The Axemann Gage: Long-Term Water Resource Monitoring in the Spring Creek Watershed

Spring Creek Watershed Association
Water Resources Monitoring Project

2009 State of the Water Resources Report

Table of Contents

SPRING CREEK WATERSHED ASSOCIATION

A grassroots stakeholder initiative

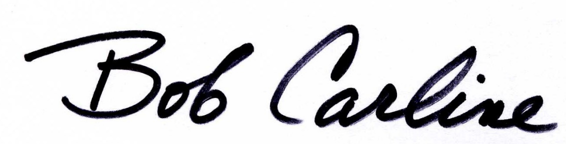
From the Chair

Annual reporting of environmental monitoring can challenge one to find something interesting to discuss when there has been little apparent change from the previous year. This is one reason why our committee decided to feature a thematic topic in each of our recent annual reports. In this report we examine the long-term record of stream flow and water quality data that has been collected at the U.S. Geological Survey's Axemann gage, which is about one mile downstream of Fisherman's Paradise on Spring Creek. We chose to focus on this site because it has the longest continuous data record in the watershed and represents about 60% of the surface area of the watershed. Our preference would have been to describe stream flow and water quality at Milesburg, but the water quality record from that site is only 11 years long.

Much of the data and discussion in this report were first compiled for a manuscript[1] on Spring Creek that is now in production and should be available this fall. We added an additional four years of data and reanalyzed the records. The conclusions remained unchanged: (1) stream flow and groundwater levels do not seem to have been substantially influenced by development over the past 60 years; (2) the pH and alkalinity at this site have not declined owing to acidic deposition, (3) phosphorus concentrations are much reduced from historic levels; (4) nitrite and ammonia, which are linked to poorly treated wastewater, are barely detectable; and (5) nitrate concentrations remain elevated. Much of the improvement in water quality over the past 60 years can be traced to fewer wastewater discharges and efficient treatment by the existing plants. We focused on wastewater treatment in the watershed in last year's annual report.

One of the water quality variables we would have liked to examine is total suspended solids (TSS), i.e., how much sediment is being transported by Spring Creek. Unfortunately, we do not have a long-term record of TSS. This variable is of great interest, because it is often mentioned as one of the reasons for biological impairment in certain reaches of Spring Creek. Since 1999, we have been collecting TSS data at 14 surface water sites in the watershed, but this record is not long enough to reveal possible trends.

Long-term data sets, like those from the Axemann gage, are invaluable in understanding how our water resources are changing. We expect the U.S. Geological Survey to continue monitoring at this site, and their data combined with ours, which has a much more comprehensive geographic distribution, will help to ensure that municipal officials are in a good position to make sound management decisions.



[1] Carline, R. F., R. L. Dunlap, J. E. Detar, and B. A. Hollender. 2010. The Fishery of Spring Creek – A Watershed Under Siege. Pennsyl-

Introduction

Spring Creek downstream of the Axemann gage near Fisherman's Paradise (credit: S. Knorr)

Welcome to the Spring Creek Watershed Association's Water Resources Monitoring Project (WRMP) 2009 Annual Report. This year's report, entitled *The Axemann Gage: Long-Term Water Resource Monitoring in the Spring Creek Watershed*, examines trends in the water quality and flow of Spring Creek at the United States Geological Survey's Axemann gaging station over the past 68 years. Long-term data sets are invaluable to scientists and land use planners as they struggle to strike a balance between natural resource conservation and growing human populations. By comparing historical stream flow and water quality data to current conditions, it is possible to identify changes that may have occurred over time and attempt to correlate them with human activities in the watershed.

The long-term data set being amassed by the WRMP provides the means to detect changes in the quantity and quality of surface waters and groundwater in the Spring Creek watershed. The type and quantity of information collected by the WRMP is unique for a watershed of this size. Measurement of the conditions within the Spring Creek Watershed will be useful in the management of this resource for years to come.

In addition to an in-depth look at the Axemann gage, this report also reviews trends in water quality and quantity throughout the Spring Creek Watershed in 2009. Daily stream flow and temperature, as well as quarterly water quality data, are available upon request by contacting the Water Resources Monitoring Project Manager, Brianna Hutchison, at (814) 237-0400.

Long-term Trends at the Axemann Gage

Contributed by WRMP committee chair Bob Carline (PA Fish and Wildlife Cooperative Research Unit, USGS—retired)

When hydrologists and water quality specialists attempt to assess the status of a stream they often look back over long-term, historic records to first determine how flow and water quality may have changed through time. These retrospective analyses can be useful when correlated with land use changes and other developments to see which human activities may have either improved or degraded water quality and stream flow. For many watersheds, good long-term records are scarce. We are fortunate here in the Spring Creek watershed because we have continuous stream flow records spanning more than 60 years and water quality data for nearly as long.

The longest record of stream flow and water quality in the watershed is from the Axemann gage on Spring Creek, which is about one mile downstream of Fisherman's Paradise and the Bellefonte State Fish Hatchery (see Figure 7, page 15, for WRMP sampling locations). The U.S. Geological Survey (USGS) installed the first permanent stream gaging station in the watershed at this site in 1941. This gage is about 1.5 miles from the village of Axemann, from which it takes its name. About 60% of the watershed's surface area (145 m^2) is upstream of this gage, making this site a good indicator of average watershed conditions.

Annual mean daily flow at this gage has varied considerably over the past 67 years. It has ranged from a low of 43 cubic feet per second (cfs) in 1965 to a high of 172 cfs in 2004 (Figure 1). The average for the period is 96 cfs. This variation in stream flow reflects changes in annual precipitation, which has ranged from 29 inches to 59 inches and averaged 39 inches per year over the period of record. Despite some rather large year-to-year variations in stream flow, there is no indication that flows have either increased or decreased over this period of record.

One concern with increased development and increased groundwater withdrawal is a reduction in stream flow. These data suggest that mean daily flow has not been influenced by development or groundwater withdrawal. Reduction in infiltration and groundwater recharge is another concern with development, particularly the increase in impervious surface area. Impervious surfaces like parking lots and roofs do not allow runoff to

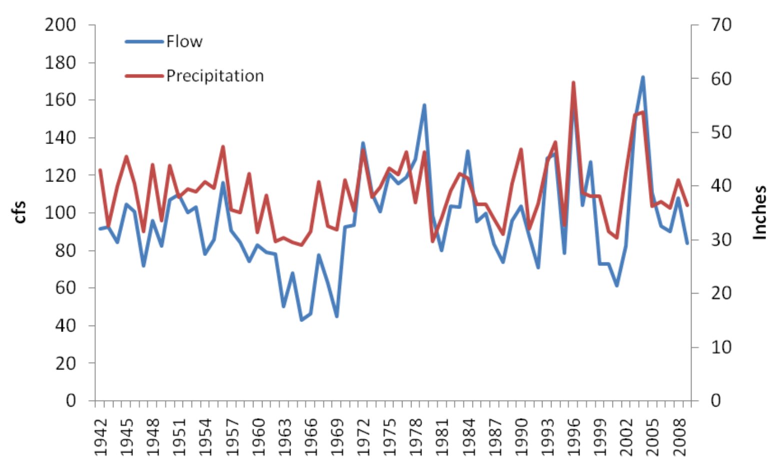


Figure 1. Mean daily flow in cubic feet per second (cfs) of Spring Creek at the Axemann gage and annual precipitation in inches from the Pennsylvania State University weather station in State College from 1942-2009.

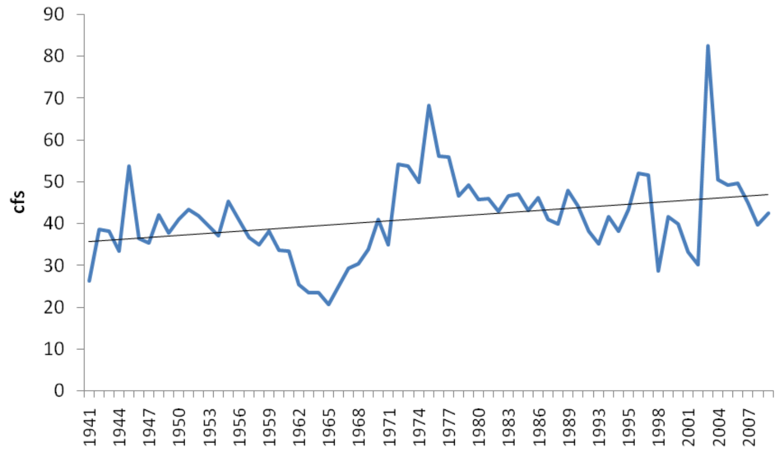


Figure 2. The 7-day low flow in cubic feet per second (cfs) of Spring Creek at the Axemann gage from 1941-2009. Data compiled by L. Fennessey.

infiltrate, resulting in decreased groundwater recharge. If current groundwater levels and discharges from springs to the stream are less than historic levels owing to reduced infiltration, one would expect to see reduced stream flows during dry periods. The entire stream discharge would consist of groundwater inputs during these periods.

One statistic that describes low stream flow conditions is the 7-day low flow, which is simply the lowest average 7-day stream flow during an entire year. If groundwater levels had been declining since 1942, we would expect the 7-day low flow to decrease with time. But, in fact, the 7-day low flow has increased slightly from 1942 to 2009 (Figure 2) rather than decreasing. These data suggest that groundwater levels on average have not declined over the past 60+ years.

Before the Pennsylvania Department of Environmental Protection and its predecessor, the Department of Environmental Resources, were organized, the Pennsylvania Department of Health conducted water quality sampling. Quarterly sampling at the Axemann gage began in 1950. Samples were analyzed for constituents that are of concern when mine drainage is present, including pH, alkalinity, acidity, aluminum, iron, and sulfate. In 1972 the state increased the number of compounds included in the analyses; among these were phosphorus, nitrate, nitrite, and ammonia. The USGS has recently taken over water quality sampling at the Axemann gage. Data from this site can be downloaded from the following USGS website: http://nwis.waterdata.usgs.gov/usa/nwis/qwdata. The site number for Axemann is 01546500.

The limestone bedrock underlying the Spring Creek watershed produces alkaline groundwater; hence, the pH at the Axemann gage is nearly always above 7.0, which is neutral. The long-term average pH is 7.9. During sunny summer days when aquatic plants and algae are actively photosynthesizing carbon materials, they take up carbon dioxide from the water. As carbon dioxide concentrations decrease, the pH of the water increases and may approach a value of 9.0. During a single day, pH can vary by as much as 1.5 units; therefore, average values for pH are the best measure to use. Since 1962 the average stream pH at the Axemann gage has remained at the same level.

Another water quality variable related to pH is alkalinity, which is a measure of water's buffering capacity or its ability to resist change in pH. Alkalinity is similar to water

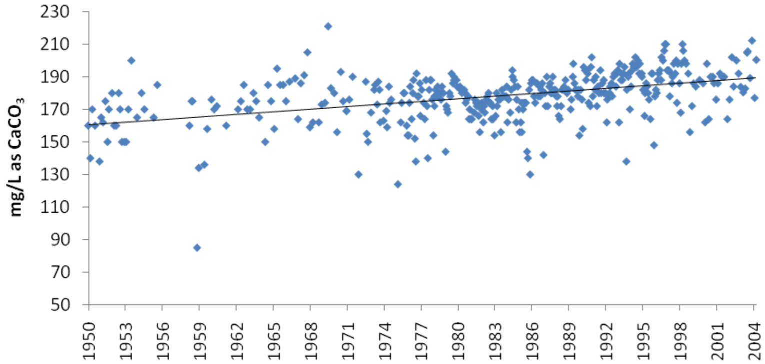


Figure 3. Total alkalinity in milligrams per liter as $CaCO_3$ (mg/L as $CaCO_3$) of Spring Creek at the Axemann gage from 1950-2004. Data available from the USGS website at http://www.nwis.waterdata.usgs.gov/usa/nwis/qwdata.

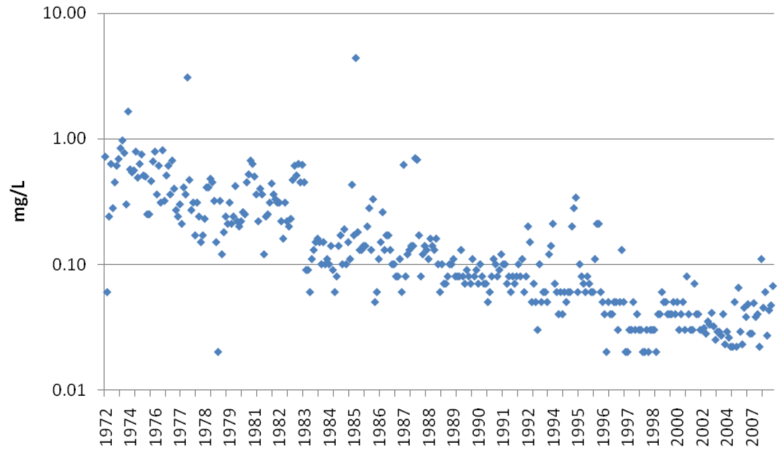


Figure 4. Concentrations of total phosphorus (milligrams per liter) in Spring Creek at the Axemann gage from 1972-2009. Data available from the USGS website at http://www.nwis.waterdata.usgs.gov/usa/nwis/qwdata.

hardness and both are often expressed as milligrams per liter of calcium carbonate. Since 1950, the long term average alkalinity at Axemann has been 178 mg/L as calcium carbonate, which would be classified as hard water. A notable trend in alkalinity has been the gradual increase from 1950 to present (Figure 3). This change in alkalinity may reflect an increase in water withdrawal from alkaline wells for household use and subsequent treatment and disposal to the stream via wastewater treatment plants during the past 50 years. In the first half of the 20th century, more residents were relying on surface water supplies, which typically came from soft water sources on the sandstone ridges. These small water systems have now been mostly replaced by large water authorities that rely on wells that draw water from deep in the limestone bedrock.

The most dramatic change in water quality variables at Axemann has been in phosphorus, a plant nutrient of much concern. Concentrations of total phosphorus declined from 0.63 mg/L in 1972-1973 to 0.045 mg/L in 2007-2008, a 93% reduction (Figure 4). Several factors have contributed to this decline. The diversion of treated effluent from the Penn State University wastewater treatment plant to spray irrigation in 1983 eliminated a major source of nutrients to the stream and, more recently, the closures of treatment plants at the Rockview State Correctional Institution and Ferguson Township have further reduced nutrient loading. The major wastewater discharger in the upper Spring Creek basin, the University Area Joint Authority (UAJA), has been using tertiary treatment to remove phosphorus from its discharge since the plant began operations in 1969. Hence, all of these changes have contributed to

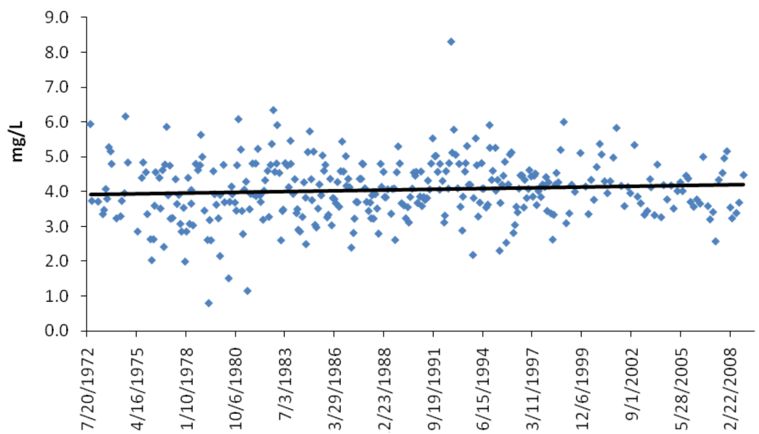


Figure 5. Concentrations of nitrate in milligrams per liter (mg/L) in Spring Creek at the Axemann gage from 1972-2008. Data available from the USGS website at http://www.nwis.waterdata.usgs.gov/usa/nwis/qwdata.

reduced phosphorus loading in Spring Creek.

The other nutrient of concern, particularly here in the Susquehanna River-Chesapeake Bay Watershed, is nitrogen, which can occur in several forms. Nitrite and ammonia may be detectable when poorly treated wastewater is discharged into a stream. In 1972, when nutrient testing was first initiated, concentrations of nitrite and ammonia each averaged about 0.1 mg/L. Since then, these two compounds have been steadily decreasing and in recent years concentrations have been so low that they are usually not detectable. However, most soluble nitrogen occurs in the form of nitrate. Concentrations of nitrate can vary from day to day, but the long term average (4.1 mg/L) has been remarkably stable since 1972 (Figure 5). Sources of nitrate include runoff from urban and agricultural areas, discharges from wastewater treatment plants and fish hatcheries, and from groundwater. During periods of base flow groundwater contributions can be significant. For example, in 2006 mean concentrations of nitrates were 4.7 mg/L in the Linden Hall Park Spring, 5.7 mg/L in Axemann Spring, and 4.0 mg/L in Benner Spring. Thus, even if discharges and runoff were completely eliminated, nitrate concentrations would still be substantial because of the groundwater contribution.

In summary, these analyses of stream flow and water quality represent mostly good news. Flow can vary greatly from year to year but it seems to be directly tied to precipitation rather than development or groundwater withdrawal. The pH of Spring Creek has remained high throughout the period of record, unlike many streams with sandstone bedrock that have shown declines in pH owing to acid rain. Concentrations of phosphorus are now at all-time lows, as are concentrations of ammonia and nitrite. Nitrate concentrations remain elevated and because of long-term inputs of nitrate to groundwater, this nutrient will continue to be problematic. While most of these flow and water quality variables have been improving, there are signs of impairment in some stream reaches where biological indices have been examined. The likely culprits are excess sediments and possibly higher nutrient concentrations at certain times of the year. Better management of non-point source pollution (urban and agricultural runoff) may be required before we see further improvements in biological indices.

Lastly, this overview of long term trends provides an instructive lesson on the value of sustained monitoring efforts. Spring Creek, like most other streams, can experience rather large variations in flow and particularly chemical constituents from week to week or month to month. Examining results from water sampling is like examining the behavior of the stock market over a short period of time – it is nearly impossible to detect trends unless one looks at a long record. If one took a 10-year record for nearly any flow or water quality variable and described a likely trend, the conclusion might be rather different than if one were able to examine the entire 60-year record. This is one of the uncomfortable facts intrinsic to environmental studies – there is simply no good substitute for long-term monitoring.

Spring Creek at Axemann (credit: S. Knorr)

Project Background

The Spring Creek Watershed Association, a grassroots stakeholder group composed of concerned citizens and professionals, initiated the Water Resources Monitoring Project (WRMP) in 1997 as part of its strategic plan for the watershed. Their goal was to gather baseline information about the quantity and quality of the water resources in the Spring Creek Watershed that could be used for the long-term protection of these resources as demands on them increase over time. A group of local environmental professionals formed the Water Resources Monitoring Committee (Table 1) in 1998 to develop and oversee the WRMP. The first surface water monitoring stations were established in late 1998/early 1999. Groundwater, stormwater, and spring monitoring stations were added as the project gained momentum (see Figure 6 for a timeline of events). Over the past 11 years, the WRMP has strived to:

A. Provide a description of the quantity and quality of the surface waters of Spring Creek and its tributaries, including springs;
B. Provide a description of the quality of stormwater runoff throughout the watershed;
C. Monitor groundwater levels in critical areas;
D. Provide the means to detect changes in quantity and quality of surface waters under both baseflow and stormwater runoff conditions, as well as groundwater reserves;
E. Provide sufficient measurement sensitivity through long-term monitoring to permit the assessment of the previously mentioned parameters.

The WRMP field stations and database are maintained primarily by the Water Resources Coordinator, a full-time staff position housed at ClearWater Conservancy, with the assistance of volunteers and ClearWater interns. A number of local partners provide funding to carry out WRMP data collection activities, contributing over $64,000 to support this one-of-a-kind project in 2009. Donors in support of the 2009 effort included:

- Bellefonte Borough
- Benner Township
- College Township
- College Township Water Authority
- Ferguson Township
- Halfmoon Township
- Harris Township
- Patton Township
- Potter Township
- Pennsylvania State University Office of Physical Plant
- Spring Township
- Spring Township Water Authority
- State College Borough
- State College Borough Water Authority
- Spring Creek Chapter of Trout Unlimited
- University Area Joint Authority.

In addition to financial support, the WRMP received in-kind donations of professional services, laboratory analyses and supplies, technical assistance, and transportation from the following in 2009:

- Groundwater well owners
    - Howard Dashem

- PA Department of Conservation of Natural Resources
- Todd Giddings
- Penn State University Office of Physical Plant
- United States Geological Survey

- Pennsylvania Department of Environmental Protection
- Pennsylvania Cooperative Fish and Wildlife Research Unit
- United States Geological Survey
- University Area Joint Authority
- Volunteer field assistants
- Water Resources Monitoring Committee.

The Big Hollow/I-99 monitoring well (credit: S. Knorr)

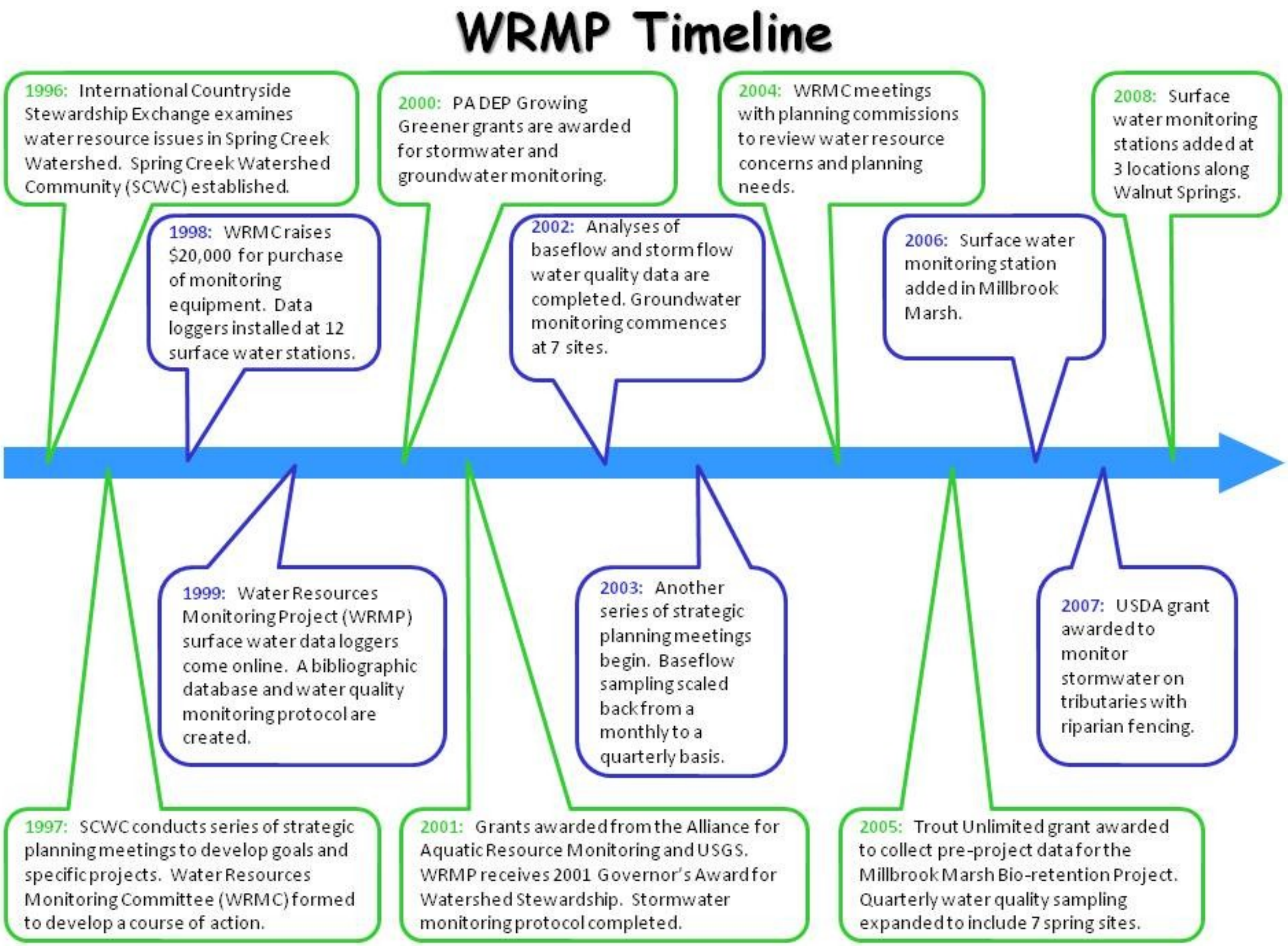


Figure 6. Timeline of major events associated with the Water Resources Monitoring Project.

Table 1. Water Resource Monitoring Project Committee Members for 2009.

WRMP Committee Member	Affiliation	WRMP Committee Member	Affiliation
Robert Carline, Ph.D. ***Committee Chair***	Pennsylvania Cooperative Fish and Wildlife Research Unit, USGS—retired	**James Hamlett, Ph.D.** Associate Professor of Agricultural Engineering	Department of Agriculture and Biological Engineering, The Pennsylvania State University
Bert Lavan ***Committee Vice-chair*** *West Nile Virus Program Coordinator*	Centre County Planning Office	**Brianna Hutchison** Water Resources Coordinator	ClearWater Conservancy
Jason Brown Project Manager	University Area Joint Authority	**Mark Ralston, P.G.** Hydrogeologist	Converse Consultants
Susan Buda Aquatic Ecologist	Susquehanna River Basin Commission	**Kristen Saacke-Blunk** Director	Agriculture and Environmental Policy Center College of Agricultural Sciences, The Pennsylvania State University
Hunter Carrick, Ph.D. Assistant Professor of Aquatic Ecology	School of Forest Resources The Pennsylvania State University	**Rick Wardrop, P.G.** Hydrogeologist and Industrial Contamination Specialist	Shaw Environmental & Infrastructure
Ann Donovan Watershed Specialist	Centre County Conservation District	**Doug Weikel, P.E., C.S.I.** Service Group Manager	Herbert, Rowland, and Grubic, Inc.
Larry Fennessey, Ph.D., P.E. Utility Systems Engineer - Stormwater	Office of Physical Plant , The Pennsylvania State University	**David Yoxtheimer, P.G.** Research Assistant	Earth and Environmental Sciences Institute, The Pennsylvania State University
Todd Giddings, Ph.D., P.G. Hydrogeologist	Todd Giddings and Associates, Inc.		

Monitoring stations

The WRMP tracks quality and quantity of surface water and groundwater reserves at a number of sites throughout the Spring Creek Watershed.

Stream Monitoring Stations

The WRMP measures conditions at four sites along the mainstem of Spring Creek and 10 tributary sites located throughout the stream's five major sub-basins (Figure 7). Twelve of the 14 sites currently included in the WRMP have been monitored since 1998. The Water Resources Monitoring Committee (WRMC) chose the 12 original sites to be representative of land use practices across the watershed. Three of the original sites were chosen to coincide with existing United States Geological Survey Gaging Stations. In 2004, the WRMC added a thirteenth site on an unnamed tributary to Buffalo Run in order to track potential impacts from acid drainage associated with pyritic rock uncovered during construction of I-99 northwest of State College. The fourteenth WRMP stream monitoring station, located on Slab Cabin Run downstream of Millbrook Marsh, was added in 2005 to assess the marsh's ability to control stormwater impacts from downtown State College and University Park.

Groundwater Monitoring Stations

The WRMP monitored water levels at six wells in 2009 (Figure 8). These wells were selected by the WRMC because they are not subject to frequent fluctuations caused by external factors such as high-yield pumping, stormwater, artificial groundwater recharge, or surface water discharges. When considered together, the seven wells provide a picture of representative groundwater conditions across the Spring Creek Watershed.

Spring Monitoring Stations

Spring monitoring became part of the WRMP in 2005 with the addition of seven spring stations (Figure 8). Like the stream and groundwater sites, these springs were chosen to be representative of various land use, geologic, and hydrologic conditions encountered in the Spring Creek Watershed. For a detailed discussion of the watershed's springs and their importance to the region, please refer to the 2006 State of the Water Resources Report.

WRMP monitoring station at Slab Cabin Run near Millbrook Marsh (credit: S. Knorr)

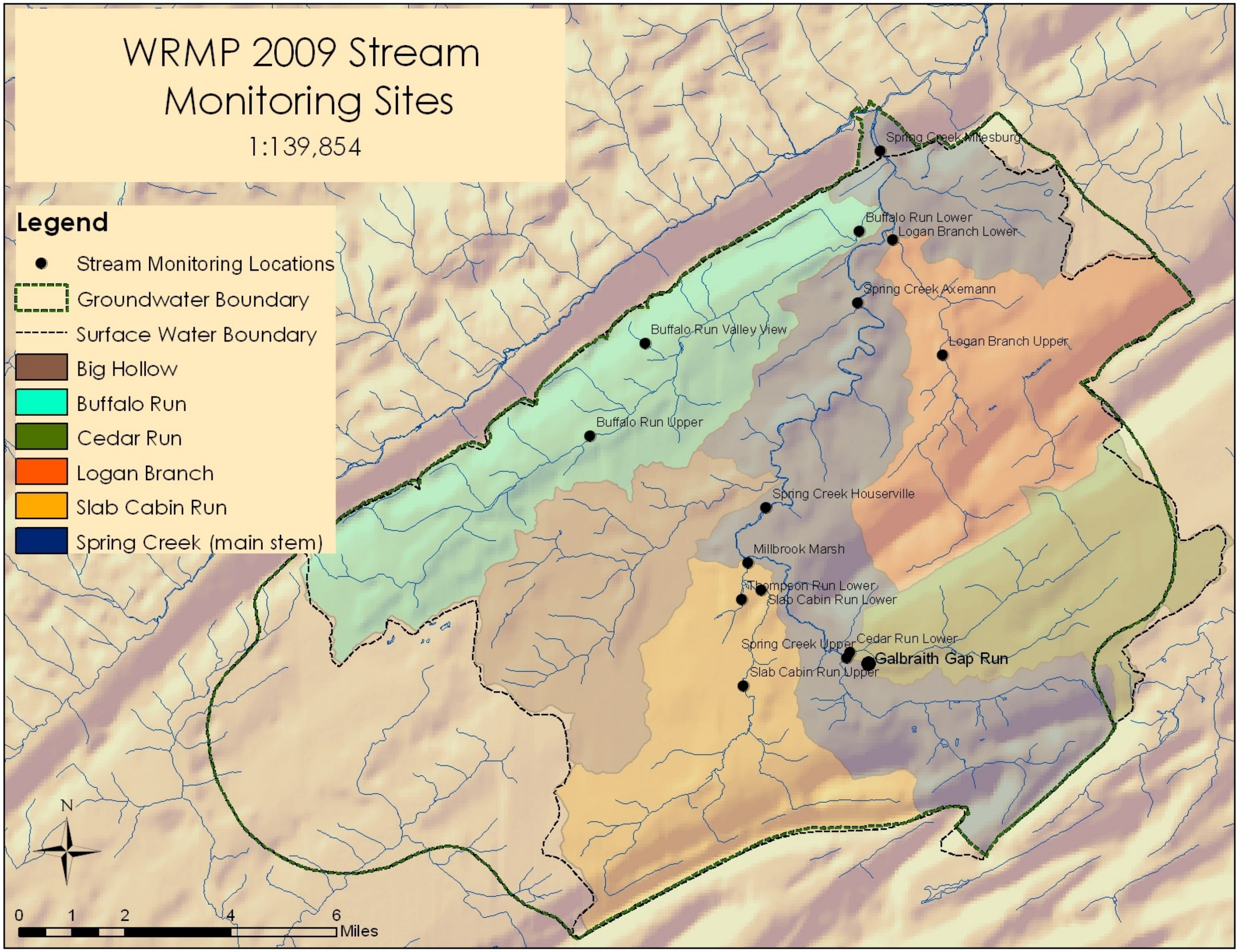


Figure 7: Stream sampling sites surveyed in 2009 as part of the Water Resources Monitoring Project.

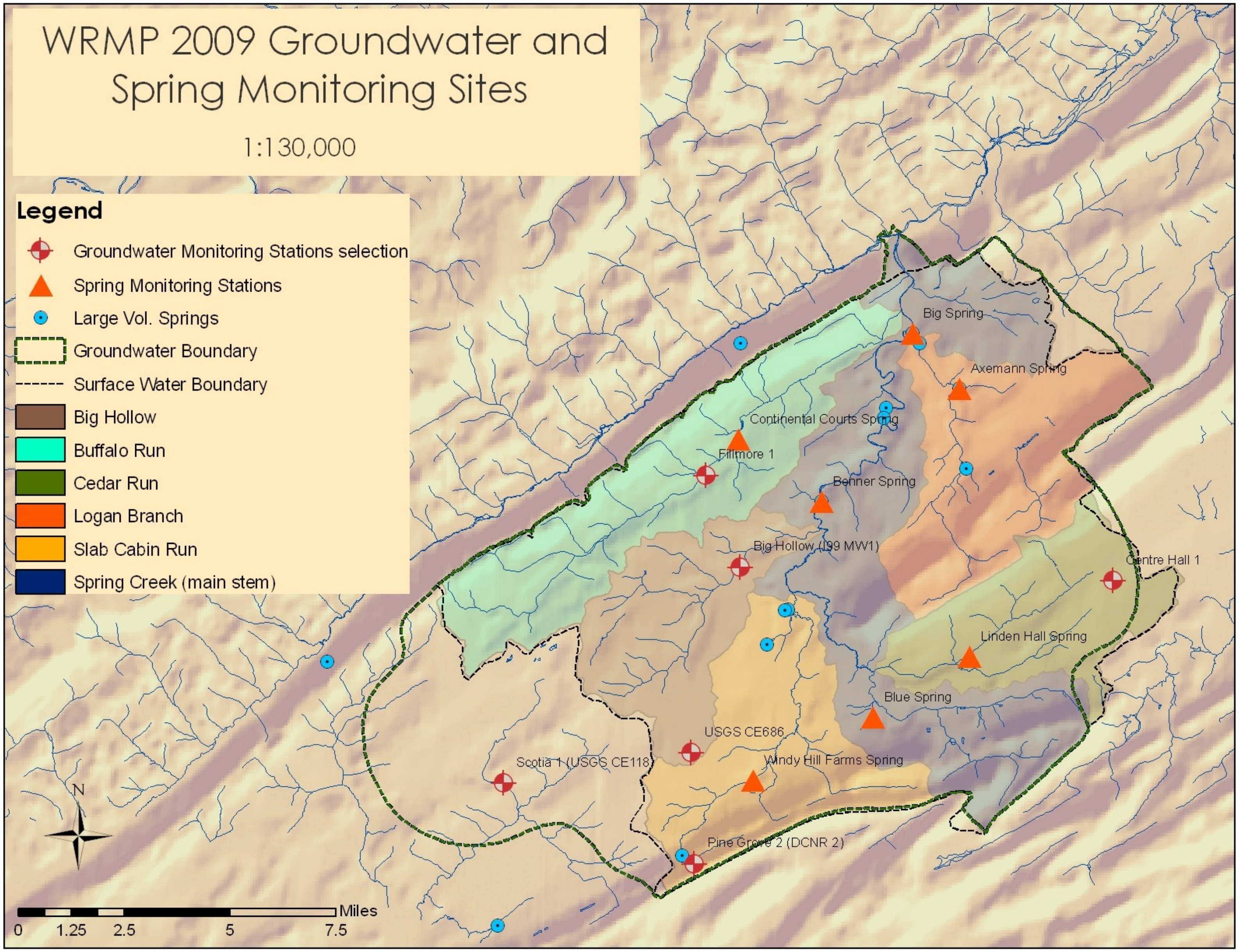


Figure 8: Groundwater and spring stations surveyed in 2009 as part of the Water Resources Monitoring Project.

To assure consistency and quality of data collected as part of the WRMP, the Water Resources Monitoring Committee developed a set of standardized procedures for data collection, sample processing, and database maintenance. A detailed description of these methods can be found in the Spring Creek Watershed Water Resources Monitoring Protocol. To review this document, please contact Brianna Hutchison, ClearWater Conservancy's Water Resources Coordinator, at (814) 237-0400.

Water Quality Monitoring

WRMP staff and volunteers collected water samples from 14 stream sites and seven springs in 2009. Sampling took place on a quarterly basis (in March, June, September, and December) when streams were at baseflow conditions. The water samples were analyzed for chemical and nutrient content by the Pennsylvania Department of Environmental Protection Analytical Laboratories. Please see Appendix 1 for a list of parameters and Appendices 3 and 4 for the results of the water quality analyses.

Continuous Measurements

Thirteen stream stations were equipped with instruments to continuously monitor stream stage. Ten of these were maintained by the WRMP and outfitted with Design Analysis Associates, Inc. DH-21 pressure transducers, which measured stream stage every 30 minutes. The equipment at the other three stream stations was maintained by the U.S. Geological Survey (USGS). Stream stage measurements were taken every 15 minutes at these stations.

WRMP technician Sarah Knorr collects a water sample from Slab Cabin Run at E. College Avenue (credit: B. Hutchison)

Water temperature was measured hourly at 11 stream stations using Onset Computer Corporation Optic Stowaway TidBitv2 data loggers. At the Thompson Run station, the temperature data logger was set to record temperature every 5 minutes instead of every hour.

Readings were taken more frequently at this station because past data have shown that temperatures in Thompson Run often fluctuate wildly in a short period of time during storm events.

Water surface elevation was recorded every 3 hours at the six wells comprising the groundwater monitoring network. WRMP staff and volunteers maintained the monitoring instruments at four of the six wells, which were equipped with InSitu miniTROLL pressure transducers. The other two wells, CE118 and CE686, were maintained by the USGS.

Discharge Measurements

In order to develop and calibrate the rating curves used to calculate stream flow from the DH-21 stage measurements, WRMP staff and volunteers took periodic instantaneous discharge measurements at each stream site using a Marsh-McBirney flow meter. These measurements were also used to detect any changes in stream channel dimensions due to sediment erosion or deposition.

Water Resources Coordinator Brianna Hutchison takes an instantaneous flow measurement in Slab Cabin Run at E. College Avenue during summer low flow conditions (credit: S. Knorr)

Water Quality

Water quality was assessed in March, June, September, and December 2009 during baseflow conditions at 14 stream and seven spring stations across the Spring Creek Watershed. WRMP water samples were evaluated for a number of common organic and inorganic pollutants (Appendix 1). A summary of water resource management issues for each municipality in the Spring Creek Watershed can be found in Appendix 2.

Trends in concentrations of the various parameters were similar to those observed for previous years' samples. Appendices 3 and 4 show median concentrations of all parameters analyzed at each of the stream and spring sites, respectively. Here are some generalizations:

- The concentration of nitrate nitrogen, a common pollutant of treated wastewater and agricultural run-off, was detected at relatively high levels across all stream sites in 2009; however, concentrations are similar to those in previous years. Nitrate levels were also high at the springs, particularly Axemann Spring, which had the highest concentration of nitrate nitrogen across all monitored sites.
- Orthophosphorus, a pollutant commonly associated with agriculture, was present at low levels (near the detectable limit) at all of the stream sites except Spring Creek at Oak Hall. Orthophosphorus was also detected at Benner Spring, Blue Spring, and Windy Hill Farm Spring in 2009.
- Chloride concentrations, which when elevated point to impacts from urbanization and water treatment processes, were similar to those observed over the history of the WRMP. Chloride concentrations tended to be higher in the winter, most likely due to runoff from anti-icing road treatments.
- Sulfates were detected at all sites except Galbraith Gap Run, Big Spring, and Blue Spring. Several years ago, Buffalo Run suffered sulfate pollution from leaking pipes associated with pyritic rock cleanup at the Interstate 99 construction site. Sulfate concentrations were high in Buffalo Run in 2007 before dropping to levels closer to those observed during the WRMP period of record in 2008. In 2009, sulfates were again slightly elevated at both the upper and lower Buffalo Run sites.
- Aluminum was detected at all sites in 2009 except Axemann Spring. Total aluminum concentrations were slightly elevated in the Slab Cabin Run subwatershed and at all of the springs compared to 2008 data. The Buffalo Run subwatershed had comparatively lower concentrations of total aluminum in 2009.
- Iron was detected at all sites in 2009. Total iron concentrations were high in upper Slab Cabin Run, Blue Spring, Windy Hill Farm Spring, upper Logan Branch, and Buffalo Run Valley View. Slab Cabin Run, Blue Spring, and Windy Hill Farm Spring periodically run dry throughout the year, which can create conditions uncharacteristic of baseflow, including elevated heavy metals. The Logan Branch subwatershed has a long industrial history and the WRMP typically documents high iron levels at the upper site. The upper Buffalo Run Valley View also had high concentrations of dissolved iron in 2009. Elevated dissolved iron concentrations in this small tributary stream may be due to the pyritic rock uncovered during construction of Interstate 99.

- Total manganese concentrations at all sites were slightly below those observed during the WRMP period of record.
- Cadmium was detected at low levels in Cedar Run in 2009. This metal, which has a number of agricultural, industrial, and urban sources, is not typically found at detectable concentrations in the Spring Creek Watershed.
- Zinc was detected at low levels in Slab Cabin Run at N. Atherton Street and below Millbrook Marsh. Benner Spring had higher levels of zinc in 2009 than are typically observed at this site.
- Fecal coliform bacteria were detected at all springs except Axemann Spring. Benner Spring had the highest concentration of fecal coliforms; however, none of the observed concentrations exceeded the Pennsylvania Department of Environmental Protections bathing standard (200 colonies/100 mL).

Stream Discharge

Stream discharge is defined as the volume of water in a stream passing a given point at a given moment in time. Larger streams have higher discharge rates than smaller ones; therefore, Spring Creek has a higher discharge than any of its tributaries. A stream's ability to move sediment and to dilute chemical pollutants is governed by discharge. Generally, the higher the discharge, the more effective a stream will be at moving sediment downstream and diluting pollutants. A stream's discharge determines the biological communities that will be found in its waters; therefore species that prefer to live in lakes or slow-moving rivers would not typically be found in a fast-flowing stream like Spring Creek. Stream discharge also fluctuates with the seasons and with storm events, making it a measurement of interest when studying the effects of runoff and flooding.

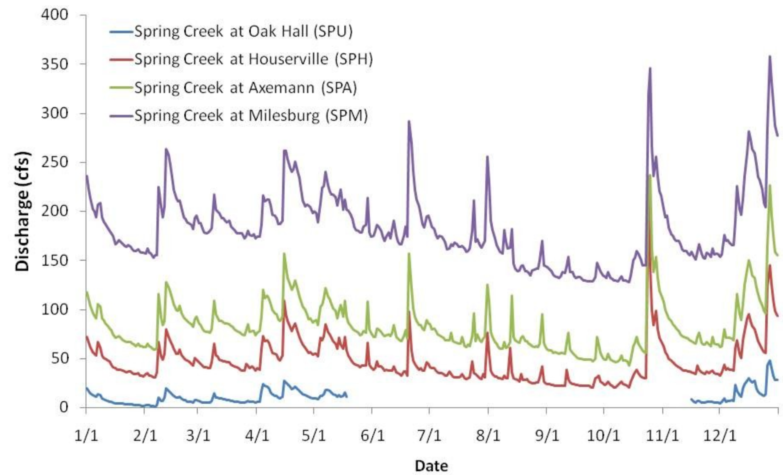


Figure 9. Average daily stream discharge (cfs) at four locations on Spring Creek in 2009.

Figure 9 depicts average daily stream discharge at four sites along the mainstem of Spring Creek during calendar year 2009. Sharp peaks in the graph represent storm or snow melt events. Average daily discharge in the mainstream of Spring Creek during the first six months of 2009 was somewhat lower than the historical median recorded for the monitoring sites. During the second half of the year, stream discharge closely approximated historical median values. Data are unavailable for the Spring Creek Oak Hall (SPU) site between mid-May and mid-November due to equipment malfunction.

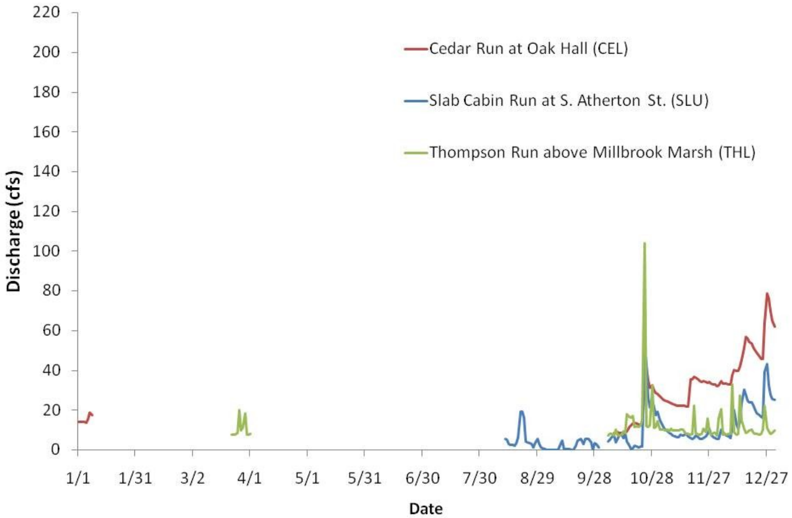


Figure 10. Average daily discharge at three sites located on tributary streams in the upper Spring Creek Watershed in 2009.

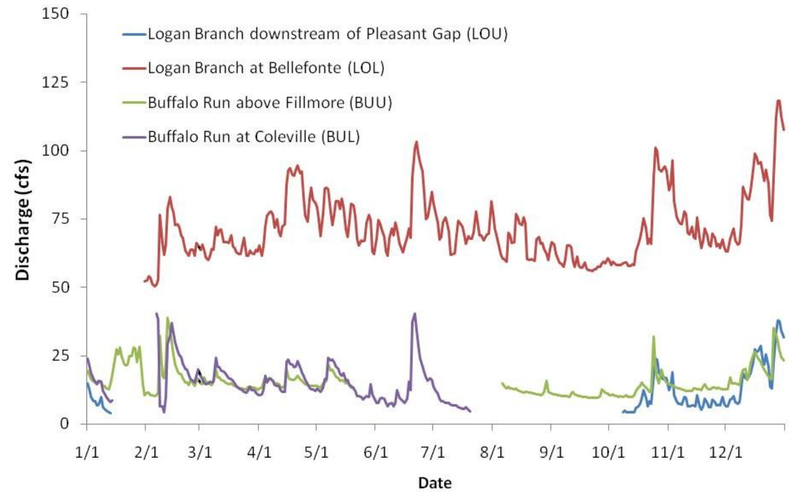


Figure 11. Average daily discharge at three sites located on tributary streams in the lower Spring Creek Watershed in 2009.

Figures 10 and 11 depict average daily stream discharges at seven tributary sites during 2009. Discharge data are unavailable for Slab Cabin Run at East College Avenue (SLL) due to monitoring station vandalism and delays in shipment of replacement equipment. Average daily discharges in 2009 were higher than or close to historical medians at several sites along tributary streams in the upper part of the watershed, including Cedar Run (CEL), Slab Cabin Run at South Atherton Street (SLU), and Thompson Run (THL). At the same time, average daily discharges were below historical median values at sites in the lower part of the watershed, including both Logan Branch (LOU & LOL) and Buffalo Run (BUU & BUL) sites.

In most streams, as drainage area increases in an upstream to downstream direction, stream discharge also increases. East College Avenue is downstream of South Atherton Street on Slab Cabin Run and Coleville is downstream of Fillmore on Buffalo Run; however, discharge is typically higher at the upstream sites. Although this was not the case in 2009, parts of Slab Cabin and Buffalo Run often run dry for periods in late summer and winter. This is because the downstream sections of these streams are perched above the water table and lose water when streams experience low flows. The surface water, in these cases, infiltrates the stream substrate to recharge the groundwater supply. This occurrence is common in karst, or limestone, settings.

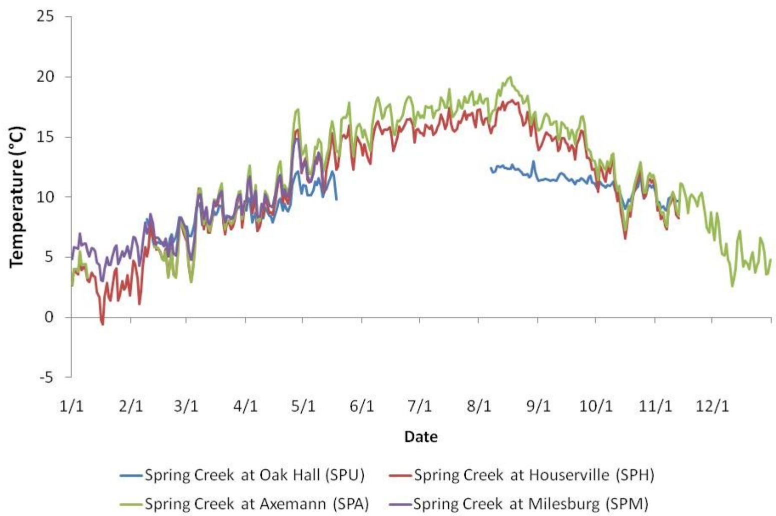


Figure 12. Average daily stream temperature at four locations along Spring Creek in 2009.

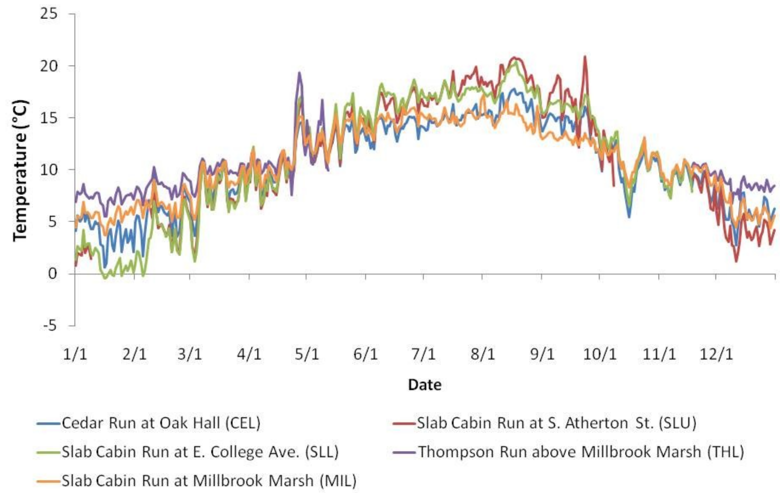


Figure 13. Average daily stream temperature at five sites on tributary streams in the upper Spring Creek Watershed in 2009.

Stream Temperature

Temperature has a profound influence on aquatic life, governing nearly every process that occurs in streams, from solubility of oxygen and various chemicals to the metabolic functions of fish and other organisms. Despite significant agricultural and urban impacts within the watershed, Spring Creek still manages to support a world-class brown trout fishery famous for its high densities of fish and large numbers of trophy-sized individuals. One of the primary reasons the stream remains so productive is that its waters are relatively cool even on the hottest days of summer. Except in times of extreme heat or drought, or during large storm events, inputs from groundwater maintain surface water temperatures in Spring Creek below the brown trout's lethal threshold of 24°C (76°F). When water temperatures rise above 24°C for extended periods of time, large-scale fish kills like the one that occurred in Slab Cabin Run in June 2005 can result.

Average daily stream temperatures in Spring Creek and its major tributaries remained below the lethal threshold for brown trout throughout 2009, ranging from about 0°C in the winter to about 20°C in the summer. Figures 12, 13, and 14 show average daily temperatures for all sites monitored by the WRMP in 2009. Although the average daily temperature remained below 24°C , the maximum daily stream temperature can sometimes exceed this threshold during the warm summer months.

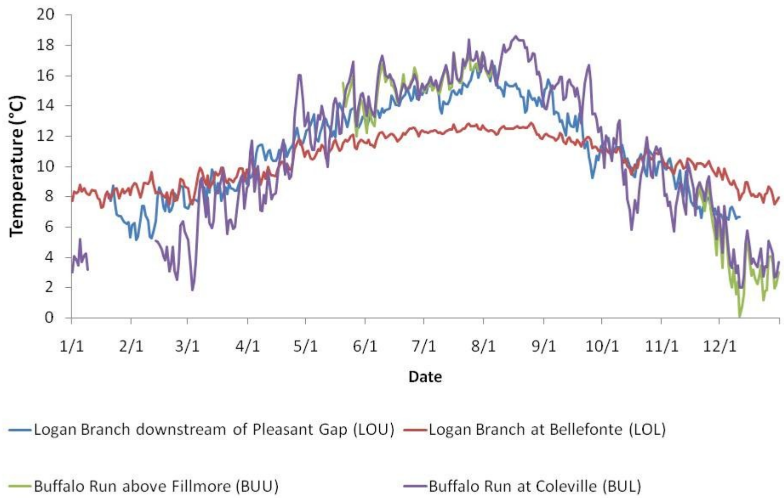


Figure 14. Average daily stream temperature at four sites on tributary streams in the lower Spring Creek Watershed in 2009.

Groundwater

In addition to supplying streams with a constant influx of cold water that supports trout and other coldwater aquatic organisms, groundwater is also important to the human inhabitants of the Spring Creek Watershed. People living in the watershed draw nearly all of their potable water from the region's many high volume springs and productive well fields. Without this groundwater resource, the watershed simply could not support such a large population of people; therefore, it is vitally important to closely monitor groundwater elevations throughout the watershed. In 2009, the WRMP collected groundwater elevation data from four monitoring wells and also assessed data from two additional wells maintained by the U.S. Geological Survey (USGS).

Groundwater elevations in the first half of 2009 exhibited normal fluctuations as a result of wet-dry periods; however, in the second half of the year a steady decline occurred, resulting in groundwater elevations well below the historical medians at the four WRMP wells. A comparison of all wells monitored as part of the WRMP during 2009 is found in Figure 15. Groundwater elevations at the USGS Centre County drought-monitoring well CE686 were low compared to levels observed in 2008 (Figure 16). Groundwater elevations at CE686 were beginning to rise at the end of 2009 following an unseasonably warm and rainy December. Figure 17 depicts groundwater elevations at USGS monitoring well CE118 for this well's entire period of record. This well is located in the Scotia Barrens, which is

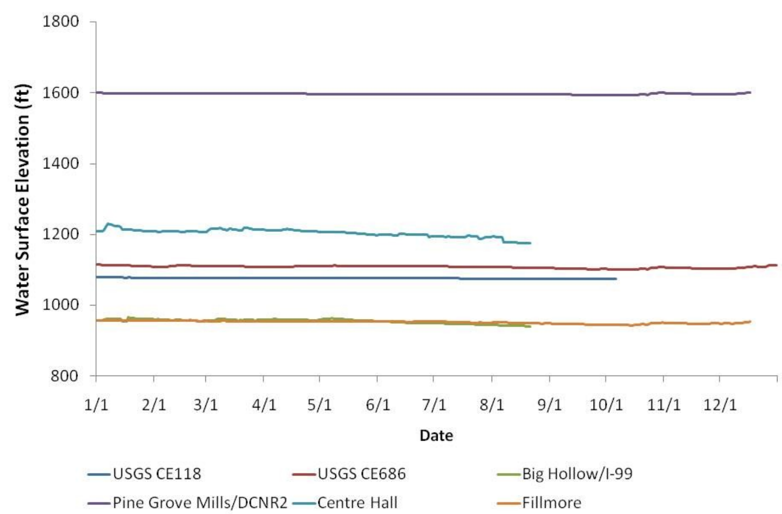


Figure 15. Comparison of daily mean water surface elevations at six wells monitored as part of the WRMP in 2009.

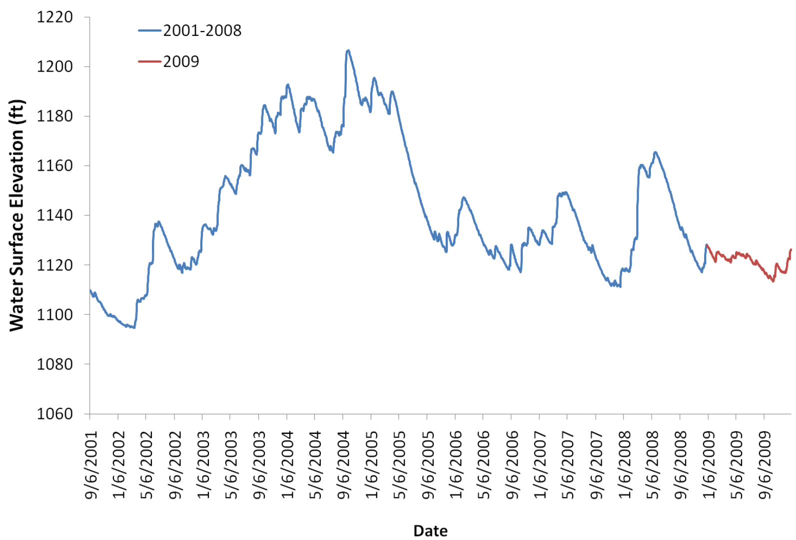


Figure 16. Daily mean water surface elevation at USGS monitoring well CE686 throughout the period of record 2001-2009.

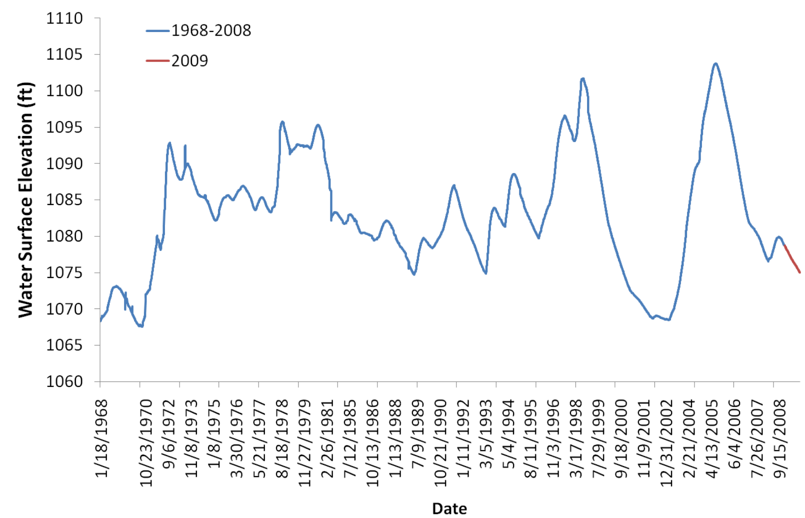


Figure 17. Daily mean water surface elevation at USGS monitoring well CE118 throughout the period of record 1968-2009.

a vitally important recharge area for Bellefonte's Big Spring. Although groundwater elevations at CE118 rose briefly in 2008, in 2009 they continued back on a long decline that began in 2005. At the WRMP monitoring well located near Fillmore, water surface elevations were steady at approximately 955 ft until mid-2009 when they dropped to around 945 ft (Figure 18). At the end of 2009, water surface elevation at the Fillmore well was on the rise.

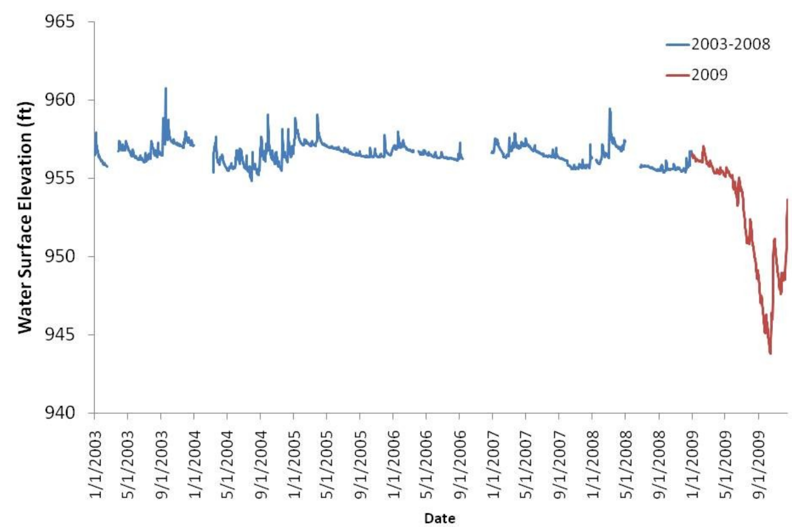


Figure 18. Daily mean water surface elevation at the Fillmore well throughout the period of record 2003-2009.

We hope that you found this year's report on the State of the Water Resources both interesting and informative. Residents of Spring Creek Watershed currently enjoy better water quality than the region has seen in nearly 100 years. Without good long-term data sets like those from the Axemann gage, it would be difficult for managers to understand how our water resources are changing and why.

The Water Resources Monitoring Project, which has been in place for over 11 years, provides vital long-term data that can be used by local planning officials to make sound land use decisions. Your continued support will help this project maintain the ability to respond to new information needs and provide credible data to monitor future changes within the watershed as our community continues to grow.

A bullfrog floats past the WRMP monitoring station on Spring Creek at Oak Hall (credit: S. Knorr)

Appendices

Appendix 1 Water Quality Parameters

Appendix 2 Summary of monitoring sites and management issues in their vicinity by municipality

Appendix 3 Stream Water Quality Results

Appendix 4 Spring Water Quality Results

Appendix 1: Water Quality Parameters

Parameter	Description	Sources	Environmental Effects	Baseflow Monitoring	Spring Monitoring
Aluminum	The most abundant element on Earth	Urban runoff, industrial discharges, and natural sources	May adversely affect the nervous system in humans and animals	X	X
Cadmium	Natural element found in the Earth's crust	Industrial sources and urban sources including fertilizer, non-ferrous metals production, and the iron and steel industry	Toxic to humans and aquatic life	X	X
Chloride	The concentration of chloride salt ions dissolved in the water	Washes off roads where used as a deicing agent	Very high chloride concentrations can be toxic to macroinvertebrates and limit osmoregulatory capacity of fishes	X	X
Chromium	A trace element essential for animals in small quantities	Found in natural deposits of ores containing other elements	Toxic to humans and aquatic life if present in excess	X	X
Conductivity	Measure of the water's ability to conduct electricity. Proportional to the amount of charged ions in the water	Sources of ions are both naturally occurring and anthropogenic in origin. Include soil, bedrock, human and animal waste, fertilizers, pesticides, herbicides, and road salt	Suspended solids clog fish gills and alter stream-bed habitat upon settling. Dissolved materials limit the osmoregulatory ability of aquatic animals	X	X
Copper	A heavy metal less common than lead and zinc in nature	Used in wiring, plumbing, and electronics. Also used to control algae, bacteria, and fungi	Toxic to humans and aquatic life. Solubility is effected by water hardness	X	X
Dissolved Oxygen	The amount of oxygen gas dissolved in the water, saturation inversely related to temperature	Dissolved oxygen is depleted by respiration and microbial breakdown of 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 temperature	X	X
Coliform Bacteria	Common intestial bacteria of warm and cold-blooded animals	Animal wastes and sewage contamination	Pathogenic to humans		X
Iron	Common element found in the Earth's crust	Urban runoff, industrial discharges, and natural sources	Toxic to humans and aquatic life	X	X
Lead	A heavy metal that occurs naturally as lead sulfide but may exist in other forms	Urban and industrial uses include gasoline, batteries, solder, pigments, and paint	Toxic to humans and aquatic life. Solubility is effected by water hardness.	X	X
Manganese	Common element found in the Earth's crust	Urban runoff, industrial discharges, and natural sources	Toxic to humans and aquatic life	X	X
Nickel	A trace element essential for animals in small quantities	Industrial wastewaters	Toxic to humans and aquatic life if present in excess	X	X
Nitrate (NO_3)	One of three forms of nitrogen found in water bodies, this form is used by plants. Organic nitrogen is converted to nitrate by bacteria	Any nitrogen-containing organic waste, including sewage from 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 or death in infants	X	X
Orthophosphate	The form of inorganic phosphorus required by plants. Often the limiting factor in plant growth	Rocks and minerals provide low natural levels. Human sources include commercial cleaning products, water treatment plants, and fertilized lawns and farmland	A small increase in orthophosphorus can cause eutrophication, the loss of dissolved oxygen through the stimulation and decay of excessive plant growth	X	X
pH	A measure of the the acidity of water on a logarithmic scale of 1 to 14 with 7 being neutral, below 7 acidic, and above 7 alkaline	Alkaline conditions can be a result of carbonate bedrock geology. Acidic conditions could be caused by acid deposition and pyritic reactions associated with acid mine drainage	Extreme acidity or alkalinity can inhibit growth and reproduction in aquatic organisms. Acidic waters also increase the solubility of metals from the sediment	X	X
Sodium	Soft metal commonly found in nature	Various salts of sodium occur in considerable concentrations in the Earth's crust	There is some evidence to suggest that these high levels of sodicity are toxic to some plants	X	X
Total Suspended Solids	Any particles carried by the water including silt, plankton,organic stream matter, industrial waste, and sewage	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	X	X
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 in some cases high turbidity is natural, it is usually the result of earth-moving activities, urban runoff, and erosion	High turbidity blocks light from the water column, inhibiting productivity of aquatic plants and periphyton. These particles also absorb sunlight and increase temperature. Also, particles will eventually come out of suspension and cause sedimentation	X	X
Zinc	A heavy metal commonly found in rock-forming minerals	Urban runoff, industrial discharges, and natural sources	Somewhat toxic to humans and aquatic life. Solubility is affected by water hardness	X	x

Appendix 2: Summary of monitoring sites and management issues in their vicinity by municipality

Municipality	Monitoring sites with the municipality	Other sites influenced by activities within the municipality	Water resources management issues
Benner Township	Unnamed tributary to Buffalo Run (BVV) Continental Courts Spring (COS) Fillmore Well Benner Spring (BES) Spring Creek at Axemann (AXS)	Buffalo Run near Coleville (BUL) Spring Creek at Milesburg (SPM) Logan Branch near Pleasant Gap (LOU)	Agricultural practices (ground and surface water) Urbanization/ Suburbanization (storm-water and water supply)
Boggs Township	Spring Creek at Milesburg (SPM)		
College Township	Spring Creek at Houserville (SPH) Slab Cabin Run at Millbrook Marsh (MIL) Slab Cabin Run at East College Avenue (SLL) Thompson Run (THL) Spring Creek at Oak Hall (SPU) Cedar Run at Oak Hall (SPU) Big Hollow/ I-99 Well Mount Nittany Well		Urbanization/ Suburbanization (storm-water and water supply) Agricultural practices (upstream areas)
Ferguson Township	Windy Hill Farm Spring (WIS) DCNR/ Pine Grove Mills Well USGS CE686 Monitoring Well USGS CE118 Monitoring Well	Thompson Run (THL)	Urbanization/ Suburbanization (storm-water and water supply) Agricultural practices
Halfmoon Township		Buffalo Run near Fillmore (BUU) Big Spring (BIS)	Agricultural practices Suburban development
Harris Township	Blue Spring (BLS) Linden Hall Spring (LIS) Galbraith Gap Run (GGU)	Slab Cabin Run at South Atherton Street (SLU) Spring Creek at Oak Hall (SPU) Cedar Run at Oak Hall (CEL)	Agricultural practices (surface and ground water) Suburban development
Patton Township	Buffalo Run near Fillmore (BUU)		Agricultural practices/ suburbanization
Potter Township	Dashem/ Centre Hall Well		Agricultrual practices
Spring Township	Logan Branch near Pleasant Gap (LOU) Axemann Spring (AXS) Buffalo Run near Coleville (BUL)	Logan Branch at Bellefonte (LOL) Spring Creek Milesburg (SPM)	Agricultural practices (surface and ground water) Suburban development Industrial water usage
Walker Township			Agricultural practices/ suburbanization
Bellefonte Borough	Logan Branch in Bellefonte (LOL) Big Spring (BIS)	Spring Creek at Milesburg (SPM)	Urbanization/ Suburbanization (storm-water)
Centre Hall Borough			Agricultural practices in surrounding areas
Milesburg Borough		Spring Creek at Milesburg (SPM)	Urbanization (storm-water)
State College Borough	Slab Cabin Run at South Atherton Street (SLU)	Thompson Run (THL) Slab Cabin Run at East College Avenue (SLL) Slab Cabin Run at Millbrook Marsh (MIL)	Urbanization/ Suburbanization (storm-water)

Appendix 3: Median Stream Water Quality Results (Metals) for 2009

Site Name	Abbrev	Aluminum (µg/L) Dissolved	Aluminum (µg/L) Total	Cadmium (µg/L) Dissolved	Cadmium (µg/L) Total	Chromium (µg/L) Dissolved	Chromium (µg/L) Total	Copper (µg/L) Dissolved	Copper (µg/L) Total	Iron (µg/L) Dissolved	Iron (µg/L) Total
Galbraith Gap Run	GGU	19.1*	29.3	ND	ND	ND	ND	ND	ND	ND	41.0
Cedar Run - Lower	CEL	5.0*	44.5	ND	0.1*	ND	ND	ND	ND	10.0*	76.5
Slab Cabin Run - Upper	SLU	ND	75.7	ND	ND	ND	ND	ND	ND	ND	258.0
Slab Cabin Run - Lower	SLL	5.0*	18.1*	ND	ND	ND	ND	ND	ND	ND	33.5
Slab Cabin Run - Millbrook	MIL	9.4*	54.1*	ND	ND	ND	ND	ND	ND	ND	74.5
Thompson Run - Lower	THL	5.0*	30.6*	ND	ND	ND	ND	ND	ND	10.0*	80.5
Buffalo Run - Upper	BUU	5.0*	50.5	ND	ND	ND	ND	ND	ND	ND	87.5
Buffalo Run - Valley View	BVV	10.9*	64.6	ND	ND	ND	ND	ND	ND	48.5	211.0
Buffalo Run - Lower	BUL	ND	45.1	ND	ND	ND	ND	ND	ND	ND	71.0
Logan Branch - Upper	LOU	5.0*	58.9	ND	ND	ND	ND	ND	ND	10.0*	119.5
Logan Branch - Lower	LOL	ND	15.1	ND	ND	ND	ND	ND	ND	ND	25.5*
Spring Creek - Upper	SPU	ND	20.9	ND	ND	ND	ND	ND	ND	ND	28.5*
Spring Creek - Houserville	SPH	5.0*	33.7	ND	ND	ND	ND	ND	ND	10.0*	63.5
Spring Creek - Axemann	SPA	8.2*	51.4	ND	ND	ND	ND	ND	ND	ND	66.5
Spring Creek - Milesburg	SPM	9.5*	36.5	ND	ND	ND	ND	ND	ND	ND	70.0

Site Name	Abbrev	Lead (µg/L) Dissolved	Lead (µg/L) Total	Manganese (µg/L) Dissolved	Manganese (µg/L) Total	Nickel (µg/L) Dissolved	Nickel (µg/L) Total	Sodium (mg/L) Dissolved	Sodium (mg/L) Total	Zinc (µg/L) Dissolved	Zinc (µg/L) Total
Galbraith Gap Run	GGU	ND	ND	ND	5.1*	ND	ND	0.6	0.7	ND	ND
Cedar Run - Lower	CEL	ND	0.05*	1.0*	3.1	ND	ND	6.6	6.8	ND	ND
Slab Cabin Run - Upper	SLU	ND	ND	3.2	14.7	ND	ND	17.4	17.4	ND	5.0*
Slab Cabin Run - Lower	SLL	ND	ND	2.7*	5.3	ND	ND	26.4	26.6	ND	ND
Slab Cabin Run - Millbrook	MIL	ND	ND	5.0	7.2	ND	ND	28.4	30.0	ND	5.0*
Thompson Run - Lower	THL	ND	ND	3.9	6.0	ND	ND	25.8	26.4	ND	ND
Buffalo Run - Upper	BUU	ND	ND	2.3*	5.9*	ND	ND	18.7	19.9	ND	ND
Buffalo Run - Valley View	BVV	ND	ND	22.5	36.5	ND	ND	14.2	14.7	ND	ND
Buffalo Run - Lower	BUL	ND	ND	4.1	6.8	ND	ND	11.3	11.9	ND	ND
Logan Branch - Upper	LOU	ND	ND	3.0	5.8	ND	ND	15.1	15.9	ND	ND
Logan Branch - Lower	LOL	ND	ND	ND	1.0*	ND	ND	11.9	12.5	ND	ND
Spring Creek - Upper	SPU	ND	ND	ND	0.1*	ND	ND	9.5	9.7	ND	ND
Spring Creek - Houserville	SPH	ND	ND	3.3	4.4	ND	ND	18.6	19.6	ND	ND
Spring Creek - Axemann	SPA	ND	ND	2.0*	4.6	ND	ND	30.9	32.7	5.0*	ND
Spring Creek - Milesburg	SPM	ND	ND	2.5*	3.7	ND	ND	21.0	21.7	ND	ND

* At least one sample had an undetectable concentration so a concentration of 1/2 detection limit set as concentration for calculations

ND All concentrations for all sites were below detection limits so no value was assigned for concentrations

Appendix 3: Median Stream Water Quality Results (Nutrients & Physicochemical) for 2009

Site Name	Abbrev	Calcium (mg/L) Total	Magnesium (mg/L) Total	Hardness (mg/L) Total	Chloride (mg/L) Total	Sulfate (mg/L) Total	Suspended Solids (mg/L) Total	Turbidity (NTU)
Galbraith Gap Run	GGU	2.8	1.5	13.5	1.7	ND	1.0*	0.50*
Cedar Run - Lower	CEL	77.3	23.7	290.5	17.9	20.3	1.0*	1.76
Slab Cabin Run - Upper	SLU	55.1	21.6	227.0	38.2	10.0*	3.5*	2.38
Slab Cabin Run - Lower	SLL	60.2	24.6	251.5	56.8	19.4	ND	0.82*
Slab Cabin Run - Millbrook	MIL	67.2	28.8	286.5	68.2	21.3	1.0*	1.66
Thompson Run - Lower	THL	70.6	30.7	303.0	62.3	17.5	1.0*	0.05*
Buffalo Run - Upper	BUU	73.0	26.3	290.5	38.6	57.3	ND	1.12*
Buffalo Run - Valley View	BVV	31.6	4.9	98.5	24.4	16.4	11.0*	2.03*
Buffalo Run - Lower	BUL	70.5	25.3	285.0	22.1	47.8	1.0*	0.73*
Logan Branch - Upper	LOU	71.4	18.7	255.5	29.1	68.5	ND	3.10
Logan Branch - Lower	LOL	53.9	20.8	221.0	26.9	25.5	ND	ND
Spring Creek - Upper	SPU	56.0	18.2	215.0	21.9	16.8*	ND	0.01*
Spring Creek - Houserville	SPH	66.9	24.3	267.0	43.4	22.1	1.0*	1.76
Spring Creek - Axemann	SPA	67.1	25.2	270.0	59.2	30.1	ND	0.90*
Spring Creek - Milesburg	SPM	57.9	22.2	236.0	42.5	27.2	ND	0.05*

Site Name	Abbrev	pH	Diss. Oxygen (mg/L)	Temperature (°C)	Conductivity (mS)	Nitrate-N (mg/L)	Orthophosphorus (mg/L) Total
Galbraith Gap Run	GGU	8.3	10.94	8.4	32.7	0.2	0.005*
Cedar Run - Lower	CEL	8.3	12.92	9.9	545.5	4.7	0.011*
Slab Cabin Run - Upper	SLU	8.1	11.56	11.6	397.0	2.7	0.024*
Slab Cabin Run - Lower	SLL	7.9	13.34	10.5	516.6	2.3	0.014*
Slab Cabin Run - Millbrook	MIL	8.1	12.33	11.2	575.0	3.5	0.015
Thompson Run - Lower	THL	8.1	12.25	11.7	577.0	4.1	0.017
Buffalo Run - Upper	BUU	8.1	11.72	8.6	414.3	1.4	0.010*
Buffalo Run - Valley View	BVV	8.1	12.56	9.0	226.5	0.3	0.026
Buffalo Run - Lower	BUL	8.3	14.22	10.1	552.5	1.8	0.009*
Logan Branch - Upper	LOU	7.9	11.33	12.2	528.5	3.1	0.057
Logan Branch - Lower	LOL	8.0	11.68	10.5	387.2	3.2	0.017
Spring Creek - Upper	SPU	7.8	9.51	9.6	368.8	2.3	ND
Spring Creek - Houserville	SPH	8.3	13.26	10.1	466.3	3.2	0.013*
Spring Creek - Axemann	SPA	8.4	13.57	11.1	520.9	4.2	0.036
Spring Creek - Milesburg	SPM	8.4	13.18	11.1	518.8	3.5	0.033

* At least one sample had an undetectable concentration so a concentration of 1/2 detection limit set as concentration for calculations

ND All concentrations for all sites were below detection limits so no value was assigned for concentrations

Appendix 4: Median Spring Water Quality Results (Metals) for 2009

Site Name	Abbrev	Aluminum (µg/L)		Cadmium (µg/L)		Chromium (µg/L)		Copper (µg/L)		Iron (µg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann Spring	AXS	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.0*
Benner Spring	BES	ND	75.2	ND	ND	ND	ND	ND	ND	ND	186.0
Big Spring	BIS	ND	5.0*	ND	ND	ND	ND	ND	ND	21.0*	10.0*
Blue Spring	BLS	ND	119.0*	ND	ND	ND	ND	ND	ND	10.0*	222.0*
Continental Courts Spring	COS	5.0*	5.0*	ND	ND	ND	ND	ND	ND	ND	10.0*
Linden Hall Park Spring	LIS	ND	14.7	ND	ND	ND	ND	ND	ND	ND	26.0
Windy Hill Farm Spring	WIS	ND	158.8	ND	ND	ND	ND	ND	ND	ND	375.0

Site Name	Abbrev	Lead (µg/L)		Manganese (µg/L)		Nickel (µg/L)		Sodium (mg/L)		Zinc (µg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann Spring	AXS	ND	ND	ND	ND	ND	ND	15.3	15.8	ND	ND
Benner Spring	BES	ND	ND	9.6*	17.6	ND	ND	23.2	23.5	5.0*	12.0*
Big Spring	BIS	ND	ND	1.0*	1.0*	ND	ND	9.3	9.9	ND	ND
Blue Spring	BLS	ND	0.5*	2.7*	4.9*	ND	ND	3.0	3.0	ND	ND
Continental Courts Spring	COS	ND	ND	ND	ND	ND	ND	9.2	9.8	ND	ND
Linden Hall Park Spring	LIS	ND	ND	ND	ND	ND	ND	3.3	3.4	ND	ND
Windy Hill Farm Spring	WIS	ND	ND	3.0	8.3	ND	ND	15.2	16.4	ND	ND

* At least one sample had an undetectable concentration so a concentration of 1/2 detection limit set as concentration for calculations

ND All concentrations for all sites were below detection limits so no value was assigned for concentrations

Appendix 4: Median Spring Water Quality Results (Nutrients & Physicochemical) for 2009

Site Name	Abbrev	Calcium (mg/L) Total	Magnesium (mg/L) Total	Hardness (mg/L) Total	Chloride (mg/L) Total	Sulfate (mg/L) Total	Suspended Solids (mg/L) Total	Turbidity (NTU)
Axemann Spring	AXS	83.0	35.4	354.0	41.3	34.1	ND	ND
Benner Spring	BED	67.3	24.4	269.0	53.6	19.7	8.0*	1.25
Big Spring	BIS	34.3	17.1	156.0	19.5	ND	ND	ND
Blue Spring	BLS	34.6	16.1	153.0	6.3	ND	ND	1.51*
Continental Courts Spring	COS	61.2	26.8	263.0	19.9	23.1	1.0*	0.50*
Linden Hall Park Spring	LIS	82	33.5	341.0	8.5	19.6	ND	ND
Windy Hill Farm Spring	WIS	63.5	28.4	275.5	33.15	18.1	7.0	0.91

Site Name	Abbrev	pH	Diss. Oxygen (mg/L)	Temperature (°C)	Conductivity (mS)	Nitrate-N (mg/L)	Orthophosphorus (mg/L) Total	Fecal Coliforms (#col/ 100mL)
Axemann Spring	AXS	7.4	9.01	10.4	510.0	6.5	ND	0.0
Benner Spring	BES	7.6	9.29	11.4	438.5	4.0	0.005*	96.7
Big Spring	BIS	7.9	11.00	10.2	238.4	1.9	ND	34.3
Blue Spring	BLS	7.8	5.91	9.5	205.4	1.5	0.01*	26.7
Continental Courts Spring	COS	7.7	7.48	10.3	363.2	2.3	ND	1.3
Linden Hall Park Spring	LIS	7.4	7.26	9.9	430.6	4.9	ND	0.7
Windy Hill Farm Spring	WIS	7.2	6.97	9.3	375.9	3.6	0.009*	20.0

* At least one sample had an undetectable concentration so a concentration of 1/2 detection limit set as concentration for calculations

ND All concentrations for all sites were below detection limits so no value was assigned for concentrations

$ Values possibly affected by low flow or stagnant conditions due to drought