 155.6µS/cm to 245.0µS/cm. Ranges were largest throughout Opequon Creek ranging from 517.0µS/cm to 710.0µS/cm (Figure 12).

Total Phosphorus

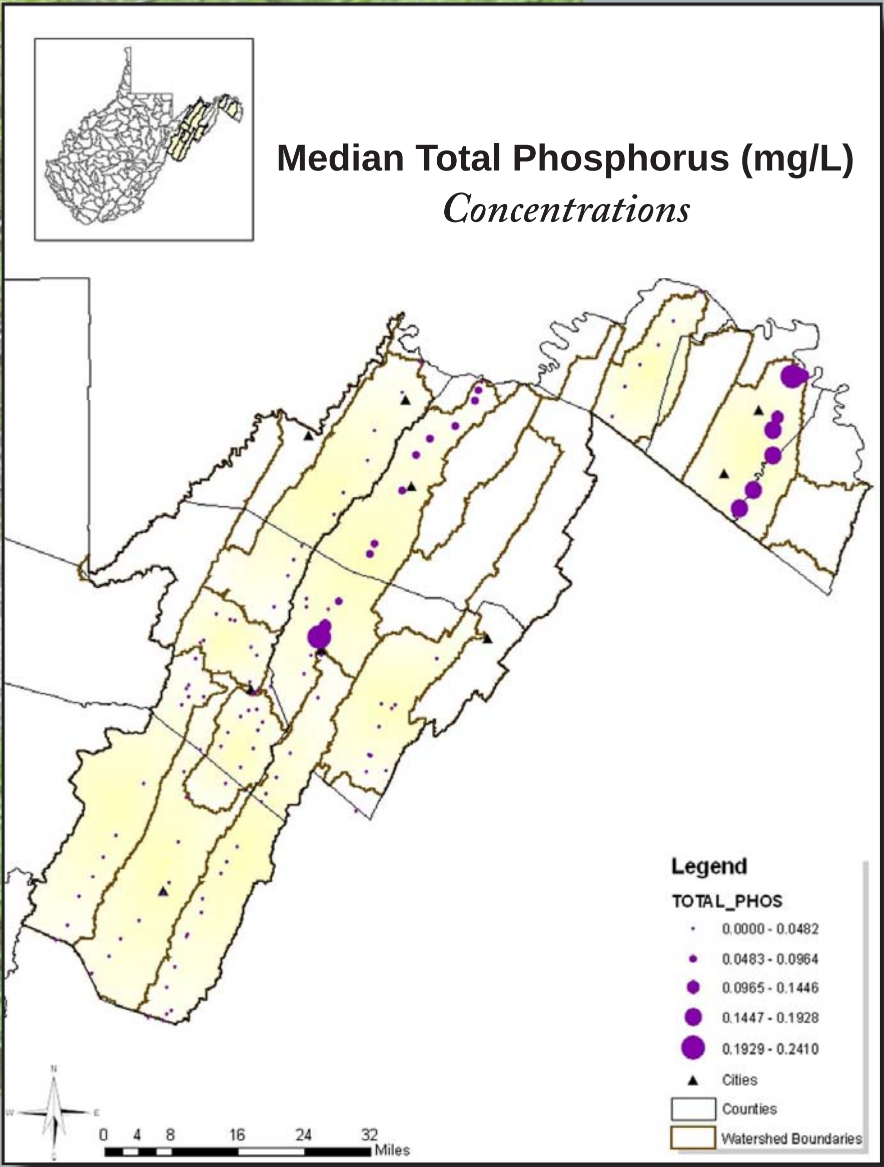


Figure 13: Median total phosphorus distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

Watershed Comparisons

Total Phosphorus

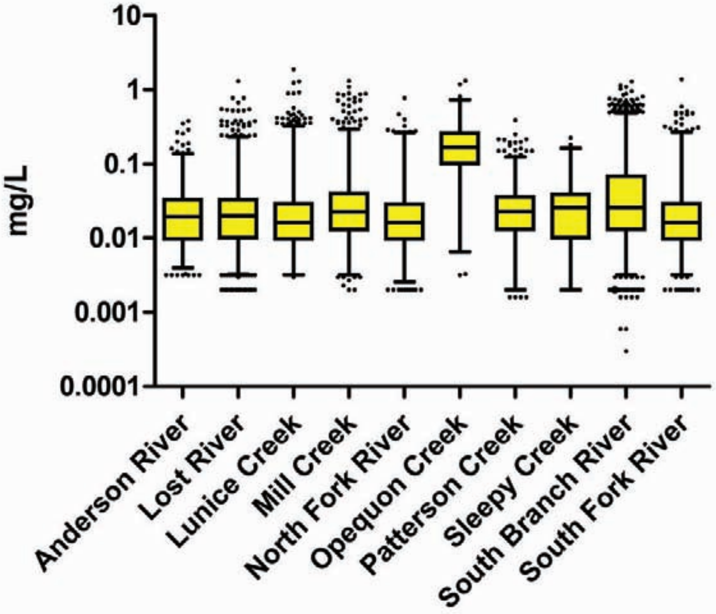


Figure 14: Median total phosphorus for watersheds found throughout the eastern panhandle from 1998 to 2008.

Total phosphorus medians were fairly consistent with the exception of Opequon Creek (Figure 13). Medians ranged from 0.0162mg/L observed throughout Lunice Creek, North Fork River and the South Fork River to 0.1690mg/L at Opequon Creek. Opequon Creek watershed's interquartiles ranged from 0.0537mg/L to 0.3730mg/L (Figure 14). The highest total phosphorus medians observed were SB15 (Below Moorefield, South Branch) at 0.2410mg/L and throughout all of Opequon Creek's sampling locations, M = 0.1690mg/L at OP07 (Mouth of Opequon at County Route 12/7) to 0.2410mg/L at OP06 (Bridge at County Route 12).

Nitrate-Nitrogen

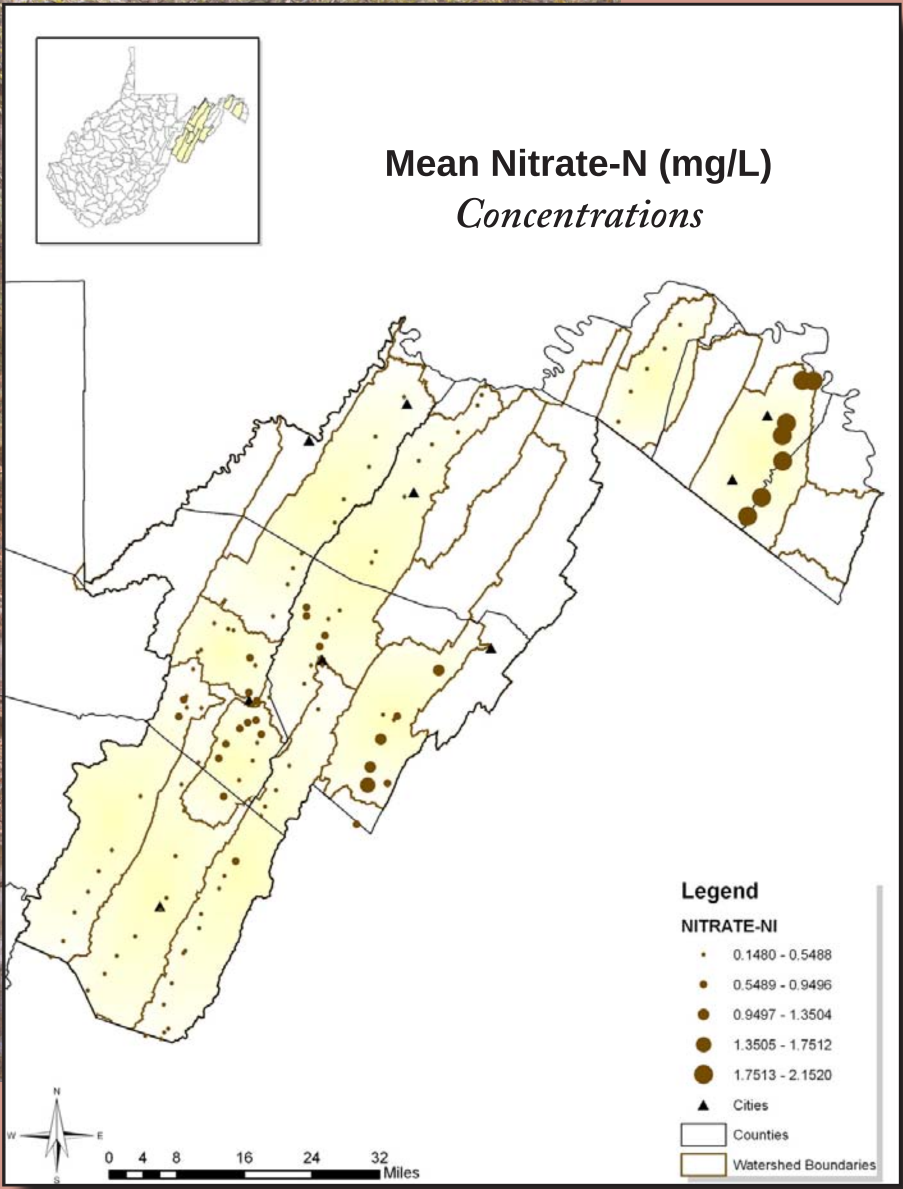


Figure15: Mean nitrate-n distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

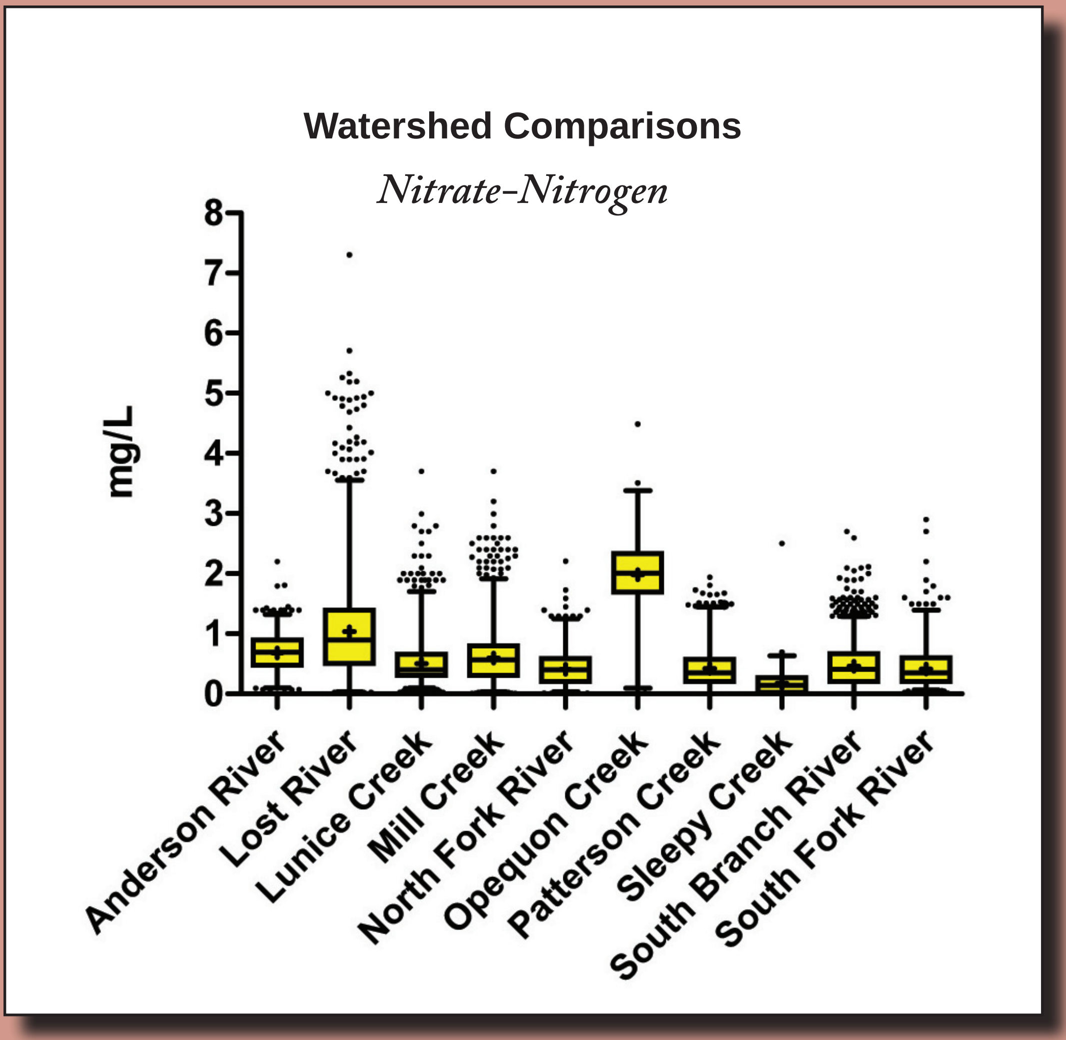


Figure 16: Mean nitrate-n for watersheds found throughout the eastern panhandle from 1998 to 2008

Mean nitrate-n values were steady throughout the region, except within Lost River and Opequon Creek. Means ranged from 0.179mg/L within Sleepy Creek to 1.986mg/L throughout Opequon Creek. Sleepy Creek's values were quite low; interquartiles differed by 0.315mg/L. However, Lost River 25th and 75th percentiles ranged from 0.100mg/L to 1.800mg/L and interquartiles ranged from 1.530mg/l to 2.550mg/L at Opequon Creek (Figure 15). High nitrate-n values were recorded at various sites throughout Lost River (m = 1.497mg/L at LR01, Cullers Run) with even higher results throughout all of Opequon Creek (m = 1.874mg/L at OP05, Stone Bridge to m = 2.152mg/L at OP02, Bridge on State Route 51).

Ammonia-Nitrogen

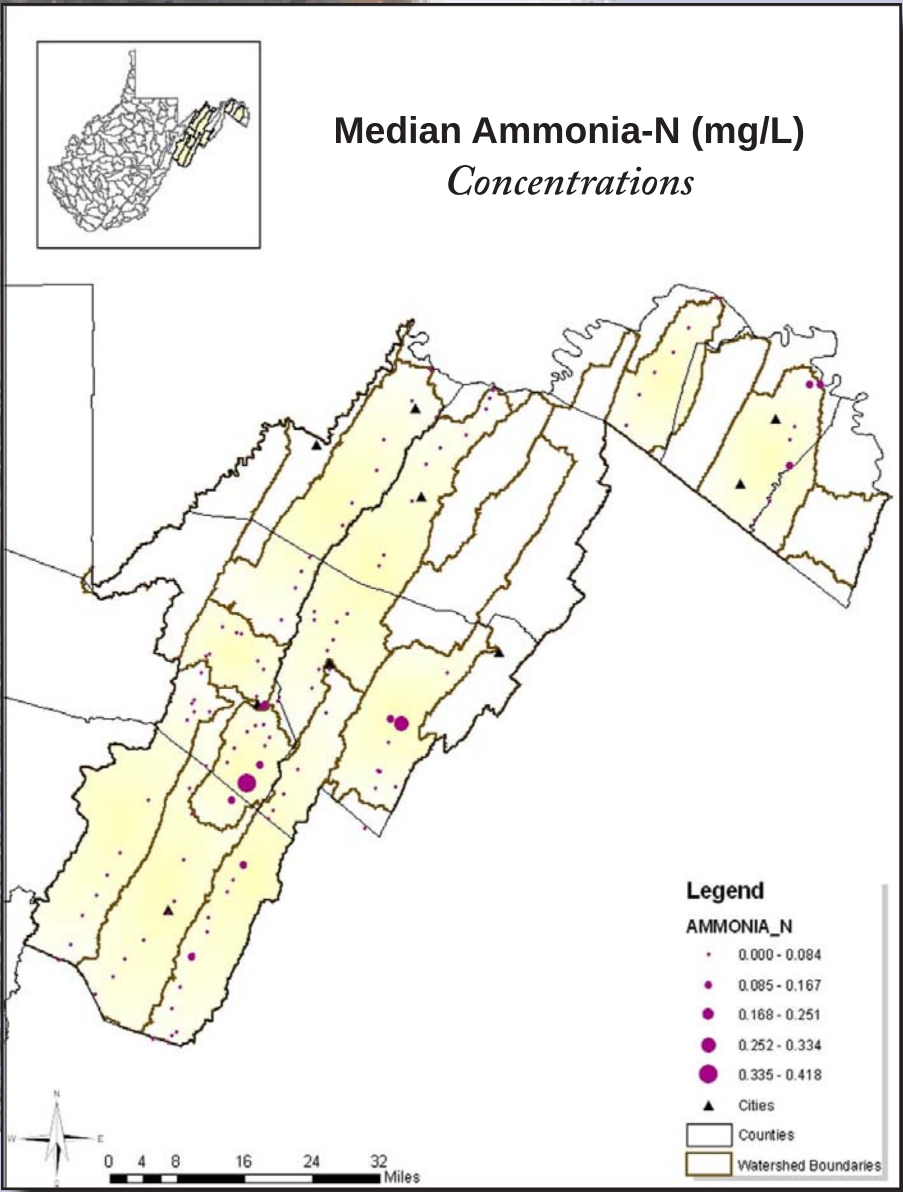


Figure 17: Median ammonia-nitrogen distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

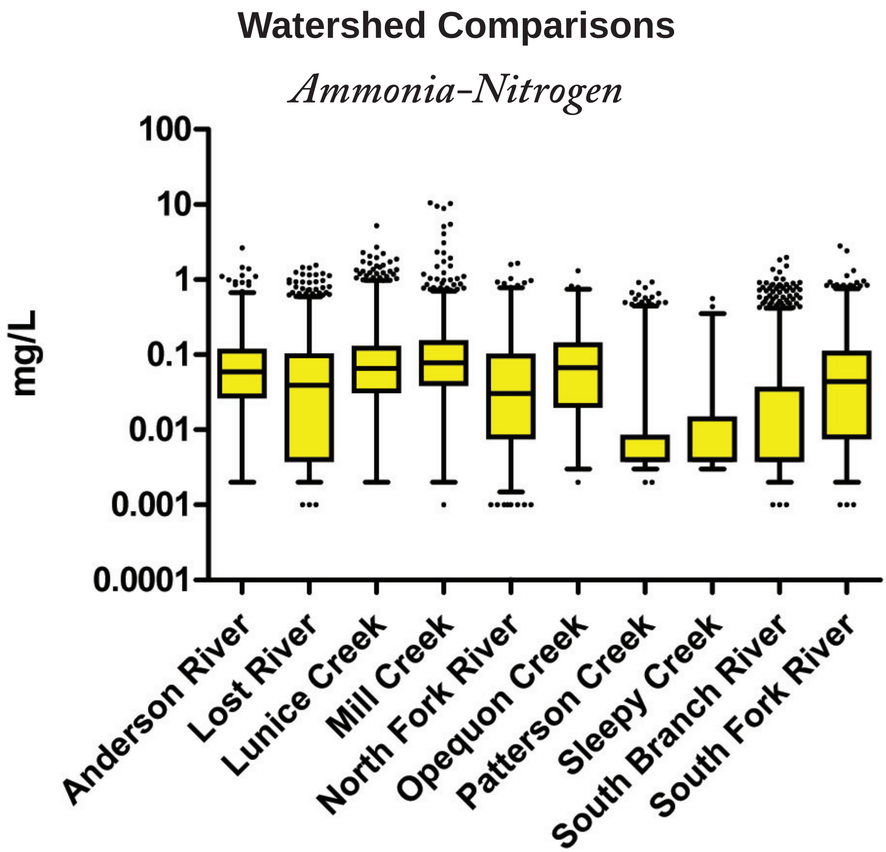


Figure18: Median ammonia-n for watersheds found throughout the eastern panhandle from 1998 to 2008.

Watershed medians ranged from a low of 0.004mg/L throughout Patterson Creek, Sleepy Creek, and the South Branch River. The highest median was recorded in the Mill Creek watershed (M = 0.078mg/L) **(Figure 17)**. The 25th percentile was the lowest at 0.004mg/L recorded at Lost River, Patterson Creek, Sleepy Creek, South Branch River and South Fork River. The 75th percentile was highest at Mill Creek, with a value of 0.145mg/L **(Figure 18)**. Note: In 2005 Sleepy Creek and Patterson Creek added several sampling sites. This same year more sensitive sampling equipment was purchased, altering ammonia-n values. Highest median ammonia-n values were recorded at Lost River (LR10 (Kimsey Run below dam), M = 0.299mg/L) and Mill Creek (MC02 (South Mill Creek below dam), M = 0.418mg/L) .

Fecal Coliform

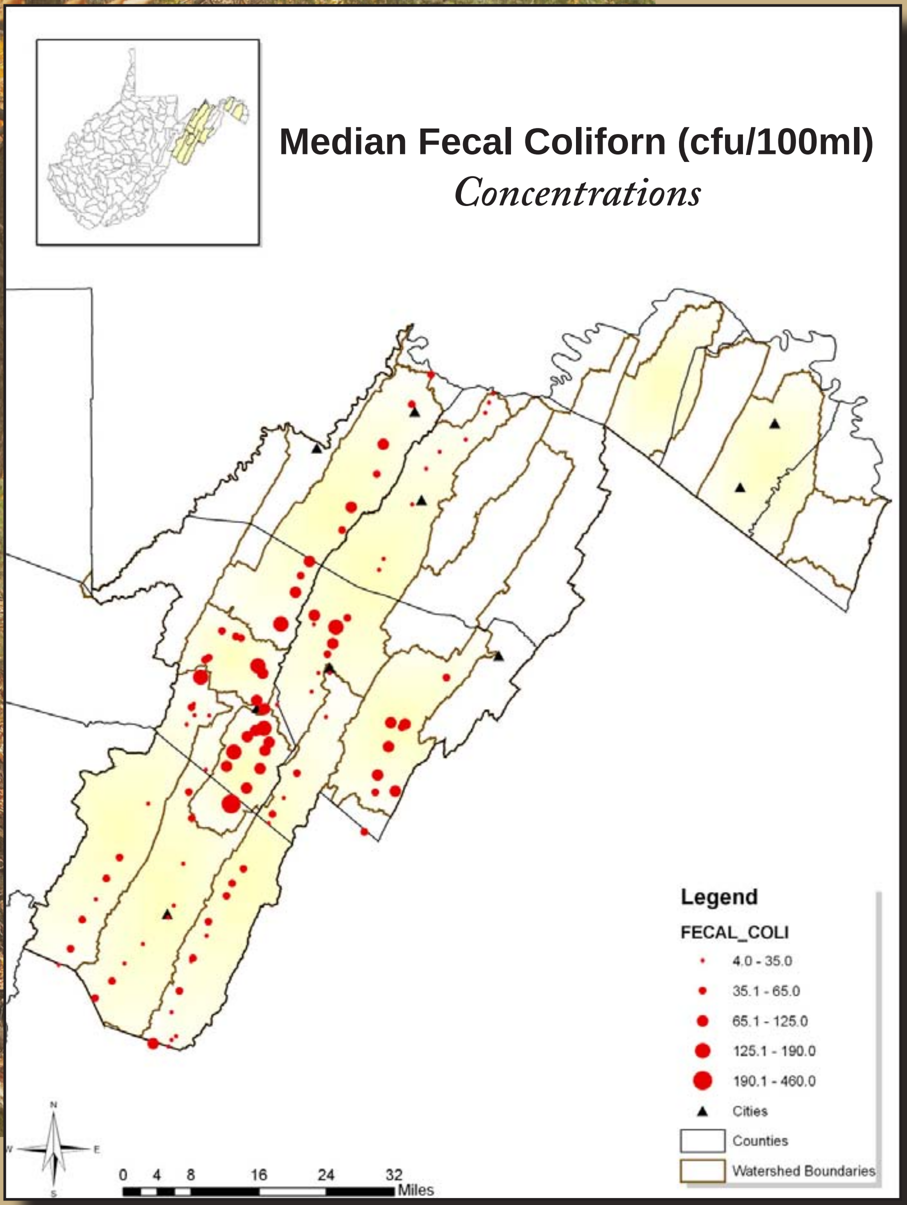


Figure 19: Median fecal coliform distribution per sampling location for watersheds found throughout the eastern panhandle from 1998 to 2008.

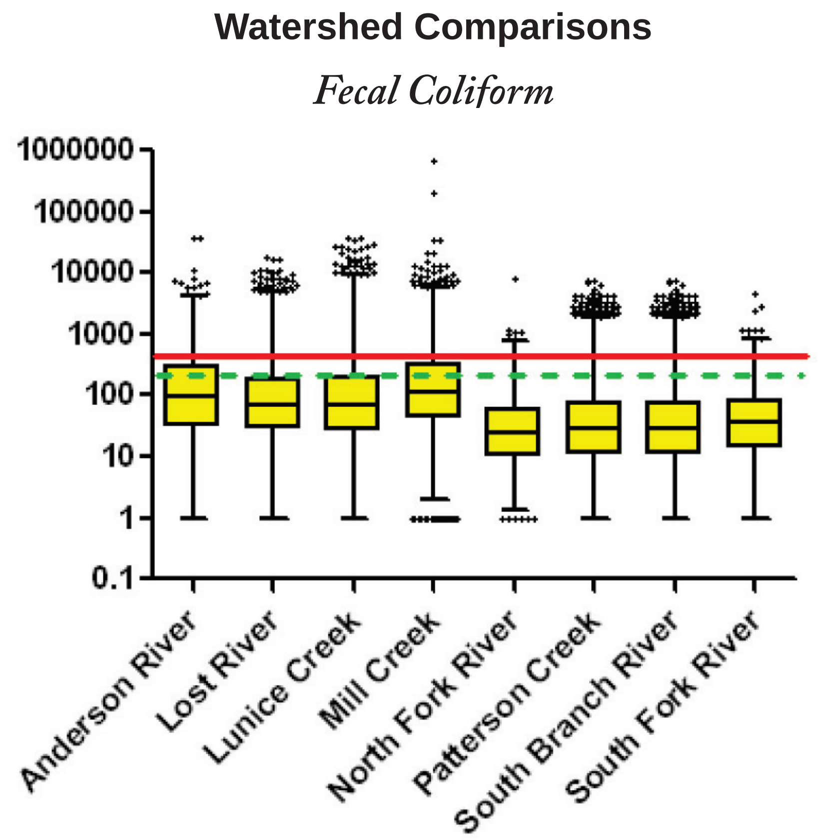


Figure 20: Median fecal coliform for watersheds found throughout the eastern panhandle from 1998 to 2008.

Fecal coliform medians ranged from 24cfu/100ml at North Fork River to 155cfu/100ml at Mill Creek (Figure 19). Interquartiles throughout North Fork River ranged from 4cfu/100ml to 113cfu/100ml, whereas values throughout Mill Creek ranged from 32cfu/100ml to 1,460cfu/100ml (Figure 20). The lowest amount of fecal coliform data below 200cfu/100ml was sampled throughout the North Fork River. Of the 633 samples collected and analyzed 93.8% were below this limit and only 2.6% were above the critical threshold. On the other hand, of Mill Creek's 3,799 samples, 64.1 % were below the 200cfu/100ml limit and 21.9% were above the 400cfu/100ml limit. Lost River (M = 125cfu/100ml at LC07, Lost River) and Mill Creek (M = 190.0cfu/100ml at MC10, Mill Creek below Forks and M = 460.0cfu/100ml at MC01, South Mill Creek Church) saw the highest median values throughout the watersheds.

Note: Opequon Creek and Sleepy Creek were excluded from this dataset do to the fact that fecal coliform was not a parameter that was analyzed in these watersheds.

Next Steps

In research programs carefully designed to measure changes in water quality due to improvements in land management, the typical study design calls for two or more years of baseline data collection followed by three to six years of sampling after implementation of new land use practices (Lombardo et al 2000). There is a need for patience in measuring change in water quality in watersheds primarily impacted by nonpoint sources, and the West Virginia Department of Agriculture (WVDA) understands this need. Although program parameters have changed over time, and may need to change further to accommodate shifting needs of information, WVDA water quality programs will continue to collect data to accurately ascertain the conditions of rivers and streams throughout West Virginia (WVDA 2006).

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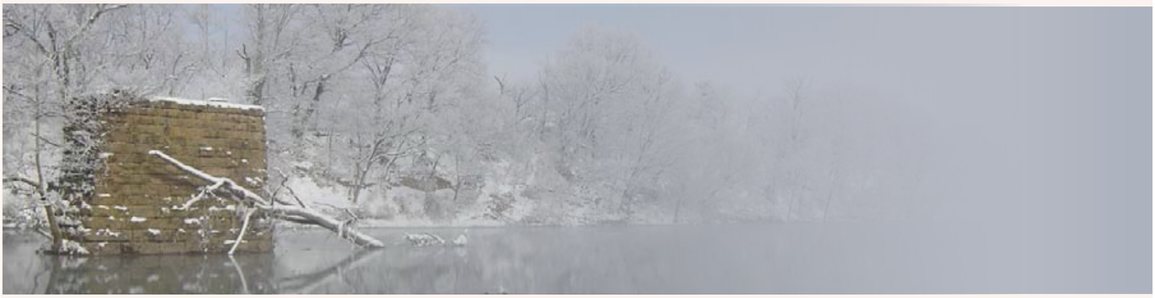

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