2002 Annual Report

Water Resources Monitoring Project

SPRING CREEK WATERSHED COMMUNITY

Cover image - persistent, low flow-rate mountain slope spring

Contents

Copies of this report are available at the ClearWater Conservancy office:

2555 North Atherton Street
State College, PA 16803
(814) 237-0400

or on the Spring Creek Watershed Communtiy's Web site www.springcreekwatershed.org.

Data collected by the Water Resources Monitoring Project is also made available on the Web site.

Front cover picture taken by Mark Ralston

1.0 ABOUT THIS REPORT

Welcome to the Water Resources Monitoring Project (WRMP) 2002 Annual Report. This project was conceived in 1998 by the Spring Creek Watershed Community to measure the quantity and quality of water resources in the Spring Creek Watershed. This project has received financial and in-kind support from local governments, agencies, organizations, and industries. The intent of this document is to detail how this support is being used, illustrate how the project has evolved over the years to reflect the needs and concerns of the Watershed, and to provide summarized water quality and quantity data.

The WRMP has now completed five years of baseflow measurements on Spring Creek and its tributaries. In 2002, a significant effort was made to analyze the baseflow and stormwater data. John Sengle, a Pennsylvania Department of Environmental Protection (PA DEP) Water Quality Specialist and WRMP Committee member, evaluated how baseflow and pollutant load are distributed among the tributaries and sub-basins. In conjunction with new stormwater regulatory initiatives (Act 167), the WRMP began stormwater sampling to assess the impact of storm events on the Watershed. The Spring Creek Chapter of Trout Unlimited sponsored a fellowship at The Pennsylvania State University to analyze both the baseflow and stormwater data. Summaries of these findings are presented in this report along with additional data highlights from 2002 (see inset on right).

In 2001, in conjunction with a new PA DEP initiative, the project began assembling a network of wells in which to install instrumentation for the purpose of measuring groundwater levels in the Spring Creek Watershed. This effort continued into 2002, with seven wells eventually composing the network.

A Sampling of Data Highlights from the Water Resources Monitoring Project

(see following sections for details)

- Precipitation during 2002 was about 10% above normal, but flows in Spring Creek near Milesburg were about 17% below average, which reflected the below normal levels of groundwater.
- The above average precipitation in 2002 resulted in a 40-foot rise in a monitoring well two miles southwest of State College, which marks the beginning of the end of the extended regional drought.
- Logan Branch, which contributes the largest flow among all tributaries, nearly doubles the flow in Spring Creek near their confluence in Bellefonte.
- Nitrate concentrations in Spring Creek and its tributaries were always less than the drinking water standard of 10 mg/L, with most samples less than 5 mg/L. Cedar Run was the largest contributor of nitrate to Spring Creek.
- During stormflows, copper, zinc, and lead were most often detected, and at the highest levels, in lower Logan Branch, Thompson Run, and Spring Creek at Milesburg. Among all stations copper was the least frequently detected (about 15% of the time) and lead was most frequently detected (more than 70%).
- During stormflows, concentrations and total amounts of ammonia, chloride, total organic carbon, orthophosphate, and total suspended sediment were highest in Slab Cabin Run and Thompson Run. Logan Branch consistently delivered the lowest amounts of organic carbon and suspended sediments.
- Concentrations of dissolved oxygen, which were consistently high at all sampling stations, were more than adequate to support aquatic life.
- The average pH among all stations was about 8.0 (basic conditions), and it rarely fell below 7.0 (mildly acidic conditions).

Until 2003, all water monitoring conducted by WRMP has coincided with prolonged periods of low groundwater and reduced stream flows. This report shows that a dramatic increase in water-table levels has occurred since late 2002. Precipitation levels over this timeframe, while greater than the three previous years, might not seem to explain totaly the significant increase in groundwater level. This also will be discussed later in the report.

A noteable event that occured in 2002 was the announcement from PA DEP that 16.2 miles of Spring Creek and its tributaries, or 20% of its total length, are impaired, meaning these stream reaches are not meeting their designated uses. This report discusses how stream impairment is determined, how it relates to WRMP monitoring efforts, and most importantly what is being done and what must still be done to address this problem.

Also included in this document are WRMP project background information and methodology, a list of agencies and authorities who have used WRMP data, and recommendations based on WRMP data. An addendum to this report provides a summary of 2002 baseflow data and is available upon request. If you are interested in receiving a copy, contact the project manager at (814) 237-0400.

2.0 PROJECT BACKGROUND

THE WATERSHED

The Spring Creek Watershed as delineated from surface topography is approximately 145 square miles in area. Due to hydrogeologic conditions, the groundwater boundary is larger and is approximately 175 square miles in area. The Spring Creek Watershed is home to approximately 94,000 people, 14 municipalities, and The Pennsylvania State University. The average daily flow from the Spring Creek Watershed is approximately 148 million gallons based on 34 years of record. This water leaves the Watershed at Milesburg where it flows into Bald Eagle Creek. It continues to flow into the West Branch of the Susquehanna River and then into the Chesapeake Bay.

The citizens living within the Watershed are almost entirely reliant upon groundwater sources for public drinking water supplies and domestic wells. About 25 Public Water Supply (PWS) systems exist in the Watershed. Approximately 16.8 million gallons of groundwater are pumped daily from the limestone and dolomite aquifers located under the valley floor to meet the drinking water needs of the Watershed's citizens. In general, groundwater is withdrawn, treated, delivered to the public, and then conveyed to wastewater treatment/ disposal facilities. Goundwater withdrawal and water resource management have been identified as potentially limiting factors on growth and development in the Spring Creek Watershed.

An increase in urbanization coupled with changing land use patterns may adversely affect the overall health of Spring Creek and its tributaries by increasing groundwater withdrawal, decreasing the volume of groundwater recharge, and potentially increasing the volume of pollutants that enter the streams.

THE WATER RESOURCES MONITORING COMMITTEE

The Water Resources Monitoring Committee is a volunteer group comprised of environmental professionals who oversee and guide the activities of the Water Resources Monitoring Project (Table 1).

Table 1. The 2002-2003 Water Resources Monitoring Committee.

NAME	AFFILIATION
Mark Ralston P.G.* Committee Chair, Hydrogeologist	Converse Consultants
Robert Carline, Ph.D. Committee Vice-Chair, Adjunct Professor and Leader	Pennsylvania Cooperative Fish & Wildlife Research Unit, USGS
Chris Finton, P.G. Hydrogeologist	Meiser & Earl, Inc.
Steve Foard, P.E. ** Environmental/Safety Manager	Murata Electronics North America, Inc.
Todd Giddings, Ph.D., P.G. Hydrogeologist	Todd Giddings and Associates, Inc.
James Hamlet, Ph.D. Associate Professor of Agricultural Engineering	Department of Agricultural and Biological Engineering The Pennsylvania State University
Bert Lavan Senior Process Engineer	Corning Asahi Video Products
Katie Ombalski (staff) Project Manager	ClearWater Conservancy
Gene Proch Regulatory Affairs & Facilities Manager	Corning Asahi Video Products
John Sengle Water Quality Specialist	PA Department of Environmental Protection
Becky Shirer and Mary Walsh (staff) Water Monitoring Technicians	ClearWater Conservancy
David Smith Assistant Executive Director	University Area Joint Authority
Shana Tritsch, P.G. Senior Hydrogeologist	USFilter Groundwater Services
Rick Wardrop, P.G. Hydrogeologist and Industrial Contamination Specialist	USFilter Groundwater Services
Dave Yoxtheimer, P.G. Senior Hydrogeologist	USFilter Groundwater Services

* Professional Geologist
** Professional Engineer

PROJECT FUNDING

In 2002, financial support for the WRMP came from a variety of watershed stakeholders including State College Borough Water Authority, University Area Joint Authority, Danone Waters of North America, Penn State University Office of Physical Plant, Centre County Commissioners, Benner Township, Bellefonte Borough, Halfmoon Township, Harris Township, Milesburg Borough, Patton Township, Spring Township, State College Borough, the Spring Creek Chapter of Trout Unlimited, and PA DEP.

IN-KIND CONTRIBUTORS

The WRMP received over $75,000 of in-kind contributions in 2002. These contributions included laboratory facilities and analyses, professional services, fundraising materials, groundwater monitoring wells, stilling well maintenance, technical assistance, chemical supplies, and transportation. In-kind contributors for 2002 include:

- Converse Consultants
- Exygen Research
- Pennsylvania Cooperative Fish and Wildlife Research Unit, United States Geological Survey
- Pennsylvania Department of Environmental Protection
- United States Geological Survey
- University Area Joint Authority
- Volunteer field assistants, technical assistants, and PSU students
- Well owners (Corning Asashi, Howard Dashem, PA DCNR, Todd Giddings, and PSU-OPP, USGS)
- Water Resources Monitoring Committee

3.0 MONITORING STATIONS

BASEFLOW AND STORMWATER MONITORING STATIONS

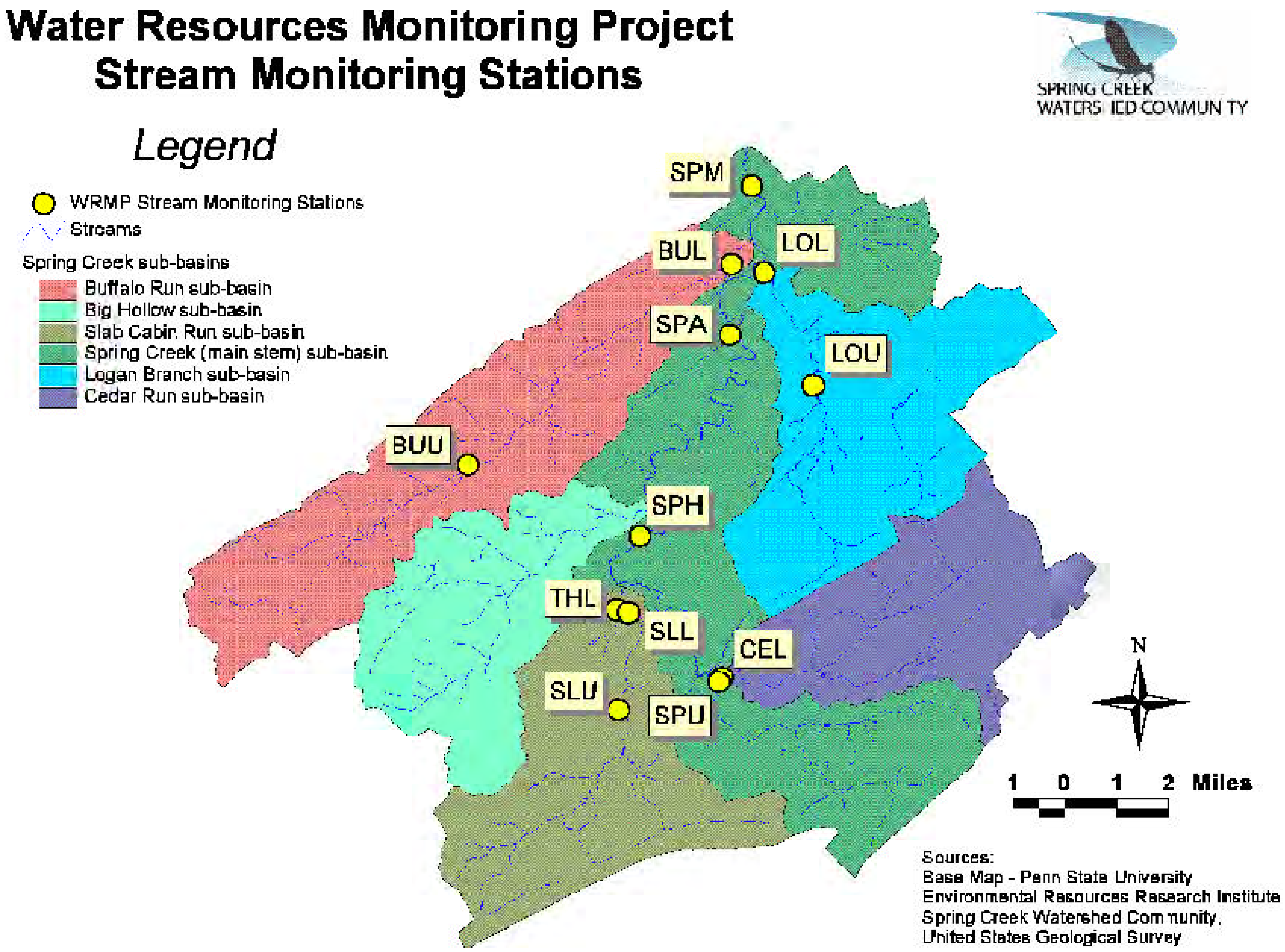
The rationale used to establish stream monitoring stations was to divide the watershed into smaller hydrologic units, called sub-watersheds or sub-basins, and to characterize the quantity and quality of water flowing from these sub-basins into the main stem of Spring Creek (Figure 1). The existence of three USGS gaging stations on the main stem of Spring Creek and three gaging stations maintained by the Pennsylvania Cooperative Fish and Wildlife Research Unit was also taken into account (Table 2).

When land use patterns were similar throughout a sub-basin, a single monitoring station was located at the point where flow from the sub-basin joined Spring Creek to describe water quantity and quality from the sub-basin. But, when land use patterns changed throughout a sub-basin, a monitoring station was located near the middle of the sub-basin and near its confluence with Spring Creek. Thus, data collected from the monitoring stations allow us to describe the amount of suspended and dissolved materials contributed from each sub-basin and describe how the quantity and quality of water in the main stem of Spring Creek changes as it travels from the upper part of the Watershed near Boalsburg to its confluence with Bald Eagle Creek in Milesburg.

Table 2. Stream Monitoring Stations

MONITORING STATION	LOCATION	OPERATOR
Spring Creek Milesburg (SPM)	Downstream of McCoy Dam in Milesburg	USGS
Buffalo Run Lower (BUL)	Upstream of the confluence with Spring Creek in Coleville	SCWC
Logan Branch Lower (LOL)	100 feet upstream of SR150 crossing in Bellefonte	SCWC
Spring Creek Axemann (SPA)	50 feet downstream of the bridge on Spring Creek Road	USGS
Logan Branch Upper (LOU)	Behind International Order of Odd Fellows building on SR144	SCWC
Spring Creek Houserville (SPH)	50 feet upstream of the intersection of Houserville, Trout, and Rock roads	USGS
Slab Cabin Run Lower (SLL)	In Millbrook Marsh, behind College Twp. Municipal Building	SCWC
Thompson Run Lower (THL)	In Millbrook Marsh behind the Millbrook Marsh Nature Center.	SCWC
Slab Cabin Run Upper (SLU)	20 feet upstream of the bridge on S. Atherton, near Branch Road	PCFWRU
Cedar Run Lower (CEL)	200 feet upstream of the intersection of Brush Valley & Linden Hall roads	PCFWRU
Spring Creek Upper (SPU)	100 feet upstream from the Linden Hall Bridge at Oak Hall	PCFWRU
Buffalo Run Upper (BUU)	Off SR550, approximately 1000 feet upstream of Filmore	SCWC

USGS - United States Geological Survey, SCWC = Spring Creek Watershed Community
PCFWRU = Pennsylvania Cooperative Fish and Wildlife Research Unit


Water Resources Monitoring Project
Stream Monitoring Stations

Sources:
Base Map - Penn State University
Environmental Resources Research Institute
Spring Creek Watershed Community,
United States Geological Survey

Figure 1. Water Resources Monitoring Project Stream Monitoring Stations

GROUNDWATER MONITORING WELLS

Groundwater monitoring wells (Table 3) were selected based on the following criteria:

- Reasonably complete information is available for well as-built characteristics (Appendix A). Well owner is willing to permit long-term data collection and publication of groundwater level data.
- Well is not situated near a high-yield pumping well or well field (groundwater levels would be artificially controlled).
- Well is not situated in a location that is unduly influenced by stormwater or artificial groundwater recharge (groundwater levels would be artificially controlled).
- Well is not situated near a stream or groundwater discharge point (groundwater level fluctuation would be subdued).
- Well can reasonably represent groundwater level conditions over a large area (i.e., wells should represent broad hydrogeologic environments, such as carbonate valley, shale valley, mountain setting, etc.) (Figure 2).

Table 3. Groundwater Monitoring Wells

WELL	SUB-BASIN	HYDROGEOLOGIC ENVIRONMENT
Centre Hall 1	Cedar Run	Valley Center Upland
I-99 MW-1	Big Hollow	Valley Bottom
Pine Grove Mills 2 (DCNR2)	Slab Cabin Run	Mountain Foot
Mt. Nittany Base 1	Logan Branch	Mountain Foot
Fillmore 1	Buffalo Run	Valley Bottom Floodplain
USGS CE 118 (Scotia 1)	Gatesburg Upland	Valley Center Ridge
USGS CE 686	Big Hollow	Valley Center Upland

4.0 METHODS

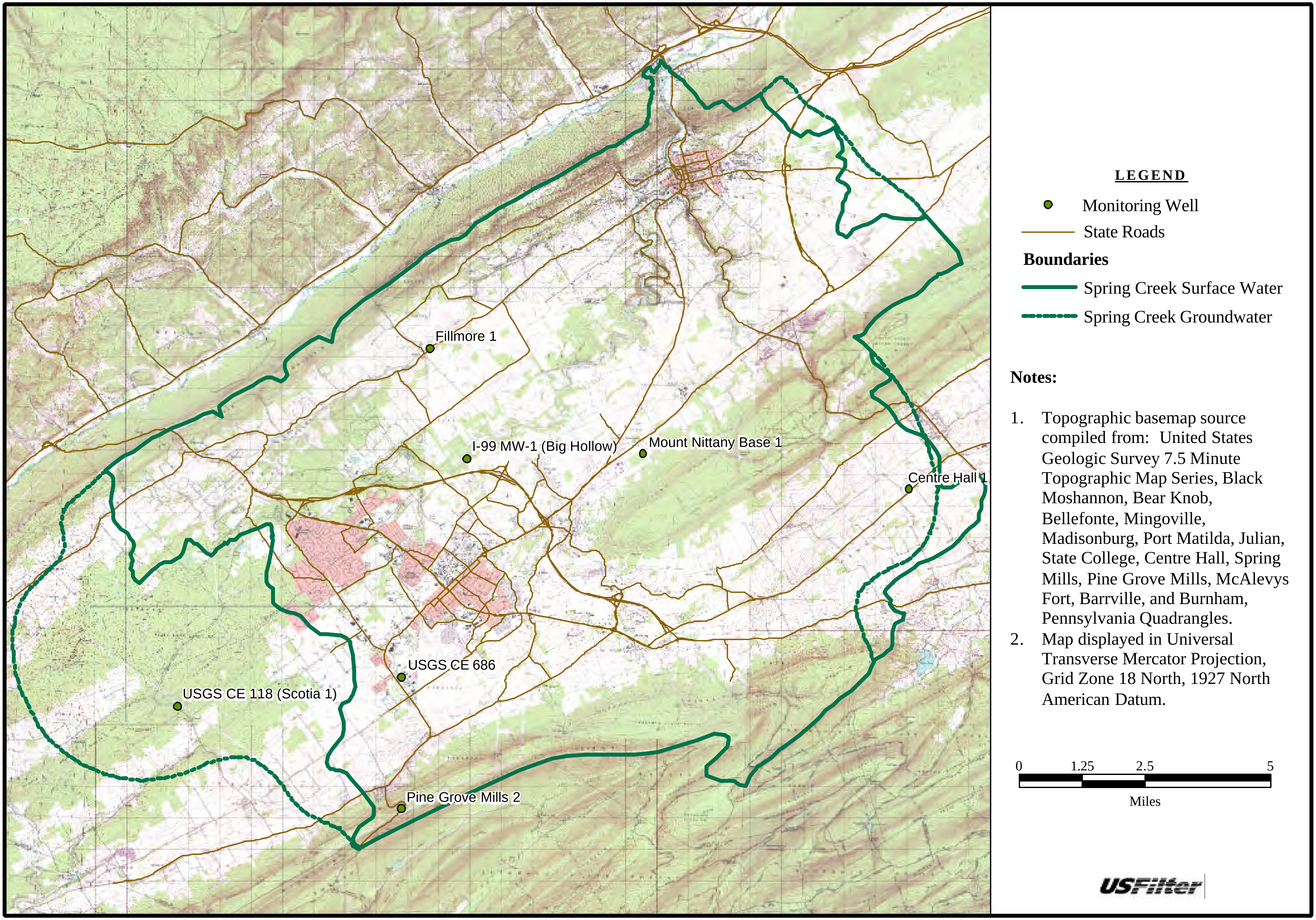
Baseflow and stormwater monitoring are cooperative efforts between the Pennsylvania Cooperative Fish and Wildlife Research Unit (PACFWU), USGS, and the Spring Creek Watershed Community's WRMP. Standardized methods have been developed for data collection and sample processing to provide quality assurance for all data collected by the WRMP. Detailed methods for baseflow and stormwater monitoring are documented in the Spring Creek Watershed Water Resources Monitoring Protocol and the Spring Creek Watershed Stormwater Monitoring Protocol, respectively. Both documents are available on our Web site (www.springcreekwatershed.org) or upon request. The following is a brief description of the parameters measured for baseflow, stormwater, and groundwater monitoring.

BASEFLOW MEASUREMENTS

Continuous Measurements

Stream flow - Streamflow is measured at all 12 monitoring stations. Nine of the 12 monitoring stations are equipped with instruments that record water level every 30 minutes. The water level data are then converted to stream flow using station-specific rating curves (a rating curve relates water level to flow). Streamflow is recorded every 15 minutes at the three USGS stations (Spring Creek Houserville, Spring Creek Axemann, and Spring Creek Milesburg).

Water temperature - Water temperature is recorded hourly at all 12 monitoring stations



Notes:

1. Topographic basemap source compiled from: United States Geologic Survey 7.5 Minute Topographic Map Series, Black Moshannon, Bear Knob, Bellefonte, Mingoville, Madisonburg, Port Matilda, Julian, State College, Centre Hall, Spring Mills, Pine Grove Mills, McAlevys Fort, Barrville, and Burnham, Pennsylvania Quadrangles.
2. Map displayed in Universal Transverse Mercator Projection, Grid Zone 18 North, 1927 North American Datum.

Figure 2. Groundwater monitoring well locations.

MONTHLY MEASUREMENTS

Every month, water samples are taken during baseflow conditions at each of the 12 monitoring stations using standardized procedures and sent to a laboratory for analysis. Samples are analyzed for 10 constituents (Appendix B). Monthly measurements also include dissolved oxygen and pH, which are measured in the field at each station when water quality samples are collected.

STORM EVENT MEASUREMENTS

Stormwater runoff was monitored from June 2001 to May 2002 for storms that had greater than 0.25" of precipitation. Seven automatic samplers were located at each of the twelve monitoring stations on a rotating basis with the goal of capturing a minimum of one storm at each station per season. Once collected, samples from each station were combined, based on flow data, into three larger composite samples to represent the beginning, middle, and end of the stream's response to the stormwater runoff. These samples were analyzed for the constituents listed in Appenix B, excluding dissolved oxygen and petroleum hydrocarbons. Stormwater measurements also included ammonia.

GROUNDWATER LEVEL MEASUREMENTS

The groundwater level monitoring network was under development in 2002; therefore, groundwater levels were only measured at Centre Hall 1 and the two USGS wells (CE 118 and CE 686) (Figure 2) during 2002. Groundwater levels are recorded every three hours.

5.0 RESULTS AND ANALYSES

5.1 Stream Chemistry and Hydrology during Baseflow in Spring Creek and its Major Tributaries

Written by John Sengle, Water Quality Specialist
PA Deptartment of Environmental Protection

The following report is a brief synopsis of a larger document entitled Controls on Baseflow Hydrology/Chemistry in a Mixed Land-Use, Karst Basin, prepared in December 2002 for completion of the author's Master of Forest Resources degree program at Penn State University. The water quality and streamflow data used to characterize the various subbasins of Spring Creek were drawn exclusively from data collected by the WRMP during the first two years of that project, from 1999 through 2001. Sengle's complete document is available in hard-copy or electronic format through ClearWater Conservancy, State College, PA.

INTRODUCTION

One of the primary goals of the WRMP is to collect baseline streamflow and water quality information to characterize the status of water resources in the main stem of Spring Creek and its major tributaries. Rapid population growth, urbanization, and land-use changes are significant potential threats to the health and viability of Spring Creek water resources. This report analyzed streamflow and selected water quality data collected exclusively during baseflow conditions (periods of no significant precipitation or stormwater runoff) in the Spring Creek watershed during the calendar years 1999 through 2001, in an attempt to answer several key questions:

1. What are the streamflows, and concentrations (mg/L) and loads (kg/day) of key pollutants, exported from Spring Creek and its tributaries?

2. What are the magnitudes of flow (m³/sec) and pollutant contributions (kg/day) from point-source discharges on the Spring Creek basin?
3. What are the total flow (m³/sec), hydrologic yield (cm/day), total load (kg/day), and unit load (kg/ha/yr), contributions from each of the sub-basins of Spring Creek?
4. Are differences in pollutant concentrations and unit loads across the sub-basins of Spring Creek related to differences in the relative distribution of various land-uses across those same sub-basins?

The study area reported here is the Spring Creek Watershed, and nine nested sub-basins represented by nine stream monitoring stations. The flow and water quality data collected at nine monitoring stations are used to quantify flow and pollutant contributions from Upper Spring Creek, Cedar Run, Slab Cabin Run, Thompson Run, Spring Creek at Houserville, Spring Creek at Axemann, Logan Branch, Buffalo Run, and Spring Creek at McCoy's Dam. Monitoring stations on Upper Buffalo Run, and Upper Slab Cabin Run were not used in this analysis due to dry stream conditions that precluded collection of streamflow data, or calculation of hydrologic yields or pollutant loads.

The water quality parameters analyzed for this report are chloride, nitrate-N, ortho-P, copper, lead, and zinc. These parameters are important indicators of water quality, and also may be influenced by the relative proportions of various key land uses found on the Spring Creek basin.

Land-use distribution data for each of the nine sub-basins were quantified for six major land-use types: forest, agricultural, residential/commercial, transportation/utilities, industrial, and mining. The 1995 Centre County Existing Land Use GIS database was the sole source of land use information for quantifying land-use distributions in the nine monitored sub-basins.

Flow and pollutant concentration data for the seven major point-source discharges in the Spring Creek basin were a combination of National Pollutant Discharge Elimination System (NPDES) effluent self-monitoring, industrial waste pre-treatment and PA DEP effluent data.

RESULTS AND DISCUSSION

Streamflow and Drought The two-year data record analyzed in this report represented a period of extreme and persistent drought throughout the Spring Creek basin. Total rainfall on the basin was well below long-term annual mean levels (97.3 cm/yr), at 80.2 cm and 77.0 cm respectively for 2000 and 2001. This lack of rainfall was reflected in below normal streamflows and below normal flows from the large-volume karst springs spread across the basin that are so critical to sustaining stream baseflow. In five of the nine monitored sub-basins, mean winter baseflow (October-March) was significantly less than mean summer baseflow (April-September). This unusual feature of the data speaks to the severity of the drought during 2000-2001, and the nearly total lack of normal fall-winter recharge so necessary to replenish groundwater supplies depleted during the summer growing season.

Logan Branch provided by far the largest flow contribution to the main stem of Spring Creek, nearly doubling Spring Creek baseflow at their confluence. Slab Cabin Run provided the smallest flow contribution to Spring Creek during the study period, providing less than one-tenth the flow of Logan Branch despite being roughly three-fourths the size of the Logan Branch basin.

Baseflow discharge data are particularly interesting with respect to the dynamics of the Spring Creek basin when flow is analyzed on a flow per unit area basis. Comparison of total stream flow from the various sub-basins does not account for the large differences in the size of the contributing watersheds. This analysis developed an index called hydrologic yield, expressed in cm/day, to quantify the volume of baseflow contributed for a unit land area. Calculation of a sub-basin hydrologic yield simply converts the mean baseflow discharge rate in m^3/sec to a daily baseflow discharge in m^3/day, thence through unit conversions and dividing by basin area to an equivalent depth of water over the sub-basin, expressed in cm/day. Hydrologic yield allows us to compare the relative amount of stream baseflow contributed from a unit watershed area and allows a direct comparison of stream baseflow levels for basins of vastly different size. Hydrologic yields for the nine sub-basins reported are widely variable, ranging from a high of 0.257 cm/day for Logan Branch, to a low of 0.033 cm/day for Slab Cabin Run, a nearly eightfold difference. High variability in hydrologic yield across nine basins draining relatively similar geologic landscapes was not expected. However, the weathered karst geology underlying large portions of the Spring Creek basin provides ample opportunity for transfer and/or exchange of groundwater between surface water basins. Previous investigations have revealed that the Spring Creek groundwater basin is roughly 19% larger than the Spring Creek surface water basin. A complex karst terrain, combined with anthropogenic influences, primarily groundwater and/or spring water withdrawl, are probably the primary reasons for the high variability in hydrologic yields.

Slab Cabin Run exhibited the highest variability in discharge at baseflow. The coefficient of variability for flow at Slab Cabin Run was roughly 45% greater than the next closest basin. The reasons for this variability are not known, but may be related to groundwater withdrawl on portions of the Upper Slab Cabin Run basin.


Photo by Katie Ombalski

Slab Cabin Run near South Atherton Street (2001).

Point-Source Discharges Point-source discharges accounted for 24% of stream baseflow during the study period. The Pennsylvania Fish and Boat Commission (PFBC) hatcheries at Benner Spring, Bellefonte and Pleasant Gap are the largest point-source discharges in the basin. Treated wastewater flows from the University Area Joint Authority are the largest sewage discharge on the basin. As greater proportions of the the Spring Creek basin are urbanized, the volume of treated domestic sewage being discharged to streams will likely increase, at the same time the increase in the amount of impervious surfaces will likely reduce precipitation infiltration and groundwater recharge, thus the point-source discharge component of baseflow is expected to increase.

Pollutant Concentration The in-stream concentrations of chloride, nitrate-N, and ortho-P for all sub-basins were within ranges commonly reported in the literature. Concentration of these pollutants typically showed two- to fourfold variability across the basin, with concentrations typically in the lower to middle range of concentrations reported in the literature for basins with similar land-use patterns. At baseflow Spring Creek does not show unusually high or potentially harmful concentrations of these pollutants.

Data for in-stream baseflow concentrations of copper, lead, and zinc were dominated by laboratory results reported as “less than detection limit”, except for data reported for Logan Branch. Logan Branch exhibited dramatically different results for copper, lead, and zinc than any other basin on Spring Creek. Logan Branch had 64% of baseflow metals samples at greater than detection limit, while all other sub-basins had roughly 7% of baseflow metals samples exceeding detection limit. Logan Branch received wastewater discharges from Corning-Asahi Video Products and Cerro Metal Products. When baseflow loads (kg/day) of metals on Logan Branch were computed it was determined that point-source discharges account for roughly 100% of the lead load on Logan Branch, but only around 13% of the zinc load. Clearly variations in concentrations of metals in Logan Branch are not simply a function of point-source discharges, and may be related to the influence of historical airborne deposition of metals on significant portions of the Logan Branch basin.

Total baseflow loads (kg/day) of pollutants were calculated for chloride, nitrate-N, and ortho-P for all sub-basins, and then “normalized” to a load per unit land area (kg/ha/yr) to account for variability in basin size. Pollutant unit loads, pollutant concentrations, percent metals exceeding detection limit, and relative proportions of key land-uses were analyzed in a correlation matrix to evaluate correlations between various measured indices. Correlation analysis revealed several noteworthy trends.

The baseflow loads per unit area of chloride, nitrate-N, and ortho-P on sub-basins are significantly correlated to the hydrologic yields of sub-basins, but are not correlated to the in-stream concentrations of chloride, nitrate-N, and ortho-P respectively. This correlation is partly a function of the similarity in terms used to compute hydrologic yield and unit load, but is also the result of much greater variability in hydrologic yield than in-stream pollutant concentration across Spring Creek sub-basins. Variability in baseflow loads of pollutants are much more a function of the hydrologic yield differences across Spring Creek than differences in in-stream pollutant concentrations.

Land-Use Correlations Several noteworthy features of baseflow pollutant dynamics and land-use patterns bear mentioning. The in-stream concentration of nitrate-N was negatively correlated with the proportion of forest land-use on the Spring Creek sub-basins. Forest land-use proportions ranged from 7% to 56% for the nine sub-basins, and as the proportion of forest land-use decreased, the in-stream concentration of nitrate-N increased. This correlation is a result of the strong nutrient retention feature of most intact forest ecosystems, coupled with the elevated nitrogen fluxes typically associated with the land-uses that most frequently replace forests on the Spring Creek basin, namely agriculture, and residential/commercial development.

Chloride loads per unit land are positively correlated with the proportion of residential/commercial land-use. The primary sources of in-stream chloride, winter de-icing and wastewater chlorination, are increased as the proportion of lands devoted to a transportation network and residential development increase. Chloride concentrations and baseflow loads would be expected to increase as urbanization increases on the Spring Creek basin.

The percent of metals samples that exceeded detection limit is significantly correlated with the proportion of mining and industrial land uses. While this correlation was the strongest tested, it is highly influenced by data from Logan Branch. There is not a uniform distribution in the proportion of mining and industrial land-uses across the Spring Creek basin; Logan Branch drains roughly three times the proportion of mining and industrial land-uses of the next closest sub-basin. When the same correlation analysis is run without data from Logan Branch there is no correlation between in-stream metals concentration and mining and industrial land-uses.

Logan Branch and Slab Cabin Run From a broader basin-wide perspective, two sub-basins emerge as substantively different at baseflow. Logan Branch exhibits distinctly different in-stream metals concentration dynamics than all other basins in Spring Creek. The exact reasons for those differences warrant further study, but would appear to be related to some mixture of the current point-source discharges on that basin and the historical airborne deposition of metals on portions of the watershed.

Slab Cabin Run is notable for exhibiting the lowest hydrologic yield in conjunction with the highest variability in baseflow discharge and chloride, nitrate-N, and ortho-P concentrations at baseflow. These features are likely the result of some combination of natural hydrogeologic differences and anthropogenic influences, possibly including groundwater withdrawl and urbanization.

The quantitative results of this study that include the pollutant concentrations and load contributions of major point-source discharges, baseflow pollutant concentrations for sub-basins, baseflow pollutant load and load per unit area for sub-basins, baseflow discharge and hydrologic yield, and land-use distribution data are too lengthy to include here but are available from figures and tables in the original document, and readers are encouraged to examine those data for a more detailed analysis.

Cleary the Spring Creek basin is a dynamic watershed with notable differences among sub-basins. Point-source dis-

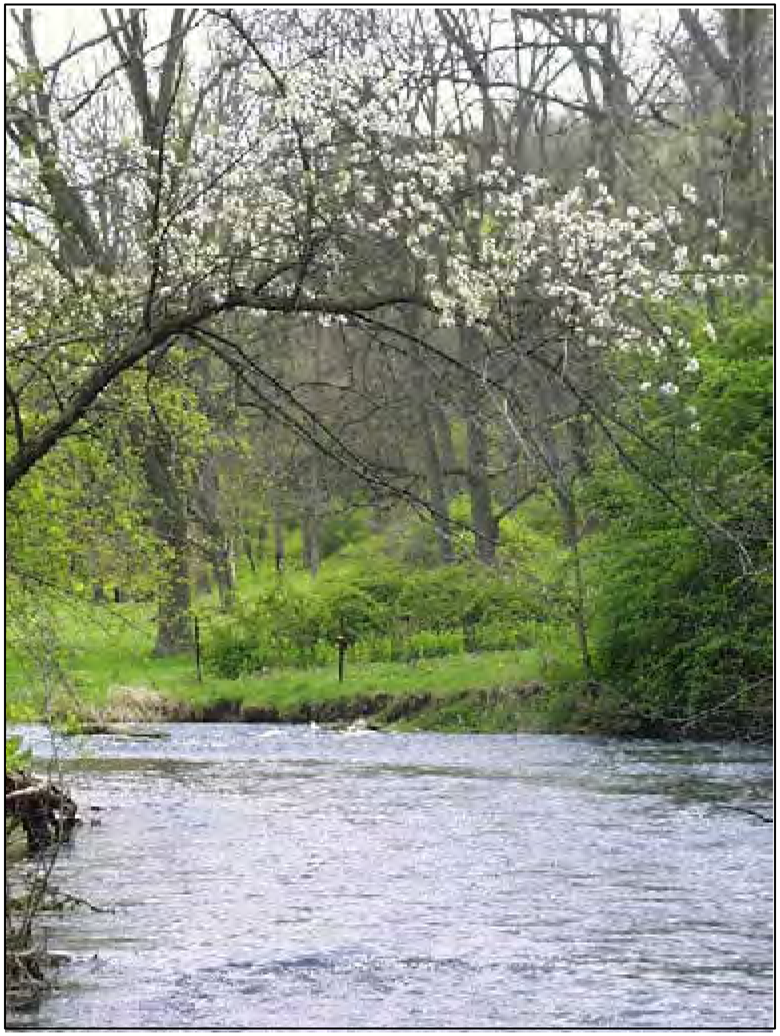


Photo by Becky Shirer

Logan Branch near Cerro Metals (2001).

charges contribute a significant proportion of baseflow discharge and pollutant loads. Some land use differences are correlated to differences in some pollutant concentrations and loads, but the relationship between land use and baseflow water quality is not always straightforward. The severe drought during the two-year study period clearly influenced the magnitude of pollutant loads from the sub-basins, since pollutant load is highly influenced by stream discharge rates.

The collection of baseline streamflow and water quality data by the WRMP made this report possible. I am grateful for the support of the diverse group of project funders that made and continue to make this work a reality, and provide the basic hydrologic information so vital to assessing both the current status and long-term trends of water resources on the Spring Creek basin.

Readers who have questions or comments are strongly encouraged to contact the author by email at jsengle@state.pa.us, or by phone at 814-342-8138.

5.2 Stormflow Runoff and Pollutant Concentrations

Written by J.M. Hamlett, Ph.D., P.E
Department of Agricultural and Biological Engineering
The Pennsylvania State University

The Spring Creek Chapter of Trout Unlimited funded a fellowship at Penn State University in 2002 to analyze the stormwater data collected by WRMP. The following is a non-technical summarization of the analysis completed by Rem Confessor and Jim Hamlet, Ph.D., P.E.

Stormwater runoff from 18 storms (8 during the Jan. to Dec., 2001 period and 10 during the Jan. to May, 2002 period) were monitored, and flow samples periodically collected at twelve sub-basin locations within the Spring Creek Watershed. Due to manpower, equipment, and financial constraints, between one and seven stations were monitored for each event. The number of storms monitored at any given station ranged from two (at Upper Buffalo Run) to 13 (at Spring Creek Milesburg). Because of this wide variation in number and times of storms monitored across the various sub-basins, it is difficult to draw many definitive conclusions about water quality as a result of storm flow runoff.

Total streamflow (equal to surface runoff plus baseflow), pollutant concentrations (mg/l), total storm event loads, and pollutant loads per unit area per unit runoff were investigated for each storm and for the various sub-basins monitored. A more complete description of the methodology for station instrumentation, data collection and analyses, and data results are presented elsewhere (see Spring Creek Watershed Community, 2002, and Confesor and Hamlett, 2003).

SURFACE RUNOFF

Streamflow as a percentage of rainfall (measured at the

Walker Building on the Penn State Campus) was compared for all stations and storms. With the exception of the November 11 storm on Thompson Run, relatively little surface runoff was produced during 2001, likely because of very dry conditions across the Watershed (for this period, generally less than 5% of rainfall became runoff for all stations monitored). Storm events beginning in March of 2002 generally showed a greater runoff response (as percentage of rainfall) than did the events in 2001, likely a result of increased subsurface moisture and more rapid runoff production during rainfall events. The events of March 26, April 13/14, and May 12 resulted in larger storm runoff amounts at all stations monitored than had resulted during previous storms. Typically, Thompson Run and Slab Cabin sub-basins had a higher percentage of surface runoff than did the other sub-basins, likely a result of lower baseflow contributions and greater urban land use as compared to the other subbasins.

STORM EVENT CONCENTRATIONS

Concentrations of pollutants detected in the composite stormwater runoff samples were investigated. As noted previously, not all storms were monitored at all stations; hence, a strict comparison of concentrations at each station for all storms combined is not possible. However, looking at the various storms and stations monitored does provide a glimpse of the pollutant concentrations (ranges and means) observed in stormflow. Stormflow concentrations can also be compared with baseflow concentrations at the various stations.


Photo by Katie Ombalski

Spring Creek at College Avenue and Houserville Road (2002).

For the Spring Creek basin, ammonia-N concentrations were at less than detectable levels for nearly 2/3 of all samples collected. Stations with higher flows (i.e. Spring Creek Milesburg and Axemann) had more samples with ammonia detects than did stations with lower flows. Storm event ammonia-N concentrations (for those samples for which detects were noted) were greatest for Lower Buffalo Run, Upper Logan Branch, Spring Creek Upper and Spring Creek Axemann sub-basins. Typically, ammonia-N concentrations detected were less than 0.2 mg/l, which is a common benchmark for good quality surface waters.

Chloride concentrations were highest in Lower Slab Cabin, Thompson Run, and the Spring Creek stations at Houserville, Axemann and Milesburg. Individual sample concentrations were highest (300 to 500 mg/l) for Thompson Run and Lower Slab Cabin during the storm runoff of March 2, 2002. These high concentrations likely are a result of transport of de-icing salts used in parking lots and roadways during winter periods. Chloride concentrations in stormwater runoff were substantially higher (50% greater or more) than baseflow chloride concentrations for Thompson Run, Lower Slab Cabin, and

Lower Logan Branch, whereas baseflow and storm concentrations were comparable for the other stations. Many samples had chloride concentrations above 10 mg/l, which is a common benchmark concentration for pristine freshwaters.

The maximum nitrate-N concentrations for all stations and across all storms were less than 6 mg/l, with the greatest median concentrations reported for Cedar Run, Spring Creek Axemann, Spring Creek Milesburg, and Lower Logan Branch. Surface waters that drain areas affected by anthropogenic activities often have nitrate-N concentrations in the 1 to 5 mg/l range. In all cases, the nitrate-N concentrations were substantially less than the drinking water limit of 10 mg/l. Storm nitrate-N concentrations were consistently highest for the Cedar Run sub-basin, regardless of storm magnitude or season of occurrence. These concentrations may likely be a result of contributions of agricultural fertilizers or animal wastes. As would be expected, concentrations of nitrate-N were lower during stormwater runoff (due to dilution) than for baseflow conditions, with the exception of Lower Logan Branch which showed a slightly higher stormwater concentration than during baseflow.

Concentrations of total orthophosphate (TOP) varied considerably across stations and storms, with average values in the 0.02 to 0.05 mg/l range. Thompson Run, Upper Slab Cabin, Upper Spring Creek, Upper Buffalo Run and Spring Creek Houserville generally had greater concentrations than the other sub-basins. Across all stations and storm events, only three samples had concentrations exceeding 0.10 mg/l, with the greatest sample concentration being 0.38 mg/l for Upper Slab Cabin during the March 20, 2002 event. Chapman (1996) noted that most natural surface waters have TOP concentrations in the range of 0.005 to 0.020 mg/l. Generally, concentrations of TOP were greater in stormflow samples than in baseflow, though not for all storms nor all stations.

Photo by Katie Ombalski

Thompson Run along College Avenue (2002).

Total suspended solids (TSS) concentrations also varied widely within storms and across the various stations. As expected, higher flows resulting from surface runoff carried higher concentrations of TSS than low baseflow conditions.

The stations with greatest median TSS concentrations were Upper Buffalo Run (likely due to construction disturbance), Thompson Run, Spring Creek Axemann, Upper Slab Cabin, and Upper Spring Creek. Upper and Lower Logan Branch subbasins generally had the lowest TSS concentrations. The March 26, 2002 event produced the largest TSS storm concentrations across all stations as compared to any other storms, likely a result of sediments being flushed from the overland flow and stream channel systems during this large event. During a later May 12 event, the greatest TSS concentration was observed for Cedar Run, which may have resulted due to spring agricultural tillage activities.

Upper Slab Cabin, Thompson Run, Upper Spring Creek and Lower Slab Cabin generally had higher total organic carbon (TOC) concentrations across seasons than did the other subbasins. Highest storm event concentrations observed were for the March 20, March 26, and May 12, 2002 events. Similar to TSS concentrations, the lowest TOC concentrations were reported for the Logan Branch subbasins. TOC concentrations (averaged across storms) in stormwater runoff were greater (60% to >100% higher) at all stations than were baseflow TOC concentrations, with the exception of Upper and Lower Logan Branch (which showed lower stormflow concentrations). On average, sample concentrations were below the typical value of 10 mg/l observed for many surface waters in the U.S.

Metal concentrations (copper, zinc, and lead) were most often detected, and generally detected at the highest levels, for the Lower Logan Branch and Spring Creek Milesburg stations. Copper was detected in less than 15% of the samples collected at all stations except Lower Logan Branch (10 out of 32 samples) and Upper Buffalo Run (3 out of 6 samples). During the intense rainfall-runoff event of March 26, 2002, copper concentrations above detection limits were observed for all stations monitored. Zinc was detected in less than 50% of the samples at all stations except Lower Logan Branch (27 of 34 samples detected), Thompson Run (12 of 12 samples detected), Spring Creek Milesburg (26 of 44 samples detected), and Spring Creek Axemann (6 of 9 samples detected).

Lead concentrations were detected at almost all stations regardless of storm event. Upper and Lower Logan Branch sub-basins, Thompson Run, Upper Spring Creek, Lower Slab Cabin and all the Spring Creek stations had more than 60% of their samples with lead concentrations above the detection limit. The highest lead concentrations (averaged for storms) were observed at Thompson Run and Upper Logan Branch stations.


Photo by Katie Ombalski

Confluence of Cedar Run and Spring Creek in Oak Hall (2002).

STORM EVENT LOADS

The Slab Cabin and Thompson Run sub-basins (both having appreciable urban land use areas) consistently had higher stormwater runoff (as a percentage of total flow) than did the other subbasins. Concentrations of several constituents (i.e. ammonia-N, chloride, total organic carbon, total orthophosphate, total suspended sediments, and metals) were also high for these sub-basins. Thus, on a per unit area basis, storm loads from these urbanized sub-basins tended to be larger than for other sub-basins, which had lower storm runoff and lower concentrations.

Cedar Run sub-basin had consistently higher concentrations of nitrate-N, which resulted in larger storm nitrate loads; this may be a refection of the contributions of nitrate from agricultural operations.

Total orthophosphate concentrations were similar across sub-basins and hence those sub-basins with more storm runoff tended to produce higher TOP loads.

Total suspended sediment loads were lowest for the Logan Branch stations; whereas the Upper Slab Cabin, Upper Spring Creek, and Spring Creek Milesburg stations showed higher suspended sediment loads. These higher loads may result from runoff from nonpoint sources and from channel degradation and sediment re-entrainment from the channel system.

Lead contributions were greatest from Logan Branch and Thompson Run sub-basins. Concentrations of copper and zinc were not detected in most samples and hence comparative load data are inconclusive.

SUMMARY

Stormwater runoff and water quality data were collected for a limited number of storms and a mix of stations per storm during the 17-month period reported herein. 2001 was a relatively dry year with relatively few and small magnitude stormwater runoff events. The first five months of 2002, a relatively wetter period and a period with several snowmelt runoff events, resulted in higher concentrations and loads of constituents. However, because of the relatively limited data, it is premature to draw many conclusions about comparisons of concentrations and loads across stations or by seasons. A longer term period of stormwater data is needed, with more consistent monitoring of similar stations, before thorough analyses of stormwater concentrations and loads can be meaningfully performed.

RECOMMENDATIONS

We concur with John Sengle's recommendation that a reduction in monitoring frequency of baseflow constituents would substantially reduce time and labor costs without compromising the goals of monitoring and establishing water quality trends on the Watershed. Those critical sub-basins that are contributing the hightest pollutant loads should be given special consideration when allocating monitoring efforts, particularly during storm flows. We have listed several other technical recommendations in our report.

REFERENCES

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Confesor, R.B. and J.M Hamlett. 2003. Spring Creek Watershed Water Quality Analysis. Report for Trout Unlimited, Centre County, PA.

Spring Creek Watershed Community. 2002. Spring Creek Watershed Stormwater Monitoring Protocol. Spring Creek Watershed Community, Centre County, PA.

5.3 PA DEP Preliminary Assessment Lists Spring Creek Impairments

In late 2002 PA DEP identified seven reaches of stream totaling 16.2 miles in length within the Spring Creek Watershed for possible inclusion on the 303(d) List of Impaired Waterbodies (Figure 3). These stream sections included portions of Thompson Run, Slab Cabin Run, Logan Branch, and parts of Spring Creek itself. Additionally, in early 2003 a portion of Buffalo Run was included, bringing the total stream length involved to 16.2 miles. A waterbody is determined to be "impaired" if it is not meeting its designated use, which is further explained below. Table 4 lists the impaired stream segments and gives further details including sources and causes of the impairments. To put the impairments in context, the Spring Creek Watershed has approximately 80 stream miles. PA DEP has determined that 20% of the watershed's stream miles do not meet water quality standards for their designated use.

Three of the impairments are classified as point sources of pollution: the three one-mile segments immediately below the PFBC hatcheries. PA DEP and PFBC are cooperating statewide to address this problem.

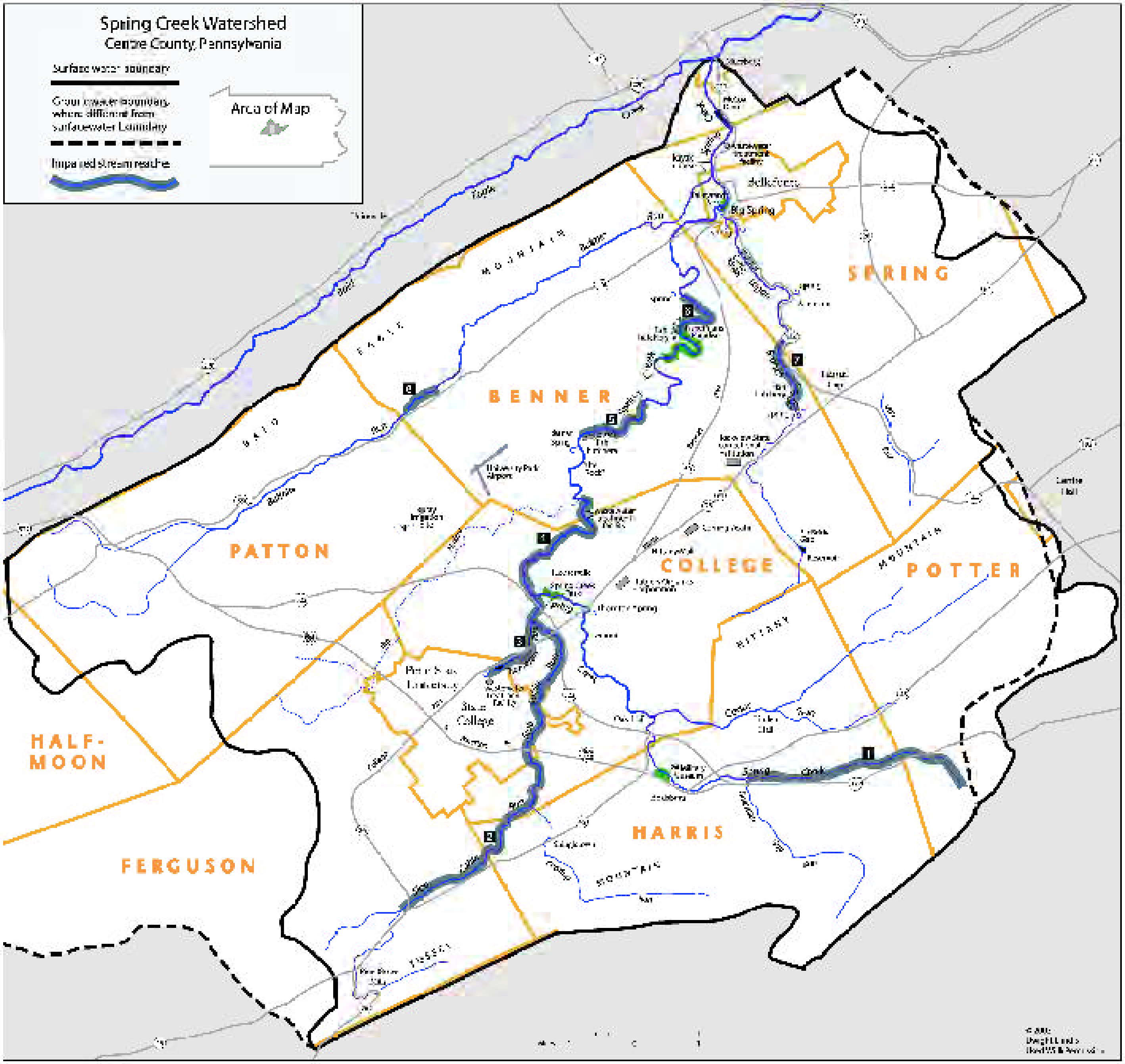
The other impairments are caused by nonpoint sources of pollution, including stormwater runoff, removal of riparian (or

Table 4. List of Streams Recommended by PA DEP for the 303(d) List of Impaired Waterbodies.

MAP ID	STREAM NAME	LENGTH (MI.)	IMPAIRMENT SOURCES	IMPAIRMENT CAUSES
1	Spring Creek - Headwaters to Galbraith Gap Run	1.9	Golf Course, Residential Runoff, Agriculture, Removal of Riparian Vegetation	Silt, Thermal Modification
2	Slab Cabin Run - Rt. 26/45 intersection to Spring Creek	7.0	Grazing, Flow Modification, Golf Course, Urban Runoff	Silt, Flow Variability, Thermal Modification
3	Thompson Run	1.0	Urban Runoff	Silt
4	Spring Creek - Slab Cabin Run to Big Hollow	2.7	Urban Runoff, Storm Sewers	Silt
5	Spring Creek - PFBC Benner Spring Fish Culture Station	1.0	Industrial Point Source	Organic Enrichment
6	Spring Creek - PFBC Bellefonte Fish Culture Station	1.0	Industrial Point Source	Organic Enrichment
7	Logan Branch - Pleasant Gap State Fish Culture Station	1.0	Industrial Point Source	Organic Enrichment
8	Buffalo Run	0.6	Agriculture	Silt
	Total Impaired Stream Miles:	**16.2**		

Source: *"Aquatic Biological Investigation, Spring Creek in Centre Co. PA"*; PA DEP; February 5, 2002

Figure 3. Spring Creek Watershed streams recommended by PA DEP for the 303(d) List of Impaired Waterbodies.



streamside) vegetation, animal grazing, and sedimentation. These are types of problems that are widespread and more difficult to address.

HOW IS IMPAIRMENT DETERMINED?

The Clean Water Act requires PA DEP to assess all of the waters in Pennsylvania. To fulfill this requirement, PA DEP created the Surface Waters Assessment Program (SWAP) in 1997. This program was designed to conduct stream assessments as quickly and effectively as possible, complete a statewide assessment of all streams within ten years, document point source and nonpoint source impairments, and identify the causes and sources of these impairments.

The first step in the SWAP process is to review information on land cover, land uses, abandoned mine drainage, water quality, and known point source discharges within the Watershed. The assessment biologist then conducts a reconnaissance of the watershed to verify current land-use patterns; confirm known point source discharge locations; and categorize stream habitat types, flow conditions, accessibility, and other conditions that would determine where sampling stations are placed. In-stream assessments begin after the reconnaissance is completed. The assessment process uses widely accepted aquatic biology sampling principles similar to the Environmental Protection Agency's (EPA) Rapid Bioassessment Protocol and habitat evaluation procedures.

The biologist collects and identifies stream bottom-dwelling invertebrate organisms such as insects (mayflies, stoneflies, and caddisflies), worms, and snails. Once the biologist completes sampling and data recording, he or she reviews the families collected, their relative abundances, and pollution tolerance ratings. The results are then evaluated using biological criteria to distinguish between healthy and impaired conditions.

Next, the biologist conducts a stream habitat evaluation that considers in-stream conditions such as substrate particle composition, siltation, stream velocity and depths, sediment deposition, and riffle frequency. Riparian conditions such as stream bank erosion, vegetative cover, disruptive land uses, and buffer zones are also evaluated. The combined biological and habitat scoring results indicate whether the stream is impaired based on aquatic life and/or physical habitat conditions. Each assessment results in a summary that identifies stream segments with no obvious impairment and those with obvious water quality impairments. Entries for impaired segments include information on the source and cause of impairment.

All assessments are supplemented with data collected by outside monitors. In the Spring Creek Watershed, several local data sources were accessed, including the Water Resources Monitoring Project of the Spring Creek Watershed Community.

Water quality standards are the foundation of this water quality-based control program. The two main components of water quality standards are the designated uses of water bodies and the water quality criteria that are designed to protect the designated uses.

The water quality criteria are expressed as numeric pollutant concentrations and narrative requirements. Specific stream conditions and parameters must meet these criteria in order to prevent or eliminate pollution.

Designated uses have been defined for each water body in 25 Pa. Code §§ 93.4(a) and 93.9a—93.9z. A designated use may or may not actually be attained by a water body.

Several categories of designated uses are distinguished as "protected water uses" in the Code, including:

- Aquatic Life (ex. Cold Water Fishery (CWF), Warm Water Fishery (WWF))
- Water Supply (ex. Potable Water Supply (PWS))
- Recreation (ex. Fishing (F))
- Special Protection (ex. High Quality (HQ) & Exceptional Value Waters (EV))

In addition to designated uses, water bodies also have existing uses. Existing uses are defined in 25 Pa. Code § 93.1 as "those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards." In most cases, the existing and designated uses are the same. For example, the stream is designated as a Cold Water Fishery and its existing use is a Cold Water Fishery. However, existing and designated uses can be different.

Within the Spring Creek Watershed, there are two major designated uses for its streams, High-Quality Cold Water Fishery and Cold Water Fishery. Table 5 shows the streams in the Spring Creek Watershed and their associated designations.

Section 303(d) of the Clean Water Act requires states to list all impaired waters not supporting their designated uses even after appropriate and required water pollution control technologies have been applied. The 303(d) List includes the reasons for impairment, which may be one or more point or nonpoint sources of pollution.

WHY ARE SO MANY STREAM REACHES SUDDENLY IMPAIRED?

DEP's discovery of impaired stream reaches during 2002 was in part due to a newly instituted system of assessing streams.

Table 5. Spring Creek Watershed Stream Designations.

STREAM	SPECIFIC ZONE	WATER USES PROTECTED
Spring Creek		HQ-CWF
Unnamed Tributaries to Spring Creek		CWF
Galbraith Gap Run		HQ-CWF
Cedar Run		CWF
Markles Gap Run		HQ-CWF
McBrides Run		HQ-CWF
Slab Cabin Run	Source to PA 26 at RM 9.0	HQ-CWF
Slab Cabin Run	PA 26 at RM 9.0 to Mouth	CWF
Thompson Run		HQ-CWF
Logan Branch	Source to T-371 Bridge	CWF
Logan Branch	T-371 Bridge to Mouth	HQ-CWF
Buffalo Run	Source to T-942 Bridge at RM 0.66 (near Coleville)	HQ-CWF
Buffalo Run	T-942 Bridge to Mouth	CWF

Traditionally, PA DEP and similar agencies across the country relied principally on chemical measures to assess stream conditions. More recently, federal and state agencies have been using biological measures to assess streams, because they felt that chemical measures were sometimes not sensitive enough to detect impaired water quality. PA DEP has developed a quantitative method of examining invertebrates that live in stream bottoms. The numbers and types of bottom organisms are used to generate numerical scores, which together with physical and chemical data, are translated into assessment categories.

The impairment designations were based largely on biological criteria derived from samples of bottom organisms. PA DEP biologist Ronald Hughey noted that in several instances chemical data for a stream reach were not well correlated with biological data. In other words, biological data suggested impairment, but chemical data did not.

DO WATER MONITORING DATA AGREE WITH PA DEP'S ASSESSMENTS?

In general, yes. We used concentrations of total suspended solids, chlorides, lead, nitrates, phosphates, and total organic carbon measured during baseflow and storm flow conditions to rank monitoring stations from highest to lowest concentrations (Table 6). At baseflow, monitoring stations that ranked highest in concentrations, Spring Creek at Axemann, upper Logan Branch, and Thompson Run, were all judged impaired by PA DEP. But two stations, Spring Creek at Houserville and lower Slab Cabin Run, ranked among the bottom 50% (i.e., low concentrations), yet they displayed biological impairment. During storm flow conditions, Spring Creek at Axemann and Thompson Run still ranked highest. The upper Buffalo Run station ranked third, but only two storms were sampled here. The Spring Creek station at Milesburg ranked moderately high for both baseflow and storm flow samples, yet it was not judged to be impaired. Reasons for this discrepancy are not clear.

Overall, chemical and biological data agree reasonably well, though as Ronald Hughey noted, there are some exceptions. Perhaps the important message from this analysis is that chemical and biological data by themselves may not provide an accurate picture of stream health, and monitoring of both measures is the most prudent course of action. The Water Resources Monitoring Committee is in the process of determining how the project can most efficiently monitor both chemical and biological variables.

WHAT HAPPENS NEXT?

PA DEP is submitting their preliminary stream assessment findings to the EPA. EPA will make the final determination on which of these impaired stream reaches are added to the 303(d) List.

States or the EPA must determine the conditions that would return the water to the quality that meets water quality standards. As a follow-up to listing, the state or EPA must develop a Total Maximum Daily Load (TMDL) for each waterbody on the 303(d) List. TMDLs can be considered to be a watershed budget for pollutants, representing the total amount of pollutants that can be assimilated by a stream without causing impairment or water standards to be exceeded. A margin of safety is also provided to account for uncertainty in the loading calculations. The TMDL process allocates the amount of pollutants that can be discharged into a waterway from each category of pollutant source. The TMDL does not specify how discharges must attain particular load reductions.

Pennsylvania has committed to developing TMDLs for all impaired waterbodies and will use both traditional and new approaches to correct water quality problems. DEP will be designing and implementing TMDLs over the next decade. Eventually, the municipalities will be required to administer these TMDLs.

ACTIONS BY SPRING CREEK WATERSHED COMMUNITY STAKEHOLDERS

Release of the PA DEP impairments report prompted the Spring Creek Watershed Community (SCWC) to explore ways to eliminate some of the sources of impairment. After several meetings the Community settled on a course of action. The first proposed major project was assessment and improvement of riparian areas in the Slab Cabin Run basin. To fund this initiative, ClearWater Conservancy, a SCWC stakeholder, submitted a grant application to DEP's Growing Greener Program and to EPA's Small Watershed Grants Program. ClearWater was awarded both grants for the implementation of the Riparian Conservation Program in 2003.

Before the grants were announced, an effort was made to initiate conversations with landowners in the upper Spring Creek basin and explore ways that they might alter current management of riparian areas to improve water quality. In April 2003, several stakeholders of the Community (U.S. Geological Survey, Centre County Conservation District, Penn State, and ClearWater Conservancy) met with Dave Williams, golf course superintendent for the Elks Country Club in Boalsburg. The group inspected the entire length of Spring Creek that flows through the golf course and Williams described his efforts over the past few years to increase the width of unmowed riparian cover. The group also discussed possible tree planting along the stream. It was apparent from this inspection that the golf course was not making measurable contributions of silt to downstream reaches of Spring Creek. ClearWater Conservancy is currently working with the Elks Club to create a conservation plan for their property. The Spring Creek Watershed Community plans to continue these kinds of meetings with landowners.

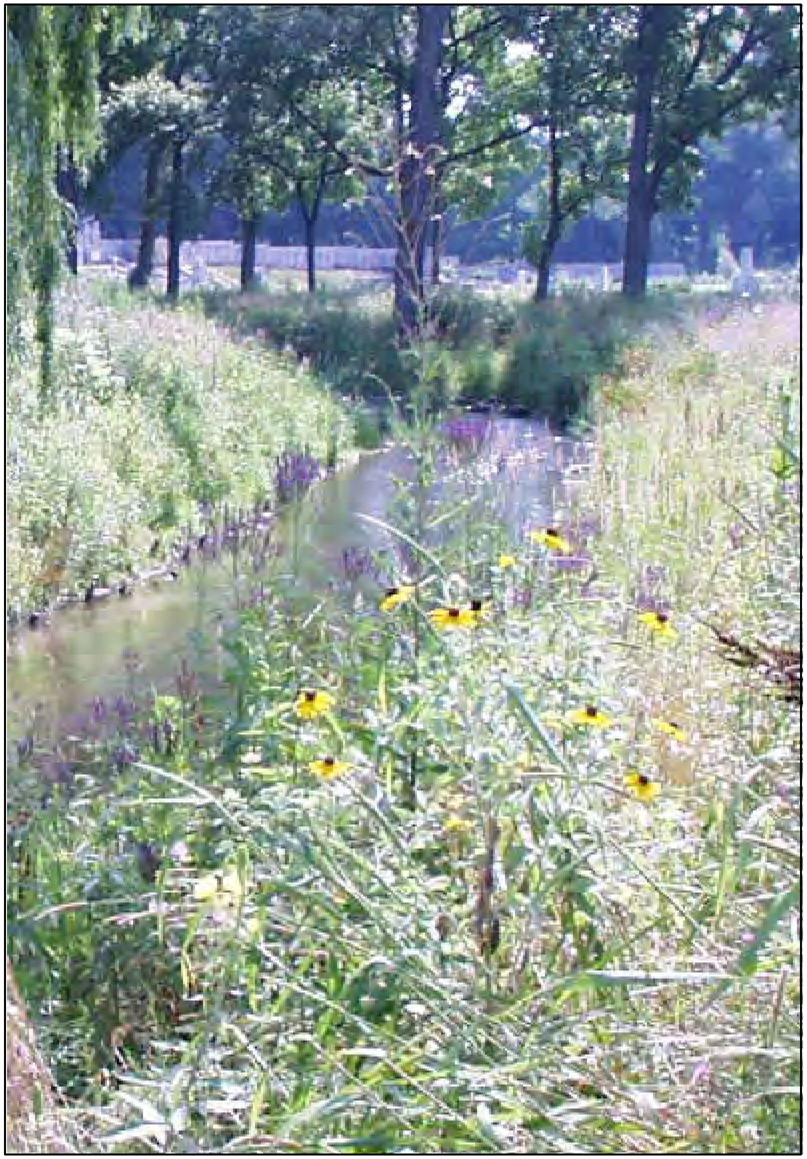


Photo by Lynn Fosbender

Restored riparian buffer at the Pennsylvania Military Museum.

Table 6. Ranking of sampling stations by concentration of chemical constituent (highest concentration ranked 1). Baseflow samples were collected monthly during 2001 when streamflow was stable. Data from the Upper Slab Cabin Run and Upper Buffalo Run stations were not included in baseflow rankings because stream sections were often dry. Stormflow samples were collected during two to 13 storms per station between January 2001 and May 2002. Stormflow constituent rankings were based on concentrations normalized for sub-basin surface area. Data taken from Confesor and Hamlett (2003).

BASEFLOW SAMPLES 2001							
	Ranking by Chemical Constituent						
Station	**Total Suspended Solids**	**Chloride**	**Lead**	**Nitrate**	**Phosphate**	**Total Organic Carbon**	**Mean rank**
Spring Creek Axemann	1	3	7	1	4	3	3.2
Logan Branch Upper	10	6.5	1	7	2	2	4.8
Thompson Run	5.5	2	7	3	5	10	5.4
Spring Creek Milesburg	10	4.5	7	4	3	6.5	5.8
Buffalo Run Lower	2	11	7	4	9	6.5	6.6
Cedar Run	4	12	7	2	7	9	6.8
Spring Creek Houserville	8	4.5	7	5	10.5	8	7.2
Slab Cabin Run Lower	12	1	7	10	10.5	4	7.4
Logan Branch Lower	10	9	2	6	8	11.5	7.8
Spring Creek Upper	7	10	7	9	12	11.5	9.4

*Shaded stations were judged impaired by DEP

Table 6. (continued)

STORMFLOW SAMPLES JANUARY 2001 TO MAY 2002							
	Ranking by Chemical Constituent						
Station	**Total Suspended Solids**	**Chloride**	**Lead**	**Nitrate**	**Phosphate**	**Total Organic Carbon**	**Mean rank**
Spring Creek Axemann	3	3	4	1	4	4	3.2
Thompson Run	5	2	1	5.5	2	4	3.3
Buffalo Run Upper	1	8	3	12	3	4	5.2
Slab Cabin Run Upper	2	9	10	11	1	1	5.7
Spring Creek Milesburg	8	5	5	4	7	10	6.5
Buffalo Run Lower	4	10	7	8	9	4	7.0
Spring Creek Houserville	9	4	6	7	8	8	7.0
Logan Branch Upper	12	7	2	5.5	5	11	7.1
Slab Cabin Run Lower	10	1	11	9.5	11.5	4	7.8
Spring Creek Upper	6	12	8	9.5	6	7	8.1
Logan Branch Lower	11	6	9	3	10	12	8.5
Cedar Run	7	11	12	2	11.5	9	8.8

*Shaded stations were judged impaired by DEP

5.4 2002 Marked the Beginning of the End of the Extended Regional Drought

The extended regional drought recently experienced in Central Pennsylvania was the cumulative decline in the groundwater resources of the Spring Creek Watershed that began in the summer of 1998 and is shown by the dashed arrow on the hydrograph (Figure 4). The vertical lines are January 1st of each year, almost in the middle of each winter, and for Well CE 686 (blue line), the winter declines in the water-table levels are apparent during the drought period. During 2002 the Spring Creek Watershed received 10% above normal precipitation, and this marked the beginning of the end of the drought. The above-normal rainfall began in May 2002, and the dotted arrow on the hydrograph shows the rising water-table level trend in Well CE 686 that continued through the summer of 2003. By the end of 2002, 19 inches of snow had fallen and the snow pack had started to accumulate.

So how did the 10% above normal precipitation in 2002 and the snow pack mark the end of the drought? The answer is the timing of the precipitation. During the winter months of November, December, January, February, and March, plants are dormant and their consumption of water is negligible. Evaporation is also minimal due to the cold temperatures, limited sunshine, and the low sun angle. During the spring, summer, and early fall, plants consume water and discharge it into the atmosphere as water vapor by a process called transpiration. Evapotranspiration is the combined movement of water back into the atmosphere by both evaporation and transpiration, and this process moves approximately two-thirds of our annual precipitation back into the atmosphere each year.

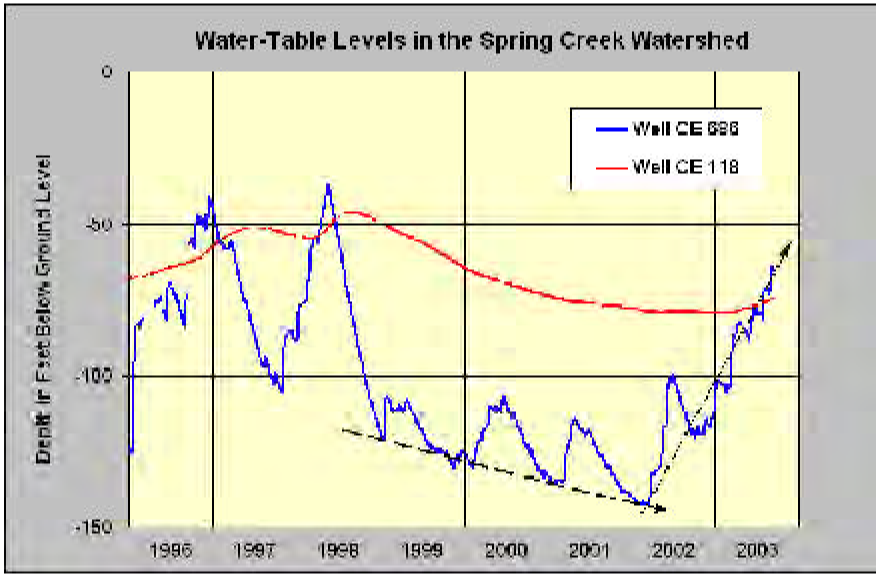


Figure 4. Hydrograph of Well CE 686 and CE 118 (1996-2003).

The blue hydrograph line of Well CE 686 (located two miles southwest of State College) shows that almost 40 feet of water-table level rise occurred during last winter. This refutes the common belief that groundwater recharge can't occur through ground frost. We were fortunate that last winter's snow pack melted rather slowly, which allowed most of the melt water to become recharge and not runoff. The timing of the precipitation in 2002, more than the total amount, contributed to the beginning of the end of the drought.

Well CE 118, shown by the red hydrograph line in Figure 4, is located 5 miles west-southwest of State College on Game Lands 176 in the Barrens. This monitoring well is located in the headwaters recharge area of Big Spring, which is located within the Spring Creek groundwater boundary. Groundwater under the Barrens flows approximately 12 miles northeast to discharge from Big Spring in Bellefonte. The response of the water-table level is very subdued in Well CE 118 due to the overlying sandy soil and the high groundwater storage capacity of the Gatesburg Formation bedrock. The sandy natural forest floor conditions and the complete lack of urbanization in this headwaters area promote groundwater recharge to this important groundwater resources area of the Spring Creek Watershed. The slight upturn in the red hydrograph line of Well CE 118 in Figure 4 also indicates the beginning of the end of the drought in this area of the Watershed.


Photo by Katie Ombalski

Chris Finton conducting a well video on Mount Nittany.

2002 Water Resources Monitoring Data Users

- Spring Township Water Authority - Streamflow data used to assess water resources impacts of development of a new public water supply source well.
- Confidential Industrial User - Streamflow data used to assess impacts upon stream from uncontrolled release of industrial material.
- State College Borough Water Authority - Streamflow and water quality data to be used for source water protection study.
- PA DEP Stream Assessment - Streamflow and water quality data used for Section 303(d) assessment of impaired reaches of Spring Creek and tributaries.
- Spring Creek Watershed Plan; USGS, Spring Creek Watershed Municipalities - Streamflow data to be used for assessment of watershed hydrologic conditions.
- Several PSU Graduate Students - Streamflow and water quality data used for M.S. research work.
- Spring Creek Watershed Community - Streamflow and water quality data used for 2002 Annual Report of the Water Resources Monitoring Project.

6.0 RECOMMENDATIONS FOR FURTHER ACTION

IMPAIRMENT AND NONPOINT SOURCE POLLUTION

Section 5.3 (*PA DEP Preliminary Assessment Lists Spring Creek Impairments*) cites the following sources of impairment to Spring Creek and its tributaries:

PADEP-ASSESSED[1] SOURCE OF IMPAIRMENT	**Spring Creek upstream from Boalsburg**	**Slab Cabin Run**	**Thompson Run**	**Spring Creek PAFBC Benner Spring Facility**	**Spring Creek – Bellefonte Facility**	**Logan Branch – PAFBC[2] Pleasant Gap Facility**	**Spring Creek- Slab Cabin to Big Hollow**	**Buffalo Run**
Golf Course	✓	✓						
Residential Runoff	✓							
Agriculture	✓							✓
Removal of Riparian Vegetation	✓							
Grazing		✓						
Flow Modification		✓						
Urban Runoff		✓	✓				✓	
Storm Sewers							✓	
Industrial Point Source				✓	✓	✓		

Table 5. Spring Creek stream impairments listed by sources.

Industrial point sources are presently being addressed by PA DEP under its National Pollutant Discharge Elimination System (NPDES) program. Most of the remaining identified potential sources of impairment fall under the broad heading of "nonpoint" sources (NPS). Most state and federal environmental management agencies would agree that the management of nonpoint source pollution is one of the most significant challenges for the future. In fact, PA DEP's Growing Greener Program was initiated, in part, to allocate resources to local stakeholder groups and other entities specifically to address nonpoint source pollution issues.

WATERSHED-WIDE RECOMMENDATIONS

The following recommendations apply to the entire Watershed with particular relevance to sections impaired by nonpoint sources. These recommendations may apply to a variety of entities and individuals: municipalities, sewer and water authorities, the Centre County Conservation District, Penn State University, environmental organizations, and land owners.

- Survey sub-basins to assess the listed 303(d) impairments. Confirm the PADEP assessment of sources of impairment. Identify possible additional causes of impairment.
- Careful implementation of the Spring Creek Act 167 Stormwater Management Plan will help to address future adverse effects of urbanization upon the natural hydrologic function of the watershed.
- Careful implementation of NPDES Phase II Stormwater Management by local municipalities will also help to address adverse effects of urban runoff.
- Protect, preserve and enhance riparian vegetation.
- Implement streambank protection such as fencing, bank and bed stabilization, and riparian buffers.
- Implement best management practices to reduce runoff, erosion and nutrient/chemical losses from agricultural land areas.
- Implement macroinvertebrate monitoring to assess effectiveness of remediation.

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[1] PADEP report

[2] PAFBC = Pennsylvania Fish and Boat Commission

SUMMARY RECOMMENDATIONS FOR IMPAIRED SUB-BASINS

RECOMMENDED ACTION	Spring Creek upstream from Boalsburg	Slab Cabin Run	Thompson Run	Spring Creek - Slab Cabin to Big Hollow	Buffalo Run
Survey Sub-basins	✓	✓	✓	✓	✓
Act 167 Implementation	✓	✓	✓	✓	✓
Low-impact development BMP's	✓	✓			✓
NPDES Phase II Implementation		✓	✓	✓	
Mitigate existing residential runoff problems	✓	✓			
Mitigate existing urban runoff problems			✓	✓	
Streambank fencing and riparian buffers	✓	✓		✓	✓

SPECIFIC RECOMMENDATIONS FOR IMPAIRED SUB-BASINS

Spring Creek Upstream from Boalsburg

- The Centre County Conservation District and environmental groups should continue working with private landowners to implement Best Management Practices on agricultural lands to improve riparian conditions.
- Municipalities should carefully examine proposed developments in this sub-basin to minimize runoff and nonpoint source pollution transport to streams.

Slab Cabin Run

- This sub-basin will probably come under severe development pressure in the near future. To ensure that water quality is not further degraded, municipalities should closely scrutinize proposed developments, insist on application of best management practices, promote preservation of open space, and seek to minimize installation of impervious surfaces.
- Water and sewer authorities should seek to reduce flow modification, such as through the UAJA Beneficial Reuse Project.
- The Centre County Conservation District and environmental groups should work with private landowners to implement BMPs on agricultural lands and to improve riparian conditions.

Thompson Run

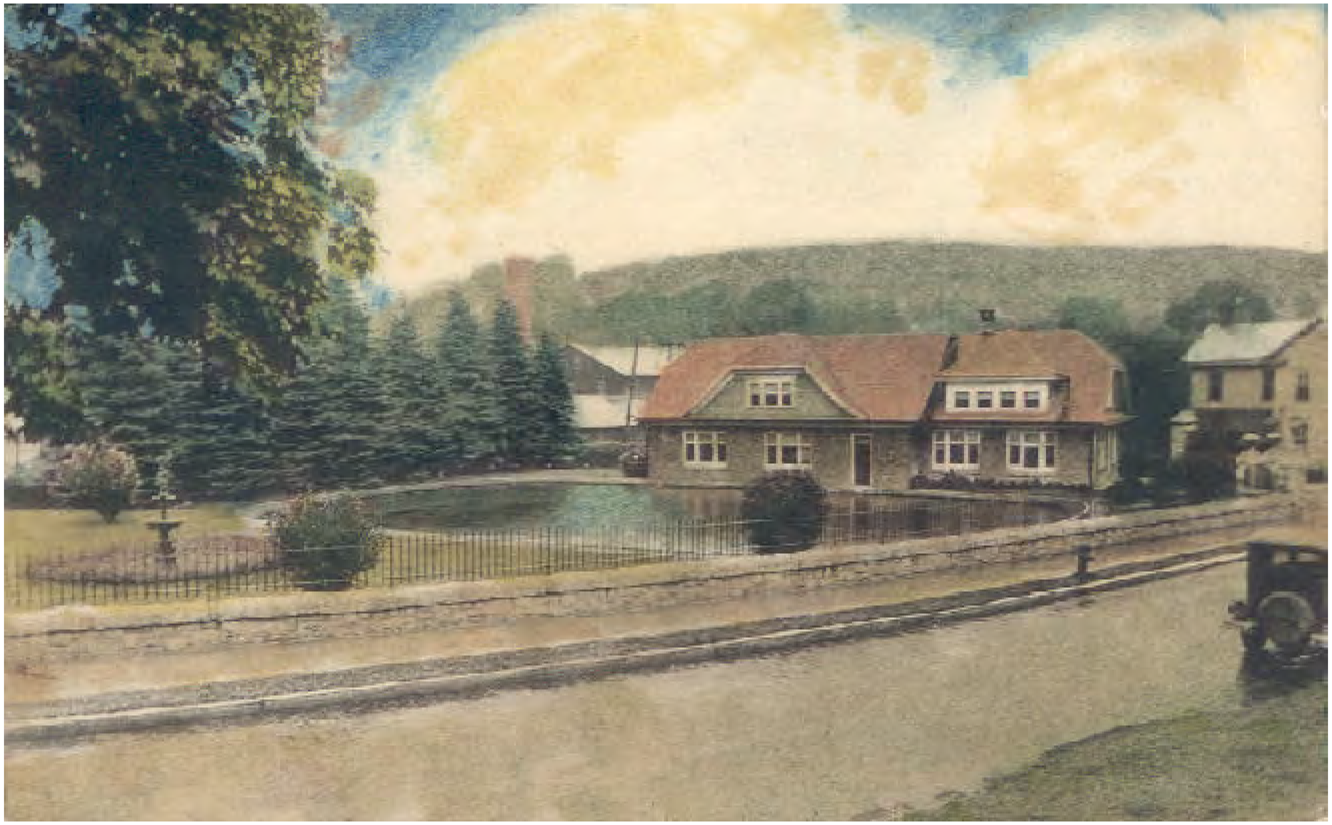
- Make progressive implementation of NPDES Phase II stormwater management measures a high priority.
- This is the most extensively developed sub-basin in the watershed and may be the most challenging sub-basin to address. Municipalities and Penn State University should seek to improve stormwater management where feasible, preserve existing open space, and avoid increasing impervious surfaces.

Spring Creek; Slab Cabin Run to Big Hollow

- Make progressive implementation of NPDES Phase II stormwater management measures a high priority.

Buffalo Run

- The Centre County Conservation District and environmental groups should work with private landowners to implement best management practices on riparian lands and on adjacent agricultural areas.



Hand-tinted, undated postcard of Bellefonte's Big Spring, circa 1920's. Postcard is captioned:

Wonderful Spring

Bellefonte, PA. Daily Flow 11,500,000 gallons, temperature of water 50 degrees at all times. This great spring was deeded to the town by Mayor Wm. F. Reynolds.

APPENDICES

NOTE: Monthly data for 2002 are compiled in an addendum to this report. If you would like to receive a copy of the addendum, please contact the Water Resources Monitoring Project Manager at (814) 237-0400.

Table A.1. Monitoring Well As-Built Characteristics.

WELL	TOTAL DEPTH, ft	CASING LENGTH, ft	DATUM ELEVATION, ft. above mean sea level (AMSL)	TYPICAL STATIC WATER LEVEL, ft. above mean sea level	BEDROCK FORMATION
Centre Hall 1	113	~ 20	1272.0	1200	Coburn-Nealmont
I-99 MW-1	149	119	1015.2	940	Gatesburg
Pine Grove Mills 2 (DCNR 2)	102	24	1637.2	1605	Juniata
Mt. Nittany Base 1 (Corning Asahi)	200	*	1131.3	1050	Linden Hall
Fillmore 1	235	19	964.7	955	Stonehenge
USGS CE 118 (Scotia 1)	130	40	1152.9	1100	Gatesburg
USGS CE 686	345	84	1236.8	1130	Nittany

* Data currently unavailable.

Table B.1. Monthly Water Qualtiy Analyses.

PARAMETER	DESCRIPTION	SOURCES	ENVIRONMENTAL EFFECTS	PA DEP CRITERIA*
pH	A measure of the acidity of water on a logarithmic scale of 1 to 14. A pH below 7 is acidic, above 7 is basic or alkaline, and a pH of 7 is neutral.	The pH of Spring Creek is slightly alkaline because of the carbonate bedrock. pH can be lowered by acid mine drainage or acid rain.	Extreme pH can inhibit growth and reproduction.in aquatic organisms. Acidic waters also release metals from the sediment, creating toxic conditions.	6-9
Dissolved Oxygen (DO)	Oxygen gas dissolved in the water is crucial to aquatic life. The amount of oxygen dissolved at saturation is inversely related to temperature.	DO is depleted by respiration and the microbial breakdown of organic wastes. It is restored by photosynthesis and physical aeration.	Low levels of dissolved oxygen are harmful to aquatic animals. This is usually the result of organic pollution or elevated temperatures.	> 7 mg/L (HQCWF**) >5.0 mg/L (CWF**)
Turbidity	A measure of water clarity expressed as the amount of light penetrating the water. It is relative to the amount of suspended material in the water.	While some clean rivers are naturally turbid, turbidity can be increased by earth-moving activities, urban runoff, and erosion from agricultural fields.	High turbidity blocks light from the water column and inhibits submerged aquatic plants. By absorbing sunlight, the particles also increase water temperature.	No criteria established.
Total Suspended Solids (TSS)	Any particles carried by the water and include silt, plankton, organic stream litter, industrial waste and sewage.	Sources include urban runoff, wastewater treatment plants, soil erosion, and decaying plant and animal material.	Suspended solids clog fish gills and alter stream-bed habitat when settled. Particles may carry bound toxic compounds or metals.	No criteria established.
Chloride	The concentration of chloride salt ions dissolved in the water.	Washes off of roads where it is applied as a deicing agent.	Very high chloride concentrations can be toxic to macroinvertebrates.	< 150 mg/L HQ-CWF**
Ortho-phosphate	Orthophosphate is the form of inorganic phosphorous required by plants. Its availability is often the limiting factor in plant growth.	Rocks and minerals provide a low natural level. Human sources include commercial cleaning products, water treatment plants, and fertilized lawns and farmland.	A small increase in orthophosphate can cause eutrophication, the loss of dissolved oxygen through the stimulation and decay of excessive plant growth.	No criteria established.
Nitrate (NO3)	One of three forms of nitrogen found in water bodies, nitrate is the form used by aquatic plants. Organic nitrogen (N) is converted to nitrate (NO3) by bacteria.	Any nitrogen-containing organic waste, including sewage from water treatment plants and septic systems, and runoff from fertilized lawns, farms and livestock areas.	High nitrate levels promote excessive plant growth and eutrophication. Excess nitrate in drinking water can cause illness of death in infants.	< 10 mg/L for Nitrate and Nitrite Combined
Total Petroleum Hydrocarbons	Molecules found in petroleum fuels. Indicates oil pollution and road runoff.	Runoff from roads, careless disposal, accidental spills, and natural deposits.	Varying degrees of toxicity to aquatic organisms and birds.	No criteria established.
Total Organic Carbon	A measure of the amount of carbon-containing compounds and thus the amount of organic material present.	Animal wastes, human wastes, plant material, agricultural chemicals, and petroleum compounds.	High carbon content in streams increases the growth of microorganisms, which depletes dissolved oxygen.	No criteria established.
Copper	A heavy metal less common than lead and zinc in nature.	Used in wiring, plumbing, and electronics, and to control algae, bacteria, and fungi.	Toxic to humans and aquatic life. Toxicity is affected by water hardness.	<12.7 ug/L***
Lead	A heavy metal that occurs naturally as lead sulfide but may exist in other forms.	Urban & industrial uses include gasoline, batteries, solder, pigments, and paint.	Toxic to humans and aquatic life. Toxicity is affected by water hardness.	<3.90 ug/L***
Zinc	A heavy metal commonly found in rock-forming minerals.	Urban runoff, industrial discharges and natural sources. Used in many alloys.	Somewhat toxic to humans and aquatic life. Toxicity is affected by water hardness.	<167 ug/L***

*From Pennsylvania Code Title 25, Chapters 16 and 93
**HQ-CWF = High Quality Cold Water Fishery, CWF = Cold Water Fishery
***Assuming a water herdness of 150 mg/L.

Addendum: 2002 Monthly Data

Table 1. 2002 Mean Monthly Stream Flow in Cubic Feet per Second (cfs).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Frozen	0.05	4.06	4.13	17.47	23.75	3.25	0.47	0.01	0.08	4.07	8.54	6.0	4.1
Slab Cabin Lower	0.08	0.25	7.43	10.13	29.34	32.82	6.04	0.84	0.55	2.25	6.74	10.80	8.9	6.4
Buffalo Run Upper	No Data	Dry	7.77	3.73	14.18	15.12	0.88	0.01	Dry	0.27	2.03	4.48	5.4	3.7
Buffalo Run Lower	2.02	3.09	16.46	10.53	38.19	30.20	4.31	1.85	0.99	1.72	5.34	9.04	10.3	4.8
Cedar Run Lower	5.67	9.47	14.00	19.51	24.04	26.91	14.68	9.39	6.89	8.40	15.57	17.80	14.4	14.3
Thompson Run Lower	6.25	6.54	8.95	8.94	18.86	27.82	16.39	12.87	9.79	8.67	8.15	8.31	11.8	8.9
Logan Branch Upper	17.28	21.36	32.01	42.20	58.40	47.85	21.01	16.22	16.21	17.05	23.40	29.65	28.6	22.4
Logan Branch Lower	50.45	53.99	68.47	86.92	118.66	111.47	66.06	59.75	55.18	58.01	71.15	74.49	72.9	67.3
Spring Creek Upper	7.06	11.73	25.09	19.00	46.11	54.30	9.74	7.59	8.62	14.18	32.08	32.30	22.3	16.6
Spring Creek Houserville	22.58	32.36	62.13	66.20	120.00	152.47	44.29	27.42	25.97	36.16	64.60	78.19	61.0	53.2
Spring Creek Axemann	42.06	53.64	84.55	88.43	155.78	183.70	69.42	47.13	39.30	47.58	77.73	96.32	82.1	73.6
Spring Creek Milesburg	117.83	139.57	198.71	209.03	336.93	351.93	163.06	128.64	120.10	141.93	185.37	206.97	191.7	174.2

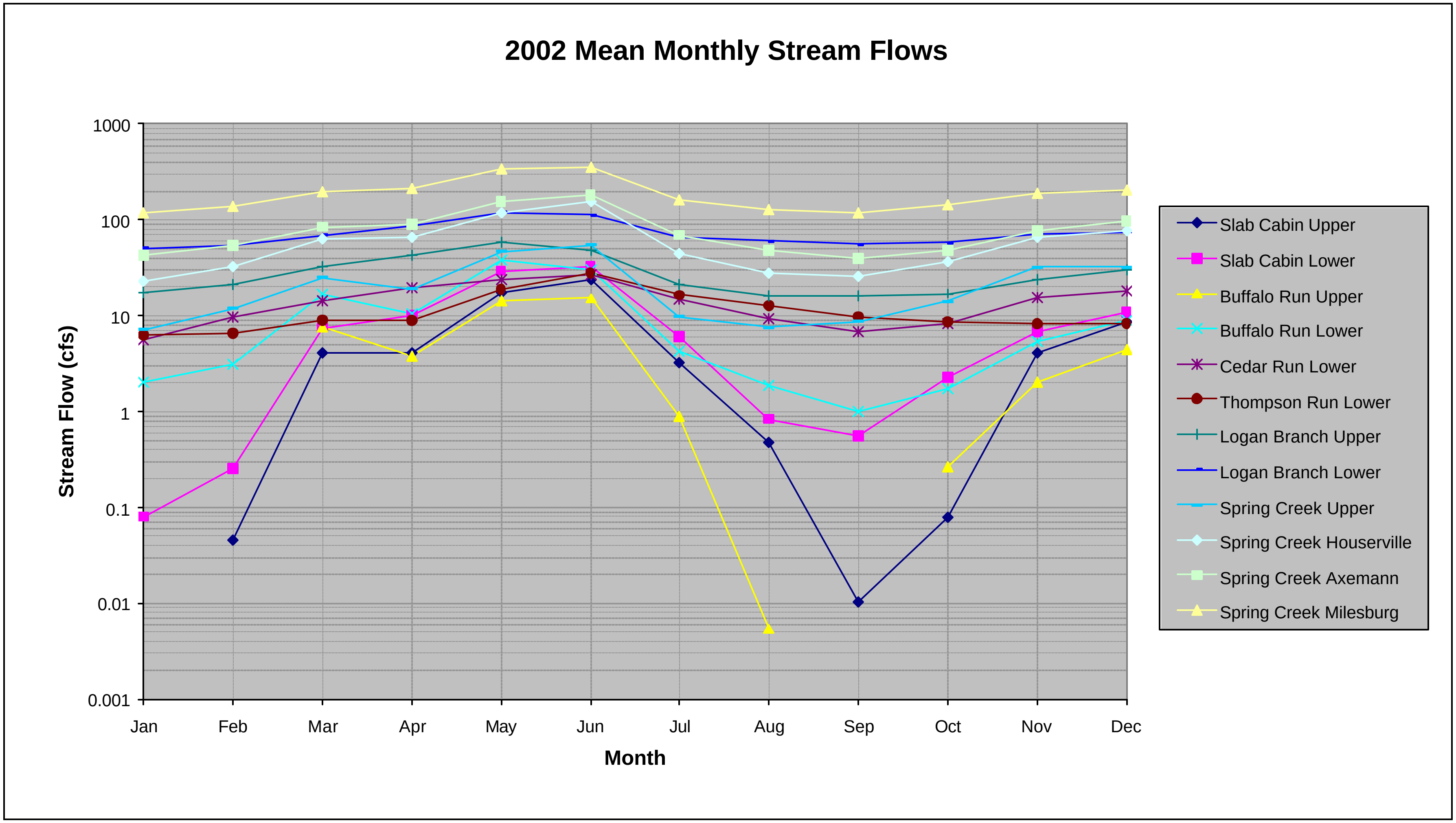


Figure 1. 2002 Mean Monthly Stream Flows.

Note: Stream Discharge on the y-axis is displayed with a logarithmic scale. Each major gradation on the y-axis is 10 times greater than the previous major gradation.

Table 2. 2002 Mean Monthly Stream Temperature in Degrees Fahrenheit.

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Frozen	36.9	42.8	52.4	54.9	58.5	63.9	68.3	Dry	50.4	44.0	38.5	51.1	51.4
Slab Cabin Lower	39.8	41.1	44.6	51.9	55.5	59.9	66.1	67.0	60.5	54.1	47.2	39.6	52.3	53.0
Buffalo Run Upper	36.1	35.5	42.8	51.5	54.9	61.1	65.6	Dry	Dry	38.9	41.5	36.9	46.5	42.1
Buffalo Run Lower	34.5	38.8	42.6	52.5	55.5	61.4	66.0	68.6	63.1	52.1	44.9	38.2	51.5	52.3
Cedar Run Lower	40.1	42.8	45.5	52.4	54.7	57.9	59.8	61.1	59.4	52.0	46.7	42.4	51.2	52.2
Thompson Run Lower	47.0	48.3	49.3	52.8	55.1	57.9	58.2	58.1	56.5	52.3	48.9	45.7	52.5	52.5
Logan Branch Upper	45.2	45.9	47.5	51.7	54.1	59.6	62.7	63.8	62.6	55.6	50.0	45.3	53.7	52.9
Logan Branch Lower	48.0	48.4	49.2	51.9	53.5	56.4	56.5	55.6	54.8	52.3	50.7	47.7	52.1	52.1
Spring Creek Upper	47.6	46.8	47.3	50.9	53.0	56.5	55.6	55.0	53.5	52.4	49.0	45.4	51.1	51.7
Spring Creek Houserville	41.3	43.5	45.8	52.9	55.4	59.7	62.8	63.7	60.2	52.8	47.1	41.7	52.2	52.8
Spring Creek Axemann	42.4	44.3	46.8	55.0	57.7	62.5	66.7	67.5	63.5	54.7	47.7	41.7	54.2	54.9
Spring Creek Milesburg	45.0	45.9	47.5	53.6	55.9	60.5	62.7	62.4	59.3	53.4	48.4	43.7	53.2	53.5

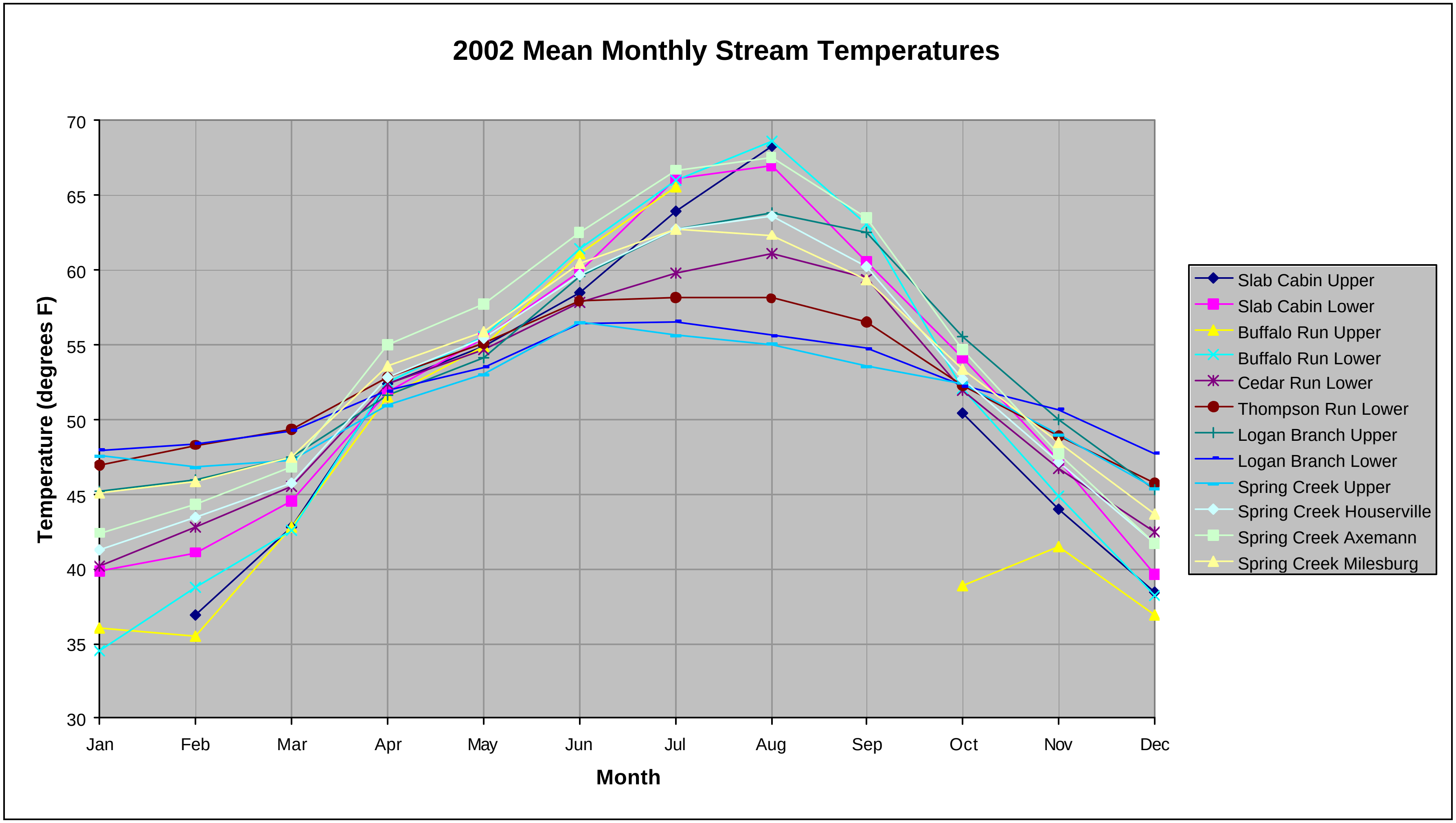


Figure 2. 2002 Mean Monthly Stream Temperatures.

Table 3. 2002 Total Suspended Solids Concentration (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	14	8	2	18	2	Dry	4	<2	10	8	8
Slab Cabin Lower	10	14	12	14	12	<2	16	4	Dry	<2	<2	6	11	12
Buffalo Run Upper	Dry	Dry	Dry	12	10	<2	12	Dry	Dry	Dry	6	6	9	10
Buffalo Run Lower	<2	4	6	12	14	14	26	6	6	<2	4	2	9	6
Cedar Run Lower	14	20	22	28	20	10	12	12	2	<2	<2	10	15	13
Thompson Run Lower	16	24	6	24	6	<2	12	14	24	<2	<2	4	14	14
Logan Branch Upper	6	4	<2	12	8	12	14	8	12	8	10	10	9	10
Logan Branch Lower	<2	8	<2	8	12	4	10	10	16	<2	4	2	8	8
Spring Creek Upper	16	10	<2	20	4	<2	18	6	<2	<2	<2	8	12	10
Spring Creek Houserville	12	24	4	14	22	6	<2	16	4	2	<2	2	11	9
Spring Creek Axemann	<2	8	4	24	16	12	12	<2	14	6	14	<2	12	12
Spring Creek Milesburg	<2	4	6	18	14	12	18	6	2	6	10	<2	10	8

Detection limit = 2 milligrams per Liter (mg/L).

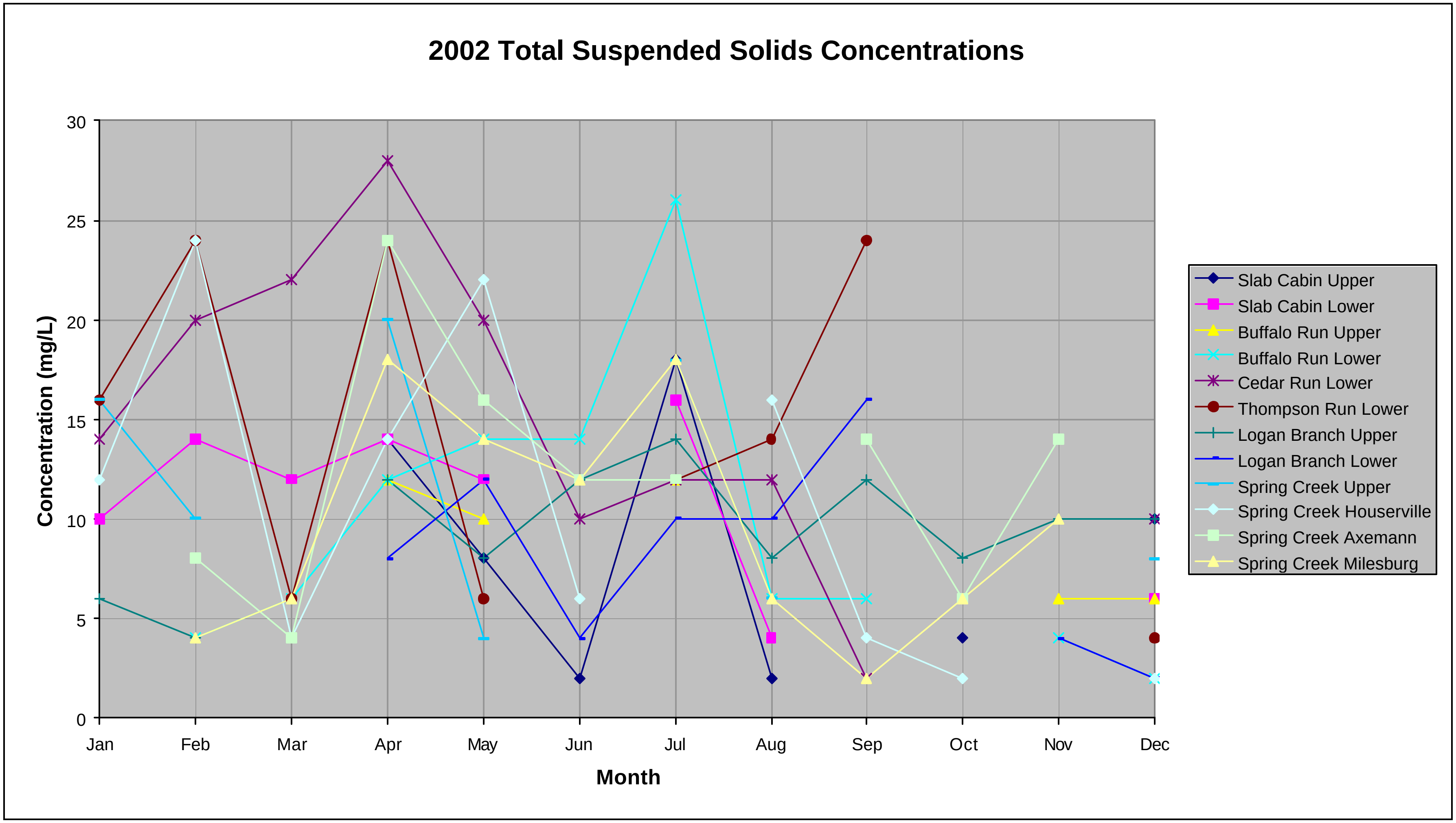


Figure 3. 2002 Total Suspended Solids.

Table 4. 2002 Turbidity Levels (NTU).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	3.3	7.24	3.85	5.58	1.34	Dry	1.61	1.77	3.27	3.50	3.29
Slab Cabin Lower	<1	<1	1.85	2.43	3.9	3.61	2.51	2.18	Dry	<1	1.47	1.08	2.38	2.31
Buffalo Run Upper	Dry	Dry	Dry	3.49	5.92	12	6.92	Dry	Dry	Dry	3.17	1.95	5.58	4.71
Buffalo Run Lower	<1	<1	1.94	3.69	4.23	6.71	4.33	1.88	2.64	1.46	1.37	<1	3.14	2.64
Cedar Run Lower	3.03	7.66	5.9	6.56	5.39	6.7	6.38	3.03	3.27	3.02	2.96	5.03	4.91	5.21
Thompson Run Lower	4.34	4	2.84	4.21	<1	2.87	2.06	13.8	1.34	1.14	1.39	2.87	3.71	2.87
Logan Branch Upper	3.9	3.66	2.04	5.41	8.05	7.31	4.25	2.14	2.43	2.65	2.6	4.11	4.05	3.78
Logan Branch Lower	<1	<1	1.31	4.07	6.11	4.27	2.39	<1	<1	<1	<1	<1	3.63	4.07
Spring Creek Upper	<1	1.63	<1	2.36	3.68	3.76	1.73	1.64	<1	1.15	<1	<1	2.28	1.73
Spring Creek Houserville	2.75	2.82	1.94	3.17	8.09	4.03	2.84	7.58	4.64	2.25	2.03	1.43	3.63	2.83
Spring Creek Axemann	2.87	2.49	2.38	4.49	5.79	6.28	4.14	1.5	2.51	2.46	2.97	1.33	3.27	2.69
Spring Creek Milesburg	2.74	4.08	3.27	5.73	4.31	5.19	3.26	1.39	1.66	1.57	2	2.26	3.12	3.00

Detection limit = 1 Nephelometric Turbidity Unit (NTU).

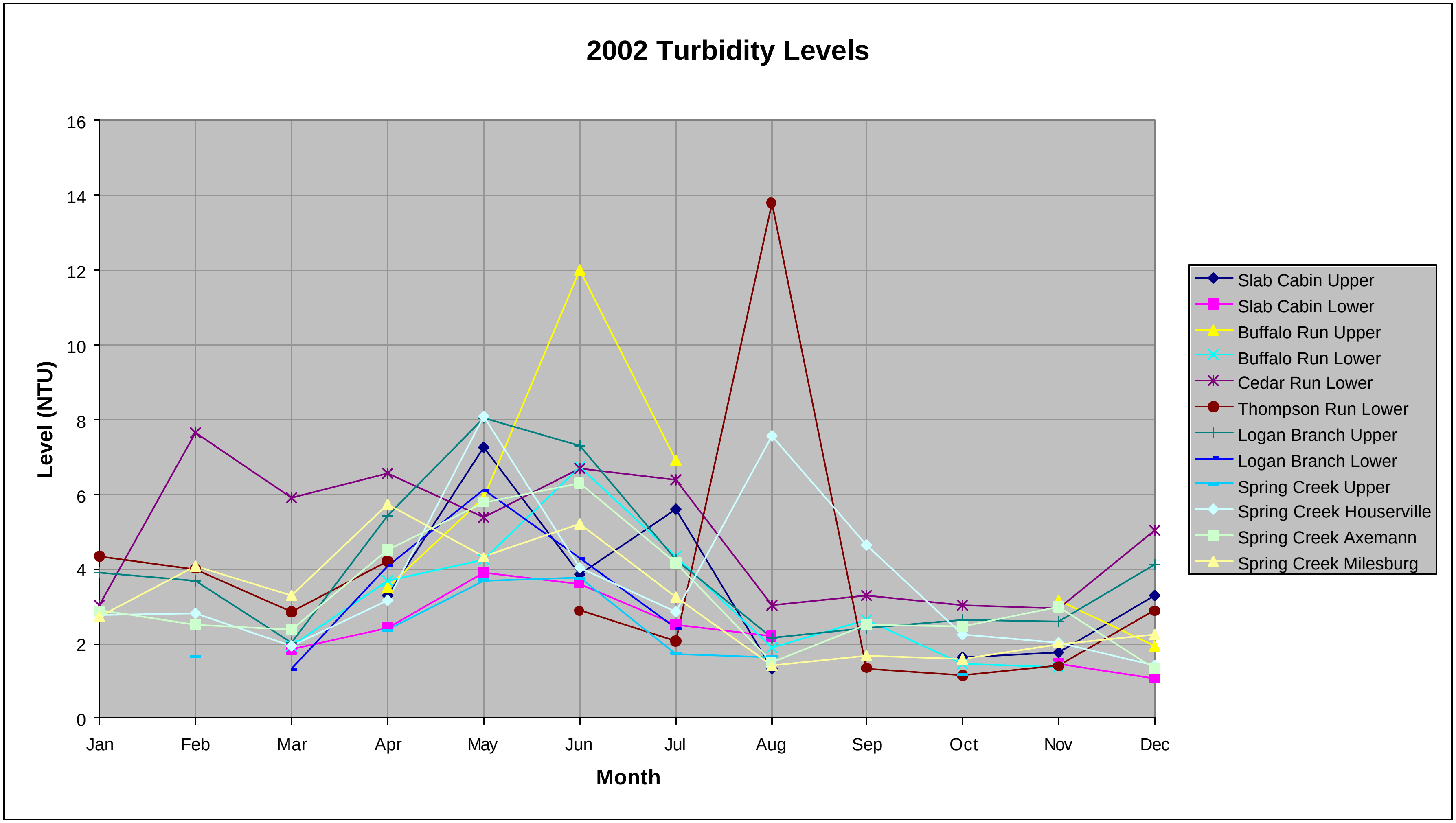


Figure 4. 2002 Turbidity Levels.

Table 5. 2002 Dissolved Oxygen Concentrations (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	11.8	13.3	10.0	8.9	6.4	Dry	7.5	9.2	13.3	10.0	9.6
Slab Cabin Lower	12.8	12.7	10.0	13.9	12.6	10.6	10.5	10.5	Dry	10.4	12.7	14.6	11.9	12.6
Buffalo Run Upper	Dry	Dry	Dry	12.6	11.9	11.0	8.6	Dry	Dry	Dry	10.0	14.1	11.4	11.5
Buffalo Run Lower	14.3	15.0	13.2	12.2	11.5	10.8	9.3	11.3	9.6	11.6	11.3	15.2	12.1	11.6
Cedar Run Lower	12.8	13.2	11.8	12.7	12.7	11.0	11.1	11.7	10.0	12.0	13.2	14.6	12.2	12.3
Thompson Run Lower	11.6	12.2	11.0	12.5	11.5	10.9	10.5	8.7	11.9	11.2	13.1	14.1	11.6	11.6
Logan Branch Upper	10.8	11.6	11.8	12.9	11.4	10.8	10.1	10.1	9.9	10.8	9.4	11.8	10.9	10.8
Logan Branch Lower	11.0	11.7	11.9	11.2	11.2	11.1	10.7	11.7	10.3	10.7	10.2	11.3	11.1	11.2
Spring Creek Upper	9.8	10.7	9.6	11.1	10.6	9.7	9.4	9.3	8.8	9.9	11.4	11.5	10.1	9.9
Spring Creek Houserville	13.9	14.3	12.4	13.8	13.4	10.8	11.9	10.8	9.7	11.9	13.9	15.6	12.7	12.9
Spring Creek Axemann	12.4	14.3	12.3	12.2	11.6	11.2	10.0	11.9	9.5	10.8	10.5	15.6	11.9	11.7
Spring Creek Milesburg	11.8	12.3	12.0	11.3	11.2	10.9	10.1	10.9	10.3	11.5	11.5	12.7	11.4	11.4

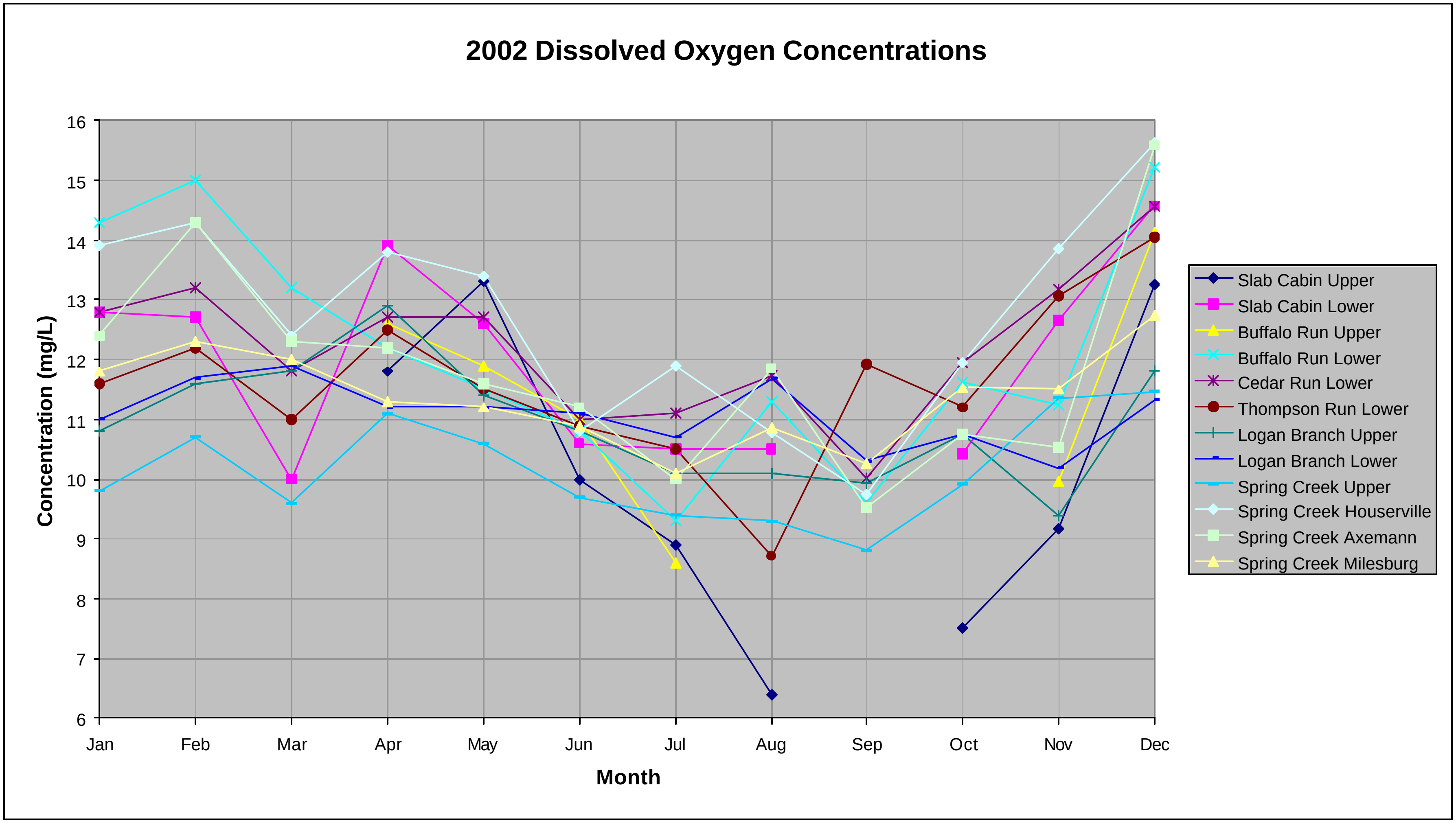


Figure 5. 2002 Dissolved Oxygen Concentrations.

Table 6. 2002 Stream pH (Standard Units).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	7.9	7.1	6.3	7.8	7.7	Dry	7.8	7.8	8.0	7.6	7.8
Slab Cabin Lower	8.0	8.0	7.8	8.3	7.9	7.9	8.2	7.9	Dry	8.0	8.1	7.9	8.0	8.0
Buffalo Run Upper	Dry	Dry	Dry	8.3	7.9	7.9	8.2	Dry	Dry	Dry	8.2	8.1	8.1	8.2
Buffalo Run Lower	8.2	8.2	8.2	8.2	7.9	8.1	8.2	8.3	8.0	8.4	8.2	7.9	8.2	8.2
Cedar Run Lower	8.3	8.3	8.2	8.3	7.7	8.1	8.2	8.2	8.2	8.2	8.4	8.2	8.2	8.2
Thompson Run Lower	8.1	8.2	8.0	8.1	7.9	7.9	8.1	7.7	8.1	8.1	8.2	7.9	8.0	8.1
Logan Branch Upper	7.8	8.1	7.8	8.2	7.7	2.7	7.9	7.6	7.5	7.8	7.9	7.7	7.4	7.8
Logan Branch Lower	8.0	7.4	7.7	7.8	7.4	7.9	7.9	7.9	7.3	7.8	8.1	7.7	7.7	7.8
Spring Creek Upper	7.2	7.6	7.6	7.6	7.4	6.7	7.5	7.5	6.9	7.7	7.9	7.7	7.4	7.6
Spring Creek Houserville	8.4	8.5	8.2	8.4	8.1	7.7	8.1	8.2	7.8	8.3	8.4	8.2	8.2	8.2
Spring Creek Axemann	8.1	8.1	8.1	8.1	7.9	8.0	8.1	8.2	7.8	8.2	8.1	8.1	8.1	8.1
Spring Creek Milesburg	8.3	8.3	8.2	8.2	8.1	8.2	8.2	8.3	7.6	8.4	8.2	7.9	8.2	8.2

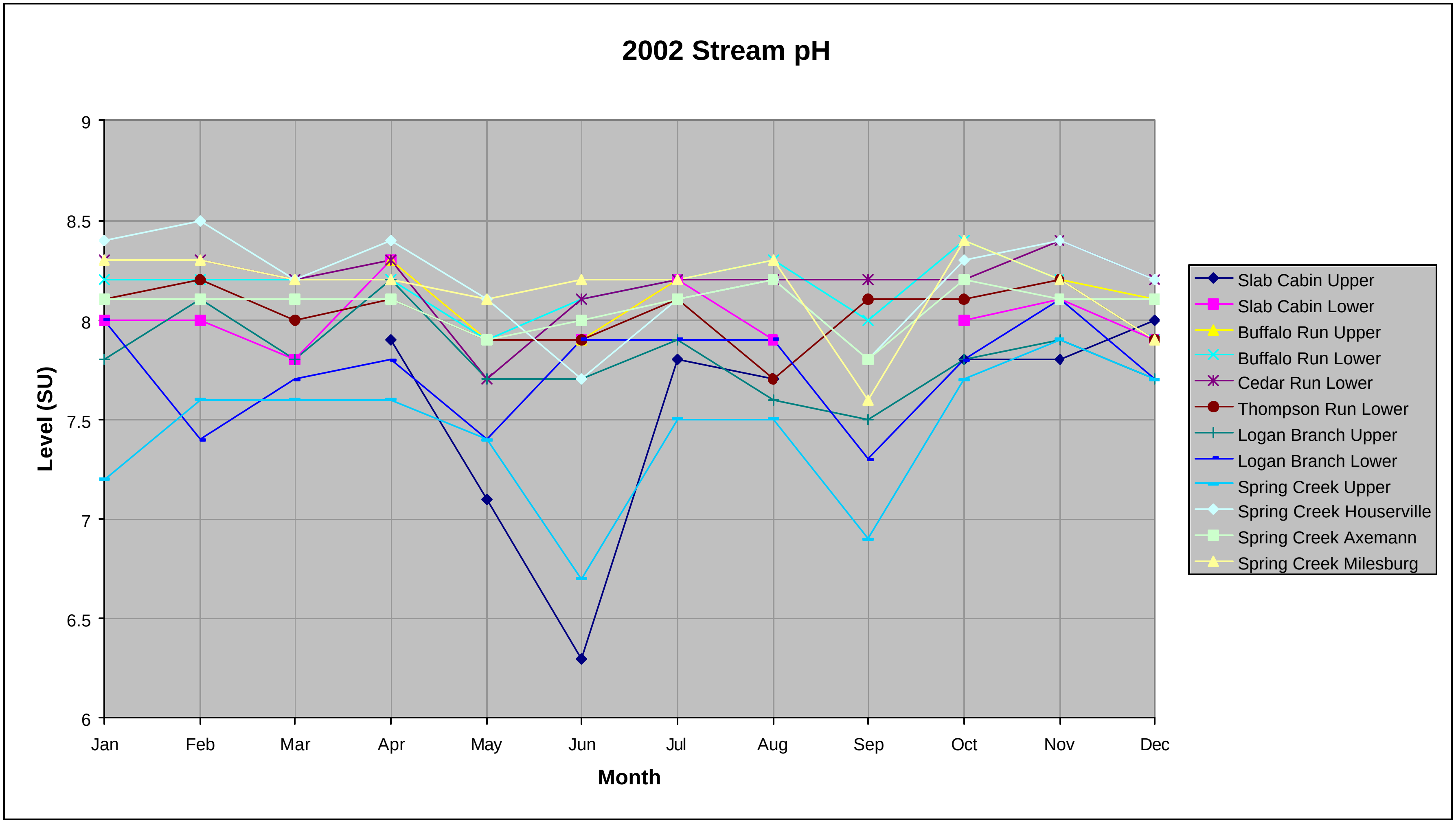


Figure 6. 2002 pH Values.

Table 7. 2002 Chloride Concentrations (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	29.0	16.0	19.0	24.0	42.5	Dry	87.2	88.1	26.9	41.6	28.0
Slab Cabin Lower	94.0	114.0	99.0	48.0	24.0	31.0	34.0	50.1	Dry	67.2	73.9	42.5	61.6	50.1
Buffalo Run Upper	Dry	Dry	Dry	22.0	16.0	19.0	24.0	Dry	Dry	Dry	24.0	24.8	21.6	23.0
Buffalo Run Lower	14.0	19.0	14.0	15.0	13.0	14.0	14.0	14.4	15.2	15.0	16.0	15.1	14.9	14.7
Cedar Run Lower	18.0	20.0	17.0	16.0	15.0	14.0	13.0	13.8	14.3	17.8	17.8	15.3	16.0	15.7
Thompson Run Lower	59.0	57.0	51.0	59.0	62.0	63.0	53.0	40.6	58.0	56.7	58.9	64.8	56.9	58.5
Logan Branch Upper	30.0	23.0	23.0	19.0	13.0	14.0	20.0	34.6	32.3	31.9	26.5	20.3	24.0	23.0
Logan Branch Lower	21.0	21.0	19.0	18.0	15.0	16.0	18.0	19.8	22.5	20.0	19.3	20.5	19.2	19.6
Spring Creek Upper	18.0	14.0	14.0	13.0	11.0	14.0	17.0	18.2	19.3	17.9	16.6	14.0	15.6	15.3
Spring Creek Houserville	42.0	35.0	31.0	29.0	23.0	28.0	29.0	29.5	35.9	36.8	36.3	32.4	32.3	31.7
Spring Creek Axemann	55.0	51.0	49.0	45.0	31.0	33.0	44.0	47.1	49.4	45.8	48.4	46.8	45.5	47.0
Spring Creek Milesburg	35.0	34.0	34.0	30.0	25.0	27.0	30.0	33.9	36.8	33.5	32.5	32.8	32.0	33.2

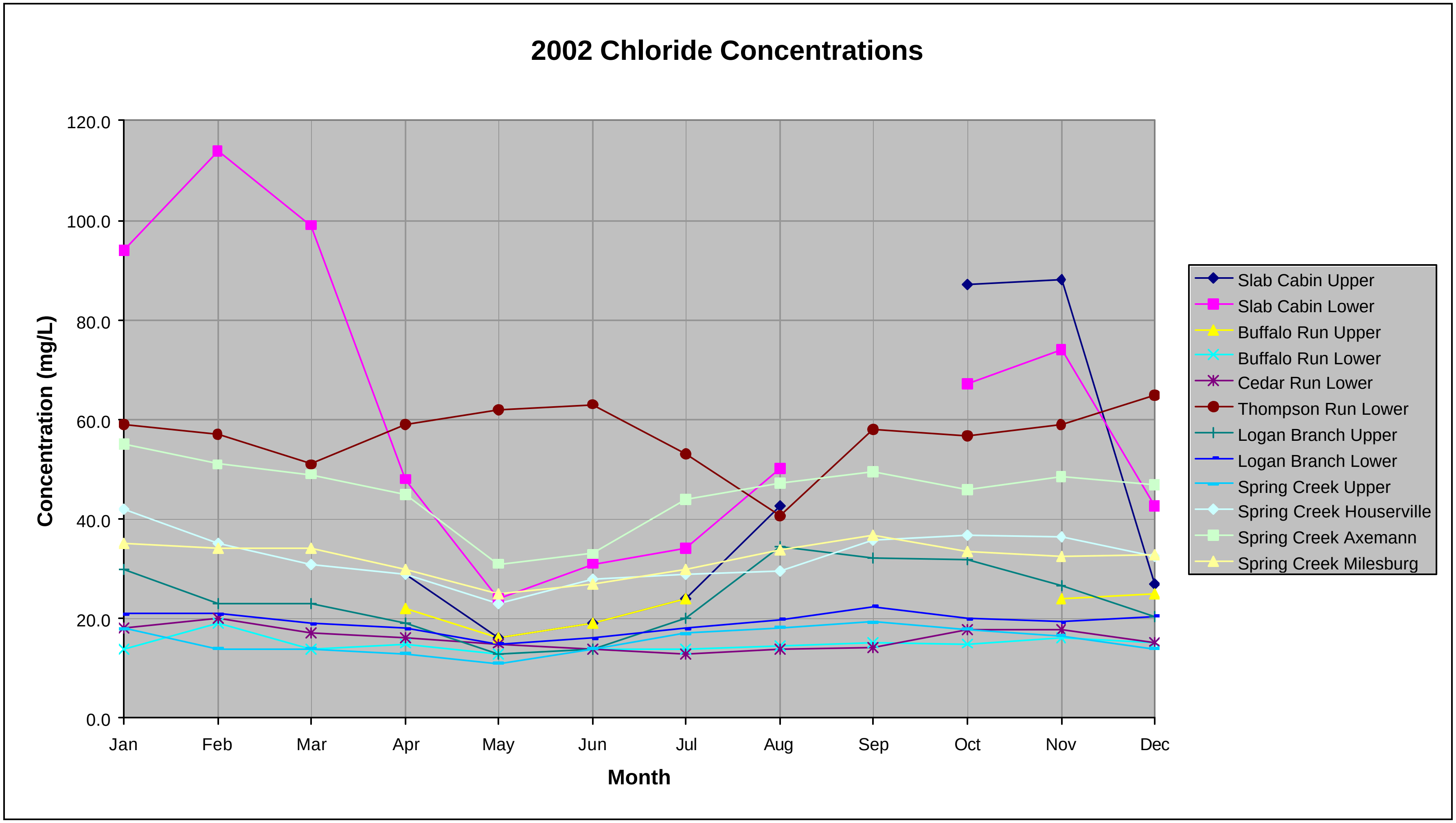


Figure 7. 2002 Chloride Concentrations.

Table 8. 2002 Lead Concentrations (ug/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	<1	<1	<1	<1	1.4	Dry	<1	<1	<1	1.4	1.4
Slab Cabin Lower	<1	<1	<1	<1	<1	<1	<1	<1	Dry	<1	<1	<1	<1	<1
Buffalo Run Upper	Dry	Dry	Dry	<1	<1	<1	<1	Dry	Dry	Dry	<1	<1	<1	<1
Buffalo Run Lower	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<10	<1	<1	<1
Cedar Run Lower	<1	<1	<1	<1	<1	<1	<1	1.3	<1	<1	<1	<1	1.3	1.3
Thompson Run Lower	<1	<1	<1	<1	<1	<1	<1	2.3	<1	<1	<1	<1	2.3	2.3
Logan Branch Upper	1.7	5.3	2.1	3.0	3.9	3.2	3.4	3.0	3.1	4.7	<10	5.1	3.5	3.2
Logan Branch Lower	<1	1.0	<1	2.3	3.5	2.5	1.8	<1	<1	1.1	<10	1.0	1.9	1.8
Spring Creek Upper	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Spring Creek Houserville	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Spring Creek Axemann	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Spring Creek Milesburg	<1	<1	<1	1.4	1.8	1.3	1.3	<1	<1	<1	<10	<1	1.5	1.4

Detection limit = 1 microgram per Liter (ug/L).

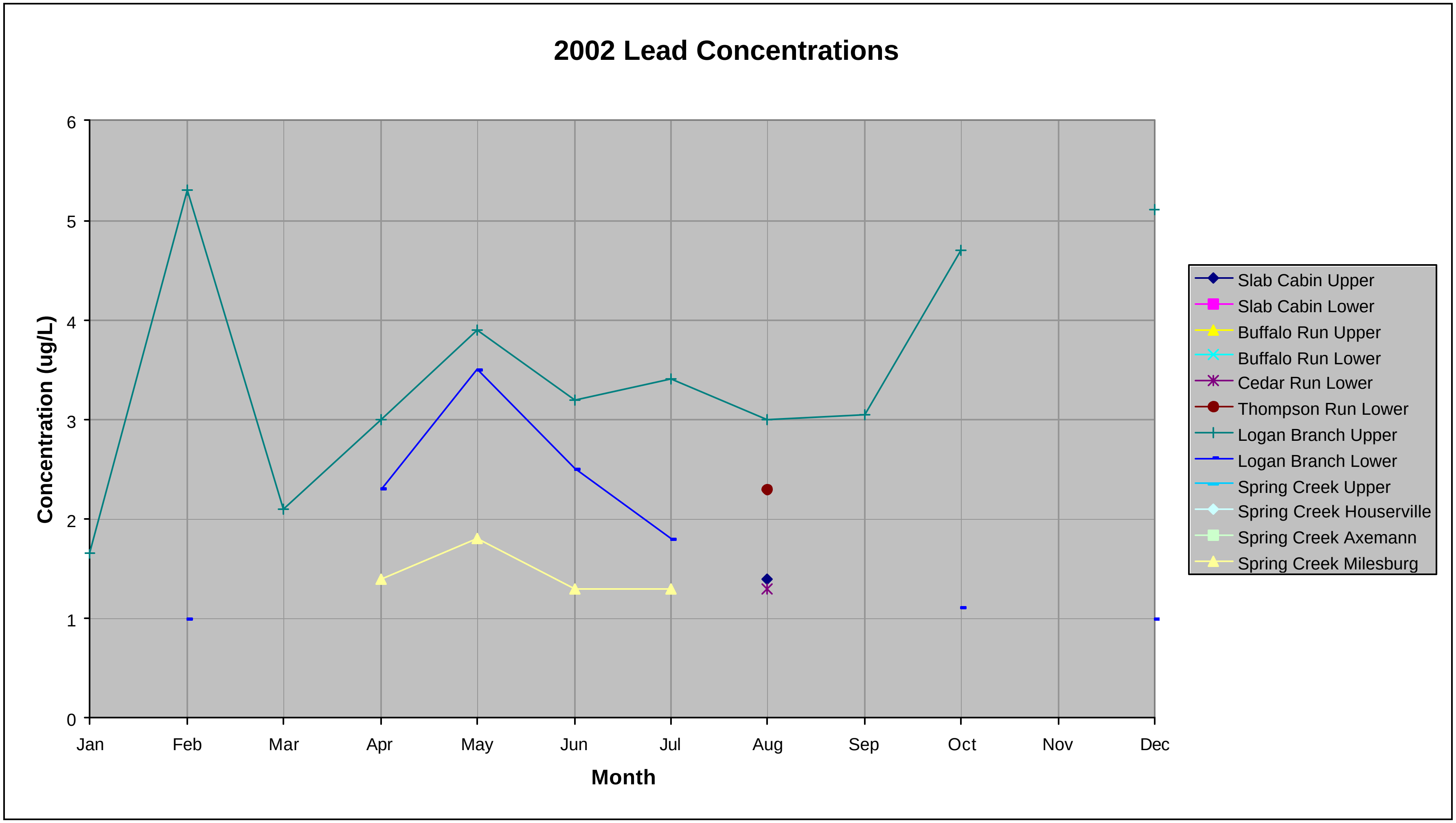


Figure 8. 2002 Lead Concentrations.

Table 9. 2002 Copper Concentrations (ug/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	<4	<4	<4	<4	5.7	Dry	<4	<4	<4	5.7	5.7
Slab Cabin Lower	<4	<4	<4	<4	<4	<4	<4	<4	Dry	<4	<4	<4	<4	<4
Buffalo Run Upper	Dry	Dry	Dry	<4	<4	<4	<4	Dry	Dry	Dry	<4	<4	<4	<4
Buffalo Run Lower	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<40	<4	<4	<4
Cedar Run Lower	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Thompson Run Lower	<4	<4	<4	<4	<4	<4	<4	8.7	<4	<4	<4	<4	8.7	8.7
Logan Branch Upper	<4	<4	<4	<4	<4	<4	<4	<20	<4	<4	<40	<4	<4	<4
Logan Branch Lower	4.6	<4	<4	4.5	5.3	<4	<4	<4	<4	4.2	<40	<4	4.7	4.6
Spring Creek Upper	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Spring Creek Houserville	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Spring Creek Axemann	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Spring Creek Milesburg	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<40	<4	<4	<4

Detection limit = 4 micrograms per Liter (ug/L).

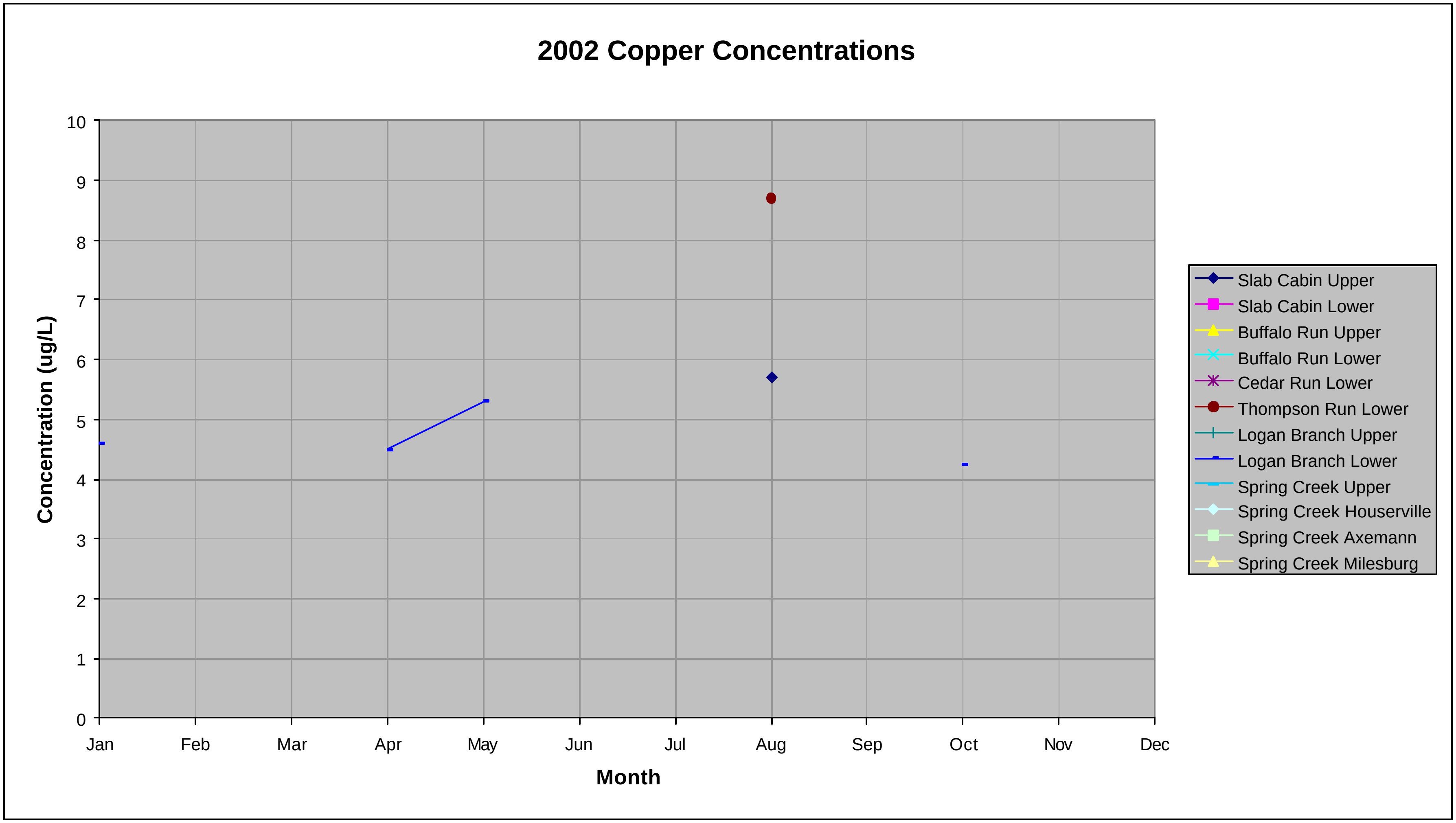


Figure 9. 2002 Copper Concentrations.

Table 10. 2002 Zinc Concentrations (ug/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	<10	<10	<10	<10	<10	Dry	13	11	<10	12	12
Slab Cabin Lower	<10	<10	<10	<10	<10	<10	<10	<10	Dry	14	<10	<10	14	14
Buffalo Run Upper	Dry	Dry	Dry	<10	<10	<10	<10	Dry	Dry	Dry	<10	<10	<10	<10
Buffalo Run Lower	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Cedar Run Lower	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Thompson Run Lower	<10	<10	<10	<10	<10	10	<10	<10	<10	22	<10	<10	16	16
Logan Branch Upper	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	21	<10	21	21
Logan Branch Lower	10	20	10	30	18	25	20	22	21	21	18	22	20	21
Spring Creek Upper	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Spring Creek Houserville	<10	<10	<10	<10	<10	<10	<10	<10	<10	14	<10	<10	14	14
Spring Creek Axemann	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Spring Creek Milesburg	10	<10	<10	10	11	<10	<10	16	10	<10	<10	12	12	11

Detection limit = 10 micrograms per Liter (ug/L).

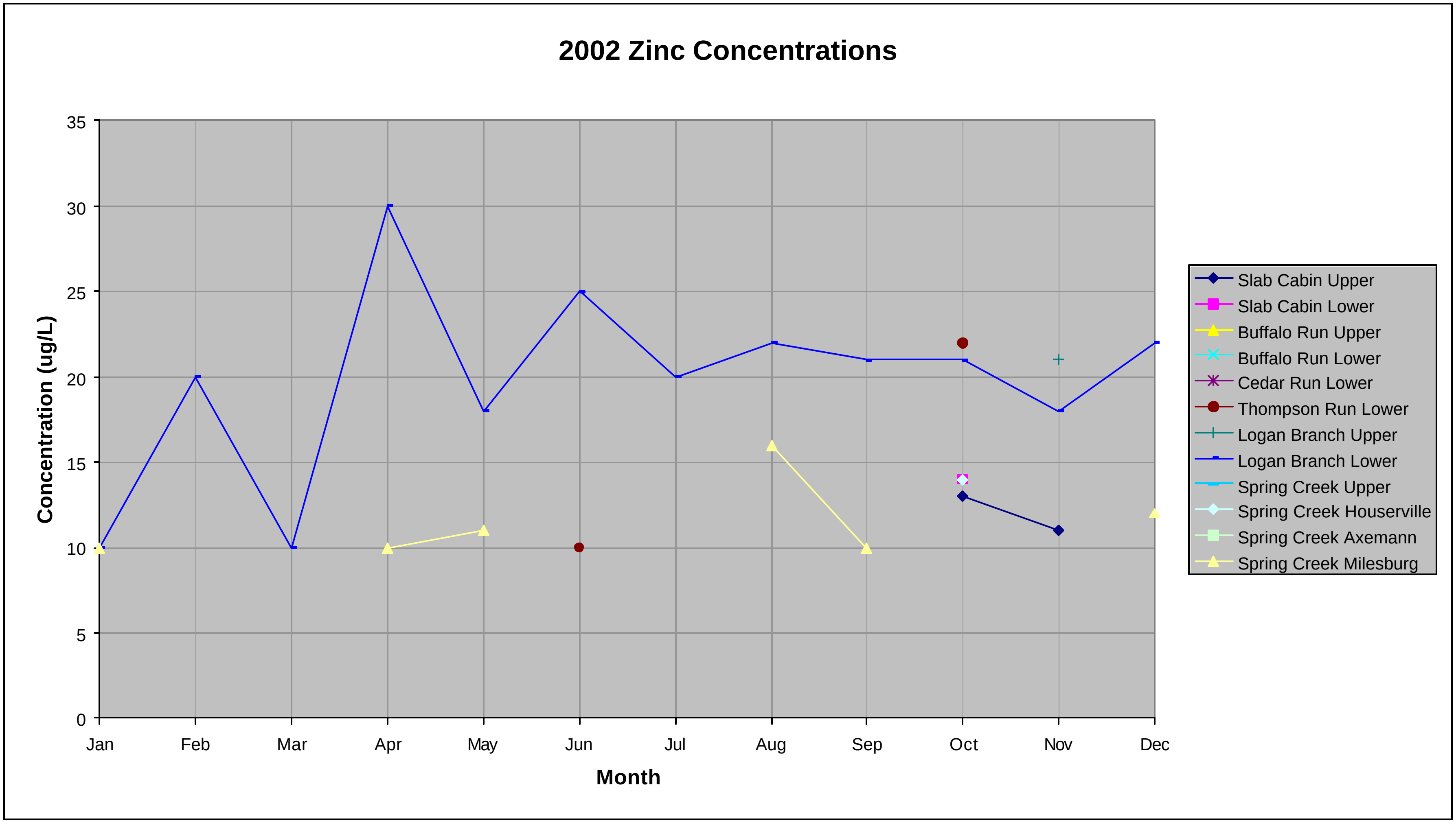


Figure 10. 2002 Zinc Concentrations.

Table 11. 2002 Nitrate Concentrations (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	2.05	1.69	2.86	3.78	2.91	Dry	3.11	3.26	3.19	2.86	3.01
Slab Cabin Lower	2.22	2.33	1.71	1.87	1.78	2.95	3.55	1.75	Dry	2.92	2.72	3.12	2.45	2.33
Buffalo Run Upper	Dry	Dry	Dry	1.21	1.09	1.39	1.74	Dry	Dry	Dry	1.09	1.77	1.38	1.30
Buffalo Run Lower	2.43	1.95	1.91	1.99	1.28	1.63	2.24	1.77	1.5	1.68	2.04	2.4	1.90	1.93
Cedar Run Lower	4.59	4.45	3.92	4.41	4.35	4.75	4.84	4.64	4.98	4.95	4.9	4.93	4.64	4.70
Thompson Run Lower	4.39	4.33	3.9	4.1	4.06	4.23	4.52	3.27	4.37	4.34	4.37	4.46	4.20	4.34
Logan Branch Upper	3.28	2.28	2.38	2.36	2.14	2.76	3.33	3.14	3.28	4.15	3.51	3.37	3.00	3.21
Logan Branch Lower	3.06	2.77	2.76	2.78	2.68	3.31	3.37	3.34	3.25	3.4	3.48	3.17	3.11	3.21
Spring Creek Upper	2.43	1.65	1.83	1.71	1.49	2.02	2.92	2.95	3.35	2.67	2.33	2.07	2.29	2.20
Spring Creek Houserville	3.4	2.76	2.98	2.84	2.51	3.16	3.87	3.14	3.82	3.47	3.44	3.49	3.24	3.28
Spring Creek Axemann	5.3	4.78	4.75	4.58	3.07	3.91	4.69	4.88	5.3	5.04	4.71	5.01	4.67	4.77
Spring Creek Milesburg	4.08	3.41	3.72	3.3	2.78	3.41	3.61	3.64	3.85	4.06	3.77	3.63	3.61	3.64

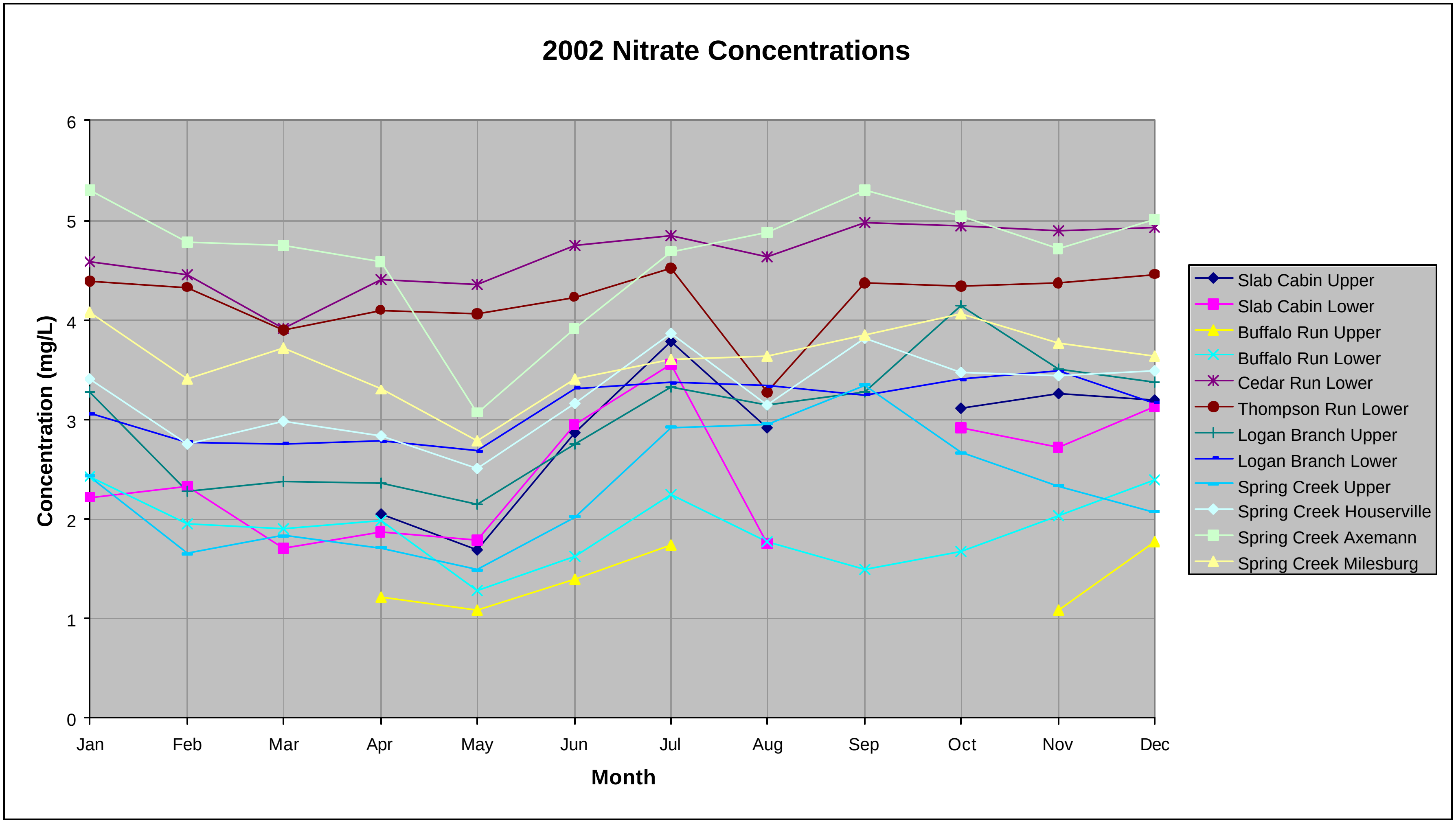


Figure 11. 2002 Nitrate Concentrations.

Table 12. 2002 Orthophosphate Concentrations (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	0.034	0.023	0.03	0.032	0.116	Dry	0.039	0.023	0.053	0.044	0.033
Slab Cabin Lower	0.014	<0.01	<0.01	0.01	0.02	0.031	0.014	0.022	Dry	0.012	<0.01	<0.01	0.018	0.014
Buffalo Run Upper	Dry	Dry	Dry	0.012	0.027	0.036	0.019	Dry	Dry	Dry	<0.01	0.012	0.021	0.019
Buffalo Run Lower	<0.01	<0.01	0.01	0.011	0.019	0.031	0.014	0.012	<0.01	<0.01	<0.01	<0.01	0.016	0.013
Cedar Run Lower	0.015	0.026	0.014	0.015	0.02	0.021	0.016	0.026	0.02	0.016	<0.01	0.012	0.018	0.016
Thompson Run Lower	0.034	0.024	0.023	0.016	0.012	0.025	0.017	0.056	0.022	0.028	0.022	0.021	0.025	0.023
Logan Branch Upper	0.049	0.04	0.066	0.024	0.034	0.03	0.019	0.034	0.013	0.035	0.037	0.037	0.035	0.035
Logan Branch Lower	0.014	0.015	0.016	0.014	0.022	0.017	0.013	0.012	<0.01	<0.01	0.012	0.012	0.015	0.014
Spring Creek Upper	<0.01	<0.01	<0.01	0.012	0.014	0.03	<0.01	0.013	<0.01	<0.01	<0.01	<0.01	0.017	0.014
Spring Creek Houserville	0.017	0.013	0.01	0.011	0.026	0.021	0.016	0.033	0.02	0.016	<0.01	0.016	0.018	0.016
Spring Creek Axemann	0.021	0.025	0.028	0.02	0.024	0.032	0.018	0.018	0.012	0.04	0.027	0.016	0.023	0.023
Spring Creek Milesburg	0.022	0.026	0.025	0.021	0.025	0.03	0.015	0.022	0.01	0.023	0.023	0.013	0.021	0.023

Detection limit = 0.01 milligrams per Liter (mg/L).

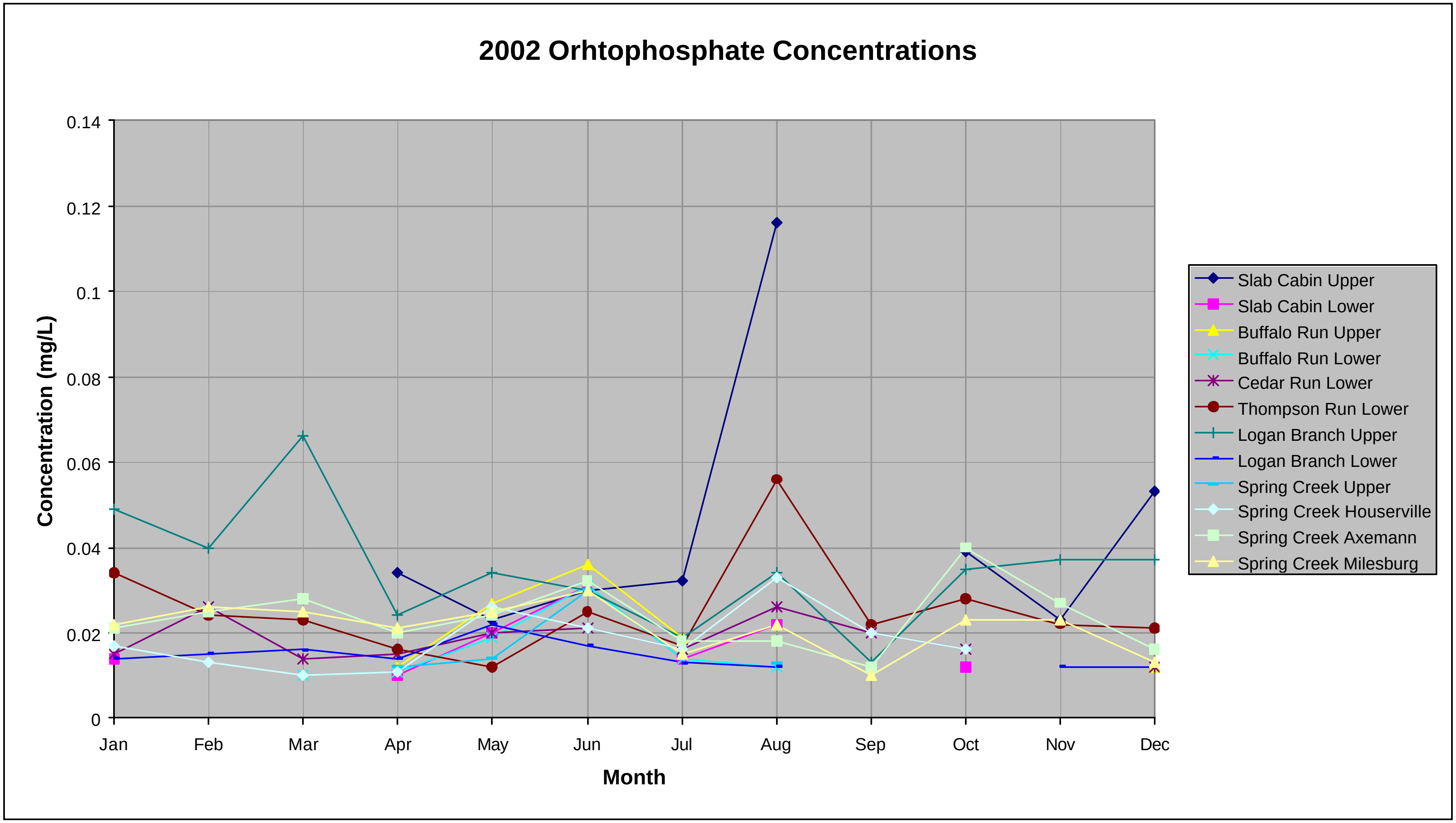


Figure 12. 2002 Orthophosphate Concentrations.

Table 13. 2002 Total Organic Carbon Concentrations (mg/L).

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Median
Slab Cabin Upper	Dry	Dry	Dry	3.0	1.3	1.7	2.3	4.9	Dry	1.9	1.9	2.9	2.5	2.1
Slab Cabin Lower	1.6	1.3	1.7	1.9	1.4	1.7	1.6	3.8	Dry	1.6	1.5	1.3	1.8	1.6
Buffalo Run Upper	Dry	Dry	Dry	1.5	1.4	1.6	1.4	Dry	Dry	Dry	2.6	1.7	1.7	1.6
Buffalo Run Lower	1.0	1.1	1.4	1.3	1.4	1.6	1.1	1.0	1.2	1.6	1.8	1.4	1.3	1.4
Cedar Run Lower	1.0	<1	1.0	1.1	1.4	1.5	1.1	1.4	1.2	1.1	1.1	0.9	1.2	1.1
Thompson Run Lower	<1	<1	0.9	1.3	0.9	1.0	1.1	3.6	1.0	1.0	1.0	0.9	1.3	1.0
Logan Branch Upper	1.7	1.7	2.3	1.7	1.4	1.5	1.5	1.6	1.6	1.9	1.8	2.3	1.8	1.7
Logan Branch Lower	<1	<1	0.8	0.9	1.0	1.0	0.7	0.5	0.5	0.8	0.7	0.8	0.8	0.8
Spring Creek Upper	<1	3.4	0.8	1.0	1.2	1.2	0.7	0.9	0.6	1.0	1.0	0.8	1.1	1.0
Spring Creek Houserville	1.1	1.0	1.1	1.3	1.3	1.2	1.2	2.7	1.1	1.2	1.2	1.0	1.3	1.2
Spring Creek Axemann	1.8	1.6	2.0	2.0	1.4	1.5	1.7	1.4	1.7	1.7	1.7	1.7	1.7	1.7
Spring Creek Milesburg	1.2	1.1	1.4	1.5	1.3	1.4	1.3	1.0	1.1	1.2	1.4	1.3	1.3	1.3

Detection limit = 1 milligram per Liter (mg/L).

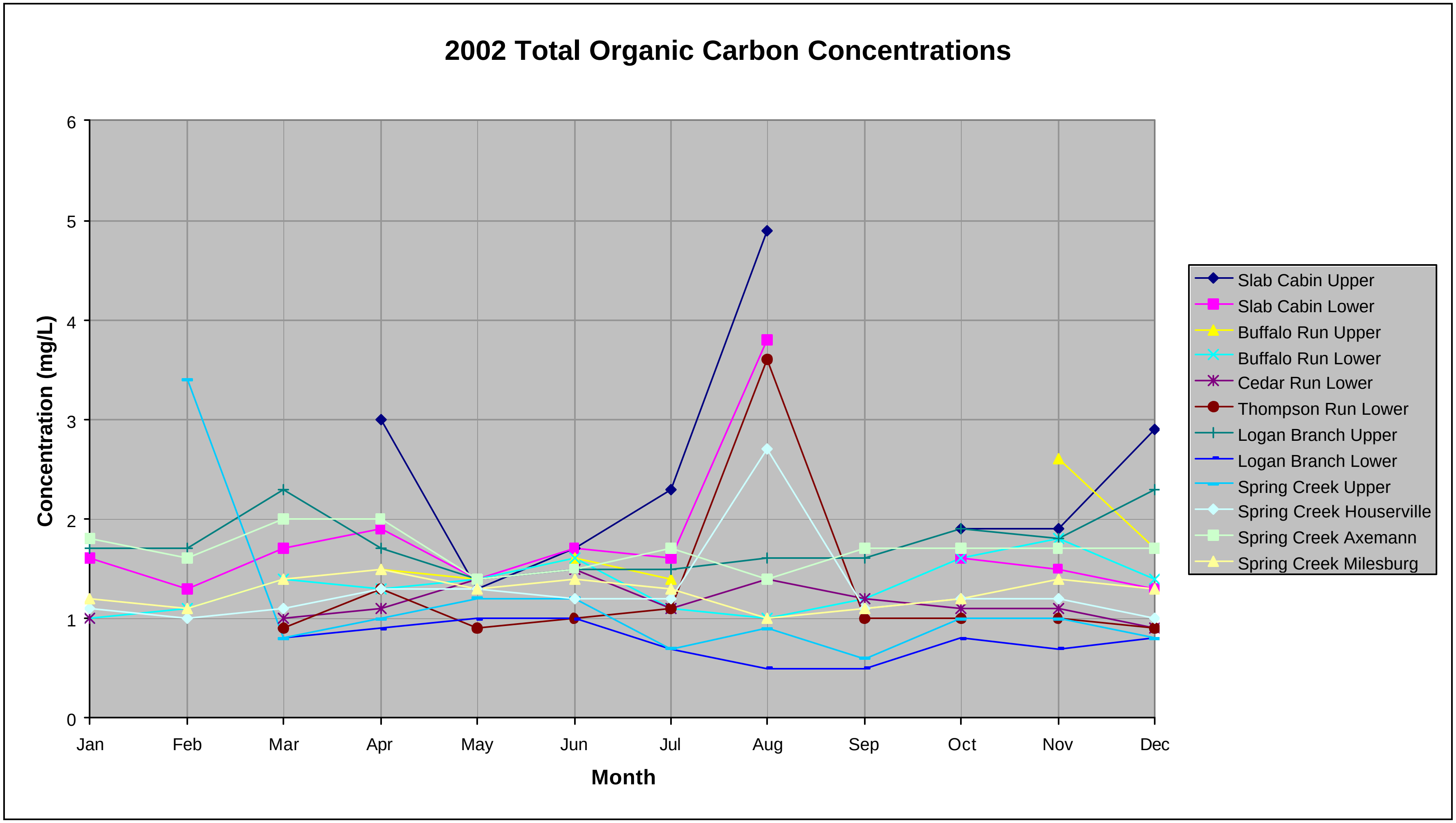


Figure 13. 2002 Total Organic Carbon Concentrations.

Table 14. 2002 Total Petroleum Hydrocarbon Concentrations (mg/L).[1]

Station Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**	**Median**
Slab Cabin Upper	Dry	Dry	Dry	<5	<5	<5	<5	<5	Dry	<5	<5	<5	<5	<5
Slab Cabin Lower	<5	<5	<5	<5	<5	<5	<5	<5	Dry	<5	<5	<5	<5	<5
Buffalo Run Upper	Dry	Dry	Dry	<5	<5	<5	<5	Dry	Dry	Dry	<5	<5	<5	<5
Buffalo Run Lower	<5	<5	<5	<5	No data	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cedar Run Lower	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Thompson Run Lower	<5	<5	<5	<5	No data	<5	<5	<5	<5	<5	<5	<5	<5	<5
Logan Branch Upper	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Logan Branch Lower	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Spring Creek Upper	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Spring Creek Houserville	<5	<5	<5	<5	No data	<5	<5	<5	<5	<5	<5	<5	<5	<5
Spring Creek Axemann	<5	<5	<5	<5	No data	<5	<5	<5	<5	<5	<5	<5	<5	<5
Spring Creek Milesburg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Detection limit = 5 milligrams per Liter (mg/L).

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[1] Since no petroleum hydrocarbons exceeded the detection limit in the streams studied, no accompanying graph is provided.