The Health of the Shenandoah River in Shenandoah County: The FOSR Water Testing Program

January, 2003

A paper prepared by the Friends of the Shenandoah River with the cooperation of the Friends of the North Fork of the Shenandoah River

ABSTRACT

This report on the Health of the Shenandoah River in Shenandoah County is the third in a series on "The Health of the Shenandoah River: The FOSR Water Testing Program." It was prepared from monitoring data collected by the Friends of the North Fork of the Shenandoah River (FNFSR) and that was analyzed in the FOSR lab. The report can be found on the FOSR web page (www.fosr.org) in the near future.

It was found that the concentrations of nitrogen in the North Fork are high, and that the trends are rising. Starting at an average level of 1 ppm in early 1997 (already at the impaired level) it had reached 2.4 ppm by August 2002. Though not yet at the severely impaired level of 10 ppm, the annual increase in nitrogen is calculated at 0.2 ppm. Therefore, in 38 years (not long in the lifetime of a river) the concentration could, if nothing is done, reach the severely impaired level of 10 ppm. One of the reasons for the high level and high trend for nitrogen compared to compared to that for Page and Clarke county might be that Shenandoah County has many more poultry rendering and other animal processing factories.

The concentrations of nitrogen and phosphorus in the tributaries are also high, though not as high as the concentrations in the North Fork. Of the twelve creeks that are regularly monitored by the FNFSR, four have average levels of nitrogen below the impaired level. Of these, Passage Creek and Cedar Creek are very pure, with nitrogen at negligible levels.

Except for George's sewage treatment plant (STP) at Stoney Creek, the levels of nutrients from the Shenandoah County STPs are roughly comparable to those of Clarke and Page County. The George's STP on Stoney Creek is now under new management and is being modernized. There is hope that the very high average level of nutrients (116 ppm for nitrogen) under its previous operator (Rocco) will be brought down.

In summary, it appears that the Shenandoah County section of the North Fork is suffering from the same malady of high nutrient levels, except more so, than we observed for Page and Clarke county.

In principle, it is very possible to reverse the increasing trend in nutrient pollution, and there are numerous programs that can accomplish this. One of the better known programs is the Virginia Agricultural Best Management Practice (BMP) Cost Share Program. It subsidizes farmers to fence buffer zones around streams to reduce stream bank erosion from livestock, to create forest buffers, and to reduce non-point source pollution. This is being done by the FNFSR for Cedar, Mill, and Smith creek. Other programs focus on reducing pollutants emissions from STPs. Such programs, and others too numerous to mention, work well if carried out efficiently and if adequately financed. However, the trends we are now observing in the North Fork indicate that more needs to be done.

Acknowledgement

Water quality assessments in this report were made possible by volunteer work, non-cash contributions, and funding from:

- Members of the Friends of the Shenandoah River (FOSR)
- Friends of the North Fork of the Shenandoah River (FNFSR)
- Robins Foundation
- River Network, Canaan Valley Institute, and Izaak Walton League
- Shenandoah County Board of Supervisors
- Virginia Environmental Endowment (VEE)
- National Fish and Wildlife Foundation (NFWF)
- Chesapeake Bay Small Watershed Grant
- Chesapeake Bay License fund
- Pure Water 2000
- Environmental Protection Agency (EPA)
- Virginia General Assembly
- James Madison University
- Shenandoah University

Introduction

This paper[1] is one of a series of studies by the FOSR and its partners in the Shenandoah River Basin Watershed, and that 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 River in Clarke County. The second report covering the South Fork in Page County was completed in October 2001. This report is the third in the series, and discusses the health of the North Fork of the Shenandoah River and its major tributaries using monitoring data collected over more than six years by the Friends of the North Fork of the Shenandoah River (FNFSR).

This study analyzes the database accumulated by the FOSR over the past five and one-half years for Shenandoah County, and from monitoring data collected by the Friends of the North Fork. The report 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 In Stream Flow study now in progress for the North Fork, and planned for the South Fork.

The water quality indicators including nitrite-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 North Fork of the Shenandoah River is generally safe for swimming, fishing and for municipal water

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[1] Charles Vandervoort, a member of the FOSR prepared this report. The names of the FNFSR volunteer monitors who collected the data are shown in the Appendix. 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 Bob Luce, the Laboratory Director.. The author acknowledges the excellent cooperation and valuable contributions provided by Pat Maier, George Sylvester, John Kreitzburg, Ray Brownfield, and others from Shenandoah County, and the members of the FOSR who made this report possible.

supply (with treatment). The level of nitrogen in the North Fork, however, is very high; over the past 5 and one-half years it has exceeded the impaired level 80 percent of the time. The level for phosphorus is also very high and exceeds the impaired level more than 70% of the time. The concentration of NH4 is usually below the impaired level.

The fluctuations in these nutrient levels above and below the average are very large. For example, during the January 1997 to August 2002 time period the level of nitrite nitrogen in the North Fork varied from zero to a high of 28 (PPM[2]). 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 and its partners collect water samples at least once a month, and twice per month for most of the larger sites. Testing only once every quarter or twice per year, though saving money, could give misleading results, and would make it difficult to establish a trend.

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 along the Potomac River and Chesapeake Bay. And high levels of ammonia, even though temporary, can kill fish very quickly.

The water in the North Fork and its 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].

The pollution of the creeks in Shenandoah County is also high: of the twelve creeks analyzed in this report, six had average levels of nitrogen well above the impaired level. The most polluted was Pugh's Run with an average level of nitrogen at 2.2 ppm. The least polluted were Cedar Creek and Passage Creek. .The nitrogen levels in these creeks were negligible. For the past several years FNFSR has been carrying out Riparian Restoration projects on Cedar Creek, Mill Creek, and Smith Creek. These efforts may account for the low pollution levels in Cedar Creek (0.11 ppm), though the levels in the other two creeks are still too high.

Levels of DO, pH and T in the small streams were usually satisfactory though, after heavy rainfalls the turbidity often increases to high levels. High turbidity indicates that the river banks may be suffering from erosion.

To prevent further harm, intensified efforts are needed to protect our streams. Some of practices (called best management practices) that will help protect our streams are: reducing erosion and fertilizer runoff from farm fields, restoring streamside forested buffers (as now being done by the FNFSR), 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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[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

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

Chapter 1 The FOSR Laboratory and Data Base.

Over the past several years the volunteer monitors for the North Fork in Shenandoah County have taken water samples from the North Fork of the Shenandoah River and its tributaries at 36 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 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, nitrite-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 largely eliminates the direct exposure of the staff to hazardous reagents such as cadmium.

Virtually all aspects involved in the determination of the concentrations of nutrients, pH, dissolved oxygen, turbidity, and temperature of the Shenandoah River water samples are strictly set out in the FOSR Quality Assurance Project Plan (QAPP). The QAPP was approved in 1997 by the Virginia Department of Conservation Resources (VADCR) and by the U.S. Environmental Protection Agency. It specifies the protocols for sample collection, preservation, analytical methods, record-keeping, and presentation of the results.

FOSR's methods for analysis of nitrogen, orthophosphate, and ammonia are taken from Standard Methods for the Examination of Water and Wastewater (1992); they are methods 353.3, 365.4, and 350.1, respectively. All are colorimetric methods. Reagents that react with the chemical species of interest are added to the water sample. The absorbance of light at a specific wavelength by the colored solution is measured by means of a spectrophotometer. It is directly proportional to the concentration of the chemical species.

Since 2000, FOSR has upgraded its field and laboratory instruments, although the nutrient analytical methods have remained the same. A limited number of WTW Multiline P4 Field Instruments are now used to measure pH, temperature, and dissolved oxygen streamside. These data are being compared with measurements taken in the laboratory, within twenty-four hours of collection, with in-lab instruments. Also, the more rapid automated Lachat QuickChem Flow Injection Analysis Instrument has replaced the Colormetric methods for nutrient analysis in the laboratory.

Currently, the FOSR are revising their QAPP to follow the format favored by the VA Department of Environmental Quality. Acceptance of the QAPP by the VADEQ should bring increased recognition of the FOSR results.

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.org), which is now improved and kept up-to-date, and is upgraded from time-to-time.

The data collected include the water quality indicators pH (acidity), dissolved oxygen, turbidity, nitrite nitrogen, phosphorus, and ammonia. The FOSR is exploring how to broaden its testing program to include tests for fecal coliform and toxic materials such as mercury and PCBs.

Chapter 2 The FNFSR Monitoring Program in Shenandoah County

The total number of volunteer monitoring sites in Shenandoah County totals 30 (See Table 8-1). The monitoring at 10 of these sites, however, was carried out only for short lengths of time to, for example, conduct short-term studies or to collect specialized data. These sites are called "inactive" sites in this report.

The other 20 sites (See Table 5-2) which were monitored for most of the time during the January 1997 and October 2002 time period are called "active" sites. In this report the main focus will be on the active sites because their larger data base provides better estimates of trends and other statistics.

The North Fork has three active volunteer monitoring sites on the river: NS-15, North Fork at Route 55; NS-25, North Fork at Lupton Bridge; NS-26, North Fork at Chapman Landing, and there are 17 creeks that feed into the North Fork with monitoring sites on many of them.

The effluent from sewage treatment plants have been sampled at eight sites: NS-23, North Fork @ Woodstock STP; NS-28, Stony Creek @ Edinburg STP; NS-33, North Fork @ Mt. Jackson STP; NS-32, Stony Creek @ Bryce STP; NS-16, North Fork @ Strasburg STP; NS-O5, Toms Brook @ TB STP; NS-33, NF @ New Market STP; and NS-14, Georges Poultry Plant on Stony Creek.

Chapter 3 Friends of the North Fork of the Shenandoah River

Friends of the North Fork is a citizens organization in the Northern Shenandoah Valley dedicated to protecting and enhancing the purity, beauty, and natural flow of the North Fork of the Shenandoah River, its tributaries, and the basin groundwater."

Monitoring the river from 1988 to 1997, our volunteer laboratory technicians, Garland Hudgins and "Doc" L. G. Johnson, found trends of high nutrients and phosphates. Friends joined the Shenandoah River Watershed project in 1997 to have their samples tested along with all Watershed samples and this has shown the approximate same degree of contamination. Therefore, in the past few years Friends of the North Fork has entered into year-long Riparian Restoration projects on Cedar Creek, Mill Creek, and Smith Creek.

Results from taking such action has been successful, in that many citizens, through education by Friends, learned of programs they might take advantage of to protect the river. With the help of local and state agencies, i.e., Department of Environmental Quality, Natural Resources and Conservation Service, the Forest Service, Department of Conservation and Recreation, and Lord Fairfax Soil and Water Conservation District, Friends and citizens have performed restoration and conservation activities on the river and its banks to prevent non-point source pollution.

Friends continue to work with a framework of dedicated monitors and the citizens of Shenandoah County spreading river preservation.

Also working to preserve the North Fork is the Southeast Rural Community Assistance program, under Rob Arner, Pollution Prevention Technician, currently engaged in a *WellAware* Program on Smith Creek.

Chapter 4 Indicators of Water Quality and Suggested Standards

The Appendix gives a list and brief description of the water quality indicators currently used in the FOSR testing program[4]. These can be divided into the three nutrients consisting of nitrogen (nitrite nitrogen), phosphorus (ortho-phosphate), and ammonia (NH3 & NH4). 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.

Nitrite 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 nitrite 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 higher levels of N have caused methemoglobinemia [blue baby] in infants. Higher N levels can also seriously increase the number of still-births of cattle.

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

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[4] The FOSR has started monitoring for fecal coliform in several locations (none currently in Shenandoah County), and hopes to broaden its program to include PCBs and Mercury.

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 (NH3) and ammonium ion (NH4+). 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.

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.

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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

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

Chapter 5 General Overview of the North Fork, Tributaries, and STPs

Overall Statistics

Table 8-1 shows the average concentration measured over the past five years at all the Shenandoah County sites, including both the 10 inactive and the 20 active sites. (As discussed in Chapter 2, the sampling at the active sites was more frequent and was carried out over a longer time interval than for the inactive sites). It can be seen that some of the inactive sites have very high levels of nitrogen. However, since the inactive sites cover a much shorter time span than the active sites, their summary statistics tend to be less reliable. We will therefore focus only on the active sites.

Table 5-2 below presents the same information, but for the active sites. Of the twelve creeks, eight have average nitrogen levels above the impaired level of 1.0 ppm. In other words, more than 70% of the creeks contain excessive levels of nitrogen.

The pH which measures the acidity or alkalinity of the water should be between 6.5 and 8.0. If it is below 6.5 the water is to "acid," as could be caused by acid rain. If the pH falls above 8.0, it is too alkaline, and as could be caused by pollution from industrial waste.

In general, because of the limestone-rich soils through which the river and tributaries flow, the water is almost always at the proper level of pH. Without the limestone-rich soils the impact of the acid rains prevalent in the Shenandoah valley could have had an adverse effect on water quality.

North Fork

Nutrient Levels: Over the past five and one half years the North Fork of the Shenandoah River has carried excessive levels of nitrogen and other nutrients such as phosphorus and ammonia. The table below (see Table 5-1) shows that, since monitoring of nutrients started in January, 1997, the nitrogen levels[8] in the North Fork were impaired almost 81 percent of the time, and severely impaired 1% of the time. (Since the concentrations of nitrogen, phosphorus, and ammonia are fairly well correlated, we have simplified this exhibit by using nitrogen as the index for nutrient pollution). It is evident that the North Fork suffers from the disease of "excessive nutrients" so typical for many of the other rivers in the Shenandoah Valley and other parts of the USA.

On an individual basis, each of the three sections of the North Fork river has an average level of nitrogen well above the impaired level. In other words, the North Fork river is polluted along its whole length in Shenandoah County.

Table 5-1: Nitrogen Pollution in the North Fork

Level of contamination	Number of observations at indicated level	Percentage
Unimpaired: < 1 PPM	49	19%
Impaired: between 1 and 10 PPM	212	81%
Severely Impaired: more than 10 PPM	1	0%
		100%

[8] Since the concentrations of nitrogen, phosphorus, and ammonia are fairly well correlated, we have simplified many exhibits by using nitrogen as an index for nutrient pollution

The graph in Figure 8-1 shows the very high variability of nitrogen levels in the North Fork. This high variability is, of course, hidden in the averages contained in the table above.

The graph also shows the large spikes in nitrogen that appear from time to time. The detailed graphs and spikes for phosphorus and ammonia are not shown because they loosely follow those for nitrogen [9].

The graph also makes it possible to estimate the trend in nitrogen pollution: this trend seems to show a show a marked increase over time

Figure 8-14 shows the trend line and the average increase for nitrogen at the three active sites in the North Fork. The increase calculates at 0.2 PPM per year: an unacceptably high rate. Therefore, in 38 years (not long in the lifetime of a river) the concentration could, if nothing is done, reach the severely impaired level of 10 ppm.

Taken individually, each of the three sites on the North Fork shows comparable rates of increase, with Chapman's Landing (see Figure 8-5) having the highest at 0.3 PPM per year.

Though extrapolation of these trends could indicate very high levels of nitrogen pollution in the North Fork within, say, ten years, it must be kept in mind that the simple linear trends calculated here take into account only historic time-related information. Extrapolation basically assumes that the conditions in the past will also prevail in the future. They do not take into account, basically because we lack the quantitative information, other important factors affecting nitrogen pollution. These include, to mention just a few: rainfall, agricultural practices, land use and urbanization, industrialization with an especially important one being animal rendering factories, technological improvements for waste water treatment, and acceptance of BMPs. Once data on these factors become available, a more sophisticated trend analysis can be applied. In the meanwhile, however, the linear projections used in this report strongly suggest that problems lie ahead if nothing is done.

The Tributaries

The pollution of the creeks in Shenandoah County is also high: of the eleven creeks analyzed in the report, six had average levels of nitrogen well above the impaired level. The most polluted was Mill Creek @ Route 614 bridge (see Figure 8-8) with an average level of nitrogen at 2.2 ppm. At the other extreme, Cedar Creek and Passage Creek (see Figure 8-10) had negligible levels of pollution. As mentioned in Chapter 3, the FNFSR has an active program of riparian restoration for Cedar and other creeks.

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

Sewage Treatment Plants

An STP that was monitored from January 1997 to October 2001, a time span too short for classification as an active site, was that of the old Rocco chicken processing plant at Stoney Creek. The average discharge concentration of nitrogen during 2001, the last year of monitoring, was 114 ppm, and the highest recorded was 313 ppm (see Figure 8-11). In 2001, this plant was bought out by the George's corporation, and was completely modernized, including the more efficient treatment of its waste products. Though its effluent is not yet being independently monitored by any of the FOSR partners, the plant is reportedly operating at

[9] Though not shown here, the spikes for phosphorus and ammonia generally follow those for nitrogen, though the synchronization, at least as revealed by the FOSR data, is not perfect. This could be caused by the fact that monitoring takes place bi-monthly, and the monitoring date may come several days after the day of a major down pour. Also, the spikes caused by runoffs from land may not necessarily occur at the same time for nitrogen, phosphorus, and ammonia. For example, nitrogen runoff may occur shortly after a heavy downpour, whereas for phosphorus and ammonia, because their propensity to dissolve in water may be very different from that for nitrogen, the timing of the runoff may take longer. The FOSR plans to initiate research to shed light on this interesting question.

a much cleaner level. When the modernization is complete, hopefully by the end of this year, the FNFSR can start monitoring again, and the site can be returned to "active" status.

The active STPs, as expected, all carry very high levels of nitrogen in their affluent. The worst of these is from the Toms Brook STP (see Figure 8-13) which emitted nitrogen effluent carrying 13.4 ppm. Phosphorus is also very high at 7.46 ppm. Though at high levels, these discharges may not be harmful because they might fall into a stream that has a sufficiently high flow to quickly dilute the contaminants to levels where they do not harm humans or wild life. In fact, this is one of the considerations taken into account by the DEQ in determining the permitted level of contaminants in the discharge.

For example, NS 18 which is downstream and close to the Tom's Brook STP does not seem much affected by the pollutants from that STP. Its nutrient levels which, although on the high side (1.04 PPM for nitrogen) are lower than those for the other river sites located further away from an STP.

Table 5-2: Average Parameter Values (PPM) for <u>Active</u> Sites

Site ID	N.	P	Amm.	pH	Turb.	DO mg/L	Type	Name
NS13	2.1	0.2	0.3	7.5	1.7	7.6	Creek	Toms Brook above STP
NS22	2.2	0.1	0.2	8.0	1.7	9.4	Creek	Pugh's Run
NS40	1.7	0.1	0.4	7.9	2.2	8.6	Creek	Holman Creek Above Dam
NS41	0.9	0.1	0.3	7.9	1.9	8.0	Creek	Holman Creek Below Dam
NS42	1.8	0.5	0.5	8.0	4.4	8.6	Creek	Smith Creek @ Rt. 620 bridge
NS44	1.4	0.0	0.2	8.1	1.5	9.1	Creek	Tumbling Run
NS45	1.5	0.1	0.3	7.7	2.7	8.3	Creek	Town Run Below Car-wash
NS50	2.2	0.1	0.2	8.1	1.5	8.8	Creek	Smith Creek @ Rt. 614 Bridge
NS51	0.1	0.0	0.1	7.9	1.2	9.0	Creek	Passage Creek @ Herb Parker's
NS52	0.1	0.0	0.1	8.0	2.0	8.9	Creek	Cedar Creek @ 606
NS53	0.3	0.1	0.1	7.8	0.9	9.2	Creek	Passage Creek @ Moreland Gap
NS55	1.1	0.2	0.0	8.2	1.4	6.9	Creek	Smith Creek @ Moreland Gap
NS15	1.4	0.5	0.2	8.5	2.6	9.5	River	North Fork Shenandoah @ Rt. 55 Bridge
NS25	2.3	0.6	0.3	8.2	2.5	9.3	River	North Fork Shenandoah @ Lupton Bridge
NS26	1.9	0.3	0.7	8.2	2.9	10.1	River	North Fork Shenandoah @ Chapman Lndg
NS05	13.4	7.5	4.3	7.3	4.9	6.7	STP	Tom's Brook @ STP
NS34	5.3	3.1	3.4	7.6	1.9	5.5	STP	North Fork Shenandoah at New Market STP
NS23	13.1	5.5	1.0	7.1	2.1	6.1	STP	North Fork Shenandoah @ Woodstock STP
NS28	9.3	3.7	2.7	7.4	3.8	7.4	STP	Stoney Creek @ Edinburg STP
NS33	6.6	2.2	3.1	7.5	1.9	6.5	STP	North Fork Shenandoah @ Mt. Jackson STP
Impaired level	> 1.0 ppm	> 0.1 ppm	> 1.0 ppm	< 6.5 >8.0 ppm	>7.0	<5.0 ppm		

Chapter 6 Comparison of the North Fork with the South Fork and Main Stem

It is interesting to compare the findings for Shenandoah County with the results from earlier reports prepared by the Friends of the Shenandoah River on the Health of the Shenandoah River in Clarke County and Page County

Compared with the other two counties (see the table below), the average levels of nitrogen and phosphorus in the North Fork are much higher. The average nitrogen level in the North Fork at 1.87 PPM is considerably above the impaired level, and the trend for nitrogen concentration is rising. In comparison, the average nitrogen level in the Main Stem and South Fork are only 0.65 and 0.99 PPM respectively, though their trends are increasing.

Phosphorus in the North Fork at 0.47 PPM is also very much above the impaired level of 0.1 PPM. This is below the level of 0.70 for the South Fork but above the level of 0.36 for the Main Stem.

The level for ammonia for the North Fork in Shenandoah County at 0.44 ppm is somewhat above the level of 0.37 for both for Clarke and Page County.

For the creeks, the level of pollution in Shenandoah County are roughly comparable to those in the other two counties. In summary, the nitrogen levels in Shenandoah County are considerably higher than those for the more northern counties – could this be because of the larger concentration of chicken and other animal processing plants in Shenandoah County?

Table 6-1: Comparison of Average Values of Parameters of the Shenandoah River for Clarke, Page and Shenandoah County

	N, ppm	P, ppm	NH4, ppm	DO, ppm	pH	T
Clarke County						
Main Stem	0.65	0.36	0.37	9.98	8.20	3.91
Creeks	1.19	0.27	0.43	8.55	7.54	2.97
Page County						
South Fork	0.99	0.70	0.37	8.94	8.22	3.16
Creeks	0.80	0.13	0.26	8.77	7.75	1.59
Shenandoah County						
North Fork	1.87	.47	.44	9.66	8.26	2.69
Creeks	1.2	0.1	0.2	8.6	8.0	2.0

Chapter 7 The Trends

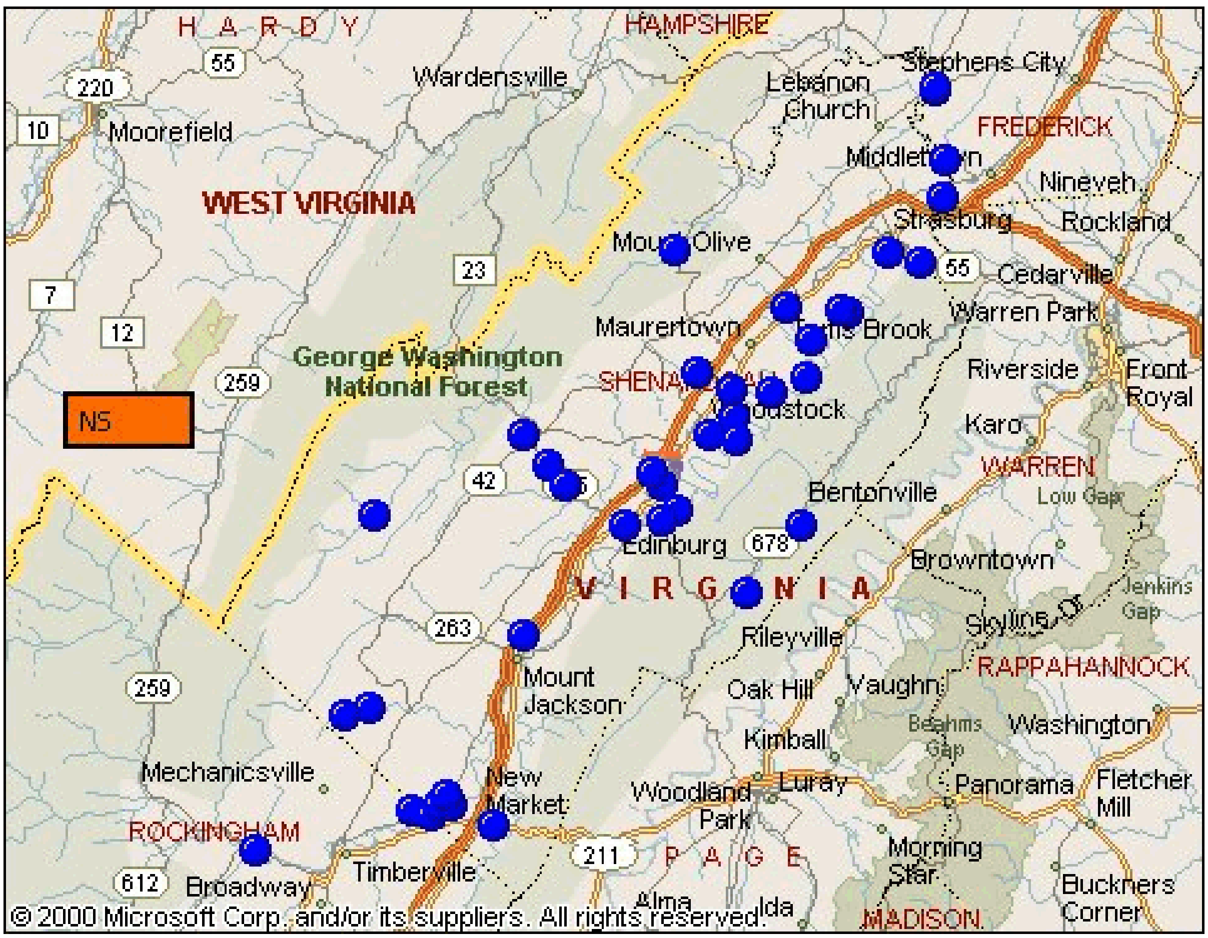
Except for the Mt. Jackson STP which shows a good decrease over time in nitrogen pollution(see Figure 8-17), the trends for nitrogen at the other STPs are up. For example, the increase in nitrogen at the Edinburg STP (see Figure 8-18) increased from 5 ppm early in 1997 to 14 ppm in late 2002, or at a rate of 1.5 ppm per year.

The overall trend for nitrogen in the creeks (see Figure 8-15) is slowly rising. Figure 8-16 shows details of the trend for nitrogen in Smith Creek at the Route 620 Bridge.

For the North Fork river as a whole (see Figure 8-14) the trend for nitrogen is also on the rise. Starting at an average level of 1 ppm in early 1997, the average level of nitrogen pollution by August 2002 had reached about 2.4 ppm. This works out to an annual increase of about .2 ppm.

Chapter 8 Exhibits

Map 8-1: Shenandoah County Monitoring Sites that are now monitored or were monitored in the past



Map 8-1 shows all the sites that are now being monitored by the FNFSR or that were monitored in the past.

Map 8-2 below identifies the 20 active sites that are now being monitored..

Map 8-2: Active Shenandoah County Monitoring Sites

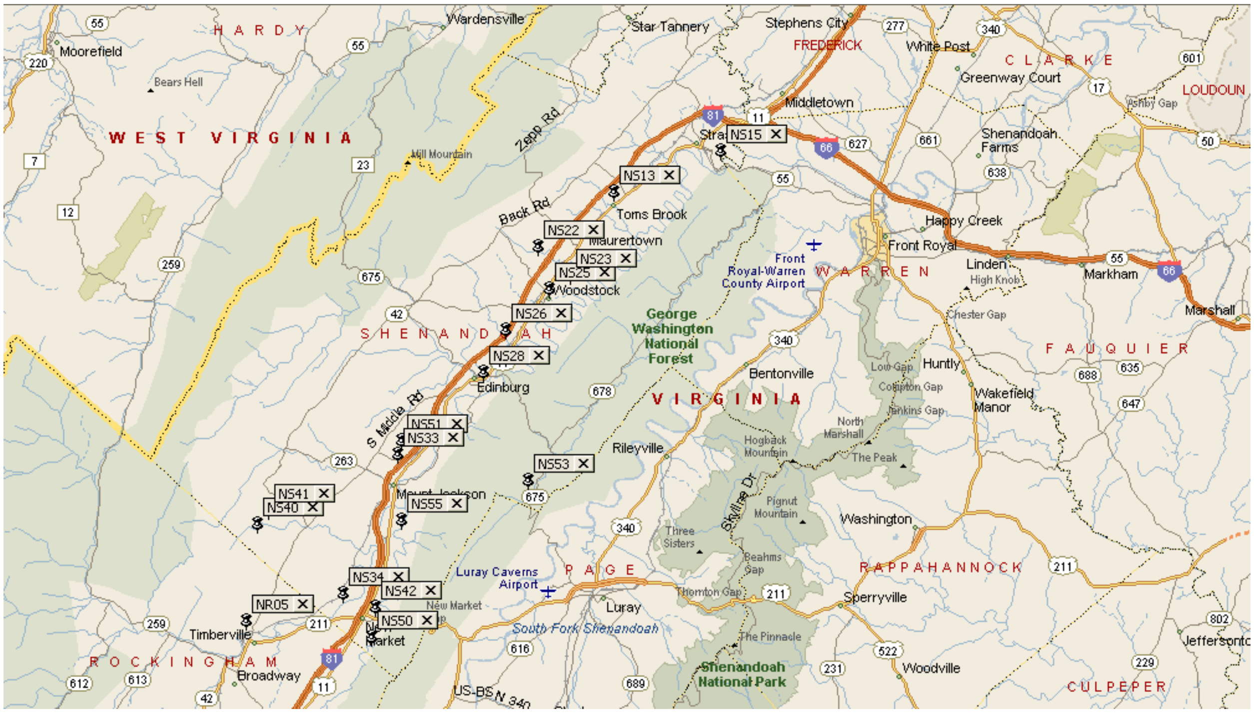
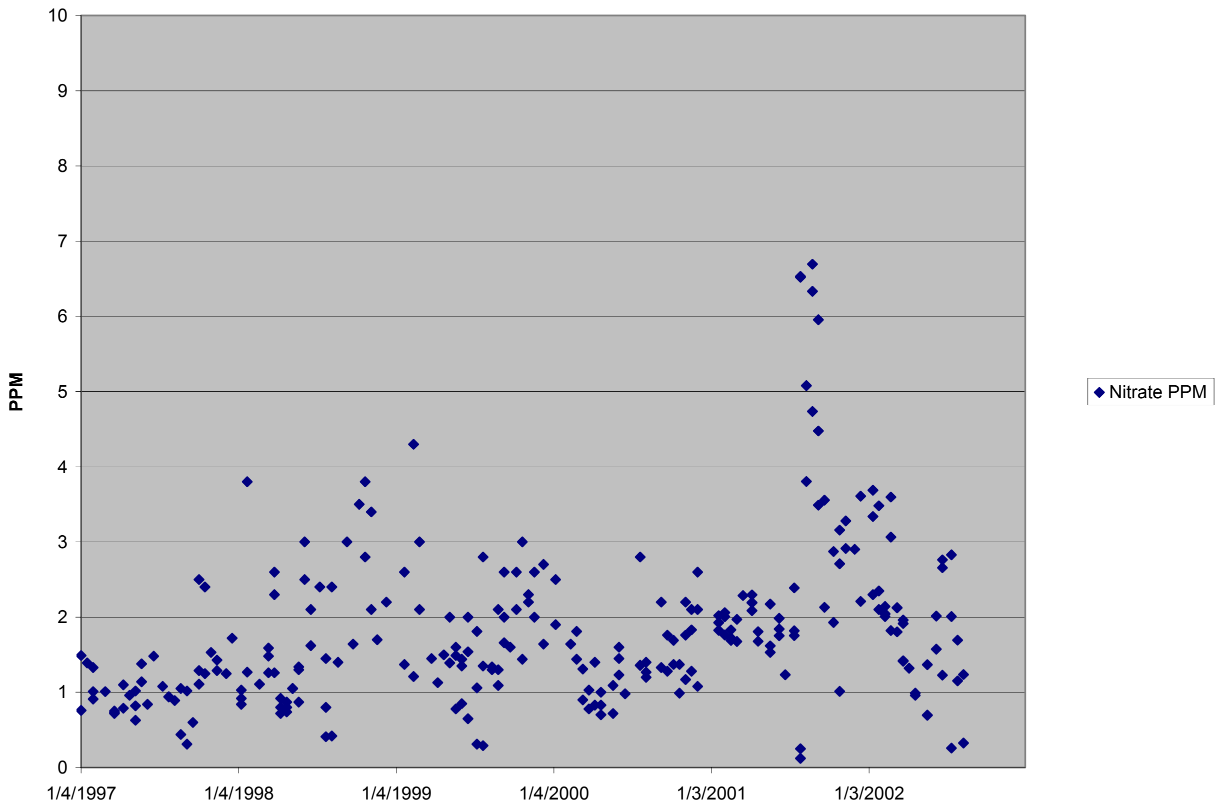


Figure 8-1: Nitrogen Impairment in the North Fork



The trend line for nitrogen in the North Fork is shown in Figure 8-14

Table 8-1: Average Parameter Levels at All Shenandoah County Sites (Active sites are shaded)

Site ID	Nitrite PPM	Ortho Phos PPM	Amm PPM	pH	Turbidity	DO mg/L	Site Name	Site Type
NS13	2.11	0.17	0.27	7.53	1.73	7.62	Toms Brook above STP	Creek
NS17	1.02	0.29	0.23	8.21	1.23	10.76	Posey Creek	Creek
NS22	2.16	0.07	0.21	7.97	1.68	9.40	Pugh's Run	Creek
NS29	9.18	5.05	0.26	7.91	1.13	9.65	Stoney Creek @682 Br.	Creek
NS30	0.17	0.06	0.16	7.93	0.90	9.42	Stoney Creek @ Rt. 675 Bridge	Creek
NS40	1.65	0.14	0.36	7.89	2.25	8.63	Holman Creek Above Dam	Creek
NS41	0.88	0.11	0.32	7.93	1.93	8.04	Holman Creek Below Dam	Creek
NS42	1.84	0.54	0.47	8.03	4.38	8.65	Smith Creek @620 Br.	Creek
NS43	0.91	0.36	0.50	8.32	3.31	10.49	Passage Creek	Creek
NS44	1.42	0.04	0.25	8.07	1.48	9.07	Tumbling Run	Creek
NS45	1.47	0.08	0.30	7.70	2.65	8.32	Town Run (Below Strasburg) Carwash	Creek
NS46	1.67	0.11	0.42	8.02	1.78	8.51	Mill Creek @614 Br.	Creek
NS50	2.16	0.07	0.23	8.13	1.52	8.76	Smith Creek @614 Br.	Creek
NS51	0.09	0.04	0.12	7.89	1.24	8.96	Passage Creek @ Herb Parker's	Creek
NS52	0.11	0.04	0.15	7.99	2.04	8.89	Cedar Creek @ 606	Creek
NS53	0.33	0.07	0.15	7.84	0.94	9.22	Passage Creek @ Moreland Gap Road	Creek
NS55	1.14	.19	.04	8.2	1.42	6.92	Smith Creek @ Moreland Gap Road	Creek
NS15	1.39	0.46	0.20	8.47	2.59	9.52	North Fork Shenandoah @ Rt. 55 Bridge	River
NS18	1.04	0.38	0.25	8.32	1.27	10.82	North Fork Shenandoah Confluence w/Posey Creek	River
NS24	2.17	0.69	0.45	8.16	3.95	8.91	North Fork Shenandoah @ Leisure Point	River
NS25	2.28	0.65	0.35	8.21	2.49	9.33	North Fork Shenandoah @ Lupton Bridge	River
NS26	1.86	0.31	0.71	8.17	2.95	10.07	North Fork Shenandoah @ Chapman Lndg	River
NS05	13.43	7.46	4.30	7.31	4.91	6.67	Toms Brook @ Sewage Treatment Plant (STP)	STP
NS14	116.04	60.00	0.72	6.95	3.88	7.54	Stoney Creek @ George's Sewage treatment Plant	STP
NS16	2.21	1.16	0.75	8.31	1.49	8.48	North Fork Shenandoah, Strasburg STP	STP
NS23	13.06	5.50	0.95	7.14	2.12	6.07	North Fork Shenandoah @ Woodstock STP	STP
NS28	9.30	3.69	2.70	7.43	3.80	7.40	Stoney Creek @ Edinburg STP	STP
NS32	4.58	2.21	2.30	7.78	1.48	8.69	Stoney Creek @ Bryce STP	STP
NS33	6.60	2.18	3.09	7.54	1.87	6.53	North Fork Shenandoah @ Mt. Jackson STP	STP
NS34	5.26	3.13	3.41	7.55	1.94	5.51	North Fork Shenandoah, New Market STP	STP

Figure 8-2: Phosphorus Impairment of the North Fork

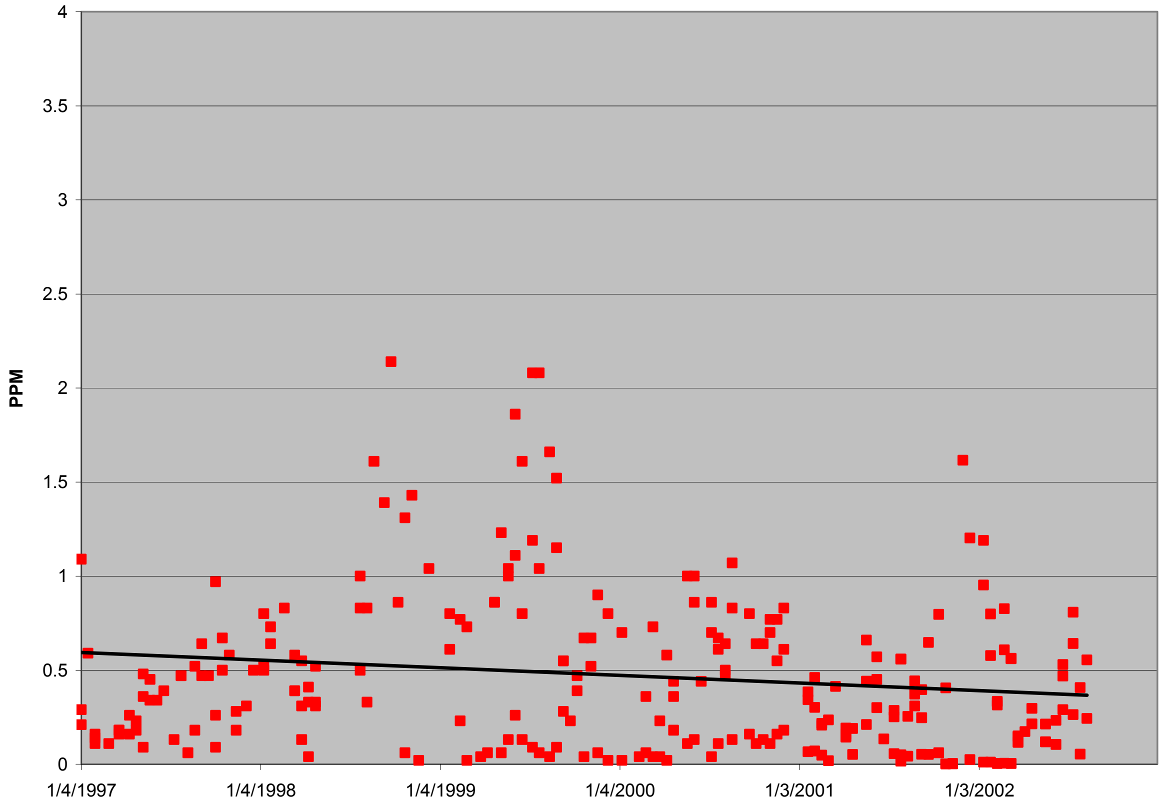


Figure 8-3: Ammonia Impairment in the North Fork River

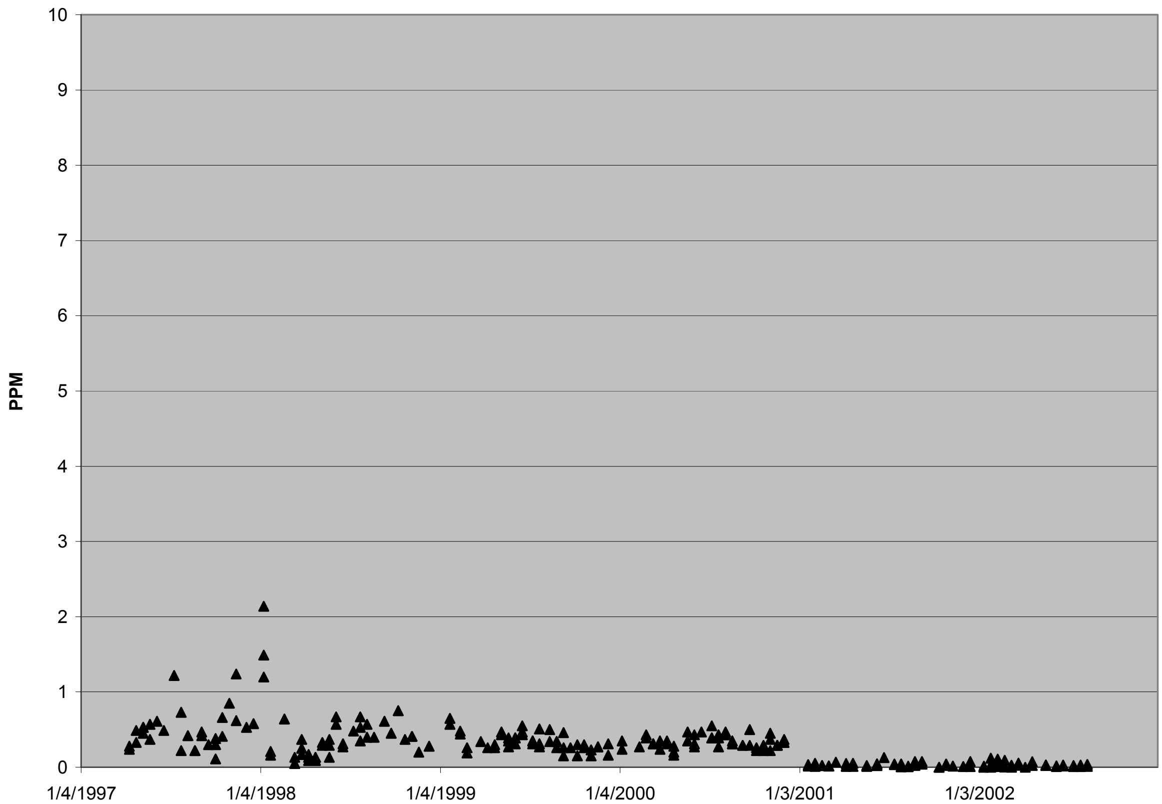


Figure 8-4: Levels of DO, pH, and Turbidity, North Fork

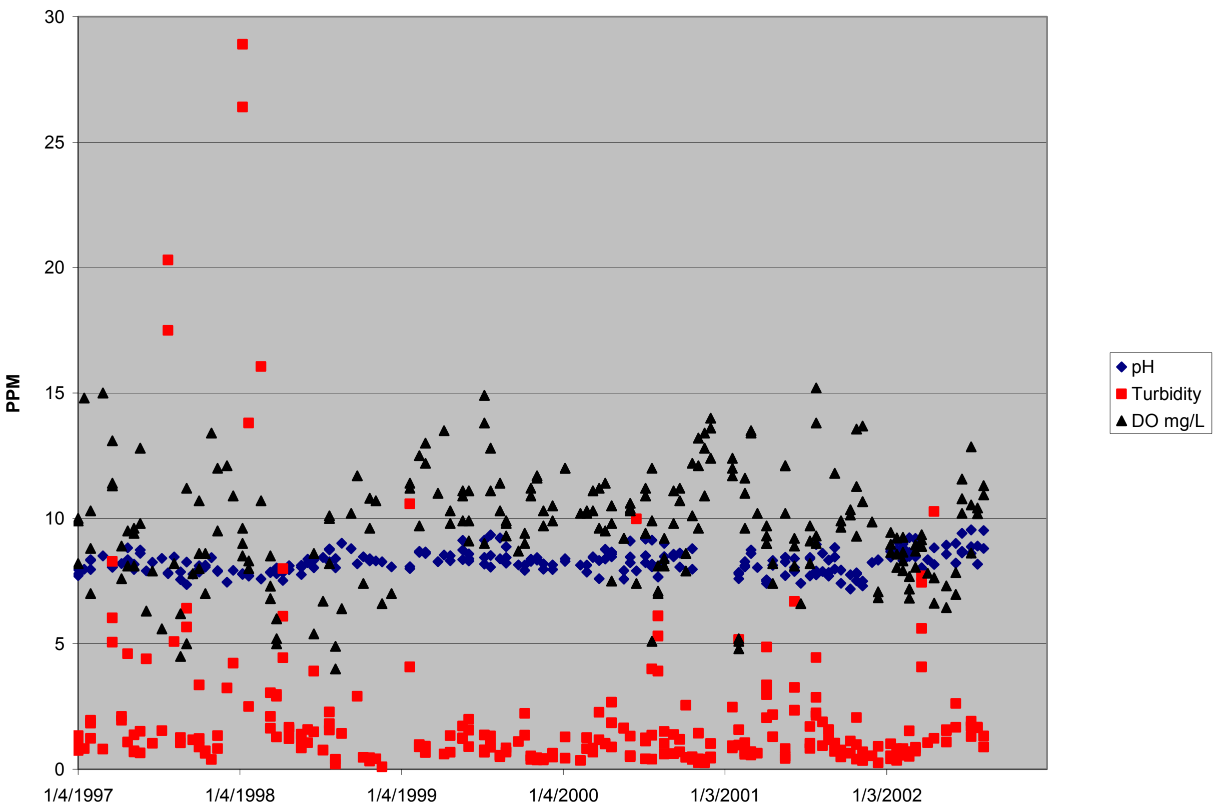


Figure 8-5: Trend for Nitrogen in the North Fork at Chapman's Landing NS26

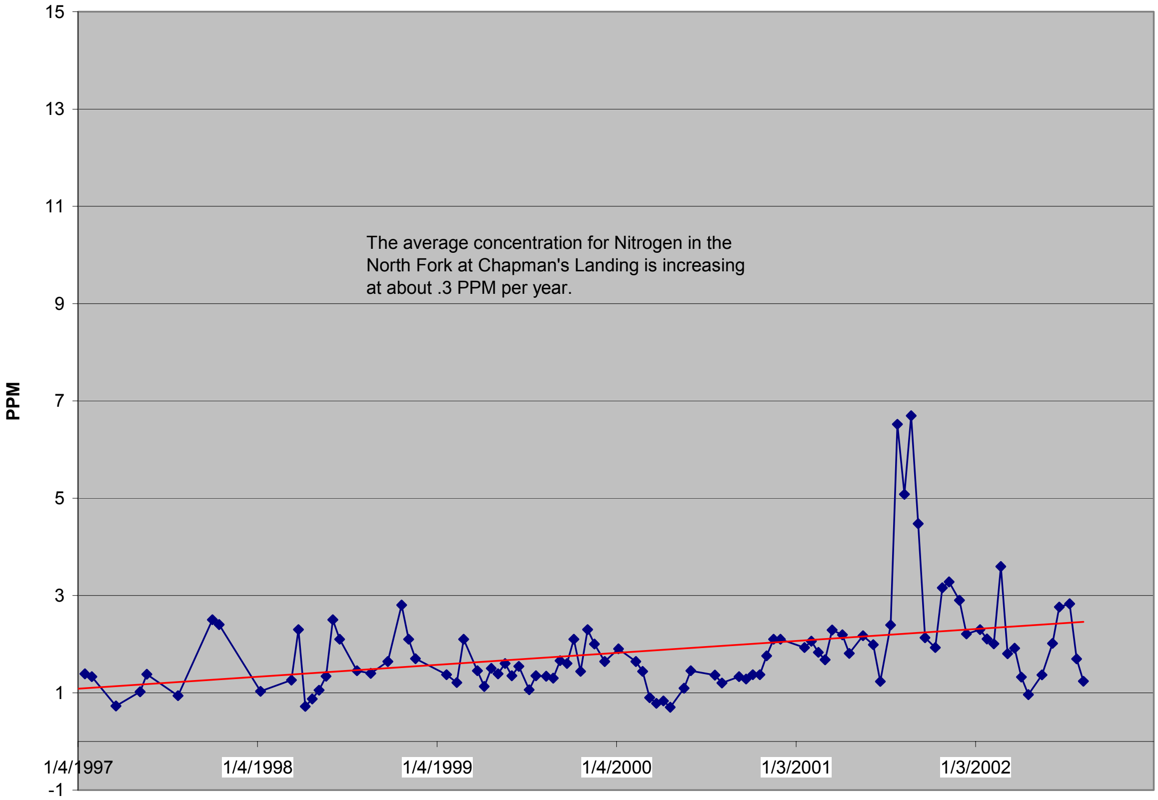


Figure 8-6: Exceedence Levels for Nitrogen (except STPs)

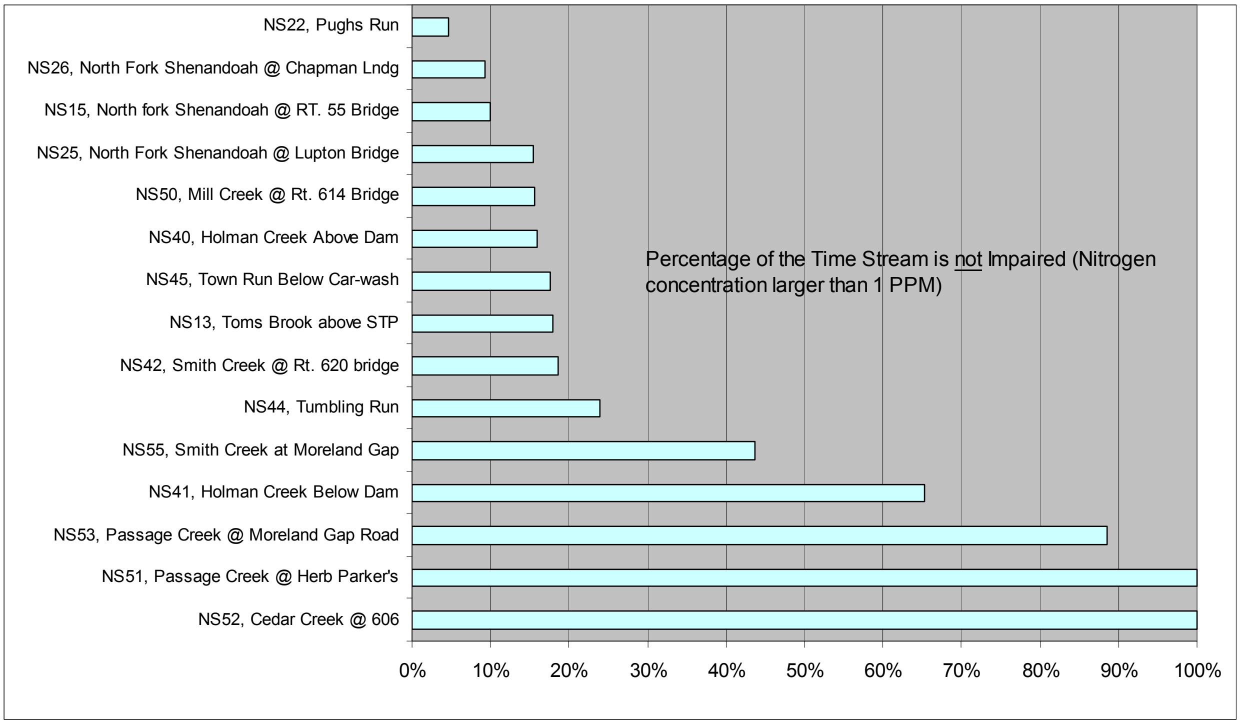


Figure 8-7: Average Concentration of N in Creeks, PPM

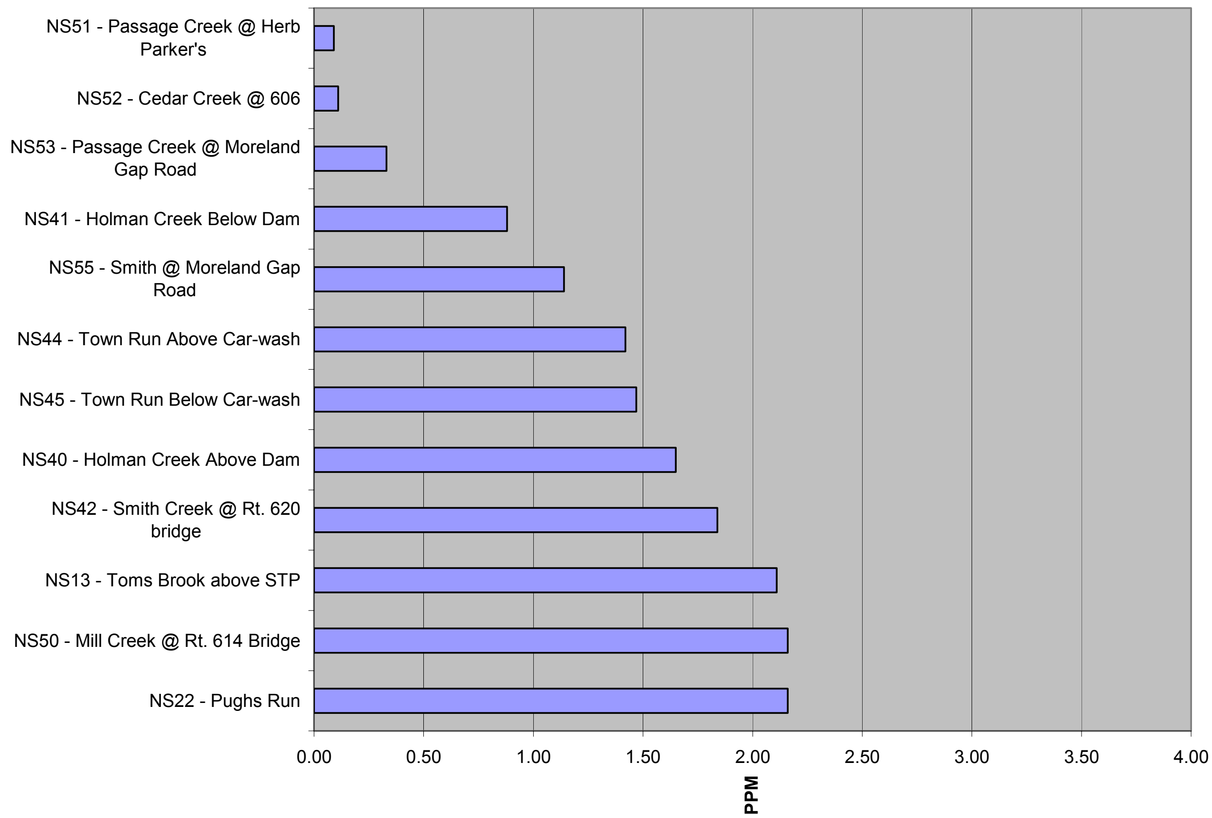


Figure 8-8: NS50, Mill Creek (highly polluted)

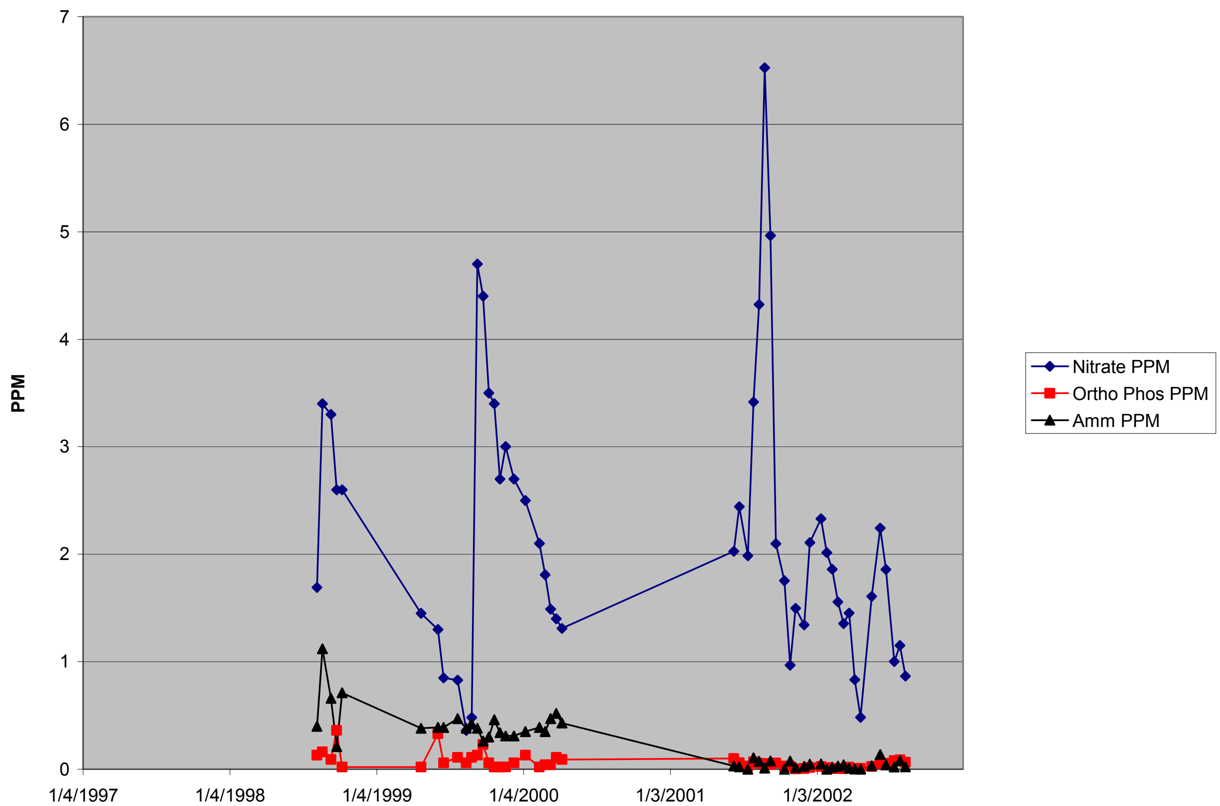


Figure 8-9: NS42 Smith Creek @ Rt. 620 Bridge (highly polluted)

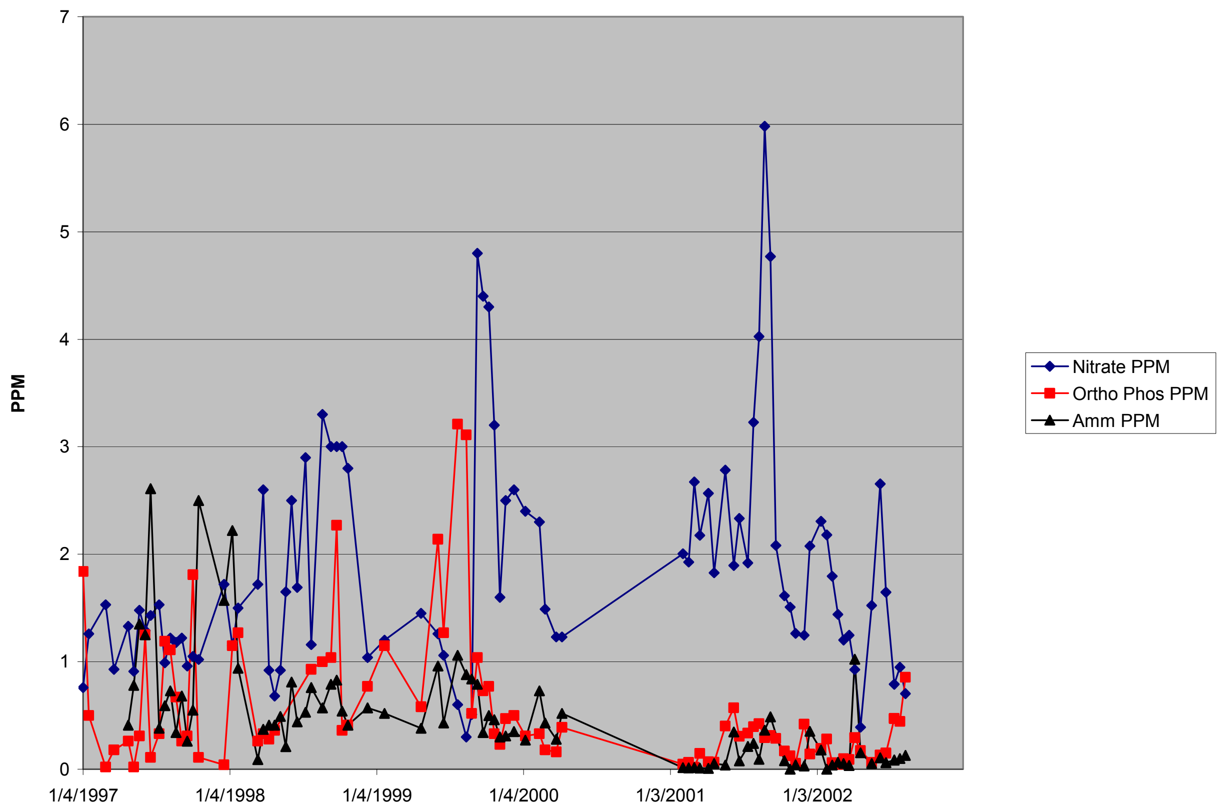


Figure 8-10: NS51 Passage Creek @ Herb Parker's (very low pollution)

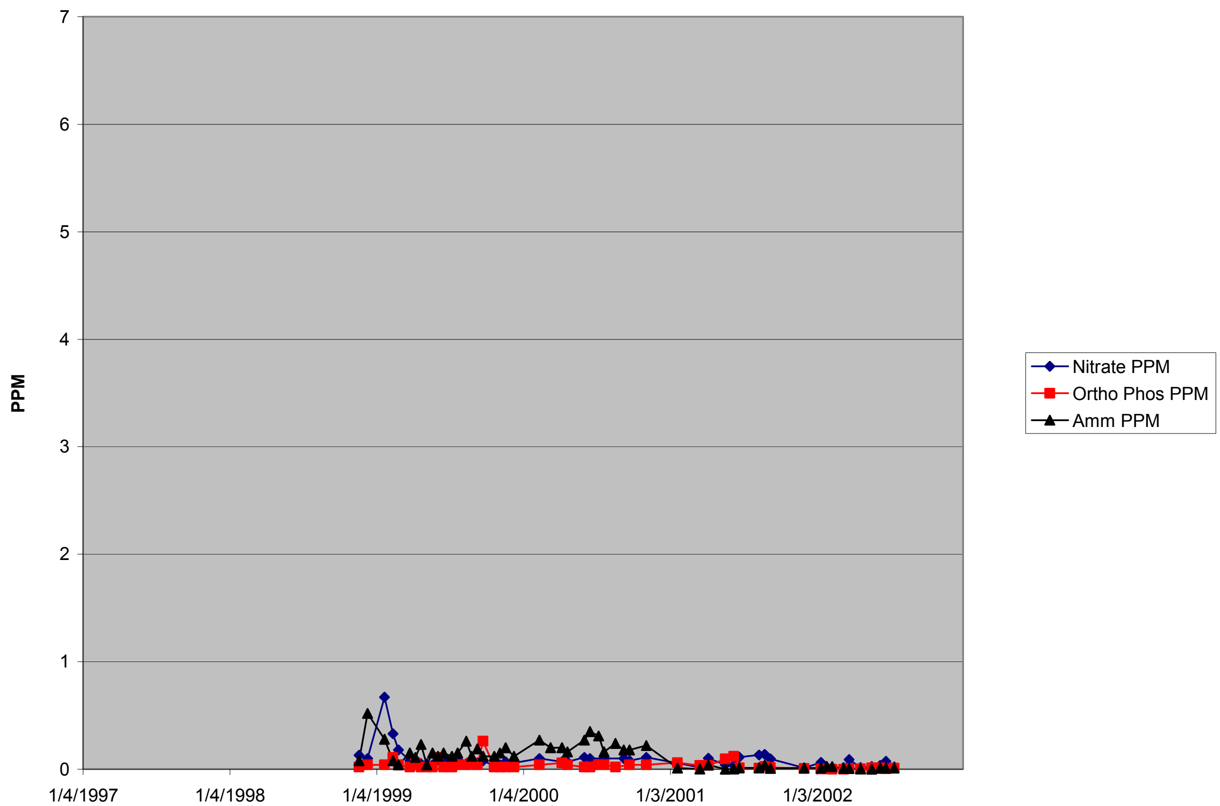


Figure 8-11: Stoney Creek at Rocco STP (NS14)

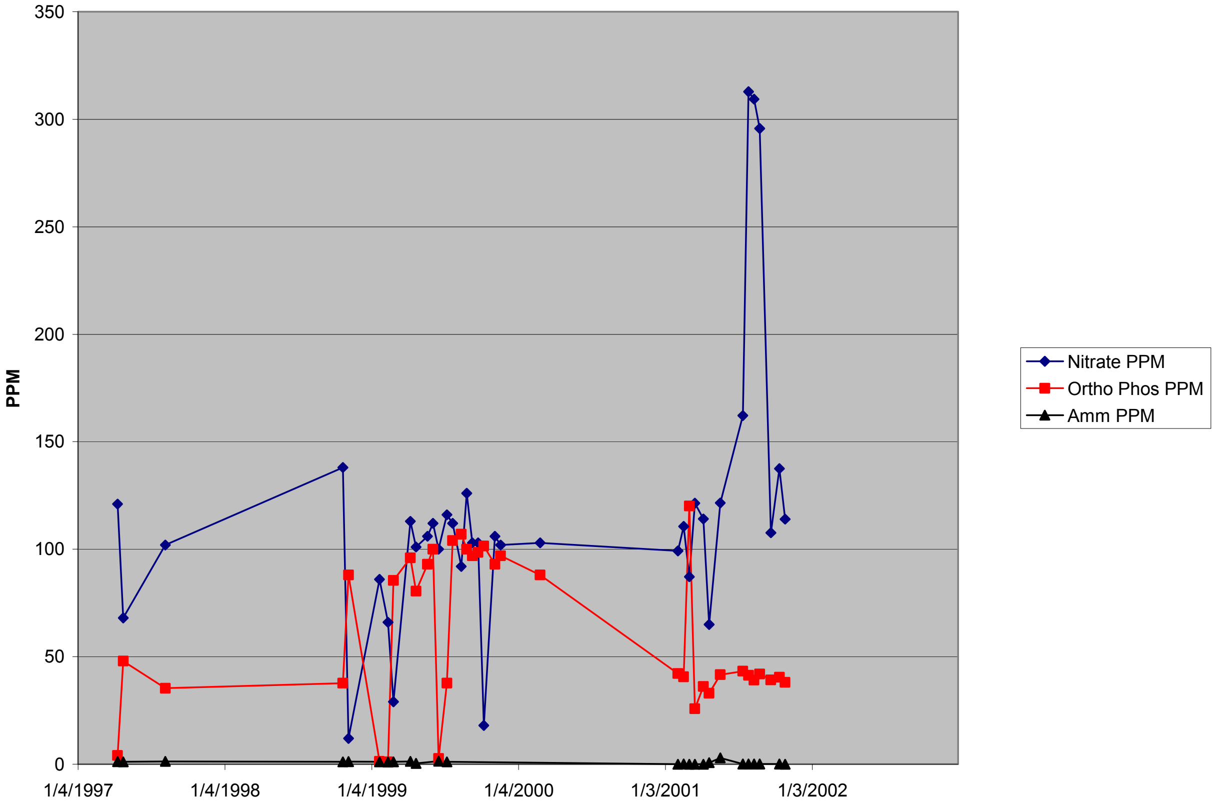


Figure 8-12: Stoney Creek @ Edinburg STP (NS28)

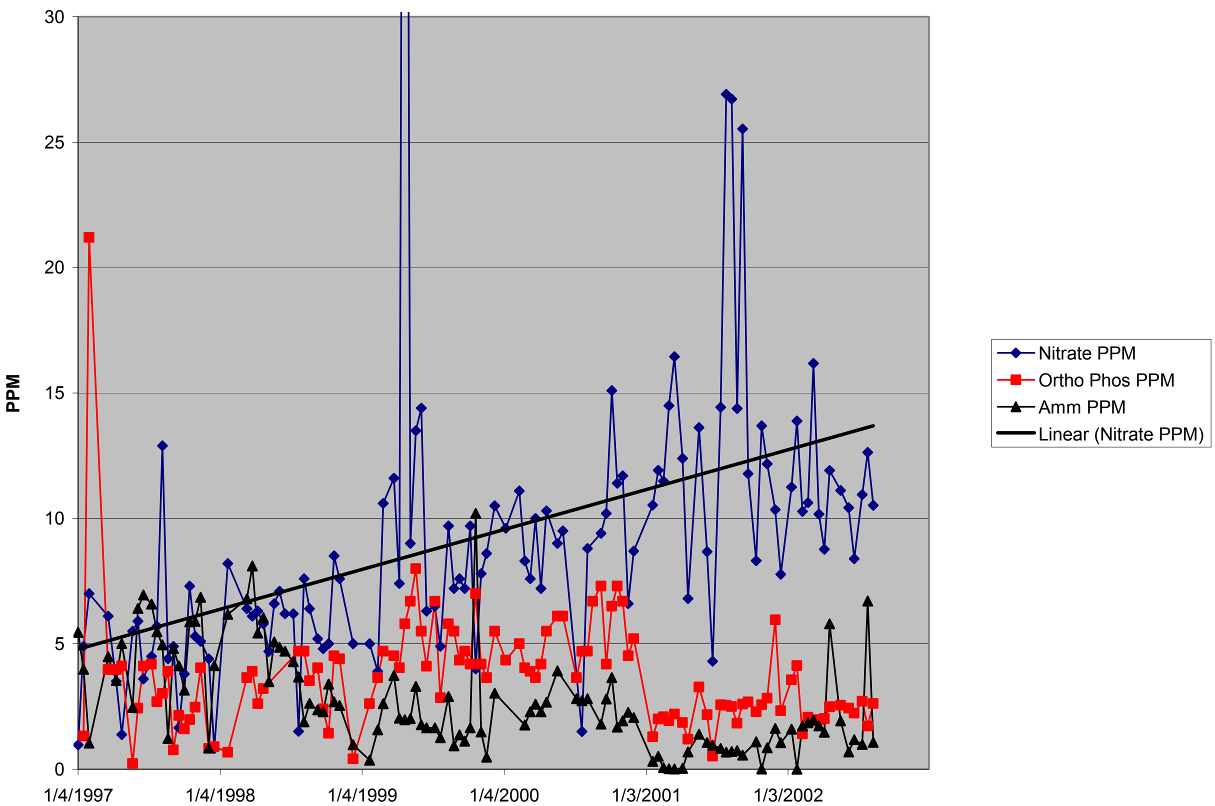


Figure 8-13: Toms Brook STP (NS05)

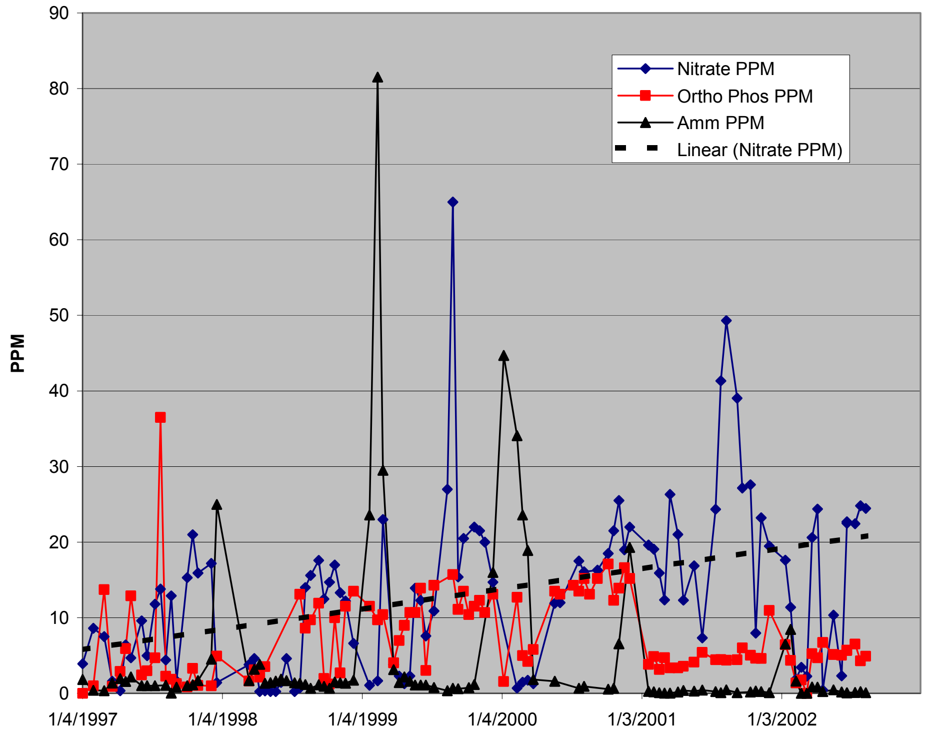


Figure 8-14: Trend for Nitrogen in the North Fork

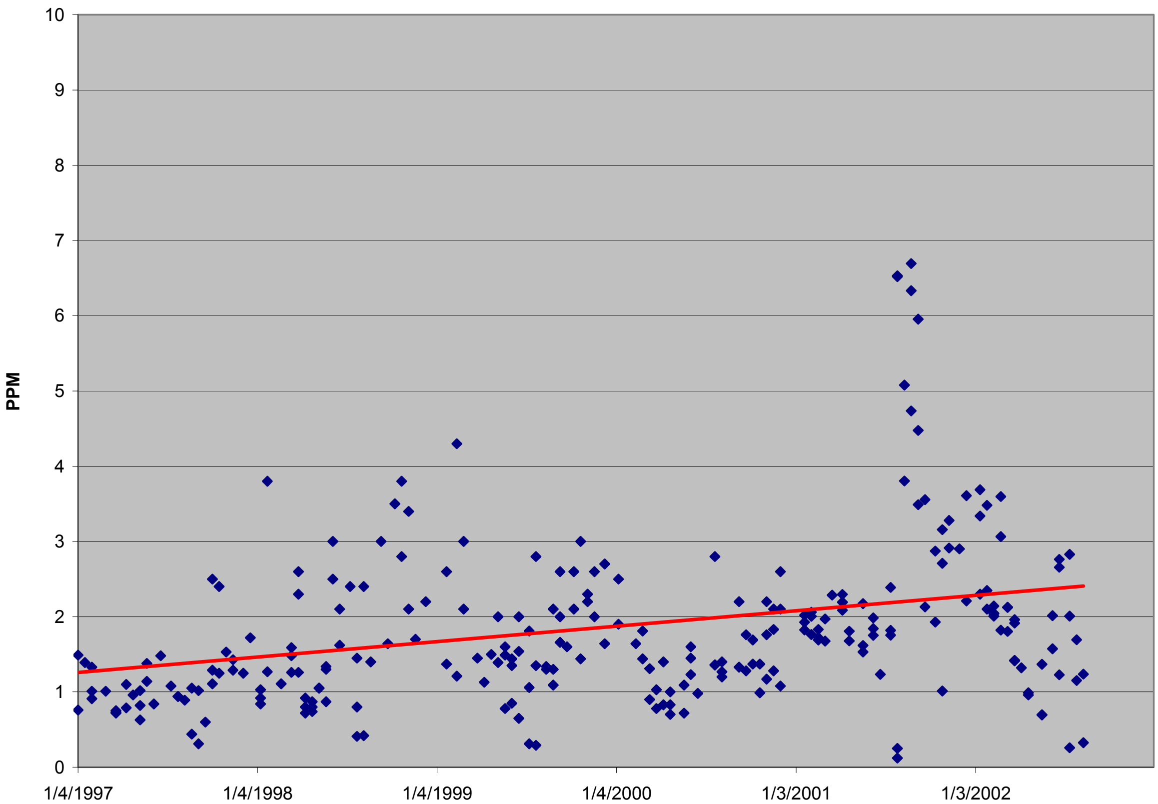


Figure 8-15: Trend for Nitrogen in the Creeks of Shenandoah County

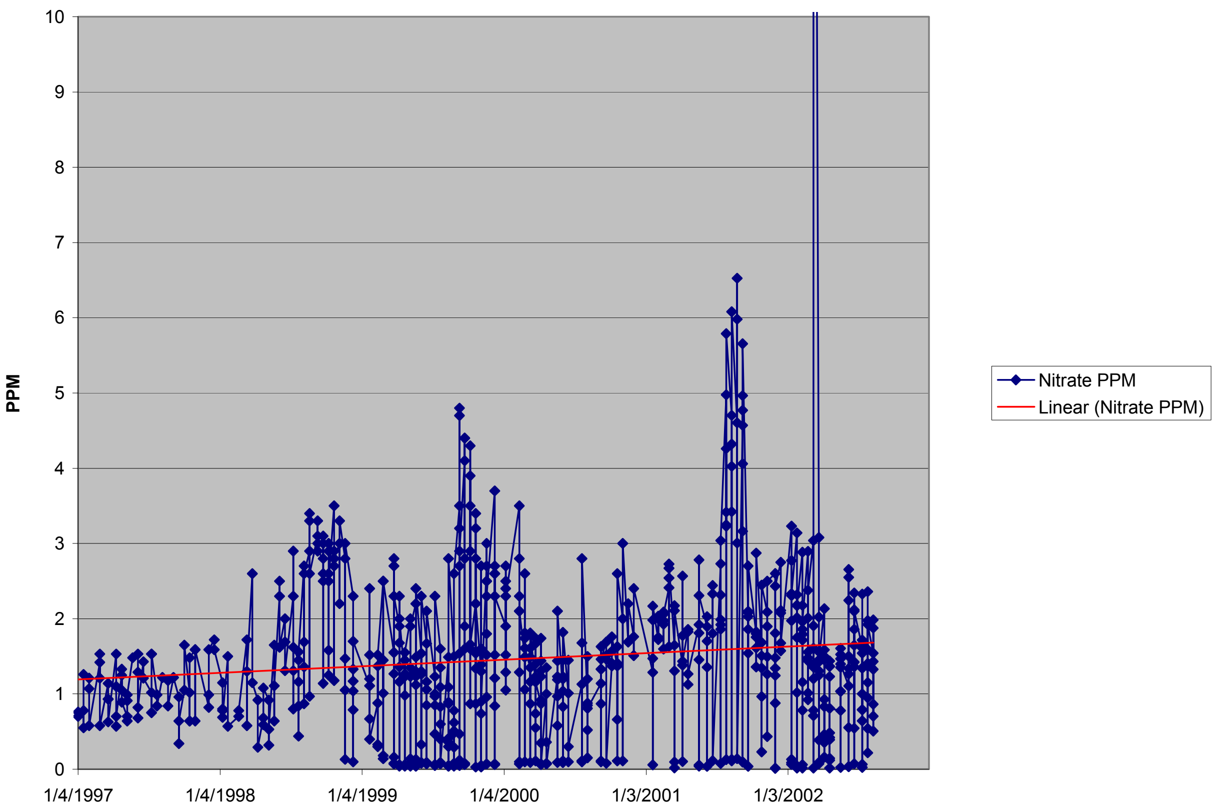


Figure 8-16: Trend for Nitrogen in Smith Creek @ Route 620 Bridge

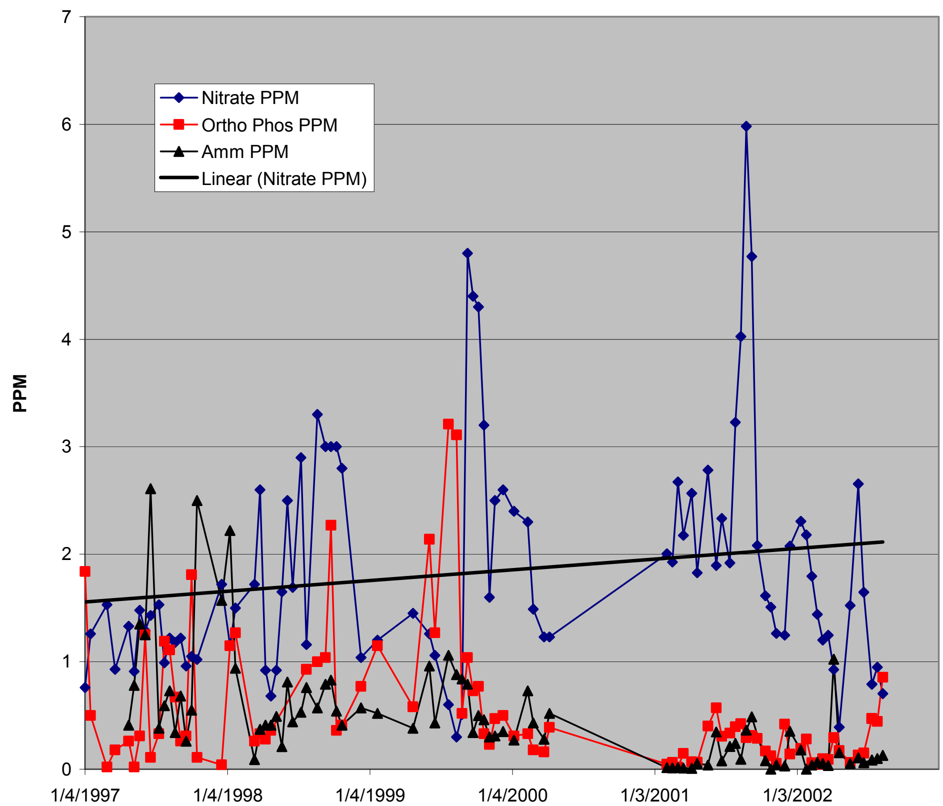


Figure 8-17: Trend for Nitrogen in the Mt. Jackson STP

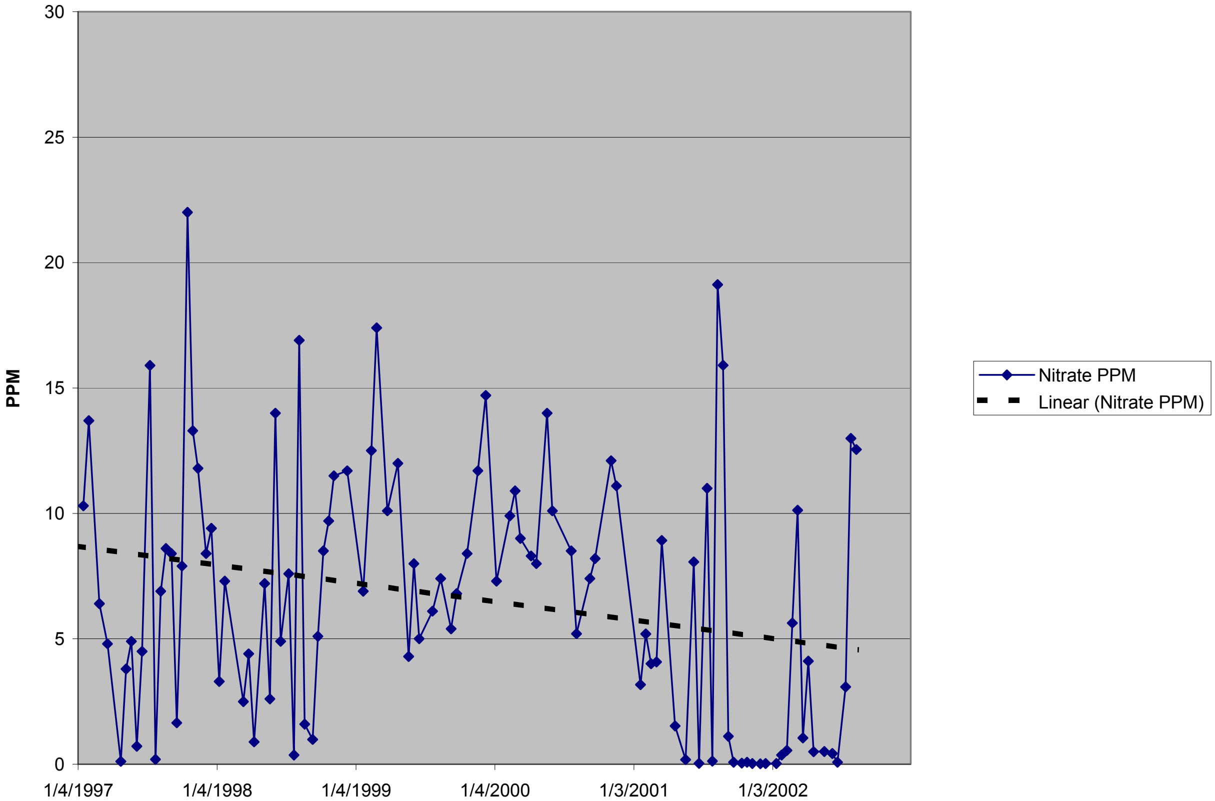
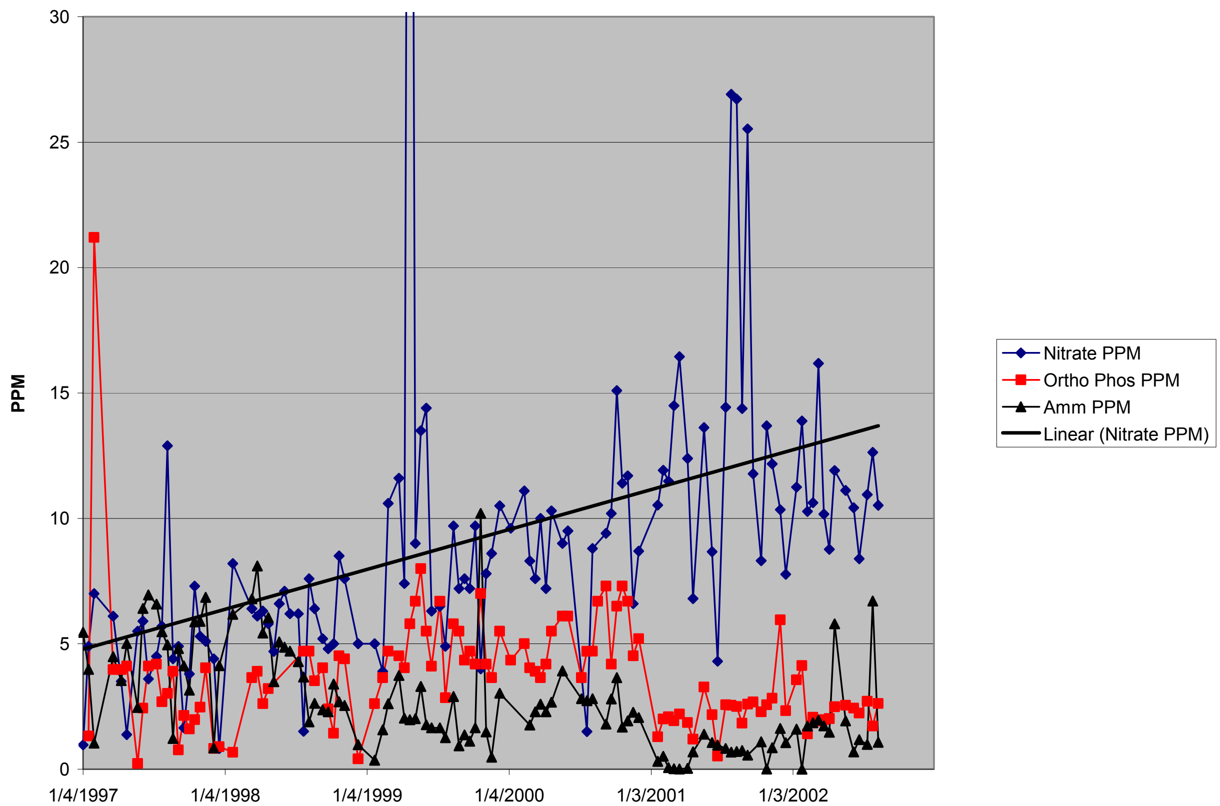


Figure 8-18: Trend for Nitrogen at the Edinburg STP (NS 28)



APPENDIX

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

Monitors: Friends of the North Fork Shenandoah River

The monitors of the Friends of the North Fork Shenandoah River who made this report possible include:

Principal Monitors as of October 1, 2002

Nancy Carr, Stephanie Cheff ,Olga Crotty, Ron Falyar, Jim Faulconer, Pieter Greeff, Charlotte Hughes, Jonathan Martin, Jay McKinley, Gale Netz, Larinda Palin, Herb Parker, Mike Ritchie, Ron Roller, Meredith Sine, Leonard. Siler, Beverly Veatch, Charles WaIters, Leslie Watson, Charlie Hockman, and the Wevers family.

The alternates included:

Pat Harrington, Jan Summerfeldt, Rick Mayo, and Pat Maier.

FNFSR Lab Technician: Gary Proctor,