BUFFALO CREEK TIME TIM

Low pH due to Atmospheric Deposition
PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION



SPRING 2004

Buffalo Creek TMDL

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Introduction

This report presents the Total Maximum Daily Loads (TMDLs) developed for stream segments in the Buffalo Creek Watershed. Buffalo Creek has been identified by the Pennsylvania Department of Environmental Protection (PA DEP) as not supporting its designated uses for the pH criteria on the state's 1996, 1998, and 2002 Section 303(d) list of impaired waters. This segment is also proposed for inclusion in the Pennsylvania's 2004 Integrated List of All Waters. A water quality criterion, as described in PA Code § 93.7, requires the pH to be between 6.0 and 9.0. This report is to address the impairments noted on the 1996 Pennsylvania Section 303(d) list of impaired waters, required under the Clean Water Act, and covers one segment on this list (shown in Table 1). Low pH level is the cause for these impairments. All impairments resulted from atmospheric deposition of acidic material. The TMDL addresses the pH by analyzing the balance between acidity and alkalinity.

Table 1: Buffalo Creek Listings on 303(d) List

			Sta	ate Water Plan	(SWP) Subbasin: 10-C		
Year	Miles	Name	Segment ID	Designated Use	Data Source	Source	Cause
1996	2.8	Buffalo Creek		HQ-CWF	305(b) Report	Atmospheric Deposition	pН
1998	2.89	Buffalo Creek		HQ-CWF	Surface Water Monitoring Program	Atmospheric Deposition	pН
20041	8.8	Buffalo Creek	20000712- 1100-GGM	HQ-CWF	Surface Water Assessment Program	Atmospheric Deposition	pН

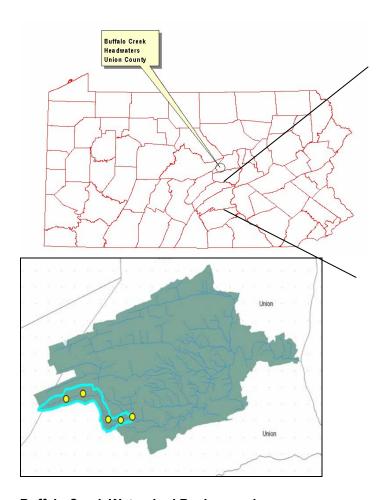
Directions to Buffalo Creek

The headwaters of Buffalo Creek are located in the Bald Eagle State Forest, northwest and north of the village of Hartleton. Hartleton is on Route 45, approximately 15 miles west of Lewisburg. Buffalo Creek flows east, through Mifflinburg and enters the Susquehanna River just north of Lewisburg. Figure 1 shows the approximate location of the Buffalo Creek Headwaters addressed by this TMDL. In the figure the Segment addressed in this TMDL is outlined as well as the location of sample sites within the watershed.

Figure 1: Location of Buffalo Creek Watershed

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¹ Pennsylvania's 1996, 1998, and 2002 Section 303(d) lists were approved by the Environmental Protection Agency (EPA), the 2004 list is still in draft form. The 1996 Section 303(d) list provides the basis for measuring progress under the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA*.

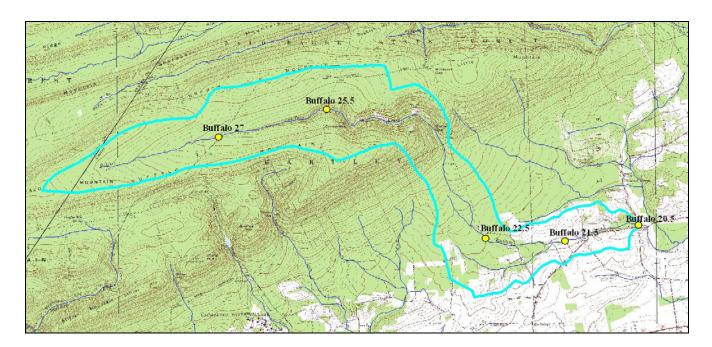


Lewisburg

Buffalo Creek Watershed Background

The Buffalo Creek watershed consists of forested upper third, a rapidly developing agricultural middle third and a lower developed third. The upper portion of the watershed is 60 % forested, situated in the Bald Eagle State Forest. The middle third of the watershed has lost approximately 30,000 acres of agricultural lands to development in the past 30 years. The upper third of the watershed which flows east from the headwaters to PA State Route 3005, considered impaired, is shown below in Figure 2.

Figure 2: Buffalo Creek Watershed Map



Acid precipitation is prevalent in the entire watershed, but the adverse stream effects are limited to the headwaters of the stream. The streams below, in the valley, are buffered by the limestone geology and are not acidified. Other problems resulting from agriculture and development are more widespread than those resulting from the acid precipitation. Stream bank erosion and sedimentation present problems for the instream biologic community in parts of the valley areas of Buffalo Creek, but these impairments are outside the segment addressed by the TMDL.

The Mifflinburg wastewater treatment plant has a history of water quality problems from sewage. The Mifflinburg Borough water supply sedimentation facility has a history of water quality problems resulting from chlorine residual.

The historic loss of wetlands in the watershed, once providing a riparian buffer, is another detriment. Additional habitat provided by these wetlands is gone.

Buffalo Creek Watershed Characteristics

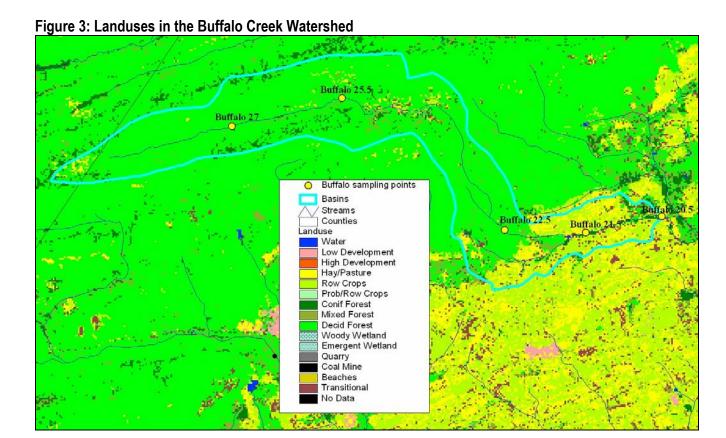
Buffalo Creek drains approximately 134 square miles and flows approximately 28 miles through the Appalachian Mountain section of PA's Valley and Ridge Province in central PA. The creek originates from the sandstone ridges northwest of Hartleton (eastern Centre County) and joins the West Branch Susquehanna River at Lewisburg. The majority of Buffalo Creek flows through Union County.

The upper reach is first order, drains forested sandstone ridges, and is classified as a High Quality Cold Water Fishery. The gradiant is about 250 feet per mile and cobble/boulder substrates predominate. The stream channel is 2 to 3 meters wide and the maximum depth is 0.4 meters. Mixed hardwoods and hemlock border most of the stream and in some areas the stream runs through dense rhododendron thickets.

The middle reach, which drains farmland and small residential development, is underlain by limestone and shale formations and ranges from third to fourth order. This reach is classified as a Cold Water Fishery and is stocked by the PA Fish and Boat Commission with hatchery trout.

There are currently no point source discharges in the watershed that may contribute to the low pH condition.

The various land uses of the upper Buffalo Creek watershed are shown in Figure 3 below, as generated by the AV-GWLF model.



loam soils similar to those on the Allegheny High Plateau and Allegheny Mountains sections are found on the forested ridgetops. Colluvial soils that are a mixture of sandstone and shale are found on the slopes. In the valleys, limestone-derived soils predominate, although some are shale-derived. The limestone-derived soils are among the most productive in Pennsylvania. They are usually deep, well drained, have high root zone available water-holding capacity, and have few rock fragments. The shale-derived soils are less productive because of their acidic nature, steep slopes, and generally low root zone available water-holding capacity. The soils in the valleys are on level or undulating land, and erosion potential is low to moderate. The valley soils are used intensively for agriculture.

The upper Buffalo Creek watershed is located in the "Ridge and Valley" physiographic province. This province is characterized by sandstone ridges, shale footslopes, and shale and limestone valleys. Sandy

The soils from the upper watershed are shown in Figure 4 below.

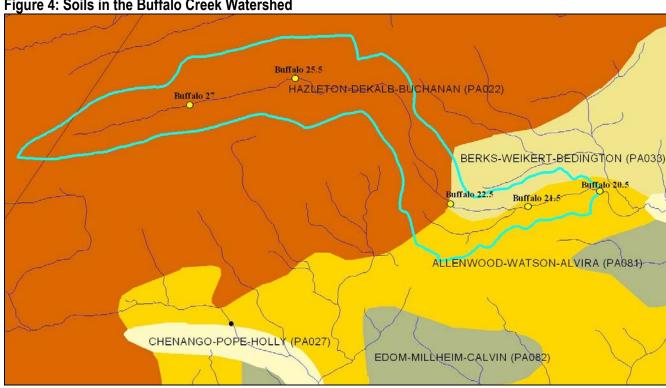
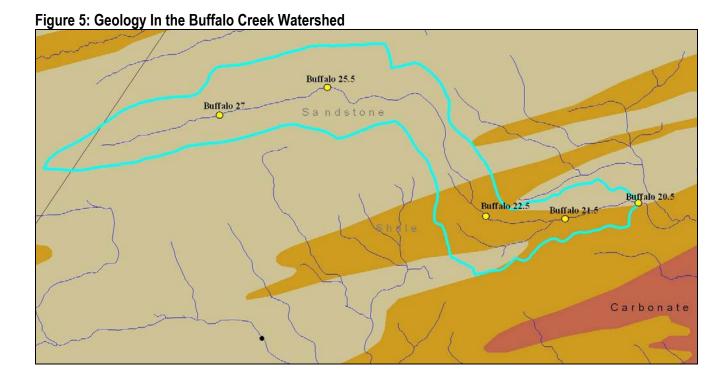


Figure 4: Soils in the Buffalo Creek Watershed

The geology is shown in Figure 5.



Buffalo Creek Assessment History

A December 30, 1998 Aquatic Biological Investigation (ABI) (performed by Department personnel) report noted the acid precipitation effects on the headwaters of the stream. It was also noted, at the time, that the reach will remain on the 303(d) list.

A March 15, 1994 ABI report focused entirely on the upper Buffalo Creek watershed. The study concluded that upper Buffalo Creek has lost all buffering capacity. Because there is no mining in the watershed and the stream does not originate in an acidic swamp, acid precipitation is the most likely cause. The benthos community was depressed at river mile (RM) 24.8 and less so at RM 22.0. Acid-sensitive Mayflies were absent at RM 24.8 and scarce at RM 22.0. An acid-tolerant group of Stoneflies dominated both collections. No brook trout were present at RM 24.8 and only several adult brook trout were present at RM 22.0. The study concluded that lack of fish was due to the acid precipitation.

The listing, from the Category 5 of the proposed 2004 Integrated List (formerly 303(d) list), is shown in Figure 6. The listing in the proposed new list does not contain any changes since the 2002 list.

Figure 6: Buffalo Creek listing in the proposed 2004 Integrated List

	Category 5: Impaired Streams	Requiring	TME)Ls		
AssessmentID	Source/Cause	List Date	Tmdl Date	Down RMI		Use Assess
	Stream Name=Buffalo Creek Watershed	d=10C Code:1	<u> 3920</u>			

Buffalo Creek Fishery

Even though the headwaters (source to SR 3005) are classified as High Quality – Cold Water Fishery, the majority of fish are found in the valley. The low pH of the headwaters precludes population of the watershed with a viable fishery.

Acid Precipitation

Acid rain, more properly called acid deposition, is caused by the emission of various pollutants to the air. The principle sources are the smokestacks of fossil fuel power plants, other industrial facilities and automotive exhausts. These emissions contain sulfur dioxide (SO2), the major contributor to the problem, and nitrogen oxide (NOx). These gases combine with oxygen and water vapor in the air to form sulfuric and nitric acids. The acids fall to the earth in two forms of deposition. When precipitation such as rain, sleet or snow containing dissolved sulfuric or nitric acid falls to the ground, it is termed wet deposition or "acid rain." If the acids descend as sulfate or nitrate particles, it is labeled dry deposition.

These acids, suspended high above the earth, may be carried hundreds of miles by the wind before they eventually drop or wash down. That's why acid rain is a problem that has no borders or territories. Compounding the problem is the fact that emissions are not spread out evenly. In the United States, almost half of all SO2 and NOx emissions produced come from seven states in the coal-burning Ohio River Valley and Missouri and Tennessee. The wind carries the gases in a northeasterly direction toward the Mid-Atlantic States, New England and Canada.

When acids enter lakes and streams, the effects on aquatic life can be devastating. Organisms ranging from fish and frogs down to microscopic plankton cannot survive in highly acidic waters. The low pH level can halt or disrupt the reproductive cycles of these organisms. The Pennsylvania Fish and Boat Commission warns that acid rain poses a threat to over 5,000 miles of streams it stocks annually.

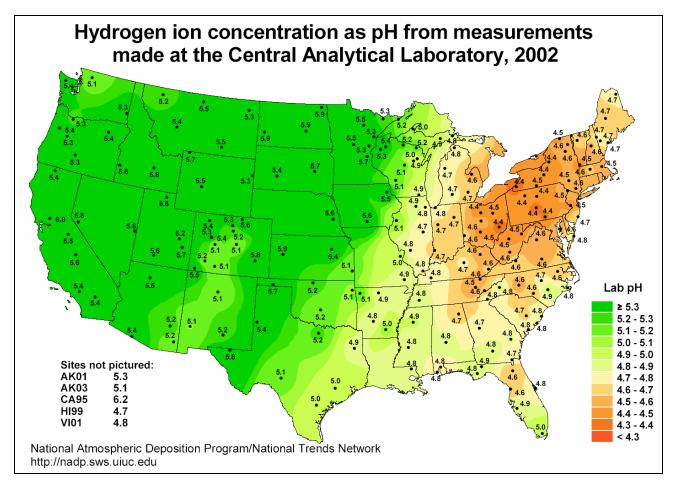
Many of PA's sandstone ridge watersheds, like that of Buffalo Creek, are susceptible to acid runoff events, due to the lack of buffering offered by the geology.

The **National Atmospheric Deposition Program/National Trends Network** (NADP/NTN)is a nationwide network of precipitation monitoring sites. The network is a cooperative effort between many different groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities.

The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The precipitation at each station is collected weekly according to strict clean-handling procedures. It is then sent to the Central Analytical Laboratory where it is analyzed for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium).

An evaluation of these data reveals that the area of Pennsylvania that includes Buffalo Creek has persistent low pH precipitation. The average pH values are in the 4.3 to 4.4 range, which is consistent with the instream sampling data that was collected as part of this study. Figure 7 shows a map of pH values collected by NADP in 2002.

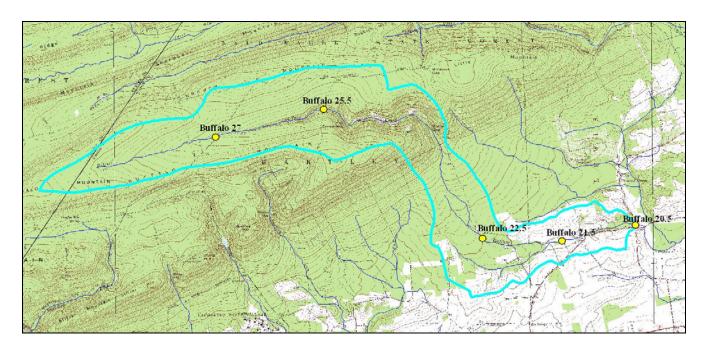
Figure 7: pH values from NADP



Sampling

The chemical sampling for Buffalo Creek was performed at 5 sites along the stream. These occurred at River Miles of 27, 25.5, 22.5, 21.5 and 20.5 as measured stream length to the junction of the West Branch of the Susquehanna River at Lewisburg. The sampling sites were chosen to be representative of changing environmental conditions in the watershed. Sites were placed where there was a change in either landuse, topology, soils, or geology. Chemical samples were taken at each sampling location, and sent to the Pennsylvania Department of Environmental Protection laboratory for analysis. Below in Figure 8 is a map that shows the sample locations. Samples were collected in January 2004, May and July 2003 to represent the most critical seasonal conditions.

Figure 8: Map showing sampling locations in the Buffalo Creek Watershed



Clean Water Act Requirements

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support the uses. Uses can include drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be "fishable" and "swimmable."

Additionally, the federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) implementing regulations (40 CFR Part 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the
 designated use of the waterbody; states must also identify those waters for which TMDLs will be
 developed and a schedule for development;
- States to submit the list of waters to USEPA every two years (April 1 of the even numbered years);
- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and
- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Despite these requirements, states, territories, authorized tribes, and USEPA had not developed many TMDLs. Beginning in 1986, organizations in many states filed lawsuits against the USEPA for failing to

meet the TMDL requirements contained in the federal Clean Water Act and its implementing regulations. While USEPA has entered into consent agreements with the plaintiffs in several states, other lawsuits still are pending across the country.

In the cases that have been settled to date, the consent agreements require USEPA to backstop TMDL development, track TMDL development, review state monitoring programs, and fund studies on issues of concern (e.g., AMD, implementation of nonpoint source Best Management Practices (BMPs), etc.).

The TMDLs in this report were developed in partial fulfillment of the 1996 lawsuit settlement of *American Littoral Society and Public Interest Group of Pennsylvania v. EPA*.

Section 303(d) Listing Process

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be on the Section 303(d) list. With guidance from the USEPA, the states have developed methods for assessing the waters within their respective jurisdictions.

The primary method adopted by the Pennsylvania Department of Environmental Protection (DEP) for evaluating waters changed between the publication of the 1996 and 1998 Section 303(d) lists. Prior to 1998, data used to list streams were in a variety of formats, collected under differing protocols. Information also was gathered through the Section 305(b)² reporting process. DEP is now using the Unassessed Waters Protocol (UWP), a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II), as the primary mechanism to assess Pennsylvania's waters. The UWP provides a more consistent approach to assessing Pennsylvania's streams.

The assessment method requires selecting representative stream segments based on factors such as surrounding land uses, stream characteristics, surface geology, and point source discharge locations. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment can vary between sites. All the biological surveys included kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates are identified to the family level in the field.

After the survey is completed, the biologist determines the status of the stream segment. The decision is based on the performance of the segment using a series of biological metrics. If the stream is determined to be impaired, the source and cause of the impairment is documented. An impaired stream must be listed on the state's Section 303(d) list with the source and cause. A TMDL must be developed for the stream segment. In order for the process to be more effective, adjoining stream segments with the same source and cause listing are addressed collectively, and on a watershed basis.

Basic Steps for Determining a TMDL

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² Section 305(b) of the Clean Water Act requires a biannual description of the water quality of the waters of the state.

Although all watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes or steps that apply to all cases. They include:

- 1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
- 2. Calculation of TMDL for the waterbody using USEPA approved methods and computer models;
- 3. Allocating pollutant loads to various sources;
- 4. Determining critical and seasonal conditions;
- 5. Public review and comment period on draft TMDL,
- Submittal of TMDL to EPA.,
- 7. USEPA approval of the TMDL

TMDL Elements (WLA, LA, MOS)

A TMDL equation consists of a wasteload allocation, load allocation and a margin of safety. The wasteload allocation is the portion of the load assigned to point sources. The load allocation is the portion of the load assigned to nonpoint sources. The margin of safety is applied to account for uncertainties in the computational process. The margin of safety may be expressed implicitly (documenting conservative processes in the computations) or explicitly (setting aside a portion of the allowable load).

Targeted TMDL values were than used as the basis for load allocations and reductions in the Buffalo Creek Watershed, using the following equation:

1. TMDL = WLA + LA + MOS

where:

TMDL = Total Maximum Daily Load WLA = Waste Load Allocation (point sources) LA = Load Allocation (nonpoint sources) MOS = Margin of Safety

Allocation Summary

The allocation of the TMDL in this report is based on available data. These TMDLs will focus remediation efforts on the identified numerical reduction targets for each watershed. As changes occur in the watershed, the TMDLs may be re-evaluated to reflect current conditions. Table 12 presents the estimated reductions identified for all points in the watershed. The TMDLs by Segment section gives detailed TMDLs by segment analysis for each allocation point.

Margin of Safety

For this study, the margin of safety is applied implicitly. The allowable concentrations and loadings were simulated using Monte Carlo techniques and employing the @Risk software. Other margins of safety used for this TMDL analysis include the following:

• The data were analyzed to determine if there was reason to suspect any samples were significantly different than the rest of the data set. If it were determined that there was reason to suspect that any of the data were outliers, those data were processed through Chauvenet's Criterion algorithms to determine if they were statistical outliers (Kennedy 1964.) Because the 99 percent level of protection is designed to protect for the extreme event, it was pertinent not to filter the data set unless there is reason to believe that the sample is statistically different from the rest of the samples. Some of the reasons for a sample being statistically different may lie in the sampling procedures and equipment, the laboratory procedures or equipment, or the sample may have been compromised at any stage of processing.

Consideration of Critical Conditions

The AVGWLF model was used to calculate average flows that were used in the development of the TMDL. The AVGWLF model is a continuous simulation model, which uses daily time steps for weather data and water balance calculations. Monthly calculations are made based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally a significant lag time between the introduction of low pH atmospheric deposits to a waterbody and the resulting impact on beneficial uses, establishing this TMDL using average annual conditions is protective of the waterbody. Additionally, the concentration of acid instream is varied through the seasons, thus the timing of sampling was spread over a year.

Low pH Atmospheric Deposition TMDLs Methodology

A two-step approach is used for the TMDL analysis of atmospheric deposition impaired stream segments. The first step uses a statistical method for determining the allowable instream concentration at the point of interest necessary to meet water quality standards. This is done at each point of interest (sample point) in the watershed. The second step is a mass balance of the loads as they pass through the watershed. Loads at these points will be computed based on average annual flow.

The statistical analysis describes below can be applied to situations where all of the pollutant loading is from non-point sources as well as those where there are both point and non-point sources. The following defines what are considered point sources and non-point sources for the purposes of our evaluation; point sources are defined as permitted discharges or a discharge that has a responsible party, non-point sources are any pollution sources that are not point sources. For situations where all of the impact is due to nonpoint sources, the equations shown below are applied using data for a point in the stream. The load allocation made at that point will be for all of the watershed area that is above that point. For situations where there are point-source impacts alone, or in combination with nonpoint sources, the evaluation will use the point-source data and perform a mass balance with the receiving water to determine the impact of the point source.

Allowable loads are determined for each point of interest using Monte Carlo simulation. Monte Carlo simulation is an analytical method meant to imitate real-life systems, especially when other analyses are too mathematically complex or too difficult to reproduce. Monte Carlo simulation calculates multiple

scenarios of a model by repeatedly sampling values from the probability distribution of the uncertain variables and using those values to populate a larger data set. Allocations were applied uniformly for the watershed area specified for each allocation point. For each source and pollutant, it was assumed that the observed data were log-normally distributed. Each pollutant source was evaluated separately using @Risk³ by performing 5,000 iterations to determine the required percent reduction so that the water quality criteria, as defined in the *Pennsylvania Code*. *Title 25 Environmental Protection*, *Department of Environmental Protection*, *Chapter 93*, *Water Quality Standards*, will be met instream at least 99 percent of the time. For each iteration, the required percent reduction is:

 $PR = maximum \{0, (1-Cc/Cd)\}\ where (1)$

PR = required percent reduction for the current iteration

Cc = criterion in mg/l

Cd = randomly generated pollutant source concentration in mg/l based on the observed data

Cd = RiskLognorm(Mean, Standard Deviation) where (1a)

Mean = average observed concentration

Standard Deviation = standard deviation of observed data

The overall percent reduction required is the 99th percentile value of the probability distribution generated by the 5,000 iterations, so that the allowable long-term average (LTA) concentration is:

LTA = Mean * (1 - PR99) where (2)

LTA = allowable LTA source concentration in mg/l

Once the allowable concentration and load for each pollutant is determined, mass-balance accounting is performed starting at the top of the watershed and working down in sequence. This mass-balance or load tracking is explained below.

Load tracking through the watershed utilizes the change in measured loads from sample location to sample location, as well as the allowable load that was determined at each point using the @Risk program.

There are two basic rules that are applied in load tracking; rule one is that if the sum of the measured loads that directly affect the downstream sample point is less than the measured load at the downstream sample point it is indicative that there is an increase in load between the points being evaluated, and this amount (the difference between the sum of the upstream and downstream loads) shall be added to the allowable load(s) coming from the upstream points to give a total load that is coming into the downstream point from all sources. The second rule is that if the sum of the measured loads from the upstream points is less than the measured load at the downstream point this is indicative that there is a loss of instream load between

³ @Risk – Risk Analysis and Simulation Add-in for Microsoft Excel, Palisade Corporation, Newfield, NY, 1990-1997.

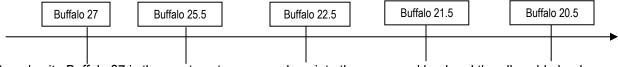
the evaluation points, and the ratio of the decrease shall be applied to the load that is being tracked (allowable load(s)) from the upstream point.

Tracking loads through the watershed gives the best picture of how the pollutants are affecting the watershed based on the information that is available. The analysis is done to insure that water quality standards are met at all points in the stream. The TMDL must be designed to meet standards at all points in the stream, and in completing the analysis, reductions that must be made to upstream points are accounted for when evaluating points that are lower in the watershed. Another key point to grasp is that the loads are being computed based on average annual flow and should not be taken out of the context for which they are intended, which is to depict how the pollutants effect the watershed and where the sources and sinks are located spatially in the watershed.

Where a stream segment is listed on the Section 303(d) list for pH impairment, the evaluation is the same as that discussed above. In Low pH Atmospheric Deposition TMDLs, acidity is compared to alkalinity as described in Attachment B. Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both in units of milligrams per liter (mg/l) CaCO₃. Statistical procedures are applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method does not specifically compute the pH value, however the use of the net acidity calculation is a representation of what is needed to satisfy the pH standard. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

Information for the TMDL analysis performed using the methodology described above is contained in the TMDLs by segment section of this report.

TMDLs By Segment



Sample site Buffalo 27 is the most upstream sample point, the measured load and the allowable load are calculated using the methodology described in the Low pH Atmospheric Deposition TMDLs Methodology section and shown in Table 2. The calculations show that there needs to be a 107.7 lbs/day reduction of acidy at that point as shown in Table 3.

Table 2: Calculation of TMDL loads at Buffalo 27

Buffalo 27		Measure	d	Allowabl	е
Flow (mgd)=	1.0	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	13.3	111.4	0.4	3.7
	Alkalinity	0.8	6.7		

Table 3: Calculation of Load Reduction Necessary at Buffalo 27

Buffalo 27	Acidity (lbs/day)	Flow (mgd)
Existing Load	111.4	1.0
Allowable Load	3.7	
Load Reduction	107.7	
% Reduction	97%	

At Buffalo 25.5, the measured load and the allowable loads are calculated and shown in Table 4.

Table 4: Calculation of TMDL loads at Buffalo 25.5

Buffalo 25.5		Measure	ed	Allowabl	е
Flow (mgd)=	2.2	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	9.6	174.9	0.8	14.8
	Alkalinity	1.5	27.9		

The calculated load reductions for Buffalo 27, must be accounted for in the calculated reductions at sample point Buffalo 25.5 as shown in Table 5. A comparison of measured load between Buffalo 25.5 and Buffalo 27 shows that there is an increase in load of 63.5 lbs/day (174.9-111.4). This shows that the watershed area between Buffalo 25.5 and Buffalo 27 is increasing the cumulative load instream by 63.5 lbs/day. Adding this watershed load (63.5 lbs/day) to the allowable load passing Buffalo 27 (3.7 lbs/day), results in a load of 67.2 lbs/day reaching Buffalo 25.5 once Buffalo 27 is meeting water quality standards. Because the allowable load (LA) at Buffalo 25.5 is 14.8 lbs/day a reduction of 52.4 lbs/day is necessary.

Table 5: Calculation of Load Reduction Necessary at Buffalo 25.5

Summary of all Load That Affect Buffalo 25.5	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Buffalo 25.5	174.9	2.2
Difference in measured Load between Buffalo 27 and		
Buffalo 25.5	63.5	
Additional allowed to pass Buffalo 27	3.7	
Total load tracked between Buffalo 27 and Buffalo 25.5	67.2	
Allowable Load @ Buffalo 25.5	14.8	
Load Reduction @ Buffalo 25.5	52.4	
% Reduction required at Buffalo 25.5	78%	

At Buffalo 22.5, the measured load and the allowable loads are calculated and shown in Table 6.

Table 6: Calculation of TMDL loads at Buffalo 22.5

Buffalo 22.5		Measure	:d	Allowabl	е
Flow (mgd)=	4.1	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	10.1	342.5	1.1	35.8
	Alkalinity	2.1	69.8		

The calculated load reductions for Buffalo 25.5, must be accounted for in the calculated reductions at sample point Buffalo 22.5 as shown in Table 7. A comparison of measured load between Buffalo 22.5 and Buffalo 25.5 shows that there is an increase in load of 167.6 lbs/day (342.5-174.9). This shows that the watershed area between Buffalo 22.5 and Buffalo 25.5 is increasing the cumulative load instream by 167.6 lbs/day. Adding this watershed load (167.6 lbs/day) to the allowable load passing Buffalo 25.5 (14.8 lbs/day), results in a load of 182.4 lbs/day reaching Buffalo 22.5 once Buffalo 25.5 is meeting water quality standards. Because the allowable load (LA) at Buffalo 22.5 is 35.8 lbs/day a reduction of 146.6 lbs/day is necessary.

Table 7: Calculation of Load Reduction Necessary at Buffalo 22.5

Summary of all Load That Affect Buffalo 22.5	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Buffalo 22.5	342.5	4.1
Difference in measured Load between Buffalo 25.5 and Buffalo		
22.5	167.6	
Additional load allowed to pass Buffalo 25.5	14.8	
Total load tracked between Buffalo 25.5 and Buffalo 22.5	182.4	
Allowable Load @ Buffalo 22.5	35.8	
Load Reduction @ Buffalo 22.5	146.6	
% Reduction required at Buffalo 22.5	80%	

At Buffalo 21.5, the measured load and the allowable loads are calculated and shown in Table 8.

Table 8: Calculation of TMDL loads at Buffalo 21.5

Buffalo 21.5		Measure	:d	Allowable	е
Flow (mgd)=	4.7	Concentration	Load	Concentration	Load
		mg/L	lbs/day	mg/L	lbs/day
	Acidity	6.9	273.9	1.2	46.7
	Alkalinity	5.4	213.3		

The calculated load reductions for Buffalo 22.5 must be accounted for in the calculated reductions at sample point Buffalo 21.5 as shown in Table 9. A comparison of measured load between Buffalo 21.5 and Buffalo 22.5 shows that there is a loss in load of 68.5 lbs/day (273.9-342.5). This shows that the watershed area between Buffalo 21.5 and Buffalo 22.5 is decreasing the cumulative load instream by 20 percent which believed to be due to a change in buffering capacity. The increase in buffering capacity in this section is likely due to a change in geology and soils from a sandstone base with no calcareous materials to that of shale with calcareous materials incorporated in both the soils and the underlying geology. A 20 percent loss is also applied to the load that is allowed to pass Buffalo 22.5, which results in a load of 28.6 lbs/day being tracked to Buffalo 21.5. The buffering that occurs in the area between sample points the results in no additional reduction necessary to meet the allowable load (LA) of 46.7 lbs./day at this sample location.

Table 9: Calculation of Load Reduction Necessary at Buffalo 21.5

Summary of All Load That Affect Buffalo 21.5	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Buffalo 21.5	273.9	4.7

Difference in measured Load between Buffalo 22.5 and Buffalo 21.5	-68.5
Percent loss due to buffering in the watershed Between Buffalo 22.5	
and Buffalo 21.5	20%
Additional load allowed to pass Buffalo 22.5	35.8
Percentage of load from Buffalo 22.5 that reach Buffalo 21.5	80%
Total load tracked between Buffalo 22.5 and Buffalo 21.5	28.6
Allowable Load @ Buffalo 21.5	46.7
Load Reduction @ Buffalo 21.5	0.0
% Reduction required at Buffalo 21.5	0%

At Buffalo 20.5, the measured load and the allowable loads are calculated and shown in Table 8.

Table 10: Calculation of TMDL loads at Buffalo 20.5

Buffalo 20.5		Measured		Measured Allowable		Э
Flow (mgd)=	5.2	Concentration	Load	Concentration	Load	
		mg/L	lbs/day	mg/L	lbs/day	
	Acidity	2.6	112.1	2.0	85.5	
	Alkalinity	11.2	482.8			

A comparison of measured load between Buffalo 20.5 and Buffalo 21.5 again shows that there is a loss in load as the stream continues to gain buffering capacity. The additional buffering occurring between Buffalo 21.5 and Buffalo 20.5 results in the TMDL being met at Buffalo 20.5 with no additional reduction being required. Table 11 shows the calculation of the buffering that occurs between Buffalo 21.5 and Buffalo 20.5. The final cumulative load that is calculated at Buffalo 20.5 is 11.7 lbs/day.

Table 11: Calculation of Load Reduction Necessary at Buffalo 20.5

Summary of All Load That Affect Buffalo 20.5	Acidity (lbs/day)	Flow (mgd)
Existing Load @ Buffalo 20.5	112.1	5.2
Difference in measured Load between Buffalo 21.5 and Buffalo 20.5	-161.9	
Percent loss due to buffering in the watershed Between Buffalo		
21.5 and Buffalo 20.5	59%	
Additional load allowed to pass Buffalo 21.5	28.6	
Percentage of load from Buffalo 21.5 that reach Buffalo 20.5	41%	
Total load tracked between Buffalo 21.5 and Buffalo 20.5	11.7	
Allowable Load @ Buffalo 20.5	85.5	
Load Reduction @ Buffalo 20.5	0.0	
% Reduction required at Buffalo 20.5	0%	

Summary of Loading Calculations in the Buffalo Creek Watershed

Figure 9 and Table 12 show the TMDL load tracking through the Buffalo Creek Watershed. The diagram shows the load reductions necessary at each of the sample points after mass balance calculation as well as the modeled load that is flowing between sample sites. The results shown in the table are also reflective

of the mass balancing of loads tracked through the watershed, which takes credit for upstream reductions at downstream allocation points.

Buffalo 27 Acidity (lbs/day) Flow (mgd) load =111.4 lbs/day Existing Load 111.4 1.0 allowable Load 3.7 Load Reduction 107.7 % Reduction 97% **Buffalo 27** Buffalo 25.5 Acidity (lbs/day) Flow (mgd) load = 67.2 lbs/day Existing Load 174.9 2.2 Allowable Load 14.8 52.4 Load Reduction % Reduction 78% Buffalo 25.5 load = 182.4 lbs/day Buffalo 22.5 Acidity (lbs/day) Flow (mgd) Existing Load 342.5 4.1 Allowable Load 35.8 Load Reduction 146.6 % Reduction 80% Buffalo 22.5 Buffalo 21.5 Acidity (lbs/day) Flow (mgd) load = 28.6 lbs/day Existing Load 273.9 4.7 Allowable Load 46.7 Load Reduction 0.0 Buffalo 21.5 % Reduction 0% load = 11.7 lbs/day Buffalo 20.5 Acidity (lbs/day) Flow (mgd) Existing Load 112.1 5.2 Allowable Load 85.5 Load Reduction 0.0 Buffalo 20.5 % Reduction 0%

Figure 9: Stream Modeling Diagram with Data for the Buffalo Creek Watershed

Table 12: Summary of Loading in the Ruffalo Creek Watershed

Table 12: Summary of Loading in the Burlaio Creek Watershed					
Parameter	Measured Load	WLA	LA	Load Reduction	% Reduction
Buffalo 27					
Acidity (lbs/day)	111.4	0	3.7	107.7	97%
Buffalo 25.5					
Acidity (lbs/day)	174.9	0	14.8	52.4	78%
Buffalo 22.5					
Acidity (lbs/day)	342.5	0	35.8	146.6	80%
Buffalo 21.5					

Acidity (lbs/day)	273.9	0	46.7	0	0%	
Buffalo 20.5						
Acidity (lbs/day) 112.1 0 85.5 0 0%						

Recommendations

Passive treatment systems for acid impaired waters can be divided into two categories; category I, which neutralize acidity by raising pH and alkalinity and category II, which remove metals (in addition to raising pH and alkalinity)(Schmidt, 2002.)

Category I treatment methods include watershed liming, in-stream limestone sand, wetland liming, pumping of alkaline groundwater, limestone diversion wells and anoxic limestone drains. None of these methods are 100% effective and are very dependent on site-specific characteristics.

Watershed liming consists of spreading ground agricultural limestone over part or all of a watershed to neutralize acidity. The limestone added to the watershed reacts with precipitation moving through the soil and makes it less acidic. This method prevents the acidic water from leaching metals into streams and provides for better forest health. Most studies have shown this method to be appropriate for lake mitigation. For streams, the effects do not last as long.

In-stream limestone sand is placed directly in the streambed of high-gradient headwater streams. The sand dissolves in the water column as it spreads downstream during high-flow periods. CaCO₃ is added by the limestone sand, which results in higher pH and acid neutralizing capacity and lowered aluminum concentrations. Factors affecting the use of limestone sand include roads, weather, water quality and type of sand.

Wetland liming involves the direct application of finely ground limestone to wetlands, where it mixes with upper soil layer. Where wetlands make up a significant portion of the watershed, this method is most successful.

Pumping of alkaline groundwater takes groundwater previously stored in limestone bedrock and transfers it to the headwaters of small streams. This method has been used in PA on an episodically acid-impacted stream to restore the seasonal trout- stocked stream.

Limestone diversion wells are large diameter shallow wells, which contain limestone. These are situated in the ground, adjacent to a stream. The fluidized bed of limestone slowly dissolves and is added to the stream. These can treat streams with small flows.

Anoxic limestone drains are buried trenches of limestone that receive acid mine drainage and convert net acidic water to net alkaline water under anoxic conditions. The anoxic conditions prevent the limestone from becoming coated with metals, which occurs when oxygen is present.

Category II treatment methods include aerobic wetlands, anaerobic wetlands and successive alkalinity producing systems. These systems have been used mainly for treating acid mine drainage. Some could be used for acid impaired streams, but the cost-benefit ratio is an important factor. Another factor to

consider is that each of these systems is designed to be efficient for a different set of water quality parameters.

Aerobic wetlands are used to treat alkaline mine drainage that contains low to moderate metals concentrations. The wetland aerates the water and removes the metals through oxidation and hydrolysis.

Anaerobic wetlands are similar to aerobic wetlands but have a thick permeable organic substrate that is either mixed with limestone or placed over a limestone bed. The substrate allows the water to move through the system without the addition of oxygen.

Successive Alkalinity Producing Systems combine the characteristics of the anoxic limestone drains with those of the anaerobic wetlands. Water flows vertically through the wetland and an anoxic limestone bed into another bed of underlying drainage pipes, which convey the water to a settling pond or aerobic wetland.

Selection of a method, or combination of methods, is dependent on the chemistry of the impaired water and the treatment objectives. Objectives may vary from restoring a fishery to improving the downstream habitat of aquatic insects.

Public Participation

A meeting was held January 21, 2003, at Mifflinburg High School, where the concept of TMDLs was introduced to the Buffalo Creek Watershed Alliance.

The draft TMDL will be published in the PA Bulletin for 30 days. The public meeting will be advertised and held during the comment period.

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Attachment A Water Quality Data

Name	Date	Sequence	pH pH units	ALKALINITY MG/L	HOT ACIDITY MG/L	Net Alkalinity MG/L
Buffalo Creek @ Headwaters	7/9/2003	31	4.7	0.8	12.4	-11.6
Buffalo Creek @ Headwaters	5/7/2003	22	4.6	0.6	9.8	-9.2
Buffalo Creek @ Headwaters	1/14/2004		4.7	1	17.8	-16.8
Buffalo Creek @ Fredrick Trail	7/9/2003	32	5.4	1.8	8.2	-6.4
Buffalo Creek @ Fredrick Trail	5/7/2003	23	4.9	1.6	7.4	-5.8
Buffalo Creek @ Fredrick Trail	1/14/2004	39	4.8	1.2	13.2	-12
Buffalo Creek @ Lower end cabin	7/9/2003	30	5.7	2.4	10.4	-8
Buffalo Creek @ Lower end cabin	5/7/2003	21	5.2	2	6.8	-4.8
Buffalo Creek @ Lower end cabin	1/14/2004	41	5.2	1.8	13.2	-11.4
Buffalo Creek @ SR3005 Bridge	7/9/2003	28	7	13.2	0	13.2
Buffalo Creek @ SR3005 Bridge	5/7/2003	19	6.1	12	7.8	4.2
Buffalo Creek @ SR3005 Bridge	1/14/2004		7	8.4	0	8.4
Buffalo Creek at horse farm	7/9/2003	29	6.6	5.2	0	5.2
Buffalo Creek at horse farm	5/7/2003	20	5.9	7	7	0
Buffalo Creek at horse farm	1/14/2004	42	6.4	4	13.8	-9.8
Lake Jean at the Dam	7/8/2003	27	6.4	3.4	14.2	-10.8
Lake Jean at the Dam	5/7/2003	15	5.6	4.4	14	-9.6
Lake Jean at the Dam	1/13/2004	37	5.5	2.6	17.4	-14.8
Lake Jean Beaver Tributary	7/8/2003	24	6.3	7.4	34.2	-26.8
Lake Jean Beaver Tributary	5/7/2003	18	5.7	5.4	22.8	-17.4
Lake Jean Beaver Tributary	1/13/2004		5.8	4	23.4	-19.4
Tributary to Lake Jean above Rt. 487	7/9/2003	25	4.9	1.2	43	-41.8
Tributary to Lake Jean above Rt. 487		25 17	4.9	1.8	43 27.2	-41.6 -25.4
Tributary to Lake Jean above Rt. 487			4.8	1.0	23.6	-23.4
Tributary to Lake Jean above Nt. 407	1/13/2004	30	4.0	1.2	23.0	-22.4
Tributary to Lake Jean below Rt. 487	7/8/2003	26	5	1.4	36.2	-34.8
Tributary to Lake Jean below Rt. 487	5/7/2003	16	5	1.8	21.2	-19.4
Tributary to Lake Jean below Rt. 487	1/13/2004	38	4.9	1.4	23.2	-21.8

Attachment B PH Method

Method for Addressing Section 303(d) Listings for pH

There has been a great deal of research conducted on the relationship between alkalinity, acidity, and pH. Research published by the Pa. Department of Environmental Protection demonstrates that by plotting net alkalinity (alkalinity-acidity) vs. pH for 794 mine sample points, the resulting pH value from a sample possessing a net alkalinity of zero is approximately equal to six (Figure 1). Where net alkalinity is positive (greater than or equal to zero), the pH range is most commonly six to eight, which is within the USEPA's acceptable range of six to nine and meets Pennsylvania water quality criteria in Chapter 93.

The pH, a measurement of hydrogen ion acidity presented as a negative logarithm, is not conducive to standard statistics. Additionally, pH does not measure latent acidity. For this reason, and based on the above information, Pennsylvania is using the following approach to address the stream impairments noted on the 303(d) list due to pH. The concentration of acidity in a stream is at least partially chemically dependent upon metals. For this reason, it is extremely difficult to predict the exact pH values, which would result from treatment of abandoned mine drainage. Therefore, net alkalinity will be used to evaluate pH in these TMDL calculations. This methodology assures that the standard for pH will be met because net alkalinity is a measure of the reduction of acidity. When acidity in a stream is neutralized or is restored to natural levels, pH will be acceptable. Therefore, the measured instream alkalinity at the point of evaluation in the stream will serve as the goal for reducing total acidity at that point. The methodology that is applied for alkalinity (and therefore pH) is the same as that used for other parameters such as iron, aluminum, and manganese that have numeric water quality criteria.

Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Net alkalinity is alkalinity minus acidity, both being in units of milligrams per liter (mg/l) CaCO₃. The same statistical procedures that have been described for use in the evaluation of the metals is applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for mine waters is not a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

There are several documented cases of streams in Pennsylvania having a natural background pH below six. If the natural pH of a stream on the 303(d) list can be established from its upper unaffected regions, then the pH standard will be expanded to include this natural range. The acceptable net alkalinity of the stream after treatment/abatement in its polluted segment will be the average net alkalinity established from the stream's upper, pristine reaches. Summarized, if the pH in an unaffected portion of a stream is found to be naturally occurring below six, then the average net alkalinity for that portion of the stream will become the criterion for the polluted portion. This "natural net alkalinity level" will be the criterion to which a 99 percent confidence level will be applied. The pH range will be varied only for streams in which a natural unaffected net alkalinity level can be established. This can only be done for streams that have upper segments that are not impacted by mining activity. All other streams will be required to meet a minimum net alkalinity of zero.

Reference: Rose, Arthur W. and Charles A. Cravotta, III 1998. Geochemistry of Coal Mine Drainage. Chapter 1 in Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Pa. Dept. of Environmental Protection, Harrisburg, Pa.

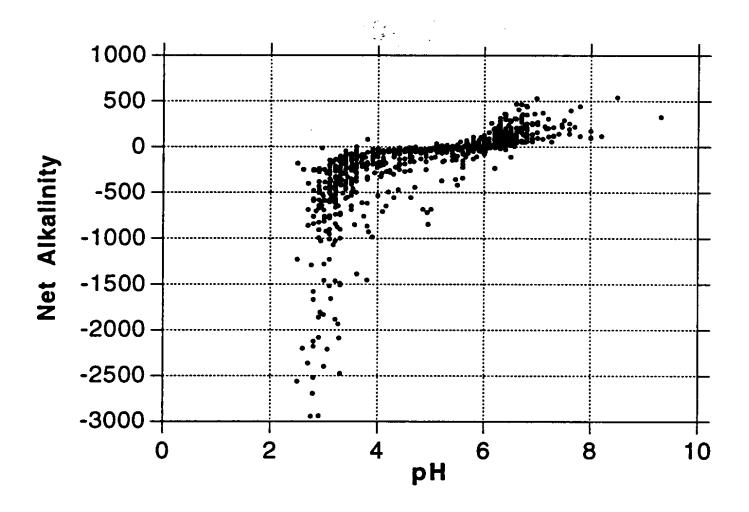
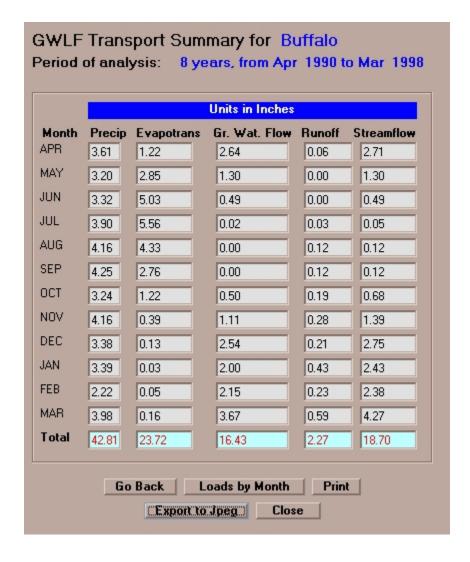


Figure 1. Net Alkalinity vs. pH. Taken from Figure 1.2 Graph C, pages 1-5, of Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania.

Attachment C AVGWLF Output



Attachment D Flow Information used in the TMDL

Buffaol Creek Flow cal	culations		
Station	% 0f Watershed	AVGWLF Derived Flow (MGD)	Average Measured Flow (MGD)*
Buffalo 20.5	100%	5.2	4.4
Buffalo 21.5	91%	4.7	4.4
Buffalo 22.5	78%	4.1	1.7
Buffalo 25.5	42%	2.2	4.9**
Buffalo 27	20%	1.0	1.8

^{*} Based on two measured flows

AVGWLF was used to determine average flow conditions for the watershed because the model uses precipitation data to determine watershed runoff. Measured flow values were used to calibrate the GWLF output.

^{**} Based on one high flow measurement