THE HEALTH OF THE SHENANDOAH RIVER IN PAGE COUNTY: THE FOSR WATER TESTING PROGRAM (USING 1997 – 2000 DATA)

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A Paper Prepared By the Friends of the Shenandoah River

ABSTRACT

This is a report on the health and status of the Shenandoah River and its tributaries in Page County, Virginia. The evaluation is based on water samples collected by the FOSR over the four-year period from January 1997 to December 2000. The samples were analyzed in the FOSR laboratory at Shenandoah University for nitrate-nitrogen (N), ortho-phosphate (P), ammonia (NH4), dissolved oxygen (DO), acidity (pH), and turbidity(T). Fecal coliform samples were analyzed in the laboratory of James Madison University.

The general findings are that the South Fork of the Shenandoah River is within recreational use parameters for fecal coliform contamination, while the concentration of N exceeds the impaired level nearly half the time, and the trend for N is toward increasing concentrations. The concentration of P is too high and exceeds the impaired level almost all the time, but the trend appears to be slightly decreasing. The concentrations of NH4, DO, pH, and T in the South Fork are below the impaired levels.

The concentrations of N and P in the tributaries are too high, though not as high as the concentrations found in the South Fork. Many of the tributaries to the South Fork have very high fecal coliform counts at times during each of the years sampled. Swimming and boating in those tributaries during "high count" times is not recommended. The trends show that for N and P are increasing in many of the tributaries.

Both Stanley and Pilgrim/Wampler Foods sewage treatment plants (STPs) discharge their treated water directly into the South Fork near Alma, VA, while the Luray STP discharges to Hawksbill Creek approximately 4 miles from the confluence with Pass Run and five miles from the confluence with the South Fork. The quality of the discharged effluent varies widely between plants. For example, the Pilgrim/Wampler Foods STP discharge has an average N concentration of 68 parts per million (PPM), which is considerably more than the 3 - 5 PPM of the Luray and Stanley STPs. The concentration of P for the Pilgrim/Wampler Foods STP is also much higher than that for Luray and Stanley. Unfortunately the Virginia Department of Environmental Quality has not set any permit limits for N or P, therefore the high N and P readings from the Pilgrim/Wampler Foods STP do not violate their permit conditions.

Since the levels of N in the South Fork are close to the impaired level and since the trend for N is rising, it is becoming a problem. A major problem in the South Fork and its tributaries is the excessive concentration of ortho-phosphate. Though not lethal to humans or aquatic life, it is a major contributor to algal blooms that can cause oxygen depletion and eutrophication in sections of the Shenandoah River as well as the downstream waters such as the Potomac River and Chesapeake Bay. While fecal coliform is not a problem for recreational use of the South Fork, it is a major problem in several of the tributaries.

While the levels of N and P need to be reduced, the trends in N and P at present are not increasing dramatically. However, if land use changes such as more construction of impervious areas and/or greater runoffs from timber harvest or agricultural land change for the worse, the trends could quickly become steeper. Continued and diligent monitoring to detect changes in these trends is crucial.

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Introduction

This paper[1] is one of a series of studies by the FOSR to report on the status of the health of the Shenandoah River and its tributaries. In December 2000, the FOSR completed their first report for the Main Stem of the Shenandoah River in Clarke County. This report is the second in the series, and discusses the health of the South Fork of the Shenandoah River and its major tributary streams in Page County.

This study analyzes the database accumulated by the FOSR over the past four years for Page County, and focuses on water quality as indicated by water chemistry. We know that there are other important factors determining the quality of the physical habitat for the aquatic life, such as the volume of stream flow and the composition and adequacy of groundwater, but these topics are not addressed in this paper. Stream flow information is included in the Minimum Instream Flow study now in progress for the North Fork, and planned for the South Fork.

The water quality indicators including nitrate nitrogen (N), ortho-phosphorus (P), ammonia (NH4), dissolved oxygen (DO), acidity (pH), and turbidity (T) in the data base show that the river water in the South Fork of the Shenandoah River is generally safe for swimming, fishing and for municipal water supply (with treatment). Fecal coliform measurements in the South Fork are well below recreational use limits, but there are several tributaries where the fecal coliform count is very high from time to time, and water sports in these tributaries at those times is inadvisable.

The average level of N in the South Fork is high. It is close to the impaired level, and exceeds the impaired level about 40% of the time. The level for P is even higher, and exceeds the impaired level almost 100% of the time. The concentration of NH4 is almost always below the impaired level.

The fluctuations in these nutrient levels have been above or below the average by significant amounts. For example, during the January 1997 to January 2001 time period the level of nitrate nitrogen in the South Fork varied from a low of 0.25 parts per million (PPM [2]) to a high of 2.4 PPM - a multiple of about 10. Phosphorus concentration varied

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[1] Charles Newton, the lead monitor of the FOSR for Page County and Charles Vandervoort, lead-monitor of the FOSR for the Clarke County monitoring sites prepared this report. The Page County monitors consisting of: Elbie and Tom Blount, Wendy Cass, CT Campbell, Robert Forrest, Tom Forrest, John Gibson, Christi Gordon, Ed Higgs, Dan Hurlbert, Delores King, Cheryl Lanier, Al & Millie Lipps, Richard Little, Chester Mikus, George Nickels, S.(Jack) Rinaca, Jr., Hal Slover, Ann and Ken Sheets, Chester and Rita Taylor, Carol Wallbridge and Ron White collected the water samples. The samples for N, P, NH4, DO, pH and T were analyzed in the FOSR laboratory in space generously provided by Shenandoah University. The laboratory is operated by Karen Andersen, the FOSR Program Director, and under the supervision of Meryl Christiansen, the Executive Director. The fecal coliform samples were analyzed by Professor Bruce Wiggins and data were analyzed and tabulated by Professor Thomas Benzing, both of JMU. The authors want to acknowledge the valuable comments provided by Meryl Christiansen and other members of the FOSR who made this report possible.

[2] For the concentrations discussed in this paper one part per million (PPM) is equivalent to 1 milligram per liter in water. One ppm is equivalent to 1 milligram of pollutant per liter of water. To put this in perspective, 1 ppm is about the same as 1 drop of vermouth added to 15 gallons of gin (see G. M. Masters "Introduction to Environmental Engineering and Science, Prentice Hall, 1997

from 0.09 to 10.9 during that year - a multiple of about 121. The very high variability or "scatter" in these data is the reason that, although costly in consumption of volunteer time to collect and transport samples and in laboratory time and materials for laboratory analysis, the FOSR in Page County collects water samples at least once a month, and twice per month for many of the larger sites. Testing only once every quarter or twice per year, though saving money, could give misleading results.

High nutrient levels in rivers and streams encourage excessive growth of algae and aquatic plants during the warmer months of the year. The excessive aquatic plant life eventually dies and, through decay or eutrophication, contributes to major problems to our river and our downstream neighbors such as the Potomac River and Chesapeake Bay. High levels of ammonia, even though temporary, can kill fish very quickly.

The water in the South Fork and its Page Valley tributaries is rarely too acidic (thanks to the limestone rich soils) and the dissolved oxygen, ammonia, and turbidity of the river water is usually at reasonable levels.

Besides the fact that pollution levels for the nutrients N and P are too high for many days of the year, a major concern is that the trend in these pollution levels is up. This is discouraging, because one would have hoped that, with the implementation of best management practices, riparian buffers, and other measures, the trends would be down [3].

Except for Chubb Run and Mill Creek, which have high N, most of the streams feeding into the South Fork have levels of N below the impaired level. Similar to the South Fork, however, the level of P is above the impaired level for most of the tributary streams.

Fecal coliform is also higher than recreational use levels for many of the tributary streams. Swimming, boating and fishing in those streams therefore is not recommended.

Levels of DO, pH and T in the small streams are usually satisfactory though, after heavy rainfalls the Turbidity usually increases to high levels.

To prevent further harm to the river, we need to intensify efforts to protect our streams. Some of best management practices that will help protect our streams are: reducing erosion and fertilizer runoff from farm fields, restoring streamside forested buffers, rehabilitating stream banks to reduce erosion, preserving forest land, discouraging construction of impervious surfaces (asphalt or concrete pavement), and by applying the best available technology to STPs and septic systems to reduce the concentration of nutrients and other pollutants in their outfalls. We also need to undertake studies that relate the impact of various other human activities on the health of the Shenandoah River and its tributaries, such as on the amount of nitrates reaching surface waters from air pollution.

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[3] It is possible that non-point source nutrient reduction practices will produce benefits gradually over a long period of time. However, the effect of point source reductions should become evident quickly.

The FOSR Database

Over the past few years the FOSR monitors in Page County have taken water samples from the South Fork of the Shenandoah River and its tributaries at 33 sites (the total FOSR testing program in the whole Shenandoah basin covers about 180 sites). After being collected, the water samples are immediately put on ice and delivered within 24 hours for analysis to the FOSR laboratory at Shenandoah University[4] for analysis. Samples for the indicators whose quality deteriorates over time, such as dissolved oxygen, pH, and turbidity are analyzed as soon as possible after being delivered to the lab.

Shenandoah University provides the FOSR with laboratory space. Equipment, testing materials and staff are provided by the FOSR. The lab is well equipped and uses the best possible instruments, materials, procedures, and staff to test the water samples. The staff consists of a full time laboratory technician who is responsible for maintaining the high quality of the data and efficiency of the testing process. She is assisted by volunteers from the FOSR, students from Shenandoah University, and by several part-time paid lab assistants.

Operating the lab is financed from dues and donations from the FOSR members, special fund raising events, grants from local governments, grants from the state and federal governments and the Virginia Environmental Endowment, the Chesapeake Bay License Fund, the Chesapeake Bay Alliance, and the Fish and Wildlife Fund. The lab also tests, at cost, water samples submitted by other organizations.

The laboratory has recently been modernized by the addition of a $60,000 automated testing machine (financed by a grant from the Virginia General Assembly) which tests samples for ammonia, nitrate-nitrogen and ortho-phosphorus content. This new machine enables more rapid testing of the samples, reduces the cost of reagents used in the analyses, and also reduces the direct exposure of the staff to hazardous reagents such as cadmium.

The results of the analysis are tabulated on the FOSR computers and are reported to the US Environmental Protection Agency and the Virginia Department of Environmental Quality to be used in their water quality analysis. These data are being added to the FOSR web page (www.fosr.com), which is now being improved.

The data collected include the water quality indicators pH (acidity), dissolved oxygen, turbidity, nitrate nitrogen, phosphorus, and ammonia. At some sites data are also being collected on fecal coliform. The FOSR is exploring how to broaden its testing program to include tests for toxic materials such as mercury and PCB.

The FOSR Monitoring Program in Page County

The Page County FOSR monitors have checked the water quality of the Shenandoah River at 33 monitoring sites (See Exhibit 1). Water is taken directly from the South Fork at the following sites: the Town of Shenandoah near the dam, White House bridge, and

[4] Samples for fecal coliform are analyzed in the laboratory of the biology department at James Madison University.

Burner's Bottom. Twenty-six sampling sites are located on the many small streams that feed into the main stem. These include Hawksbill Creek, Pass Run, Rocky Branch Naked Creek, Cub Run, Chubb Run, Jeremys Run, Mill Creek, and Overall Run. At three other sites water is taken directly from the effluent out-falls from Luray, Stanley, and Pilgrim/Wampler Foods wastewater treatment plants. As this report explains, the quality of the water differs markedly between the South Fork, the tributary streams, and the sewage treatment plant out-falls.

Page County Water Quality Advisory Committee

The Page County Water Quality Advisory Committee (WQAC) was formed by the county's Board of Supervisors and held its first meeting on April 22, 1998. The committee membership includes representatives from agriculture, state environmental and health agency personnel, county residents, business members, and town managers.

At their August 1998 meeting, the committee adopted their mission statement,

"To promote water pollution prevention, prioritize and address water quality issues, and enhance environmental education in schools and communities in Page County."

Beginning in September 1998, a James Madison University laboratory under supervision of Dr. Bruce Wiggins began performing fecal coliform analysis on samples collected from Page County streams by FOSR volunteers. At about this time, Page County also contracted with the FOSR laboratory to increase the number of Page County sites for sample collection and analysis at the FOSR laboratory. Page County made use of the data from sites where FOSR was already collecting and analyzing samples and added additional sites further upstream along tributaries that were showing evidence of pollution.

Indicators of Water Quality and Suggested Standards

Appendix 1 gives a list and brief description of the water quality indicators in the FOSR testing program. These can be divided into the three nutrients consisting of nitrogen (nitrate nitrogen), phosphorus (ortho-phosphate), and ammonia (NH_3 & NH_4). These are called "nutrients" because they provide food (fertilizer) for plants.

Nutrients in the river come from municipal wastewater, septic systems, industrial wastes, and runoff from agricultural lands containing fertilizer and manure and from urban areas. Some nitrogen comes directly from the atmosphere itself. High concentrations of nutrients will stimulate excessive growth of algae and other water plants. The algal blooms and large quantities of water plants eventually die and decompose. Besides causing unsightly and smelly debris along the shoreline, the decomposition uses up much of the available oxygen. The depleted oxygen levels can harm aquatic life (including game fish such as trout and bass) and can even cause large fish kills, especially downstream from the Shenandoah River, in the Potomac River and Chesapeake Bay.

Fecal coliform bacteria, though relatively harmless by themselves, are used as indicators for more harmful pathogenic microorganisms which can cause gastrointestinal illness or more serious diseases through ingestion or by entering through broken skin. They can come from point sources such as failed septic systems, and wastewater treatment plants, and non-point sources including wildlife and domestic livestock, application of manure, run-off from paved areas, and urban storm water runoff from built-up areas.

Nitrate Nitrogen Standard:

From Page 14 of the December 1999 EPA Report "From the Mountains to the Sea: " The State of Maryland's Freshwater Streams the statement is made that "Streams with nitrate concentration greater than 1 mg/L are considered unnaturally high, compared to streams with minimal human influences. Concentrations greater than 10 mg/L of N exceed the human health standard for safe drinking water for adults, and lower levels of N have caused methemoglobinemia [blue baby] in infants.

Ortho-Phosphate Standard:

From page 7 of the 1998 USGS Report '*Water Quality in the Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia and the district of Columbia, 1992-1996*' the statement is made that "To control eutrophication, the U.S. Environmental Protection Agency (1986) recommends that the total phosphorus concentrations in flowing waters not exceed 0.1 mg/L." It also states that the ortho-phosphate is the most common form of dissolved phosphorus in natural waters.

Phosphorus (P) in water is not considered directly toxic to humans or animals so no drinking water standards have been established for P. Any toxicity caused by P pollution in fresh waters is indirect, through stimulation of toxic algal blooms or resulting oxygen depletion. The EPA recommends that total phosphorus concentrations should be less than 0.1 mg/L in rivers, and less than 0.05 mg/L where rivers enter lakes and reservoirs because concentrations greater than this could contribute to eutrophication.

Ammonia

In water, ammonia exists in two forms, which, together, are called "total ammonia nitrogen." These two forms consist of un-ionized ammonia (NH_3) and ammonium ion (NH_4^+). They exist in a state of equilibrium in the water solution, and the fractions of each depend on pH and temperature.

Un-ionized ammonia is very toxic to fish and other aqueous organisms that breathe through gills. It is a dissolved gas that can pass unimpeded through the membranes of the gills. Continuous exposure to more than .02 [5]to .05 [6] PPM of the un-ionized form can cause reduced growth, increased susceptibility to disease and premature death. It is especially toxic to young fish and aqueous water life. At levels above .05 PPM the un-ionized ammonia causes more and more damage, and at 2.0 PPM all fish will die.

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[5] EPA "Fact sheet: 1999 Update of ambient Water Quality Criteria for Ammonia - Technical Version", EPA 823-F-99-024, December 1999.

[6] Document FA-16, Fisheries and Aquatic Sciences, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, June 1996

The FOSR laboratory test results are published for the level of total ammonia in the water. The amount of toxic NH3 is a percentage of total ammonia depending primarily on the pH and temperature of the water. Higher temperature and higher pH result in higher percentages of NH3. As pH and temperature decrease, the fraction of un-ionized ammonia decreases and therefore more total ammonia can be tolerated. At the same time, however, less un-ionized ammonia NH3 is needed at lower pH to be harmful to fish and other forms of water life.

Because the amount of un-ionized ammonia depends on both temperature and pH, it is not possible to prescribe a single number. For example, at a pH of 8.0 and a temperature of 86 degrees Fahrenheit, a concentration of 1 PPM of total ammonia nitrogen corresponds to a level of .074 PPM of un-ionized ammonia NH3. This is well above the impaired range of .02 to .05 for NH3.

As discussed above, the fraction of un-ionized ammonia decreases as water temperature decreases. For example, at a pH of 8.0 and a temperature of 75 degrees Fahrenheit a concentration of 1 PPM of total ammonia nitrogen corresponds to a level of .05 PPM of un-ionized ammonia. This is at the high end of the impaired range for NH3. And at 60 degrees Fahrenheit the level of un-ionized ammonia is .03, and still within the impaired range.

By studying tables such as given by Emerson [7] we can conclude that, for the values of pH and temperature prevalent in the waters of the Shenandoah River Watershed, the following rule of thumb can be applied: *total ammonia nitrogen is unimpaired if less than 1 PPM; it is impaired between 1 and 10 PPM, and is severely impaired for levels above 10 PPM.*

PCBs and Mercury

Polychlorinated biphenyls (PCBs) and mercury can accumulate in human bodies by eating fish. These contaminants are not excreted from the human body after being consumed, are stored over long periods of time and can accumulate to toxic levels. PCBs can cause cancer and liver damage, while mercury can cause brain, nerve and kidney damage, birth defects and skin rash. For these reasons the Virginia Department of Health (VDH), using monitoring data from the Virginia Department of Environmental Quality, issues fish-eating advisories for bodies of water that are affected by these contaminants.

Large portions of the South Fork of the Shenandoah River from Waynesboro North have been identified by the VDH as affected by mercury and sections from Front Royal North have been identified as contaminated by PCBs. Fish (except stocked trout) taken from the portion of the river affected by PCBs should not be consumed. For the portion of the river contaminated by mercury, small amounts of fish may be consumed. In general, the VDH recommends that no more than one pound of fish per month be consumed. Women

[7] Emerson, K et al "Aqueous ammonia equilibrium calculations effect on pH and temperature," Journal of Fisheries Research Board of Canada. 32: 2379-2383

who are pregnant or may become pregnant, nursing mothers, and young children are advised not to consume any fish taken from the South Fork of the Shenandoah River.

General Overview: South Fork and Tributaries

South Fork

Exhibit 2a presents an overview of the average quality of water in the South Fork of the Shenandoah River and its tributaries. For all of the data except for fecal coliform, the averages are simple arithmetic averages taken over the four-year sampling period. For fecal coliform, the average is the geometric average of more than two years of data. The criteria defining the unimpaired, impaired, and severely impaired level are also given.

Exhibit 2b presents the same data, but only for those sites where the data were sufficiently plentiful (more than 75 data points) to provide reliable statistical indications of trends.

Several of the sites for the tributaries were sampled only once per month and we do not yet have sufficient data to accurately determine trends. For example, site FP-13B (Mill Creek Crossroads) provided only eight data points for nitrogen because monitoring did not start until March 2000. FP 07D returned only 14 data points because monitoring started in July 1999 and there were dry periods when the site was not monitored.

The averages in exhibit 2a and 2b give a good indication of the health (or lack of health) of the South Fork and its tributaries. The table shows that the average level of nitrogen in the South Fork at 0.99 is very close to the 1.0 impaired level. The average phosphorus level in the South Fork is even worse, and at 0.7 ppm is well above the impaired level of 0.1 ppm. The average level for ammonia (NH_4) for both the South Fork and Main Stem is good at 0.37 PPM: this is well below the impaired level of 1.0 PPM. As we shall see below, the trend for N is up, and is also up for P but at a slower rate.

Though at times slightly on the alkaline side, thanks to the limestone rich soils through which the river flows, the water in the South Fork is almost never too acidic. The levels of dissolved oxygen are also very good. Turbidity is generally good during dry periods and spikes during periods of heavy rain when turbidity reaches very high levels. For example, during January and February 1998 the turbidity peaked at 34.5 NTU. This high turbidity event happened during a period of heavy rainfall and snow melt, and is an indication of serious erosion and runoff from land. Such turbid runoff can and should be prevented by implementing better measures and policies to control the erosion and sedimentation caused by storm water.

Fecal coliform levels in the South Fork are within the Department of Health guidelines for recreational use, and the river is considered safe for boating and swimming.

Exhibit 3 shows a graph of the levels of the nutrients in the South Fork near the Town of Shenandoah. It is evident that trends for N and P are on the rise. And the trend for ammonia may also be rising slightly. Trends are examined in more detail in exhibit 9.

Tributaries

Exhibit 2a also gives the status of the tributaries to the South Fork. Because of the large number of tributary sampling points (26) they were organized into nine groups. Each group consisted of a set of tributaries in the same micro-watershed.

Except for Group 4 (Chubb Run) and Group 7 (Mill Creek) the average concentration of nitrogen for the tributaries was well below the impaired level. N does not seem to be a major problem in most of the tributaries, but should be controlled in Chubb Run and Mill Creek. Several of the tributaries have high concentrations of P, with average concentration in the impaired range for six of the nine groups.

Fecal coliform levels are sometimes high in several of the tributaries. These include the Hawksbill Creek (FP-08, FP-08F, and FP-08E), Pass Run (FP-O7), Chubb Run (FP-08B and FP-08H), all the Mill Creek sites (FP13, 13A, and 13B), and Jeremys Run at Rileyville (FP-14). For example, on January 19, 2001 Chubb Run (FP-08B) had a fecal coliform count of 6100 colonies per milliliter. This is 6 times the individual sample impaired limit of 1,000 colonies per milliliter. These small tributaries are definitely not healthy for swimming, boating and other recreational use.

Exhibits 4a through 4f show the graphs for the tributaries. These graphs show that the high average level of P in FP-07 (Pass Run), FP-08 (Hawksbill combined), FP-11 (Naked Creek), and FP-12 (Cub Run) was contributed to by high levels during 1997 and 1998. The use of detergents that contained high P levels could have contributed to these high levels. After 1998, the use of such detergents subsided, and the graphs show that the concentration of P in the tributaries also decreased considerably. However, as shown in the case of FP-06 (Hawksbill Creek) and FP-07 (Pass Run) the trends calculated over the last 15 months shows the concentration of P is increasing again.

Exhibit 6 shows the variation of DO, pH, and T over the January 1997 to November 2000 time period. We can see that the variation around the average for DO and pH, is quite small, and there does not seem to be any adverse trend. The turbidity levels have a number of flare-ups that indicate the water is extremely murky at times, although the average value for turbidity is below the impaired level.

Sewage Treatment Plants

Exhibits 5 a, b, and c show the levels of nutrients in the three Sewage Treatment Plants (STPs) in Page County. The graphs are presented on the same scale for each nutrient. This makes it easier to make comparisons between the STPs. These comparisons show that there is considerable variation in the performance of the STPs. The Town of Stanley has secured funding and will soon construct improvements to their treatment works, which should dramatically improve their effluent. The Town of Luray has also secured funding for an upgrade to their treatment works and is beginning the design process.

Exhibit 5a shows that the concentration of N in the effluent from the Pilgrim/Wampler Foods STP has an average of 68 PPM, which is well above the 3 to 5 PPM averages for Luray and Stanley. The FOSR began sampling at the Pilgrim/Wampler Foods STP in February 2000. We do not yet have enough data to establish an accurate trend and the N readings show a lot of variability. However we expect that a plant upgrade or process change will be required before the N level for Pilgrim/Wampler Foods is reduced to the levels being achieved by the towns of Stanley and Luray. The technology is readily available to allow significant reductions in the nutrient content of their effluent, but the company (and other poultry companies) are waiting for VA-DEQ to set N and P limits and make all the plants comply.

Exhibit 5b shows that the level of P for Pilgrim/Wampler Foods, at about 13 PPM is well above that achieved by Luray (1.7 PPM) and Stanley (2.6 PPM). The P levels for Pilgrim/Wampler Foods are also variable and seem to be increasing.

How much pollution do these STPs contribute to the South Fork? The Stanley, Pilgrim/Wampler, and Luray STPs emit into the South Fork very significant flows of effluents that contain a high proportion of N, P, and NH4. Though the concentration of Ammonia-nitrogen is regulated by and is undoubtedly in compliance with the law, the Virginia Department of Environmental Quality has not yet set permit limits for N and P. It is nevertheless interesting to calculate by how much the effluents affect pollution of the South Fork.

The results of these calculations for N are shown in the table below.

Impact of Page County STPs on South Fork water quality

STP	Nitrogen contributed by the STP, pounds/day	Increase in N concentration in South Fork	Percent increase
Stanley	5	From .989 to .99	0.11%
Luray	47	From .977 to .99	1.31%
Pilgrim/Wampler	454	From .82 to .99	17%

The impact of the Stanley and Luray STPs on the concentration of N is minor at only .11% an 1.31% respectively. This low value is because of the relatively low effluent discharge and moderate concentration of N of these STPs.

The impact of the Pilgrim/Wampler STP on the concentration of N is substantial. Without the discharge from the Pilgrim/Wampler STP the concentration of N in the South Fork [8]would be reduced by approximately 17%.

The table also shows the amount of N deposited by the STPs. For the Pilgrim/Wampler STP the annual deposit of N is 454 pounds.

Exhibit 5c shows that the level of NH4 at less than 1 PPM is very low for Luray and Pilgrim/Wampler. The performance of the Luray STP seems especially good since, in

[8] This calculation makes the simplifying assumption that the concentration of N in the South Fork just before passing the Pilgrim/Wampler STP is equal to the average PPM of .99 of the South Fork. It probably is slightly different from the total stream average, but the magnitude of the error introduced by this assumption is negligible.

addition to being very low, there are very few peaks. The concentration for NH4 in the Pilgrim/Wampler effluent is also very steady, though the one-year monitoring period is probably too short to make conclusions about the stability of its output. The performance of the Stanley STP is not at the same level as that for the other two STPs - its NH4 concentration is about 9 PPM, and there are frequent and significant peaks where the concentration rises above 25 PPM. This should improve dramatically when the planned treatment plant upgrade is constructed and operational.

Comparison of South Fork in Page County with Main Stem in Clarke County.

An earlier report prepared by the Friends of the Shenandoah River last year, and entitled "The Health of the Shenandoah River in Clarke County: The FOSR Water Testing Program", December 9, 2000 makes possible a comparison in pollution levels of the South Fork and Main Stem.

Compared with the Main Stem, the average levels of nitrogen and phosphorus in the South Fork are much higher. Nitrogen in the South Fork at 0.99 PPM is very close to the impaired level of 1.0 ppm. And the trend for nitrogen concentration is rising. In comparison, the average nitrogen level in the Main Stem is only 0.65PPM, though its trend is also increasing.

Phosphorus in the South Fork at .70 PPM is almost twice that of the .36 PPM of the Main Stem.

The opposite holds for the tributaries (called "runs" in the Main Stem report). The tributaries in Page County have fewer nutrients than those found in Clarke County.

Why does the Main Stem contain a lower concentration of nutrients than the South Fork? This is a complicated question that must wait until we have finished the analysis of the other parts of the Shenandoah River watershed. This will help us understand to what extent the pollution in Page County portion of the South Fork comes from upstream, or whether perhaps the North Fork and some of the cleaner tributaries which mix with the South Fork in Page and Warren Counties dilute the pollution in the South Fork. Contamination of groundwater, which provides much of the flow in the South Fork, especially during droughts, is also an important variable that needs investigation.

Table 1: COMPARING PARAMETERS FOR PAGE COUNTY AND CLARKE COUNTY

	N	P	NH4	DO	pH	T
Clarke County						
Main Stem	.65	.36	.37	9.98	8.20	3.91
Runs	1.19	.27	.43	8.55	7.54	2.97
Page County						
South Fork	.99	.70	.37	8.94	8.22	3.16
Runs	.80	.13	.26	8.77	7.75	1.59

Deviations from the Average

The averages given in exhibit 2 provide a good general sense of the health of the river. However, it is important to consider the deviations from the averages and the trends over time to achieve a true picture of the health of the river. For example, one can say that ocean water at an average temperature over the year of 70 degrees Fahrenheit is comfortable for swimming. But this average includes very uncomfortable low and perhaps fatal temperatures during the winter and high temperatures during mid-summer. Similar variability is true for the contaminant levels.

The line graphs in exhibits 3 through 6 present a general picture of the deviations from the average. More exact data are given in the pie charts presented in exhibits 7 and 8 that quantify for each parameter the percentage of time the water is at the unimpaired, impaired, or severely impaired level.

Exhibit 7 shows that while the level of N in the South Fork was at the impaired level 41% of the time, it was never in the severely impaired range. The level of P, however, was above the impaired level 95% of the time, and was severely impaired 5% of the time. The fluctuations of ammonia were almost never very high, and this contaminant was unimpaired 99% of the time (this is fortunate since, as aquarium owners know, impaired levels of ammonia can kill fish very quickly). Dissolved oxygen was always good or excellent. Turbidity, however, was too cloudy 10% of the time. This, as the graphs show, occurs during and after heavy rains. The water in the South Fork was never too acidic, but had high alkalinity 70% of the time.

Exhibit 8 shows similar information for tributaries. The concentration of N in the South Fork tributaries was in the impaired range 23% of the time, which is less than the 41% for N in the South Fork itself. Similarly, the level of P in the tributaries is impaired 37% of the time, and this is also better than that for P in the South Fork, which is impaired 95% of the time. For NH4 both the South Fork and the tributaries are unimpaired 99% of the time. Thus, we can conclude that, for N and P, the tributaries have lower concentrations of N and P than the South Fork which receives their water. The question therefore arises "where does the nutrient pollution in the South Fork come from?" Though more research is required, one would think that some must come from upstream because, since the tributaries carry lower concentration levels of nutrients and therefore are not increasing the South Fork's concentration of nutrients. Some of the nutrient pollution in the South Fork must come from the Stanley and Pilgrim/Wampler Foods STPs that empty directly into the South Fork near Alma.

The Trends

Exhibit 9 shows linear trend line projections of pollution of the South Fork at site FP-01 (Town of Shenandoah Dam). The trends for N and NH4 are clearly up, and by the year 2005 the level or N could be about 1.6 PPM. This, though reflecting impaired water, is well below the current set point for a severely impaired level of 10 PPM. If the trends continue, by the year 2005 the concentration of NH4 will approximate .75 PPM. This is also below the impaired level of 1.0 PPM.

For P the projection is more complicated because there seem to be two distinct time periods. There is the period before May 1998 where the levels of P were high and with large fluctuation, and there is the period from May 1998 onward where the levels of P are lower and the fluctuations are also significantly less. (We believe this is because prior to 1999 the level of P in household detergent was high. Starting in about 1999 the concentration of detergent in P was sharply reduced.) If we combine both periods into one trend line, the high levels of the first period will tend to tilt the trend line downward sharply. To correct for the high readings prior to 1999, this report has calculated the trends for P in the South Fork and tributaries using 1999 and 2000 data. The curtailed trend line shows that concentration of P in the South Fork is down and while P concentrations are currently at impaired levels, at least they do not seem to be increasing.

Though the trends for N and NH4 are up, linear projections suggest the severely impaired levels will not be reached in the Page Valley section of the South Fork for a long time. This, however, should not deceive us to take a sanguine view about the future. These trends are based on linear projections from a relatively short data set. Linear projections (also called "straight line" projections) assume future conditions will reflect the past. Many of the variables effecting the levels of pollution such as population growth, urbanization, movement of industry into the Shenandoah watershed, climate, etc, are changing rapidly. The actual situation therefore may be worse or better than that given by the linear projection. Chances are, however, that if paved and impervious areas, and development sprawl are allowed to continue unchecked, and population growth increases more rapidly than in the past, the actual concentration of nutrients will increase more sharply than as given by our projections. On the other hand, if sprawl and growth of impervious areas are properly managed, and if programs for stormwater runoff, best management practices, and total maximum daily load (TMDL) limits are well implemented, the trends could decrease. Clearly, it is of the utmost importance to continue close monitoring of water quality trends.

The trends for the tributaries are shown in Exhibit 4. Trends for N are up, except for Naked Creek and Cub Run where the trends are slightly downward. The trend for P is mostly down, but as explained above, the downward tilt is caused by the very high readings in 1997 and 1998. If we discard those readings and use only the last 15 months or so of data, many of the trends are up.

The trends for N from all three of the STPs are slightly on the rise. For P, the trend is up for Luray and Wampler, but slightly declining for Stanley. The trends for NH4 appear to be stable in all three STPs. Hopefully the concentrations of nutrients contributed by the Stanley STP will decrease when their planned plant upgrades become operational. The Town of Luray expects that their planned plant upgrades will allow them to better control the nutrients in their plant effluent.

Next Steps

What can be done to reverse the adverse trends in water quality? Much is already being done by expanding and intensifying current efforts aimed at promoting programs for implementing Best Management Practices (BMPs). These BMPs include the planting of riparian buffers along streams, improving the efficiency and effectiveness of STPs to reduce the nitrogen and phosphorus content of their effluent, educating the public on the need to preserve trees and minimize paved surfaces, and reducing the air pollutants from vehicles and fossil fueled electric generating plants. These BMP efforts will have to become more uniformly implemented and more targeted if we are to make real progress in halting the increasing trend in pollution.

We also need to develop a better understanding of the relative importance of the factors that cause pollution in the South Fork. For example, nitrate nitrogen in the South Fork is already at an average level of .99 PPM and just below to the impaired level of 1 PPM. How much of this is contributed by runoff from farm fields, how much by the STPs (although we do know the Pilgrim/Wampler STP increases the N concentration in the South Fork by about 20%), how much from urbanization, etc.? Right now we do not have a complete answer to this question (see note 9), and can not therefore set priorities for remedial actions. In this respect Virginia is far behind the State of Maryland which in a recent study (see note 10) on the condition of freshwater streams in Maryland developed data on human activities which have the most effect on streams, and where these activities are most pronounced. The information developed in that study can be used as a tool for planners for developing policy, and for targeting areas for restoration and preservation.

Developing such a model is, of course, a daunting task that is well beyond the financial and professional resources of volunteer organizations such as the FOSR. It must be done by a combined effort of State and Federal organizations assisted by data collection by the local volunteer groups such as the FOSR.

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[9] We do have some indications since DEQ provides an indication of discharges from STPs, and the VA Tributary Strategy estimates the amounts coming from non-point sources.

[10] EPA and State Of Maryland Department of Natural Resources, 1999, From the Mountains to the Sea: The State of Maryland's Freshwater Streams, EPA/903/R-99/023.

It should be noted that the Minimum In-stream Flow (MIF) study currently being undertaken by the USGS and Virginia Tech on the North Fork is addressing some of the important aspects of the physical habitat question. In time, the MIF study may be extended to the South Fork.

The condition of the groundwater is also an important factor that must be studied. Because of the large dependence of the citizens of Page County on wells, the importance of that study cannot be overemphasized. Furthermore, much of the region's groundwater trickles into and provides the base flow of the South Fork. Understanding the groundwater situation can therefore explain much of what is happening to the quantity of water in the South Fork.

APPENDIX 1: WATER QUALITY TESTS

INDICATORS

- **Nitrate-Nitrite (N)**
- **Phosphate (P)**
- **Ammonia**
- **pH**
- **Turbidity (T)**
- **Dissolved Oxygen (DO)**
- **Temperature**
- **Fecal Coliform**

NITRATE-NITRITE

- reported as PPM of nitrite
- promotes excessive algae and aquatic plant growth.
- high values of less than 10 PPM can cause blue babies, and abortion of fetuses in cattle.
- US EPA considers concentrations larger than 1 PPM as impaired and larger than 10 PPM as severely impaired.

NITRATE-NITRITE SOURCES

- Waste-water Treatment plants
- Run-off from Fertilized Cropland and Animal Manure Storage areas
- Failing Septic Systems
- Air Pollution/Acid Rain

PHOSPHATE

- Essential Element for Life Processes
- Measured in Part Per Million (PPM)
- Reported as Ortho or Reactive Phosphate
- In water, Phosphorus is present naturally and in very low concentrations
- EPA (1986) recommends that total phosphorus in flowing waters not exceed .1 PPM

HIGH CONCENTRATIONS OF PHOSPHORUS

- Above 0.5ppm is High
- Causes Excessive Algae Growth

- ♦ Decreased Dissolved Oxygen (DO)
- ♦ Usually associated with high Turbidity (T)
- ♦ Water Discoloration

PHOSPHORUS SOURCES

- ♦ Human, Animal and Industrial Waste
- ♦ Sewage from Wastewater Treatment Plants and Septic Tanks
- ♦ Soil Erosion from Farming (especially plowing) & Construction (soil disruption)
- ♦ Excessive use of Fertilizers for Crops, Lawns, Home Gardens
- ♦ Draining of Swamps and Marshes

AMMONIA

- ♦ Reported as Ammonia-Nitrogen in PPM
- ♦ Formed during decay of Plants or Animals
- ♦ Levels above 1 PPM can cause toxic effects
- ♦ Harmful to aquatic biology; insects, fish

pH

- ♦ Measurement of acidity or alkalinity
- ♦ Scale from 1.0 to 14.0
- ♦ 7.0 is neutral, 3.0 is the level of lemon juice, 11.0 is the level of household ammonia
- ♦ Preferable range 6.5 to 8.0
- ♦ Values below 6.0 (very acidic) considered harmful to aquatic life
- ♦ Affected by acid rain, soil/rock type, industrial waste

TURBIDITY

- ♦ Measure of Water Turbidity by Nephelometric Turbidity Units (NTU)
- ♦ NTU 1-2 Clear; NTU 4-7 Fairly Cloudy
- ♦ Caused by:
- ♦ Plant Pigments i.e. Chlorophyll
- ♦ Suspended particles i.e. Clay, Silt, Plankton, Organic Matter, Sewage and Industrial Waste
- ♦ High Levels of Turbidity
    - Allow Less Light Penetration
    - Water Less able to Support Aquatic Life

Water becomes Warmer as Suspended Particles Absorb Heat =
Lower DO

DISSOLVED OXYGEN (DO)

Vital to aquatic organisms (plants and animals)

Absorbed directly into water from atmosphere and aquatic plants

Values above 5mg/L best

Values below 5mg/L stressful to aquatic organisms

LOW DISSOLVED OXYGEN

- Higher Water temp = lower DO
- Still Water = lower DO
- Breakdown of Organic Waste from:
- Algae "Bloom" Decay
- Municipal Waste
- Agricultural Waste
- Industrial Sources

FECAL COLIFORM

- Bacteria found the in Feces of Humans and other Warm Blooded Animals
- Most E-coli not Pathogenic, only an indicator organism that water is contaminated with human or animal wastes
- High Counts indicate Greater Chance for Presence of Pathogenic Organisms
- Swimmers have Greater Risk of getting sick due to disease causing Organisms

FECAL COLIFORM SOURCES

- Livestock in confined feeding areas or in streams
- Improperly treated Sewage Sludge or Manure
- Faulty Waste-water treatment
- Untreated sewage
- Failing septic systems
- Wildlife i.e. Deer, Bear etc.
- Leaky Sanitary Landfills

Exhibit 1A: Page County Monitoring Sites, Northern Half

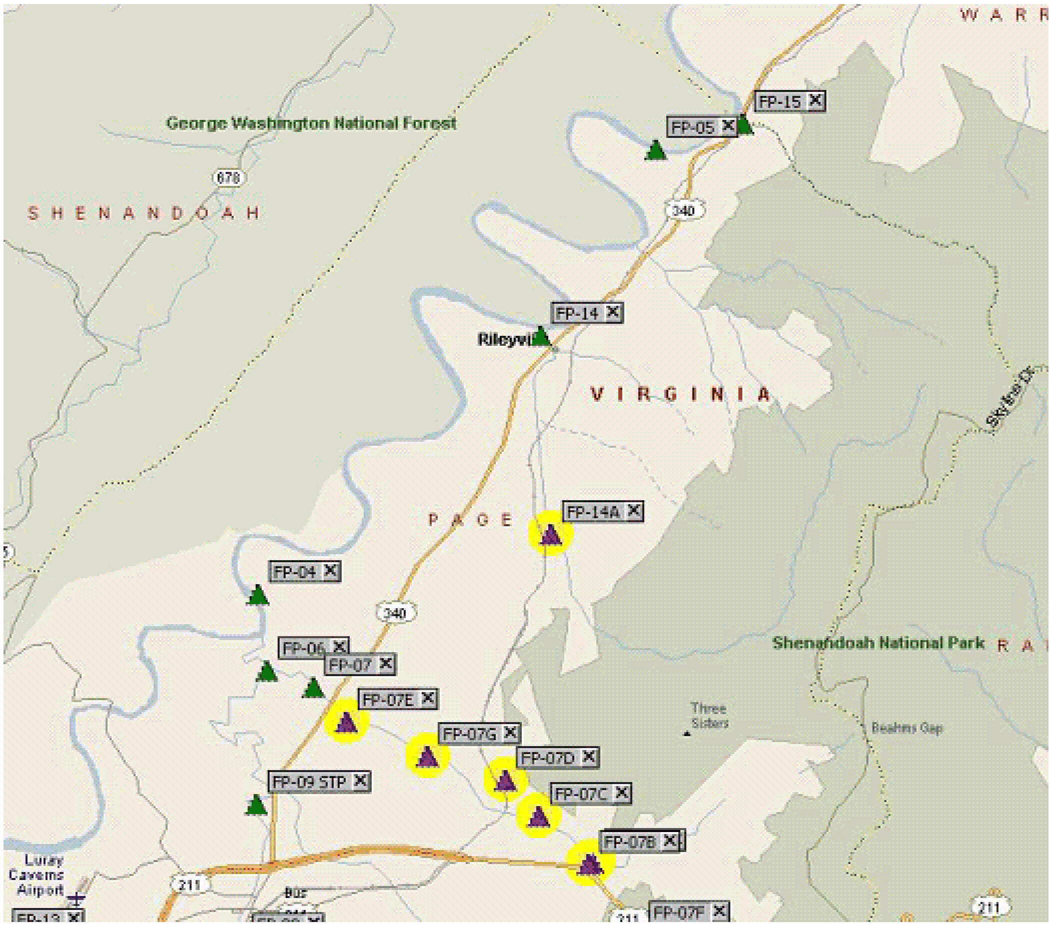


Exhibit 1B: Page County Monitoring Sites, Southern Half

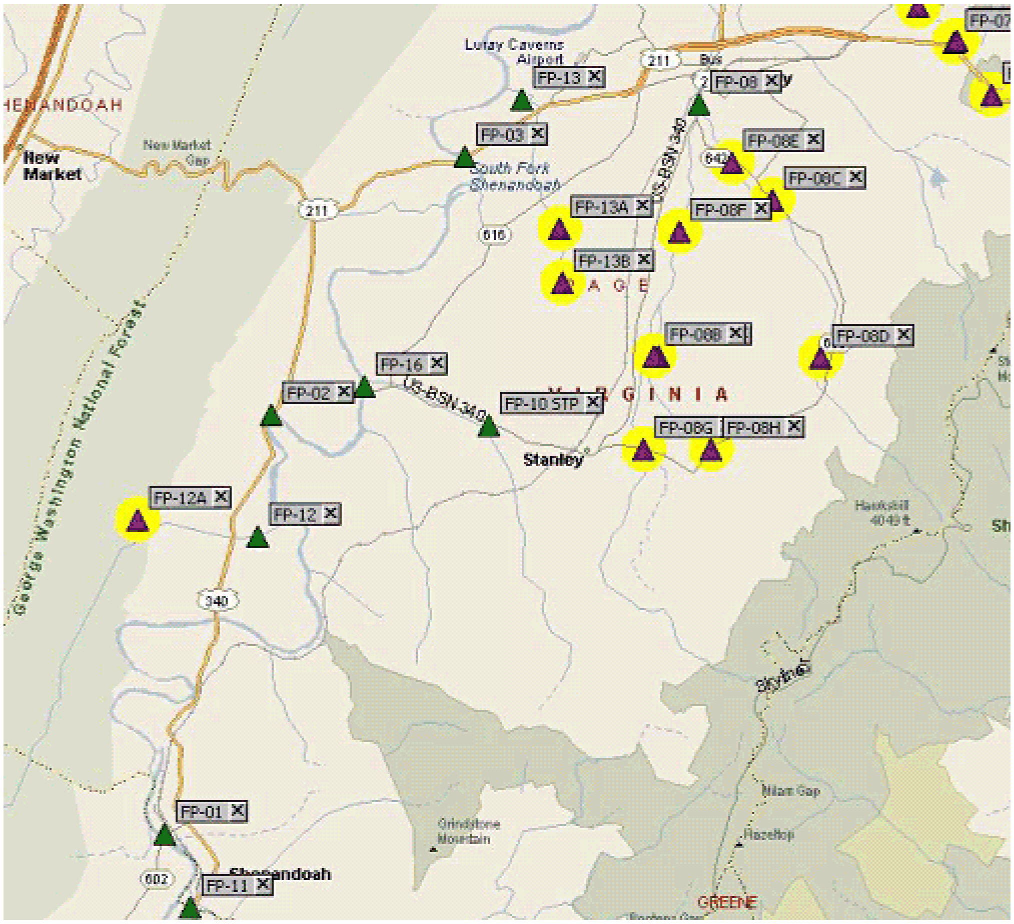


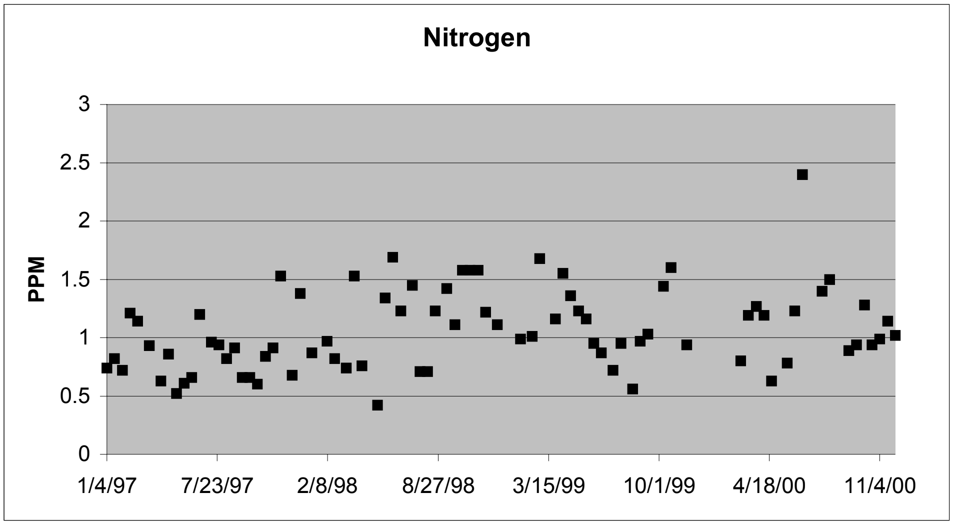
	Exhibit 2A, Average Level By Site For All Sites							
		Nitrogen (PPM)	Ortho-Phosphate (PPM)	NH4/Nit (PPM)	pH	Turbidity (NTU)	DO (PPM)	Fecal Coliform (colonies/mill)
Group	**South Fork**							
S. Fork	FP-01 Town of Shenandoah Dam	***1.06***	***1.10***	0.38	8.10	3.33	8.58	42
S. Fork	FP-02 Newport (stopped 4/2000)	0.98	***0.58***	0.35	8.29	3.91	9.12	12
S. Fork	FP-03 White House	***1.04***	***0.62***	0.41	8.18	2.38	8.89	41
S. Fork	FP-05 Burner's Bottom	0.88	***0.47***	0.37	8.33	3.01	9.19	14
	Average - South Fork Page County	0.99	***0.70***	0.37	8.22	3.16	8.94	
1	FP-06 Hawksbill Creek	***1.06***	***0.37***	0.30	8.16	1.60	9.26	102
1	FP-08 (Hawksbill Creek at Linden Street)	0.82	***0.22***	0.29	8.13	1.62	9.12	***307***
1	FP-08A (Hawksbill at SR 631)	0.46	0.07	0.22	8.51	0.95	9.29	112
1	FP-08F (Hawksbill at Redman Store Road -	***1.06***	***0.11***	0.30	8.07	1.74	9.59	***542***
1	FP-08G (at Marksville bridge)	0.31	0.05	0.22	7.62	1.08	9.26	47
	Average - Hawksbill Creek	0.74	***0.17***	0.27	8.10	1.40	9.31	
2	FP-07 Pass Run	0.71	***0.13***	0.24	8.10	3.27	9.08	***490***
2	FP-07A (from Rocky Branch)	0.14	0.08	0.17	7.71	1.22	8.63	86
2	FP-07B (from Jewell Hollow)	0.12	0.04	0.17	7.61	0.61	8.71	135
2	FP-07C (at Kimball Rd. bridge)	0.12	0.07	0.22	7.63	0.72	8.79	159
2	FP-07D (at Lynn-Mar Road)	0.15	0.07	0.17	7.69	0.93	8.64	84
2	FP-07E (at Burner’s spring)	0.53	0.08	0.18	7.39	1.03	8.19	153
2	FP-07F (at Park HQ/US 211)	0.17	0.08	0.21	7.24	1.10	8.72	19
2	FP-07G (at Whispering Hill Rd)	0.18	0.09	0.21	7.91	0.97	8.75	160
	Average - Pass Run	0.27	0.08	0.20	7.66	1.23	8.69	
3	FP-08C (at East Branch Rd.)	0.71	0.08	0.16	7.75	0.56	8.91	61
3	FP-08D (at Cross Mt.. Rd.)	0.27	0.07	0.10	6.92	0.34	8.89	30
3	FP-08E (at Stonyman Rd.)	0.99	0.07	0.24	7.61	0.99	9.53	***465***
	Average - East Hawksbill	0.65	0.07	0.16	7.43	0.63	9.11	

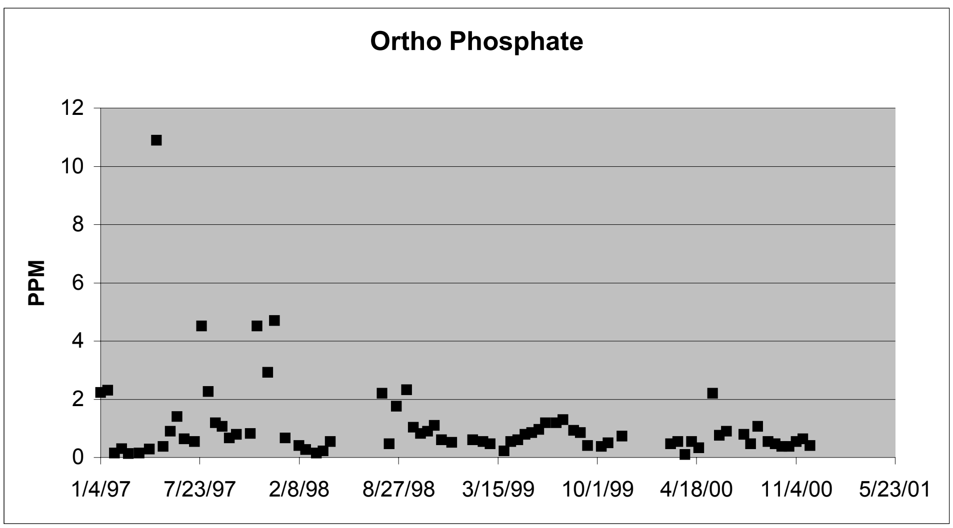
	Exhibit 2A, Average Level By Site For All Sites (continued)							
4	FP-08B (Chubb Run at SR 611)	***2.66***	***0.19***	0.33	8.11	1.80	9.89	***743***
4	FP-08H (Chubb Run at SR 689)	***1.15***	***0.13***	0.36	7.46	2.12	8.58	***416***
	Average - Chubb Run	***1.90***	***0.16***	0.35	7.79	1.96	9.23	
5	FP-11 Naked Creek	0.29	***0.15***	0.21	8.00	2.83	8.89	27*
6	FP-12 Cub Run	0.22	***0.18***	0.19	7.86	1.01	8.90	128
7	FP-13 Mill Creek	***2.79***	***0.53***	0.47	7.91	3.66	8.58	***301***
7	FP-13A @ Taylor's(JMU gps)	***3.06***	***0.20***	0.84	7.48	5.73	6.37	***813***
7	FP-13B @Mill Creek Crossroads	***2.11***	***0.20***	0.35	7.53	2.41	6.40	***250***
	Average - Mill Creek	***2.65***	***0.31***	0.56	7.64	3.93	7.11	
8	FP-14 Jeremy's Run	0.42	0.08	0.23	8.03	1.36	9.61	***277***
8	FP-14A Jeremy's @ Sunnyview	0.10	0.04	0.21	7.34	0.76	9.07	19
	Average - Jeremy's Run	0.26	0.06	0.22	7.68	1.06	9.34	
9	FP-15 Overall Run (Added 1998)	0.15	0.05	0.23	7.77	0.92	8.43	12
	Grand Average - all Tributaries	0.80	0.13	0.26	7.75	1.59	8.77	
10	FP-09 Luray Waste Water Plant	***4.09***	***1.65***	0.82	7.76	1.34	5.43	
10	FP-10 Stanley Waste Water Plant	***2.77***	***3.20***	***8.66***	7.39	***12.06***	***2.63***	
10	FP-16 Wampler/ Pilgrim Foods STP(new 3/	***68.13***	***12.77***	0.75	7.44	1.37	6.89	
	Average STPs	***25.00***	***5.87***	***3.41***	7.53	4.93	***4.98***	
		Nitrogen	**tho-Phospha**	**Ammonia**	**pH**	**Turbidity**	**DO**	**ecal Colifor**
	Not impaired	< 1.0 PPM	< 0.1 PPM	< 1.0 PPM	6.5 to 8 prefe	0 - 4 Clear	< 5 Bad (no t	<200
	Impaired	1.0 to 10.0 P	0.1 to 2.0 PP	³ 1.0 PPM	< 6.5 Too ac	4-7 Fairly cle	5 - 8 Good (E	>200
	Severely impaired	> 10.0 PPM	> 2.0 PPM		> 8 Too alka	> 7.0 Cloudy	> 8 Excellent (Trout)	

Exhibit 2b: Average Levels for Sites With Good Coverage

Group	Site	# Good Samples	South Fork	Nitrogen	Ortho-Phosphate	NH4/Nit	pH	Turbidity
S. Fork	FP-01	80	FP-01 Town of Shenandoah Dam	**1.060**	**1.104**	0.376	**8.098**	3.327
S. Fork	FP-02	73	FP-02 Newport (stopped 4/2000)	**0.978**	**0.582**	0.349	**8.288**	3.914
S. Fork	FP-03	82	FP-03 White House	**1.043**	**0.621**	0.409	**8.176**	2.380
S. Fork	FP-05	81	FP-05 Burner's Bottom	**0.875**	**0.475**	0.366	**8.329**	3.011
			Average - South Fork Page County	0.99	0.70	0.37	8.22	3.16
1	FP-06	85	FP-06 Hawksbill Creek	**1.059**	**0.374**	0.304	**8.156**	1.598
1	FP-08	82	FP-08 Hawksbill Creek Combined	**0.819**	**0.221**	0.286	**8.134**	1.621
			Average - Hawksbill Creek	0.94	0.30	0.29	8.15	1.61
2	FP-07	84	FP-07 Pass Run	0.713	**0.132**	0.243	**8.098**	3.274
			Average - Pass Run	0.71	0.13	0.24	8.10	3.27
5	FP-11	75	FP-11 Naked Creek	0.288	**0.146**	0.206	**7.999**	2.829
6	FP-12	82	FP-12 Cub Run	0.216	**0.177**	**0.189**	**7.86**	**1.011**
7	FP-13	74	FP-13 Mill Creek	**2.786**	**0.532**	0.475	**7.905**	3.656
			Average - Mill Creek	2.79	0.53	0.47	7.91	3.66
8	FP-14	75	FP-14 Jeremy's Run	0.424	0.080	0.233	**8.026**	1.358
			Average - Jeremy's Run	0.42	0.08	0.23	8.03	1.36
9	FP-15	50	FP-15 Overall Run (Added 1998)	0.151	0.054	**0.232**	**7.768**	**0.923**
			Average, all tributaries	0.80	0.19	0.27	7.92	1.89
10	FP-09	75	FP-09 Luray Waste Water Plant	**4.085**	**1.650**	**0.820**	7.762	1.339
10	FP-10	71	FP-10 Stanley Waste Water Plant	**2.775**	**3.204**	**8.665**	7.392	**12.065**
10	FP-16	15	FP-16 Wampler/Pilgrim Foods STP(nc	**68.133**	**12.769**	0.752	7.439	1.374
			Average STPs Page County	25.00	5.87	3.41	7.53	4.93
				Nitrogen	**Ortho-Phosphate**	**Ammonia**	**pH**	**Turbidity**
	Unimpaired Water			< 1.0 PPM	< 0.1 PPM	< 1.0 PPM	6.5 to 8 preferable	0 - 4 Clear
	Impaired			1.0 to 10.0 PPM	0.1 to 2.0 PPM	≥ 1.0 PPM	< 6.5 Too acid	4-7 Fairly clear
	Severely impaired			> 10.0 PPM	> 2.0 PPM		> 8 Too alkaline	> 7.0 Cloudy
		Note: Parameters within 20% of being at the impaired level are depicted in bold print.						

Exhibit 3: Levels of Nitrogen, Phosphorus, and NH4 in the South Fork at FP 01 (Town of Shenandoah Dam





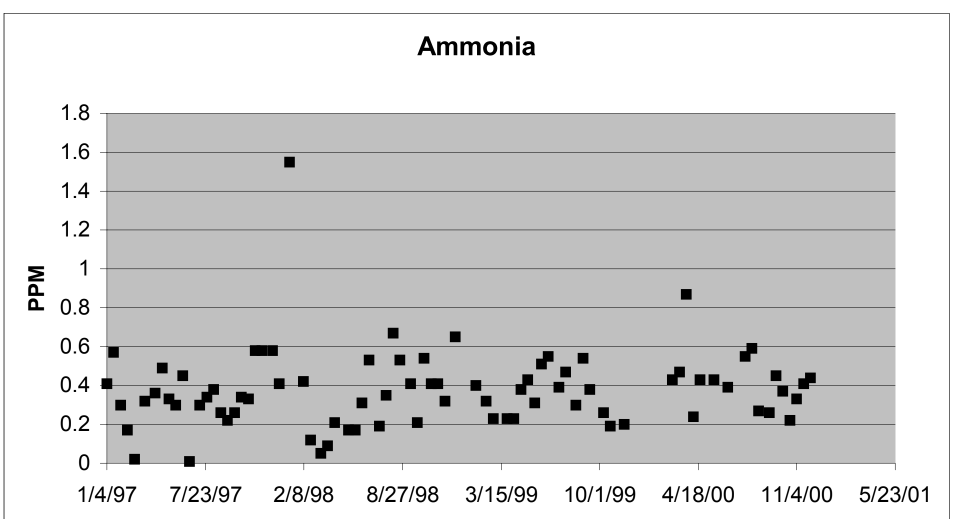
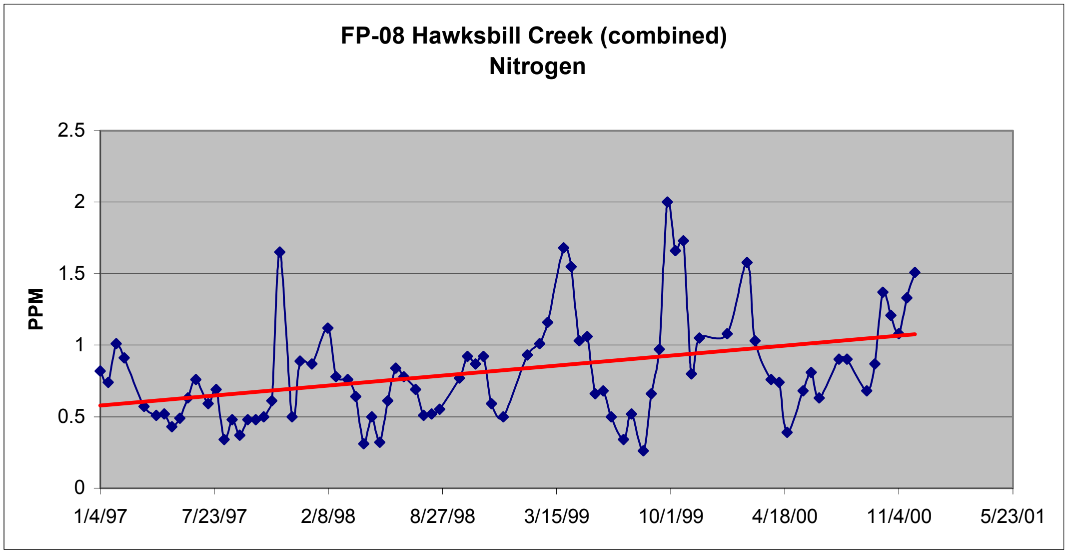


Exhibit 4b: Nutrient Trends in the Small Streams in Page County



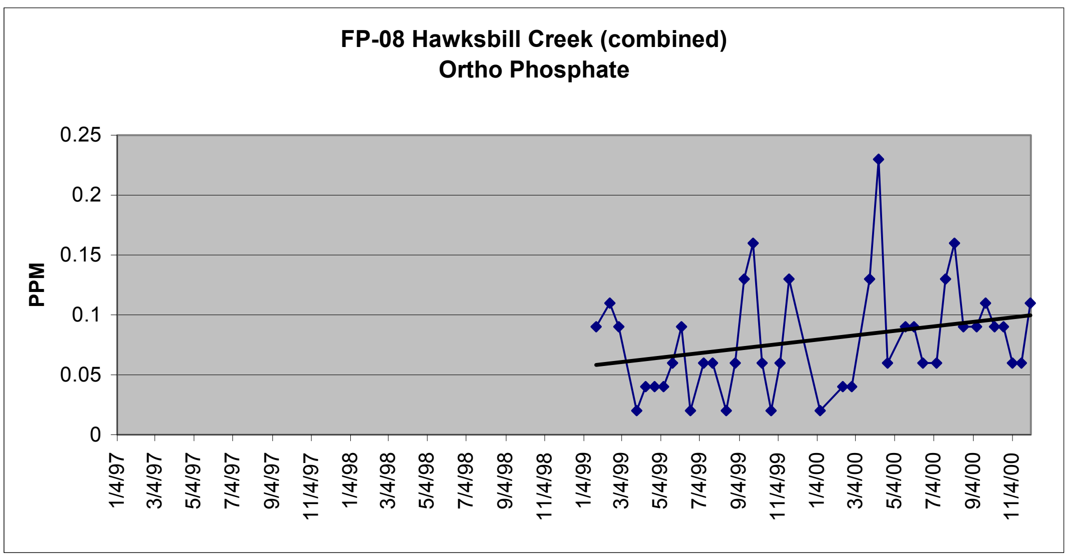
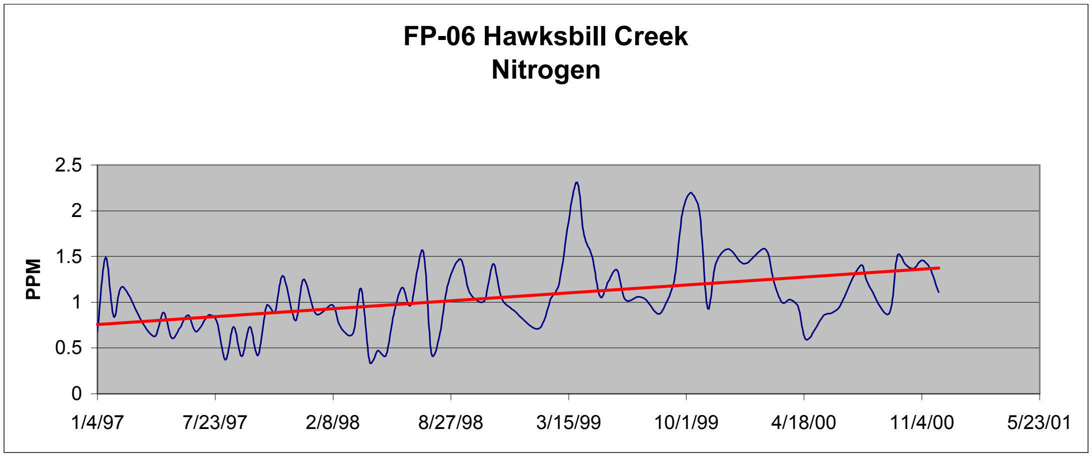


Exhibit 4a: Nutrient Trends in the Small Streams in Page County



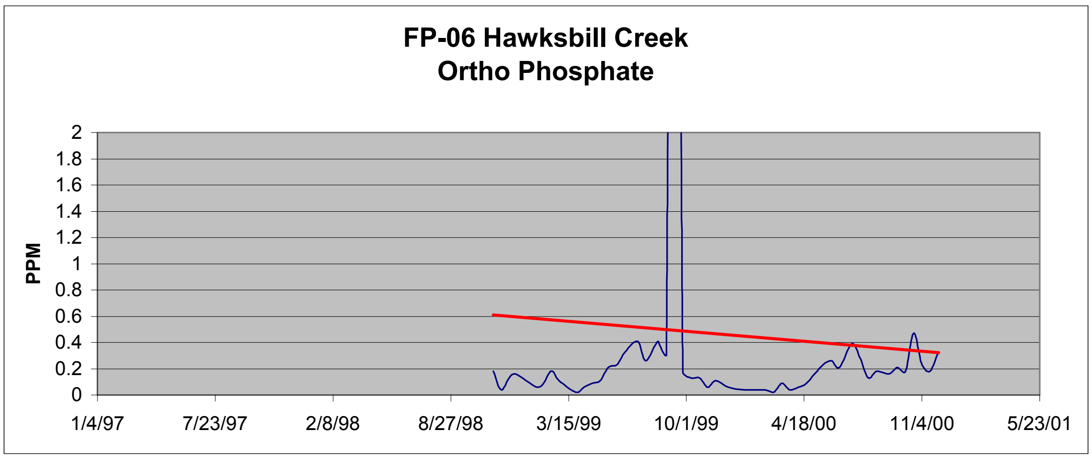
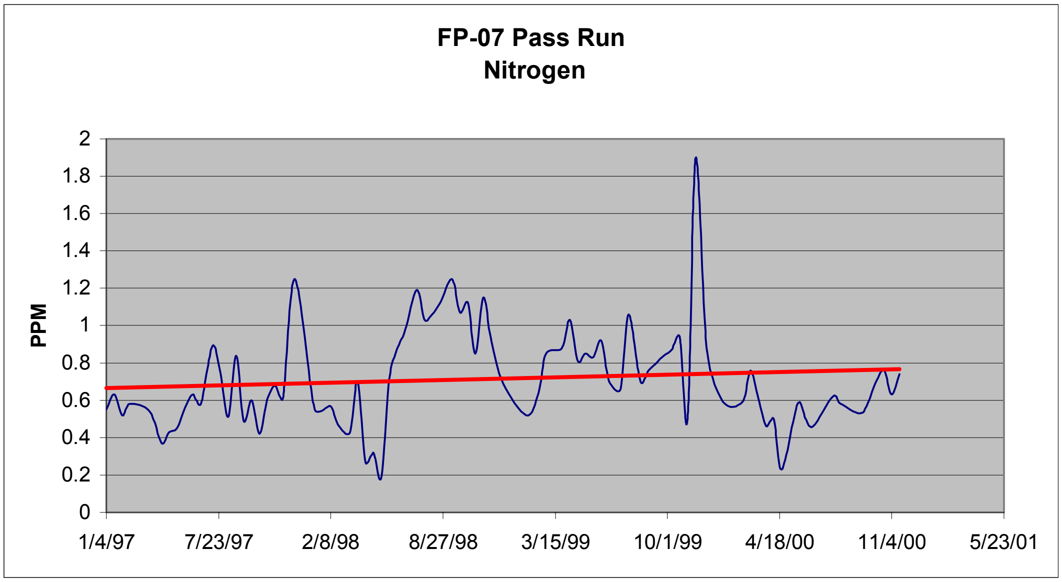


Exhibit 4c: Nutrient Trends in the Small Streams in Page County



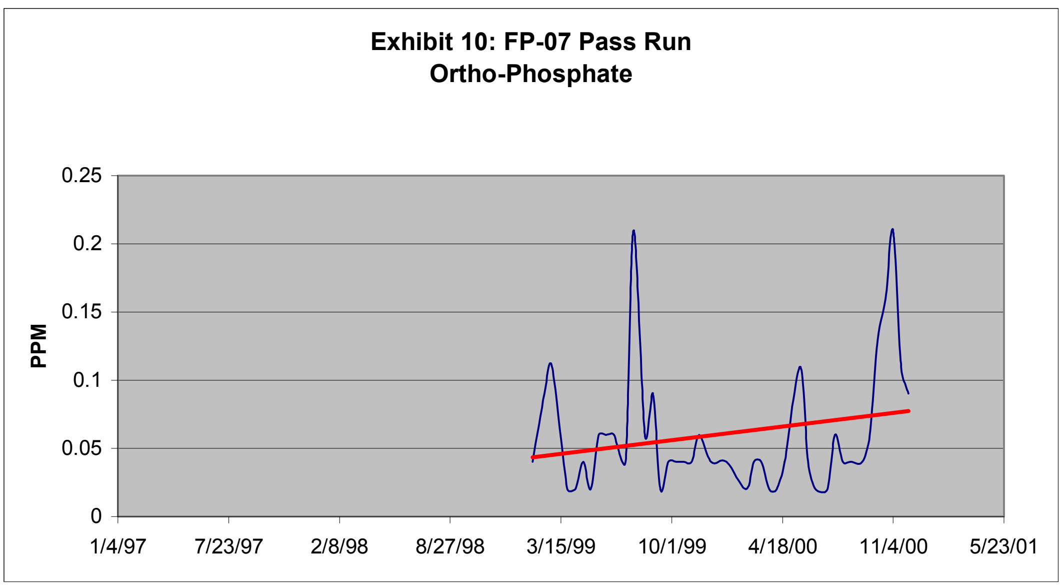
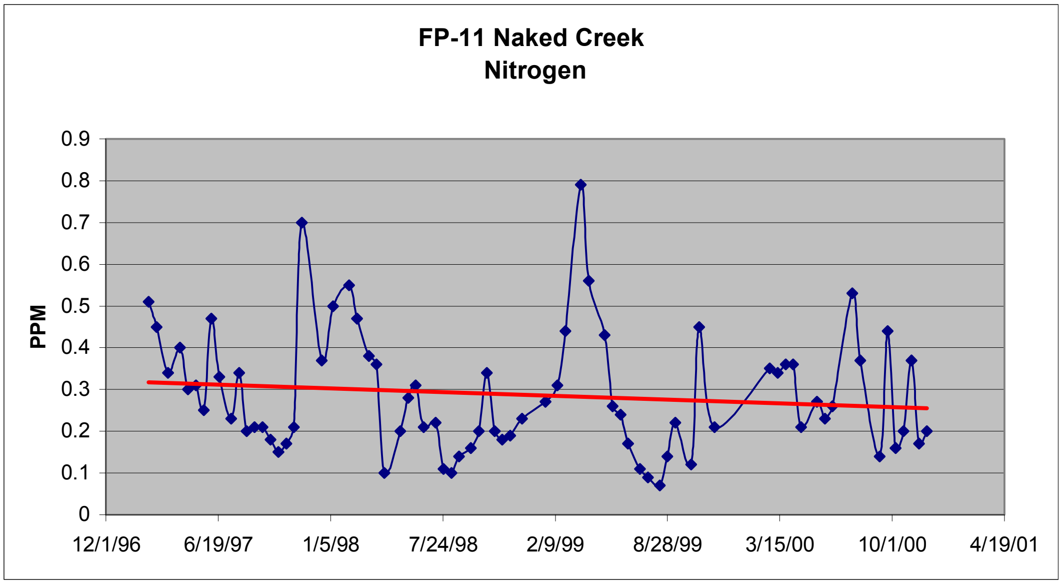


Exhibit 4d: Nutrient Trends in the Small Streams in Page County



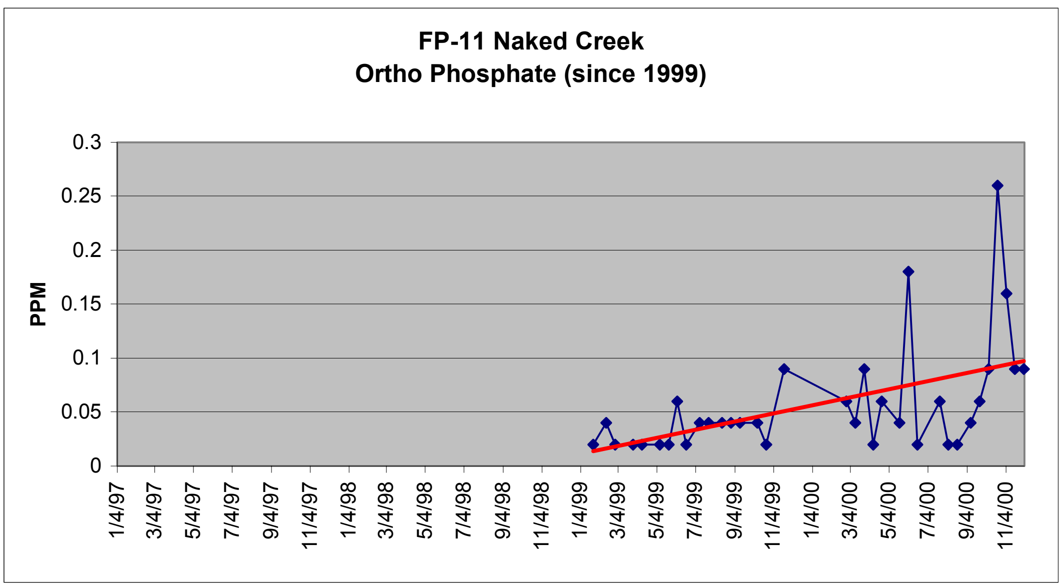
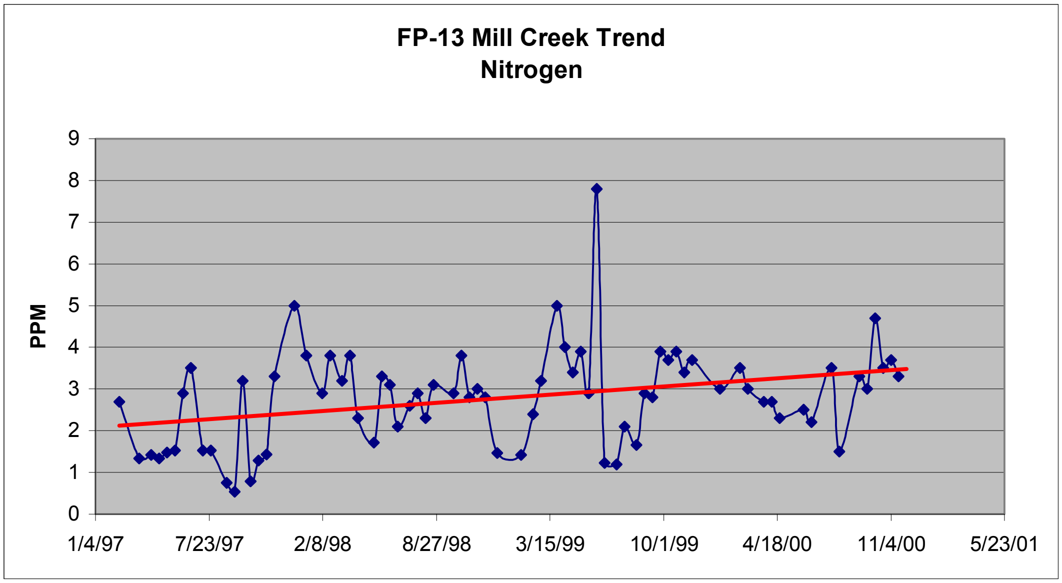


Exhibit 4e: Nutrient Trends in the Small Streams in Page County



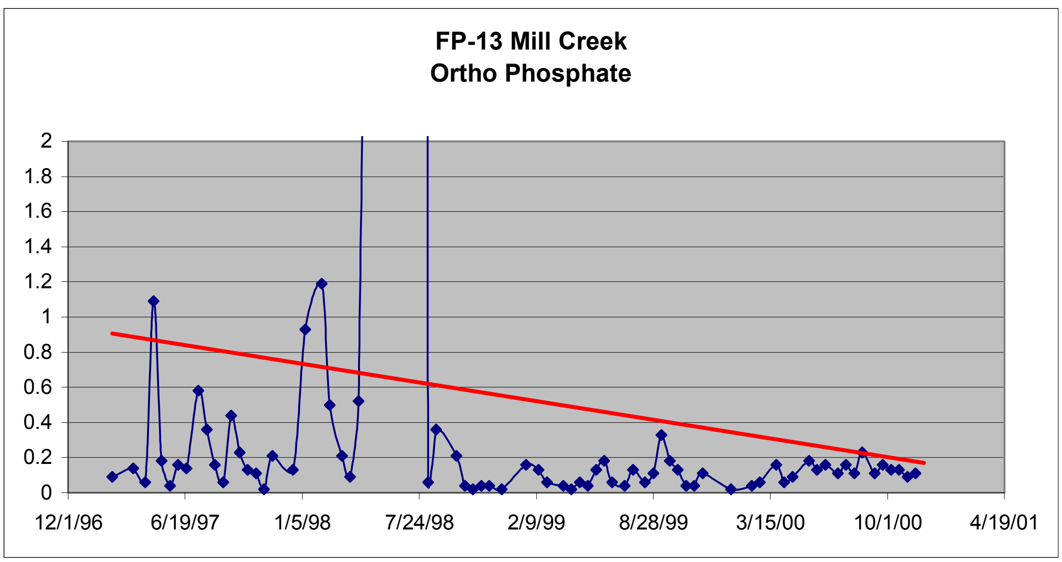
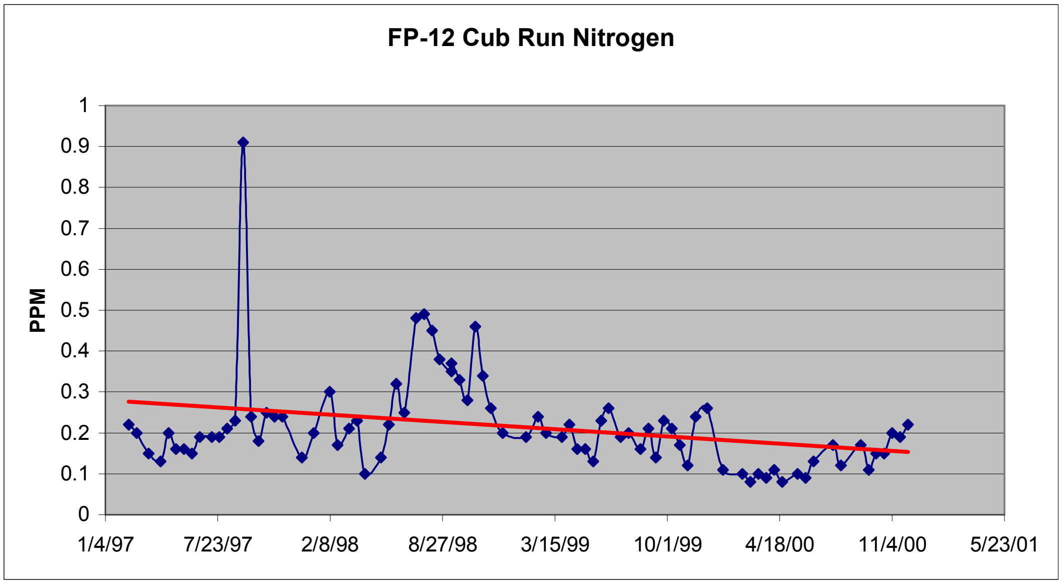


Exhibit 4f: Nutrient Trends in the Small Streams in Page County



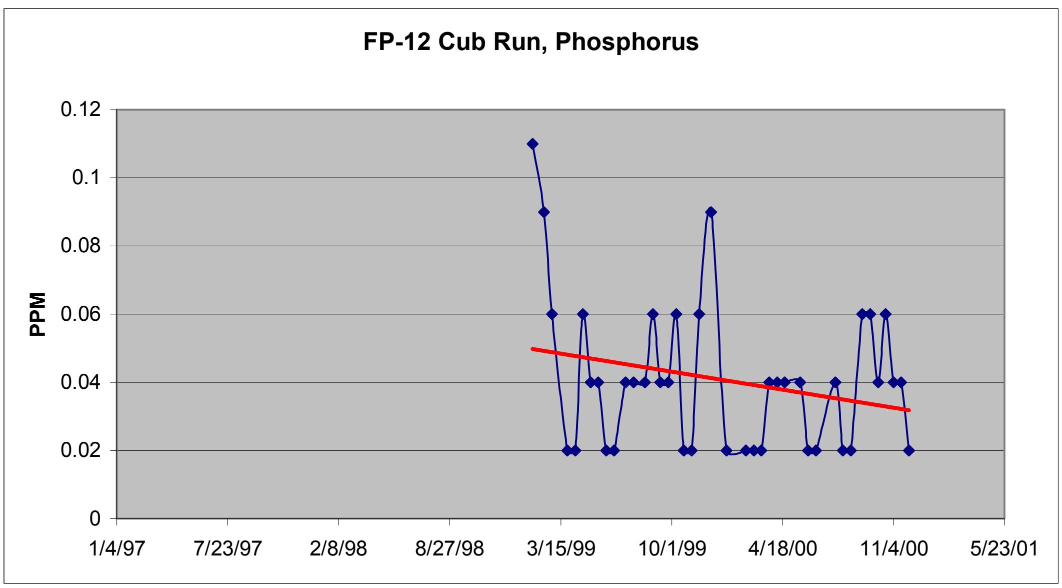
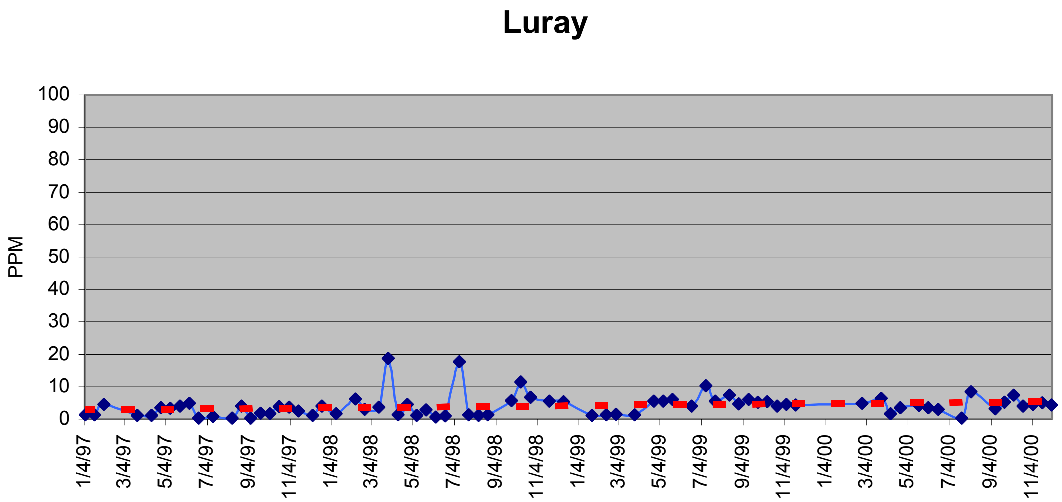
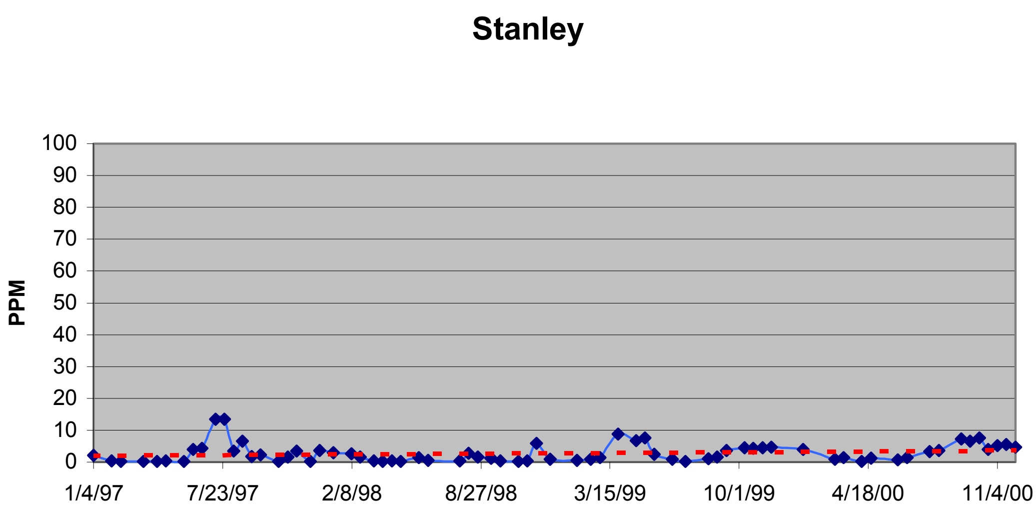


Exhibit 5a: Nitrogen Levels in the STPs





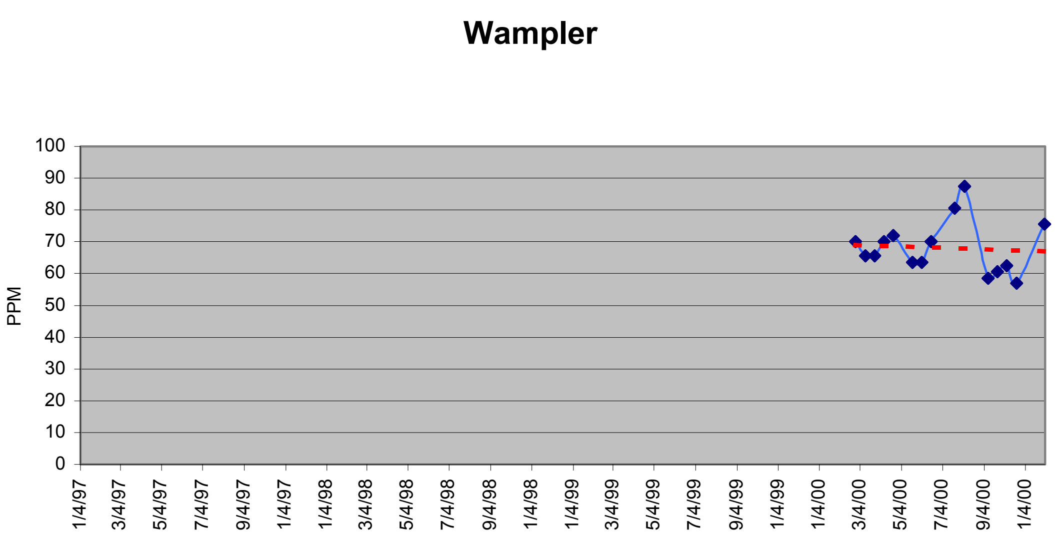
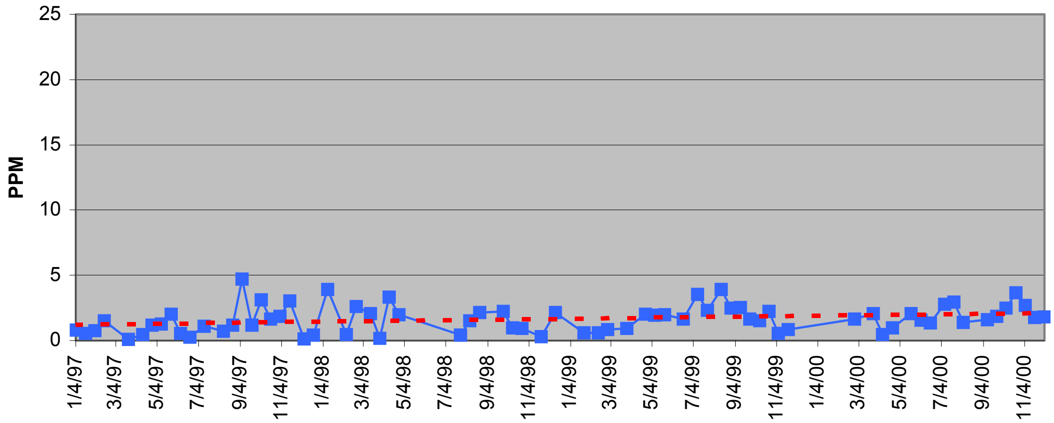
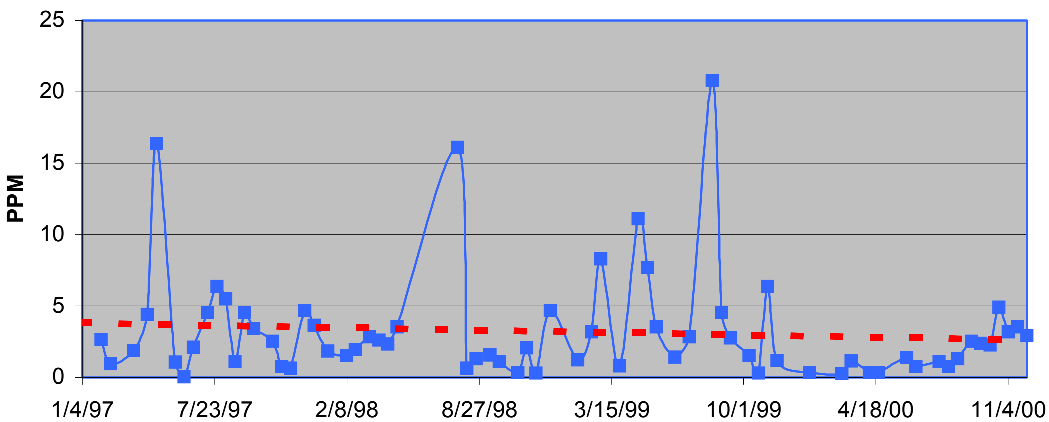


Exhibit 5b: Phosphorus Levels in the STPs

Luray



Stanley



Wampler

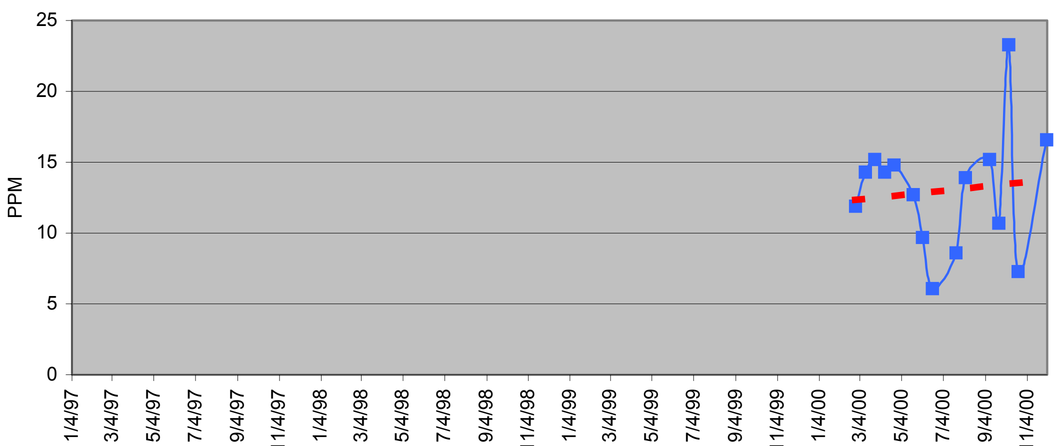
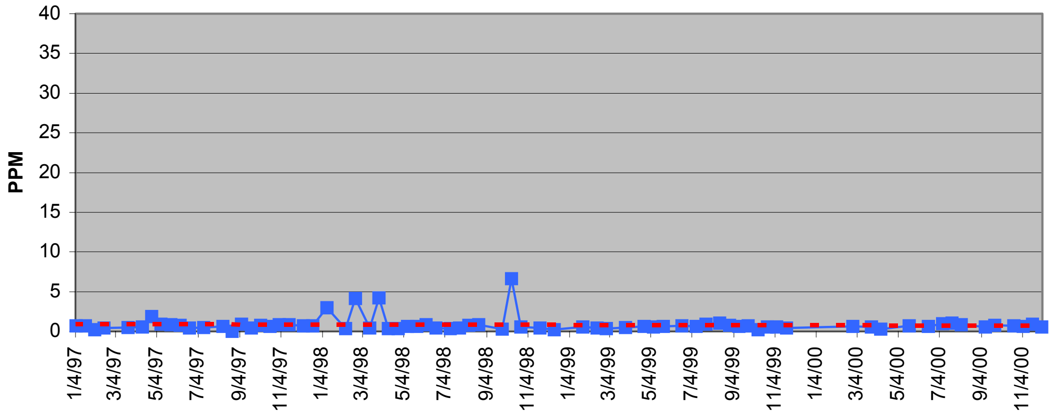
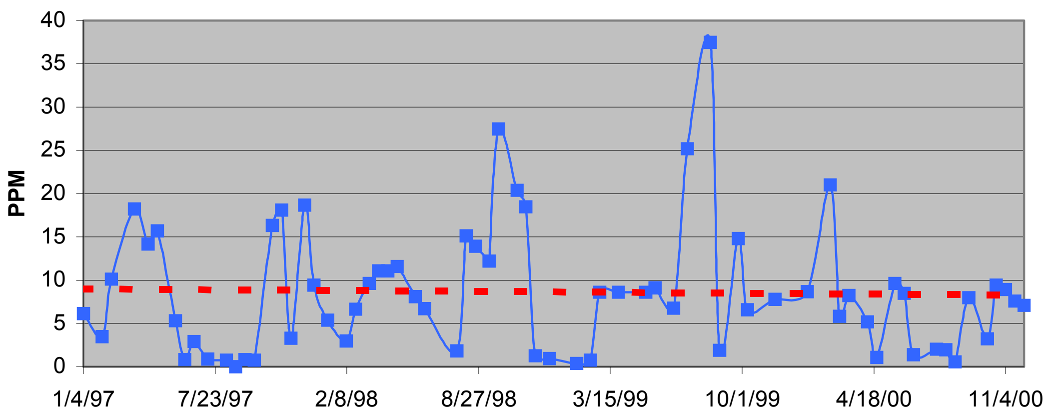


Exhibit 5c: NH4 Levels in the STPs

Luray



Stanley



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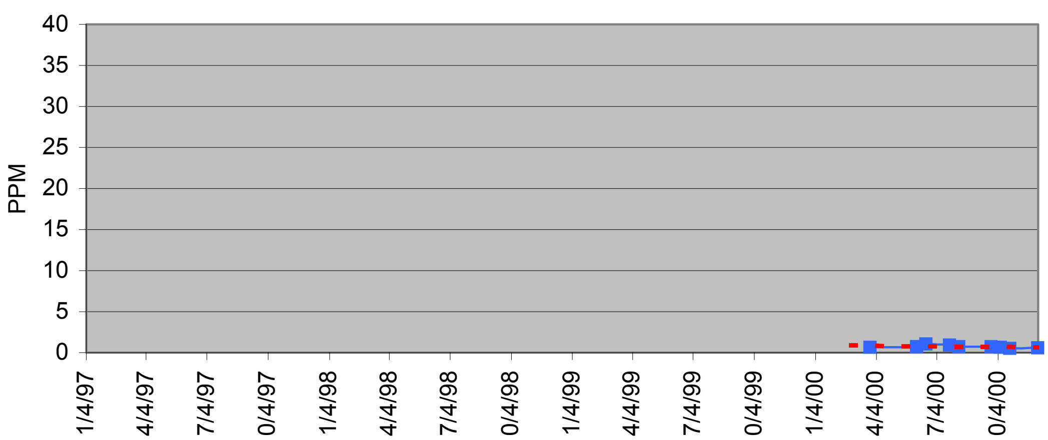
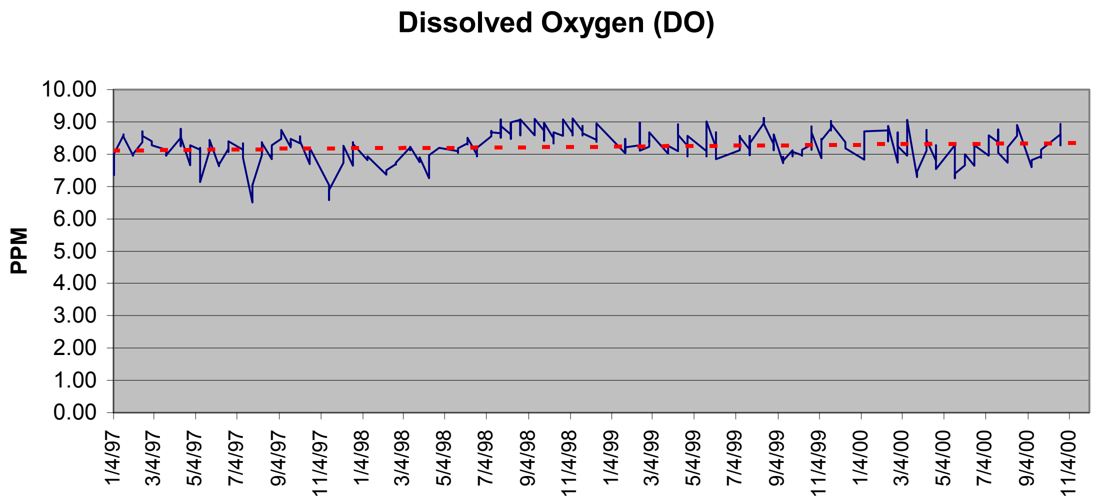
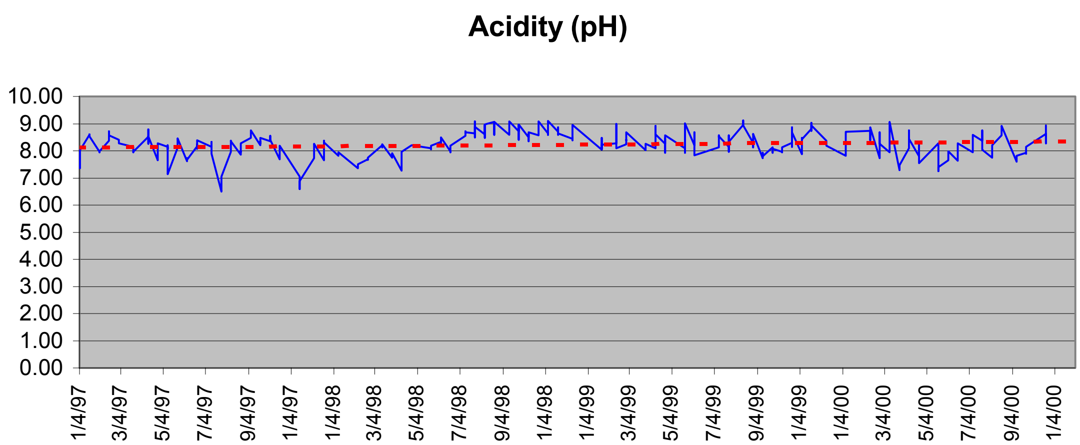


Exhibit 6: Trends for DO, pH, and T in the South Fork at FP - 01





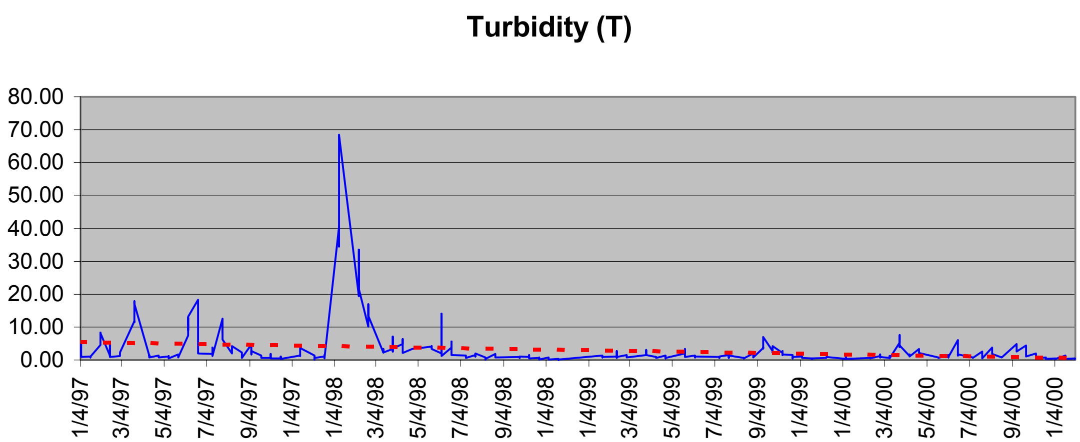
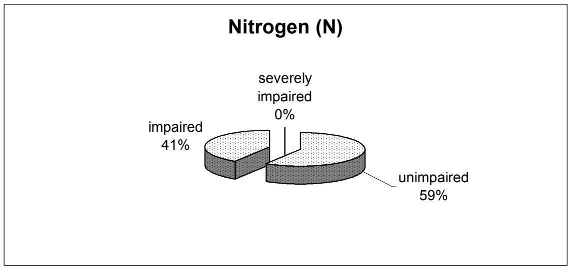
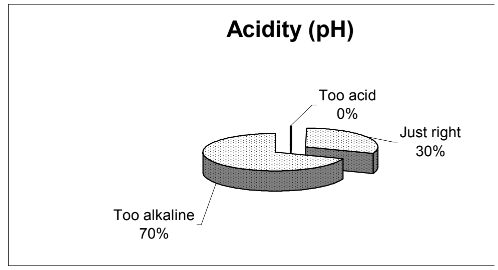
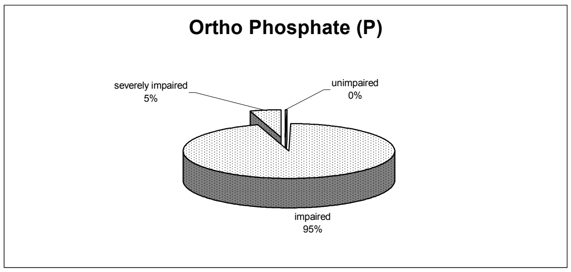
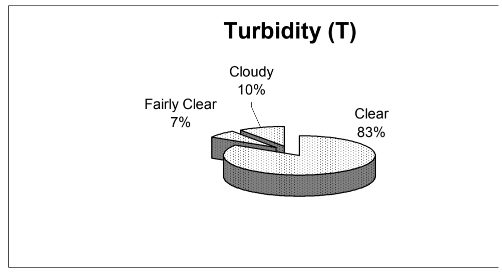


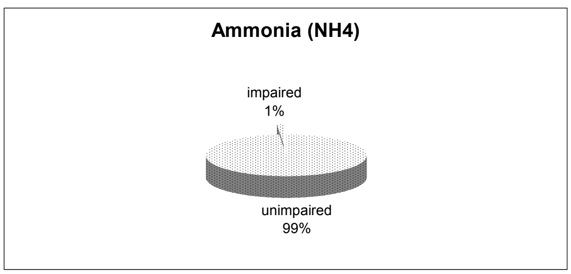
Exhibit 7: South Fork - Percentage Of Time During Last Three Years The Water Quality Measures Were At The Indicated Level











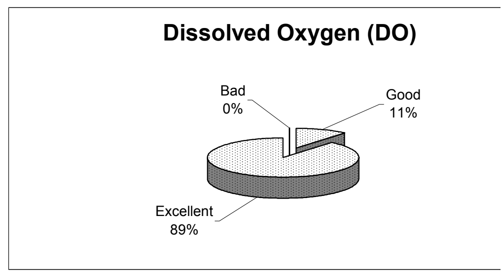
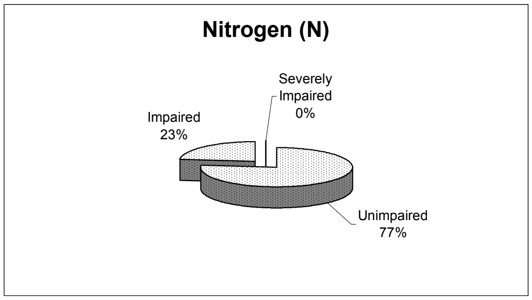
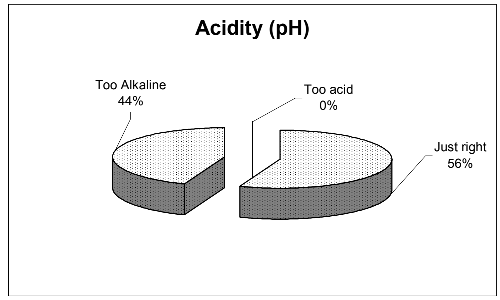
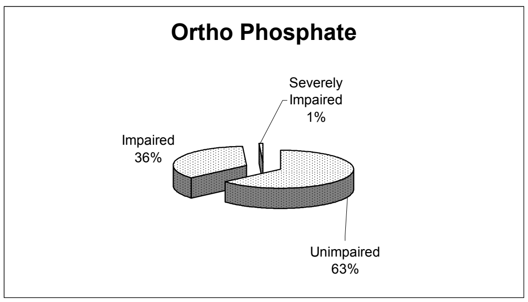
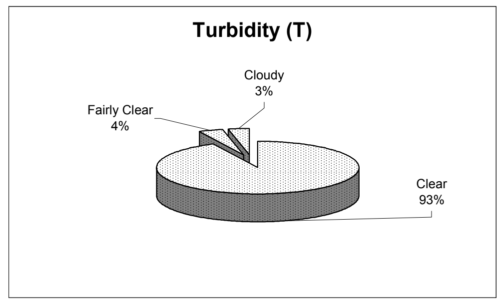


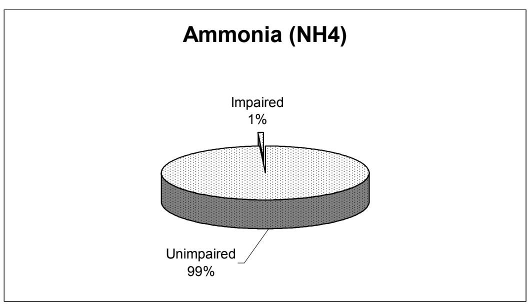
Exhibit 8: Small Streams - Percentage Of Time During Last Three Years The Water Quality Measures Were At The Indicated Level











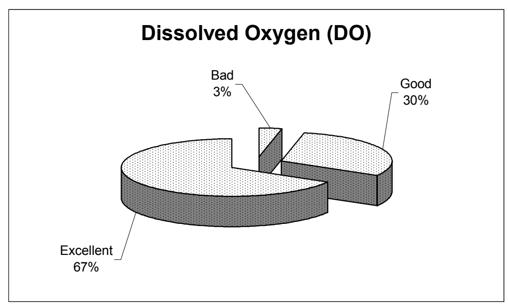


Exhibit 9: Trends for Nitrogen, Phosphorus, and NH4 for the South Fork at FP01 (Town of Shenandoah Dam)