Springs
Lifeblood of the Community

Spring Creek Watershed Community
Water Resources Monitoring Project

2006 State of the Water Resources Report

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Cover Photo: Linden Hall Spring in Linden Hall Park (Photo: G. Smith)

From the Chair

Ever since the Water Resources Monitoring Project got underway in 1998, we have relied largely upon local municipalities, water and sewer authorities, Penn State University, and conservation groups for support. We think that our supporters have recognized the value of the information that we generate, and in turn, several of them have voluntarily increased their contributions. Our pledge has been to provide unbiased, high quality data and to be responsive to supporter requests.

Several years ago, as we made presentations to municipal officials and their staffs, it was apparent that there was much interest in the quality of ground water and particularly in the springs, where the ground water emerges to the surface. These discussions prompted us to develop and initiate a monitoring program for springs.

Now that we have collected data from springs for one and a half years, it seemed appropriate to highlight the role of springs and report on our recent findings. Large limestone springs are defining features of the watershed. The naming and settlement of Bellefonte are intimately tied to Big Spring. The water that drove the waterwheel and powered the bellows in the Centre Furnace came from Thompson Spring. The three largest trout hatcheries in the state are all associated with springs here in the Spring Creek Watershed. The large and small springs alike have nurtured the residents of the region and have sustained a recreational trout fishery that has a reputation extending well beyond the borders of the Commonwealth. Given the above examples, it is safe to say that these springs are the *lifeblood of the community*.

Indeed, we are extremely fortunate to have such a wealth of springs. As we strive to better understand how springs function, we are better able to appreciate them, and we must be better able to protect them.

Introduction

Submitted by WRMP Committee Member Jim Hamlett, Ph.D.

Welcome to the Spring Creek Watershed Community's Water Resources Monitoring Project (WRMP) 2006 Annual Report. This year's report, entitled *Springs – The Lifeblood of the Community* will focus on an often overlooked but crucial element of this area's water resources; springs. In this year's report, we provide information as to why springs are important to the community, locations and uses of some of the larger springs, geologic factors that influence spring formation and locations, quality and quantity of spring flows, and flora and fauna associated with springs. Our intent is to provide various background information about our local springs and hopefully convey why springs are indeed vital to our community – thus the lifeblood to those of us who reside here.

Beginning in Summer 2005, we expanded our monitoring efforts to include baseline water quality sampling of several of the local springs. By monitoring quantity and quality of spring flow, in combination with monitoring groundwater quality, we will be able to gauge over time the long-term trends in the quality of subsurface waters in the watershed. This subsurface water quality reflects the integration of surface processes as they influence recharge of water to the subsurface. Thus, potential impacts to the surface conditions may be reflected in subsurface quality.

In addition to the primary topic covered in this year's report, we will also review the water quality and quantity for 2006 throughout the Spring Creek Watershed. This will cover both surface and ground water levels and base-flow surface water quality for the calendar year 2006. An addendum to this report provides a summary of the 2006 base-flow data for in-stream stations, groundwater wells, and springs. These data are available upon request by contacting the project manager, Geoffrey Smith, at (814) 237-0400.

Why Focus on Springs?

Springs are prevalent within the Spring Creek Watershed. Within our local watershed the emergence of groundwater flow onto the surface is common, and countless numbers of small seeps and springs exist throughout the basin. History of the local region notes that in July of 1769 early European settlers exploring the local waterways came upon a huge limestone spring and noted the site on their maps as "big spring." Today, we know this site as the location of Big Spring in Bellefonte, which discharges approximately 19 million gallons of water per day into Spring Creek and is the second largest spring in the entire Commonwealth. Other sizeable springs (some

Introduction

with flows in excess of a million gallons per day) go by the names of Blue Spring, Benner Spring, Thompson Spring, Walnut Spring, Thornton Spring, and Axemann Spring. Many smaller springs also provide continuous flows to Spring Creek and its tributaries. Indeed, the headwaters of Spring Creek emerge as springs and seeps all along the base of Tussey Mountain. "Spring Creek" is thus an apt name for our local stream that collects and carries water from these various springs and seeps.

As one might imagine, in earlier times springs were central to the establishment of local communities – both in providing continuous water supplies for individual homes and farms and as the centerpiece of small towns that developed around the larger springs. Even today, spring flow continues to provide potable water for a substantial number of people and animals within the watershed. Springs and baseflow also provide the continuous, and generally ample, summer flows of cold water that support local trout fisheries. Springs serve as water sources for the three PA Fish and Boat Commission hatcheries within the Spring Creek Watershed, which are critical to continued trout rearing and stocking within central Pennsylvania. Additionally, because of the unique topographic, geologic, and climatic conditions present in the watershed, unique communities of flora and fauna exist. Thus, the lifeblood of the local community indeed centers around springs. We hope you enjoy learning more about the local springs, the Spring Creek Watershed, and activities of the Water Resources Monitoring Project as you review this report!

Figure 1: Spring Run of Big Spring in Tallyrand Park, Bellefonte, PA (Photo: G. Smith)

Background

The Water Resources Monitoring Project was initiated in 1998 as part of the strategic planning of the Spring Creek Watershed Community. The WRMP, comprised of base flow and storm-water monitoring of surface waters as well as the monitoring of groundwater levels, was designed to be used for the long-term protection of the water resources of the Spring Creek Watershed as the demands on them increase. The project was created by the Water Resources Monitoring Committee (Table 1), a volunteer group of local environmental professionals, 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 storm-water runoff throughout the watershed;
C. Monitor groundwater levels in critical areas;
D. Provide the means to detect changes in quantity and/or quality of surface waters under base flow conditions, storm-water runoff, and groundwater reserves; and
E. Provide sufficient measurement sensitivity through long-term monitoring to permit the assessment of the previously mentioned parameters.

The WRMP receives funding to carry out data collection activities. For 2006, nearly $44,000 was donated to support the work of the project. Donors in support of the 2006 efforts include:

- 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
- Spring-Benner-Walker Joint Authority
- State College Borough
- State College Borough Water Authority
- Spring Creek Chapter Trout Unlimited
- University Area Joint Authority

In addition to financial support, the project also benefits greatly from in-kind support including professional services, laboratory analyses and

Background

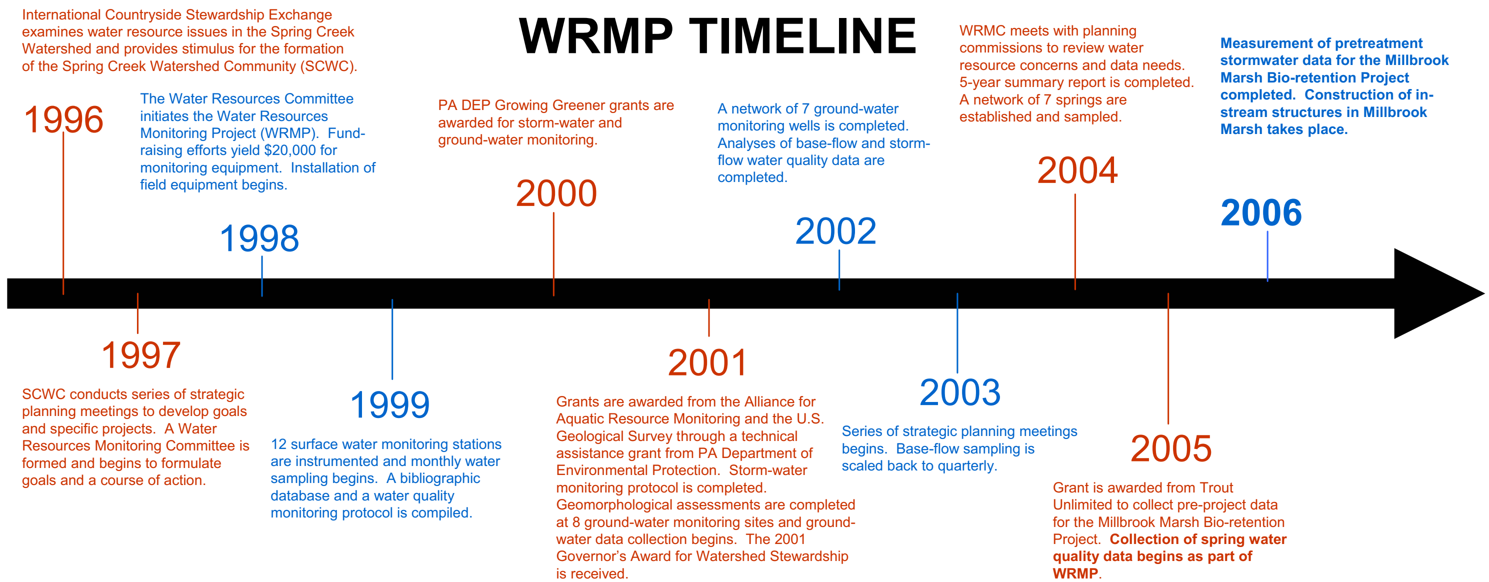

Figure 2. Timeline of activities associated with the Water Resources Monitoring Project

supplies, technical assistance, and transportation from the following:

- Ground-water Well owners
  - Corning Asahi
  - Howard Dashem
  - Pennsylvnia Department of Conservanction and Nature Resources (DCNR)
  - Todd Giddings
  - Penn State University – OPP
  - U.S. Geological Survey (USGS)
- Pennsylvania Department of Environmental Protection
- Pennsylvania Cooperative Fish and Wildlife Research Unit, United States Geological Survey
- United States Geological Survey
- University Area Joint Authority
- Volunteer field assistants
- Water Resources Monitoring Committee (Table 1)

Table 1: WRMP Committee Members for 2006

WRMP Committee Member	Affiliation	WRMP Committee Member	Affiliation
Robert Carline, Ph.D. Committee Chair Adjunct Professor and Unit Leader	Pennsylvania Cooperative Fish and Wildlife Research Unit, USGS	**James Hamlett, Ph.D.** Assoc. Prof. of Ag. Engineering	Dept. of Ag and Bio. Engineering, Pennsylvania State University
Bert Lavan Committee Vice-chair West Nile Virus Program Coord.	Centre County Planning Office	**Mark Ralston, P.G.** Hydrogeologist	Converse Consultants
Jason Brown Project Manager	University Area Joint Authority	**Kristen Saacke-Blunk** Extension Associate	Agriculture and Environ. Policy, Pennsylvania State University
Susan Buda Aquatic Ecologist	Susquehanna River Basin Commission	**John Sengle** Water Pollution Specialist	Pennsylvania Department of Environmental Protection
Hunter Carrick, Ph.D. Asst. Prof. of Aquatic Ecology	School of Forest Resources, Pennsylvania State University	**David Smith** Asst. Executive Director	University Area Joint Authority
Ann Donovan Watershed Specialist	Centre County Conservation District	**Geoffrey Smith** Water Resources Coordinator (March 2007 - Present)	ClearWater Conservancy
Rebecca Dunlap Water Resources Coordinator	ClearWater Conservancy	**Rick Wardrop, P.G.** Hydrogeologist & Industrial Contamination Specialist	Shaw Environmental & Infrastructure
Larry Fennessey, P.E. Engineer II	Office of Physical Plant, Pennsylvania State University	**Doug Weikel, P.E., C.S.I** Service Group Manager	Herbert, Rowland, and Grubic, Inc.
Todd Giddings, Ph.D., P.G. Hydrogeologist	Todd Giddings and Associates, Inc.	**Dave Yoxtheimer, P.G.** Director of Operations	ARM Group, Inc.

Monitoring
Stations

The WRMP monitors several sites across the Spring Creek Watershed to track the quality and quantity of the water resources in the basin.

Stream Monitoring Stations

The WRMP monitored fourteen stream sites quarterly at baseflow conditions throughout 2006 (Figure 6). Twelve of these stations were originally established at the inception of the project in 1998. Sites were selected from each of the Spring Creek Watershed subbasins and major land use types. Other criteria included coincidence with the existing U.S. Geological Survey Gaging Stations (Spring Creek at Axemann, Houserville, and Milesburg) and gaging stations maintained by the Pennsylvania Cooperative Fish and Wildlife Research Unit (Cedar Run, Spring Creek – Upper, and Slab Cabin Run – Upper). Beginning in 2004, an unnamed tributary to Buffalo Run was sampled as a reference to track any impacts associated with acidic discharge caused by the uncovering of pyritic rock during the construction of Interstate 99 northwest of State College. In 2005, a fourteenth site was added on Slab Cabin Run downstream of Millbrook Marsh to monitor the efficacy of the marsh on controlling the impacts of stormwater runoff from downtown State College, University Park, and other urbanized areas in the Slab Cabin Run Watershed.

Figure 3: USGS gaging station on Spring Creek at Axemann, PA (Photo: B. Carline)

Figure 4: Becky Dunlap preparing to download groundwater data from the Fillmore well (Photo: G. Smith)

Ground-Water Monitoring Wells

Ground water in the Spring Creek Watershed is monitored with a network of seven wells equipped with water-level recording devices (Figure 7). The wells were established at locations representing different groundwater conditions across the watershed and because they were not subject to frequent fluctuations caused by external factors such as high-yield pumping wells or well fields, storm water, artificial groundwater recharge, or surface water discharges.

Spring Monitoring Stations

A network of seven springs was included in the WRMP sampling framework beginning in July 2005. These sites were sampled quarterly with the base-flow surface water samples. The springs that were chosen were most representative of various land-use, geologic, and hydrologic conditions encountered in the watershed. Spring locations are shown in Figure 7. A more in-depth description of the spring monitoring can be found in later portions of this report.

Figure 5: Sampling of Big Spring, Bellefonte, PA (Photo: B. Carline)

Monitoring
Stations

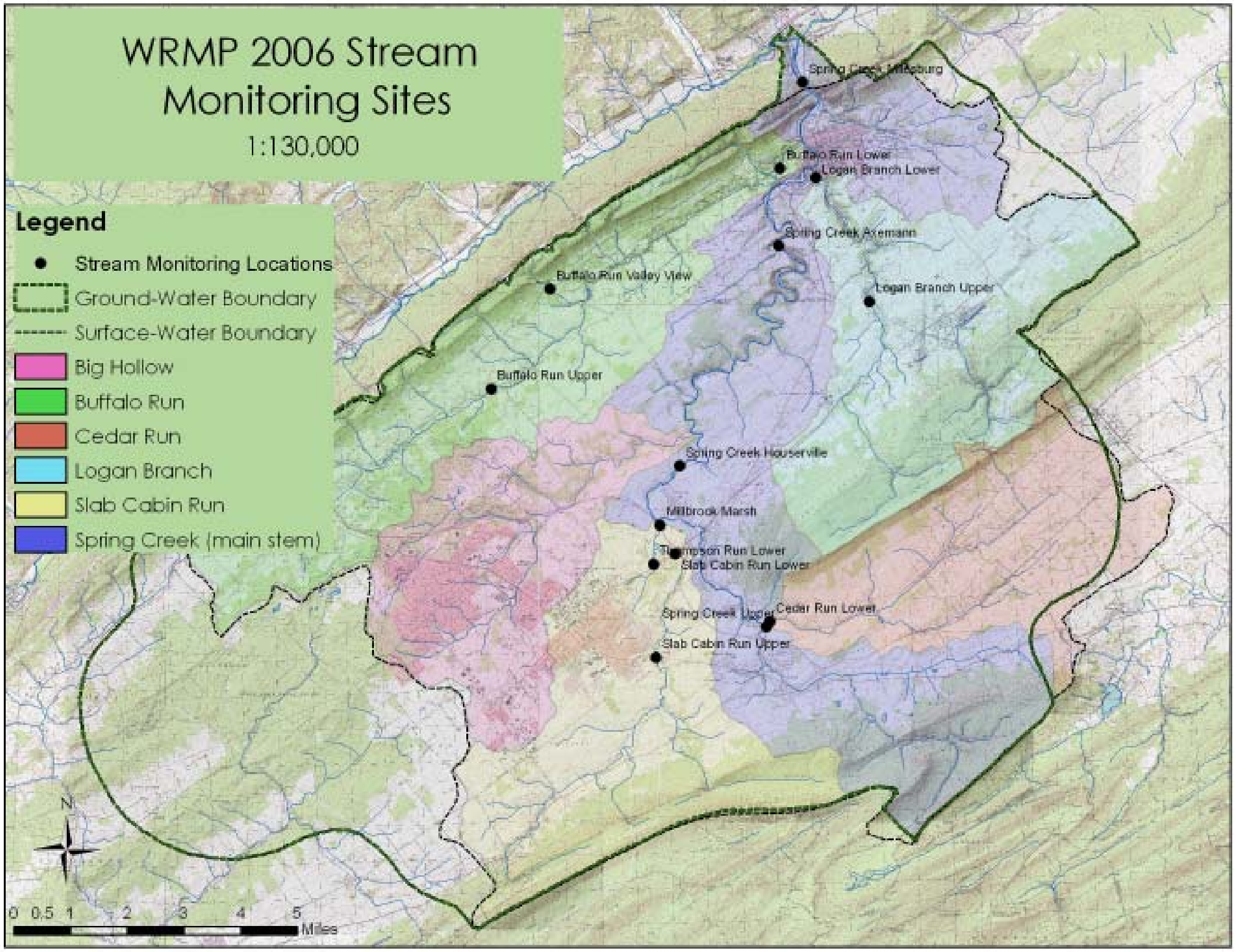

Figure 6: Stream sampling sites surveyed during the 2006 Water Resources Monitoring Project

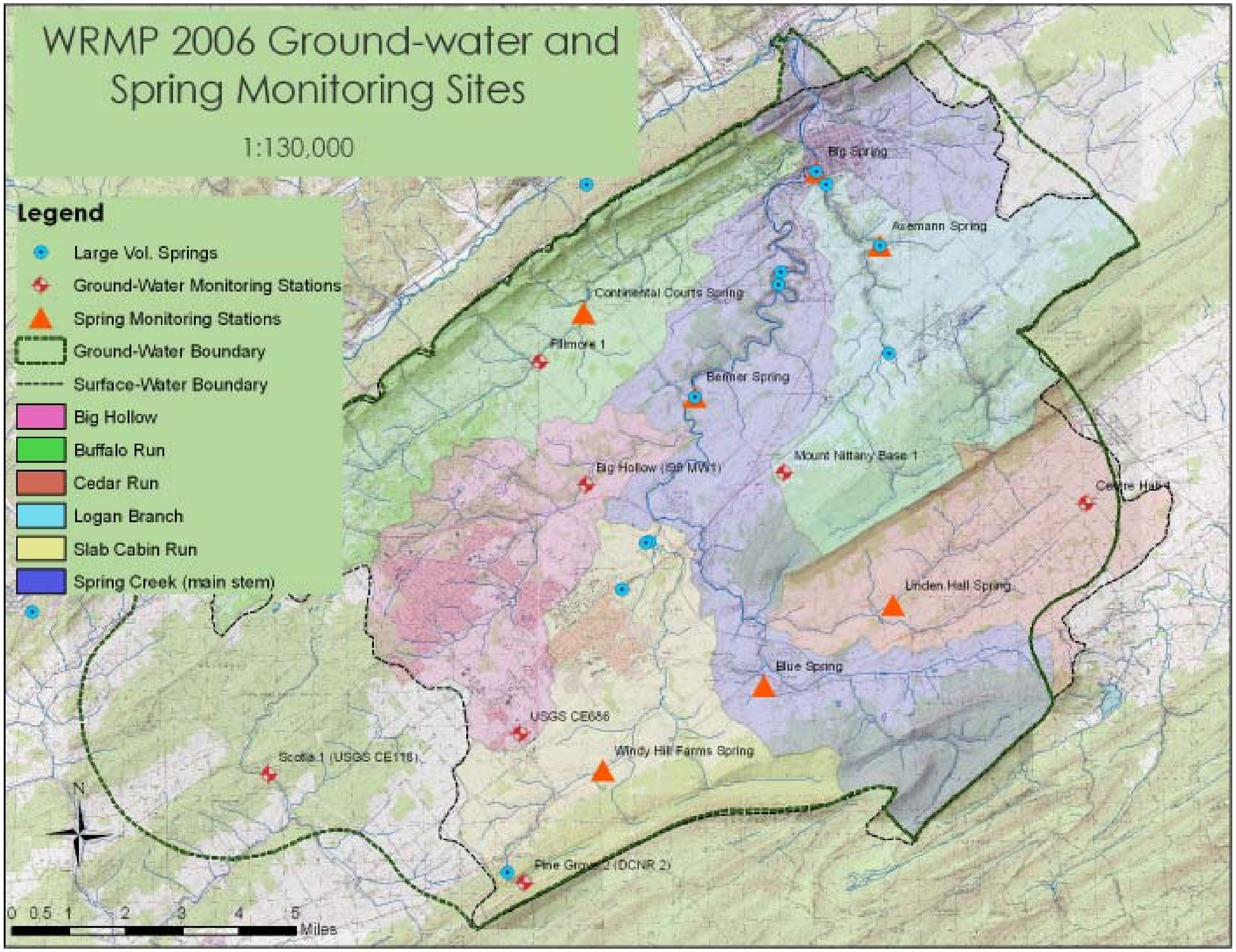

Figure 7: Ground-water and spring stations surveyed during the 2006 Water Resources Monitoring Project

Monitoring
Methodologies

Standardized methods have been developed for data collection and sample processing to provide quality assurance for all data collected as part of the WRMP. Detailed methods are documented in the Spring Creek Watershed Water Resources Monitoring Protocol which is available at www.springcreekwatershed.org or by request from the Water Resources Coordinator at (814) 237-0400.

Physicochemical samples were collected quarterly at base-flow conditions at each of the stream and spring sites. The samples were analyzed by the Pennsylvania Department of Environmental Protection Analytical Laboratories for the parameters listed in Appendix 1. An analysis of the results for each parameter can be found in Appendix 2.

Continuous Measurements

Stream stage was continuously measured at fourteen of the stream monitoring stations covered as part of the WRMP during 2006. Ten stations were equipped and maintained by the WRMP using Design Analysis Associates, Inc. DH-21 pressure loggers or Global Water Instrumentation, Inc. WL15X Water Level Loggers. The instruments were set to record every 30 minutes throughout the course of the year. The remaining three sites were maintained by the U.S. Geological Survey and equipped to take readings on a 15-minute interval.

Water temperature was recorded hourly at twelve stream stations using StowAway TidBit Temperature data loggers.

Ground-water levels at the seven wells that comprise the ground-water monitoring network are recorded at 3- hour intervals. Five of the seven are maintained by the WRMP, and the other two (CE118 and CE686) were maintained by the U.S. Geological Survey.

Discharge Measurements

Instantaneous discharge measurements were taken periodically using a Marsh-McBirney flow meter at each of the sites maintained by the WRMP. These data were used in the development of rating curves for correlations with hourly stage height data from the data loggers. These measurements were also used to detect change in stream channel dimensions and sediment erosion or deposition.

The WRMP collected quarterly base flow samples at fourteen stream sites and seven spring sites across the Spring Creek basin for the parameters listed in Appendix 1. Water quality standards were not exceeded at any of the stream sites for their particular designation (either High Quality Cold Water Fishery or Cold Water Fishery) based upon samples collected in 2006. Trends in concentrations of the various parameters analyzed were similar to or slightly lower than previous years' samples. Appendix 2 shows median concentrations of all parameters analyzed at each of the stream sites sampled as part of the 2006 WRMP.

Figure 8: Geoff Smith measures dissolved oxygen at Spring Creek at Milesburg.(Photo: B. Carline)

Generally,

- The concentration of nitrate nitrogen, a common pollutant associated with agriculture, is found at relatively high levels at all sites; however concentrations are slightly lower or unchanged from previous years.
- Total orthophosphorus concentrations, another common pollutant associated with agriculture, hovered around the lower detectable levels and remain relatively unchanged compared to previous years.
- Chloride concentrations, usually a sign of treated drinking water and urbanization impacts, were unchanged from previous years.
- Sulfate concentrations, a common indicator of acid runoff, were unchanged in the Buffalo Run watershed showing little or no sign of effects from the uncovering of pyritic rock in the Interstate 99 project.
- Total aluminum concentrations were slightly lower at all sites compared to previous years.
- Total iron concentrations were slightly lower at all sites with the exception of Logan Branch.

- Manganese concentrations were slightly lower or unchanged at all sites when compared to previous years.
- Zinc was undetectable at all sites except the lower site on Logan Branch and is probably a product of legacy effects of factories in that area. Concentrations are similar to previous years indicating no change.
- Dissolved oxygen, pH, and conductivity are similar to previous years.

A similar analysis of the spring sites was conducted and those results can be found in Appendix 3. A more in-depth breakdown of the data can be found later in the section exclusively devoted to springs

Surface Water

The hydrology of 2006 was unusual when compared to most years. Spring 2006 brought about unusually low flow periods and elevated temperatures. This type of situation is expected in summer months but not this early in the year. Usually, the late summer and early fall periods are the lowest flow periods of the year, but in 2006 this served as a period of relief that yielded higher flows than spring and early summer. This was due in large part to periodic large storms associated with tropical systems.

Figures 9 – 11 are graphs portraying discharge values for the sites covered by the WRMP during 2006 based on data collected from U.S. Geological Survey and WRMP stream gages. Gaps in data are a result of equipment failure or loss due to severe flooding. Figure 9 is a comparison of discharge values at 4 sites along the mainstem of Spring Creek during calendar year 2006. Figure 10 is a comparison of discharge values for the sites contained within the Slab Cabin Run sub-watershed. Figure 11 is a comparison of discharge values for all other tributary sites monitored by the WRMP during 2006.

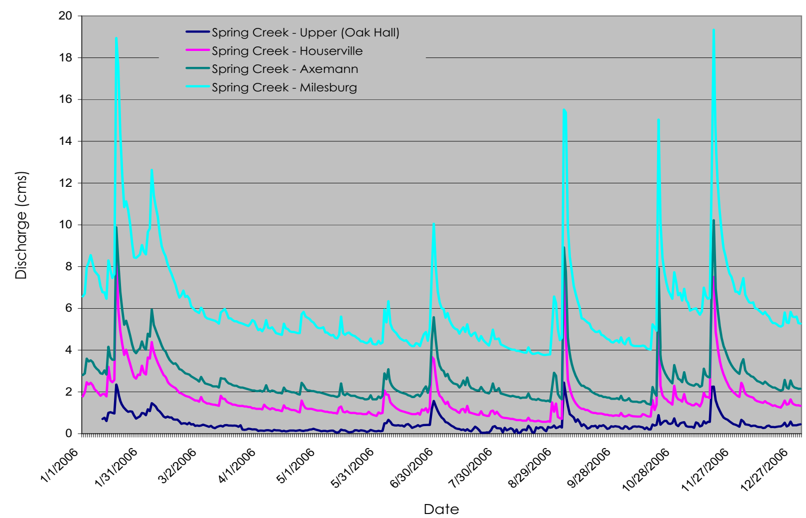

Figure 9: Comparison of discharges from 4 sites on Spring Creek during 2006

Careful analysis of the hydrographs for the Slab Cabin Run sub-watershed (Figure 10) show a rather interesting phenomenon. Comparison of the simultaneous discharge of upper and lower Slab Cabin Run sites show that discharge at the lower site is frequently less than at the upper site. In most streams, as drainage area increases, so does discharge. In this case however, Slab Cabin Run actually has a lower discharge downstream even though drainage area increases. Slab Cabin Run between these sites is a *losing* stream, meaning that the stream is losing water underground to the water table. The stream surface is perched above the water table. The surface water, in these cases, infiltrates the stream substrate to recharge the ground water supply. This occurrence is common in karst, or limestone, settings.

Lacking from the comparison of sites within the Slab Cabin Run sub-watershed is the discharge data from Thompson Run. Although stage data were collected during 2006, the rating curve to associate

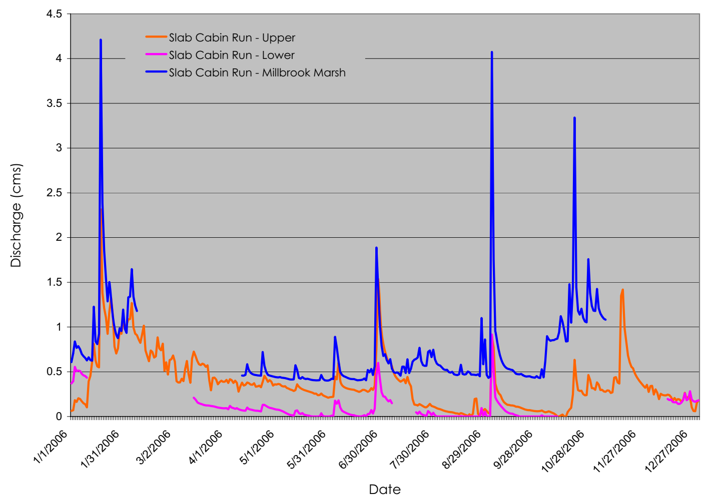

Figure 10: Comparison of discharges of sites within the Slab Cabin Run sub-watershed during 2006

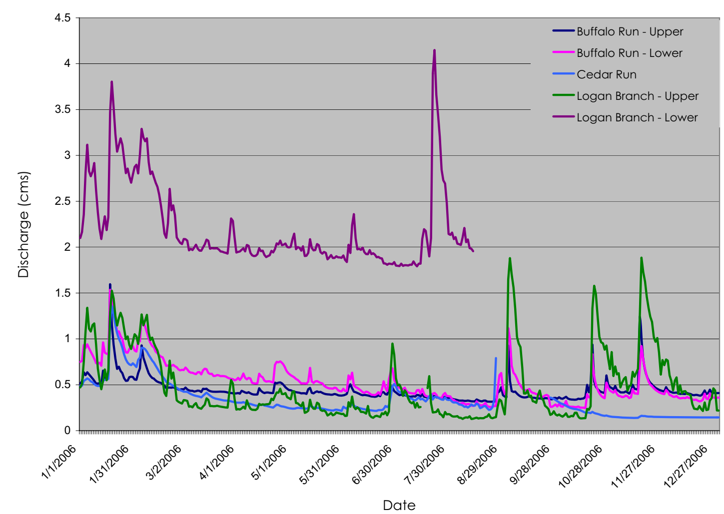

Figure 11: Comparison of discharges of other sites included in the WRMP during 2006

stage to discharge is still under development for this site. It therefore was not included.

As was noted for Slab Cabin Run, comparison of hydrographs for Buffalo Run (Figure 11) also shows it to be a losing stream. The geology of the Buffalo Run watershed is largely different than the other streams in the watershed and has far less ground water input than other streams in the watershed. However, it still exhibited signs of loss in the late summer – early autumn period.

Temperature
Temperature is arguably the most important factor influencing life in surface waters. Temperature controls, to some extent, nearly every process that occurs in streams, including solubility of oxygen and various chemicals, and the metabolic activities of fish and other life. The renowned brown trout fishery supported in the Spring Creek Watershed is directly attributable to the sustained low temperatures. Much attention is therefore paid to the temperature regime of these local streams. Trout, in general, are very sensitive to abrupt changes in temperature and prolonged high temperatures. Brown trout exhibit signs of stress when maximum daily temperatures exceed 24°C, or 76°F. The high input of ground water to the surface water in the Spring Creek Watershed maintains temperatures near or below this threshold except in times of extreme heat or drought. These periods have led to large-scale fish kills like the one that occurred in Slab Cabin Run in June 2005.

The hydrologic conditions during 2006 largely prevented the temperature from being a concern. Only for very brief periods of time did temperatures reach near this 24°C threshold, and then only at one

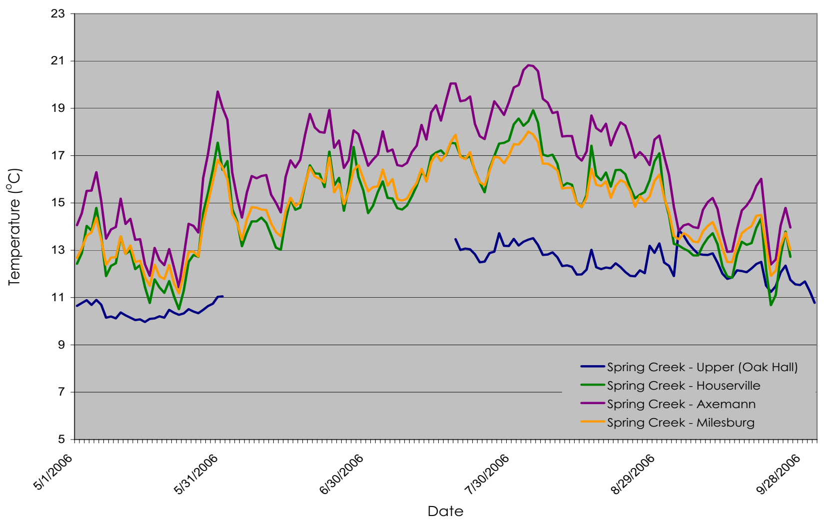

Figure 12: Temperature of Spring Creek at 4 sites along the mainstem for the critical period during 2006

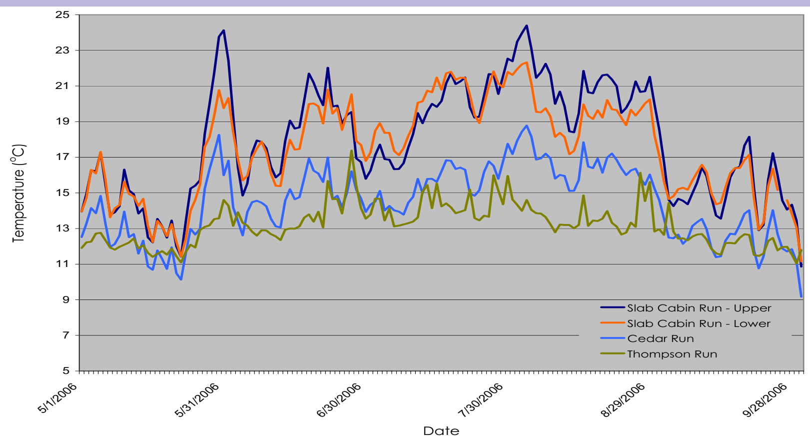

Figure 13: Temperature profile for the tributaries of Spring Creek in the upper portion of the watershed during the 2006 critical period

site - upper Slab Cabin Run near South Atherton Street in State College. Figures 12 – 14 show average daily temperatures for all sites monitored by the WRMP during the critical period between May and October.

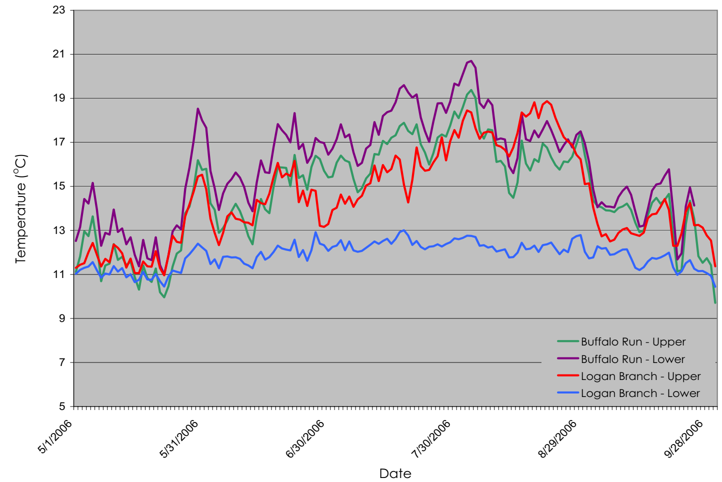

Figure 14: Temperature profile for tributaries of Spring Creek in the lower portion of the watershed during the 2006 critical period

Ground water

During 2006, the WRMP collected ground-water elevation data from five wells across the Spring Creek ground watershed. In addition to the wells monitored by the WRMP, the U.S. Geological Survey monitored the water elevation at two different wells in the Spring Creek ground watershed. Figure 7 is a map showing the location of the seven wells where elevation data were recorded during 2006.

Monitoring

Results

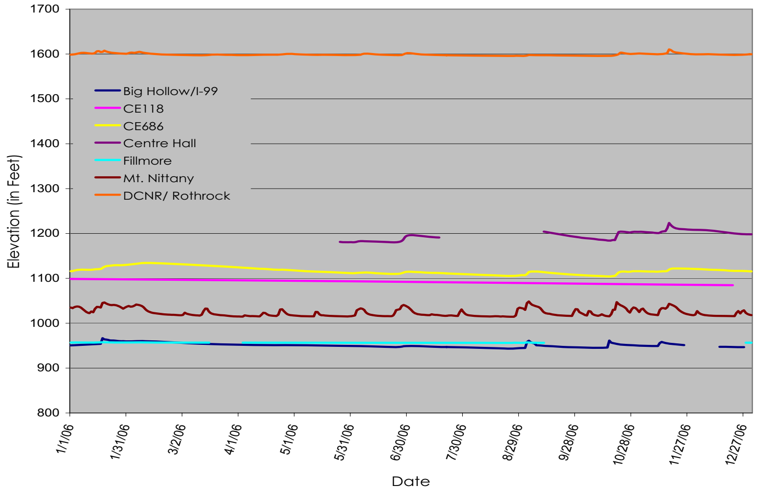

Figure 15: Comparison of water surface elevation of 7 groundwater wells in the Spring Creek ground watershed

Ground-water elevations were near normal throughout 2006. Normal fluctuations as a result of wet/dry periods were present, but there were no significant, rapid decreases in elevation at any of the sites. A comparison of all wells monitored as part of the WRMP during 2006 can be found in Figure 15. Figure 16 depicts ground water elevations for U.S. Geological Survey Well CE118 in the Scotia Barrens for the entire period of record. This graph shows a steady decrease in elevation of ground water levels during 2006 from record high levels of July 2005.

However, 2006 levels were still within the normal range of this well. The CE118 well in the Scotia Barrens is part of the vitally important recharge area for the Big Spring in Bellefonte.

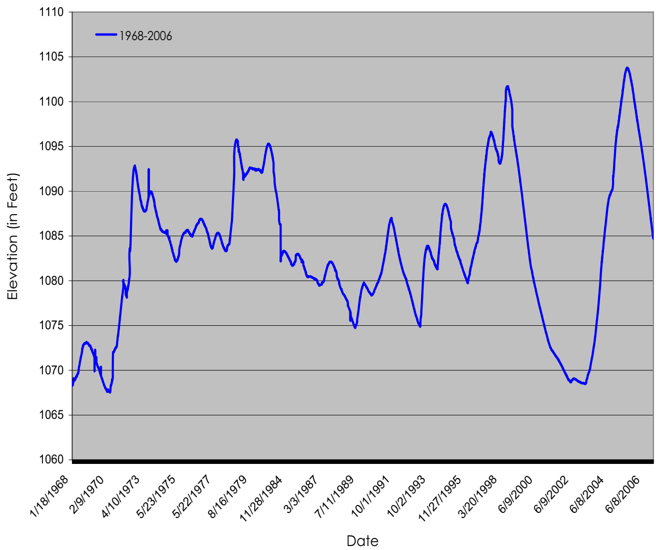

Figure 16: Elevation of water surface at USGS Well CE118 for the period 1968 - 2006

Springs
Overview

Submitted by WRMP Committee Member Mark Ralston

A spring is defined by Wikipedia as "a point where ground water flows out of the ground." In the Spring Creek Basin, we find two distinct geologic settings for springs: carbonate bedrock (limestone and dolomite), and non-carbonate bedrock (sandstone and shale).

Effects of Bedrock Type on Spring Development

The physical and mechanical properties of the host bedrock determine how a spring behaves. In general, sandstone and shale bedrock tends to allow water to circulate relatively slowly, so that springs in these bedrock settings tend to have low to moderate flow rates. Conversely, carbonate bedrock can develop conduits or caves, which can transmit huge quantities of water at very high flow rates.

Effects of Bedrock Structure and Attitude on Spring Development

The composition of the bedrock and the orientation of the planes greatly effects how springs behave. In the Allegheny Plateau area to the northeast of the Bald Eagle Valley, bedrock bedding planes tend to be oriented nearly horizontally. The Spring Creek Basin is located near the northwestern extent of the Valley and Ridge province of Pennsylvania, which is characterized by folded and faulted bedrock in which the orientation of bedding planes (i.e., bedrock "dip") varies widely. Compare the near-horizontal red and brown bedrock outcrops that you see along US Rte. 322 between Port Matilda and Philipsburg (Allegheny Plateau area) with the bedrock exposure along US Route 322 from the Benner Pike (moderately-dipping, massive-bedded limestone) to the Boalsburg exit (flat-lying, thinly-bedded limestone).

Figure 17: Three characteristic bedrock formations found in the region: sandstone in the Allegheny Plateau near Phillipsburg (left), limestone outcropping near the Benner Pike (middle), and limestone outcropping along Rt 322 near Oak Hall (right) (Photos: G. Smith)

Bedrock type and the "dip" of bedrock are important factors in the development of springs. In flat-lying bedrock areas, springs tend to develop where erosion exposes permeable rock beds; small springs in the

Springs

Overview

Allegheny Plateau area often tend to develop at a common elevation along the margin of steeply-incised valleys. In steeply-dipping bedrock areas, ground water may tend to follow bedding planes until it encounters fractures that cut across the bedding planes. Most of the springs along the northwest bank of Buffalo Run obtain water from fractures that cut across very steeply-dipping bedrock strata.

The central axis of bedrock folds is a setting where bedrock may be relatively more fractured, due to the flexing of rock that accompanies the folding process. Ground water often finds preferential flow pathways at the axes of folds; the springs on the northeast bank of Spring Creek in Oak Hall (at the nose of Mount Nittany) and the springs at Walnut Springs Park are examples of springs located in or near the axis of a bedrock fold (in this case, the upwards-concave folding of the Mount Nittany Syncline).

Carbonate Bedrock Springs

Springs in carbonate bedrock develop under a unique set of physical and geologic circumstances. Over geologic time, ground water circulation through soluble (karst) bedrock promotes dissolution of weak features such as fractures and certain bedding planes in bedrock. The outcome of this process is the development of a tree-like network of subsurface conduits and passages in bedrock. In headwaters areas, this network is similar to the highest branches of an oak tree; many in number and small in size. Between the headwaters areas and ground water discharge areas many of the small conduits join, and the dominant conduits become larger in size. Given a large enough upland area and the passage of enough time, the “trunk” of the conduit network can become very large, as you will see if you visit Penns Cave, the base of a large network of conduits in carbonate bedrock in Penns Valley. The contributing area for a

Figure 18: Axemann Spring near Axemann is a prime example of a carbonate bedrock spring (Photo G. Smith)

large carbonate bedrock spring may be many dozens of square miles.

Some carbonate bedrock springs respond rapidly to precipitation input, and spring discharge may vary by 10- to 100-fold over several days following a rainfall event. These "flashy" springs are termed "conduit-type" springs. The chemistry of these conduit-type springs may also vary widely in response to the rapid mixing of precipitation (low pH and low dissolved solids) with ground water (medium pH and higher dissolved solids).

Other carbonate bedrock springs may have much more steady discharge and more consistent groundwater chemistry. These springs, of which Bellefonte Borough's Big Spring is an example, may drain a relatively large land area and may not have any nearby sources of rapid stormwater recharge (such as "swallow-holes"). Bellefonte Borough's Big Spring is actually an *artesian* spring: water under pressure at depth finds a pathway to migrate to the ground surface, and the surrounding water table surface is lower in elevation than the elevation of the spring pool.

<u>*Shale and Sandstone Bedrock Springs*</u>

Where bedrock dip is moderate to steep, groundwater must flow across the inclined bedding planes. As a result, ground water seeks to flow through zones of fracturing in bedrock, and springs are often an indication of subsurface zones of bedrock fracturing. Because gaps and swales in local ridges develop as a result of preferential erosion of more highly-fractured bedrock, shale bedrock springs are commonly found at the toe of mountain gaps and swales, since these topographic features are typically underlain by relatively fractured bedrock.

Figure 19: Windy Hill Farm Spring along Rt 45 near Shingletown is an example of a shale/ sandstone spring (Photo: G. Smith)

An important benefit of slow ground water circulation is that the discharge from shale and sandstone-hosted springs tends to persist during drought conditions. The ridges that bound the Spring Creek Basin are composed of sandstone and shale, and the small mountain-slope tributaries generally continue to flow even during the driest years.

At the foot of the local ridges exists a bouldery, sandy overburden deposit known as *colluvium* that collects over centuries as a result of gravity. The local colluvium may be many tens of feet thick and in this area often characterised by dense clay fragipans at its base. This colluvium may conceal locations where ground-water discharges from bedrock, and the colluvium acts as a sponge-like reservoir to store water from bedrock discharge and from precipitation. Preferential ground-water flow pathways may develop between boulders in the colluvium, and low to moderate flow-rate springs may discharge from discrete locations in the colluvium.

The contributing area for a sandstone bedrock spring may be on the order of several hundred acres. Assuming that one-quarter of precipitation actually recharges ground water, this land area can yield a year-round, continuous flow of on the order of several gallons per minute.

Some of the earliest homes in the Spring Creek Basin were built a short distance downslope from the base of the mountain slopes. Water supply was developed from springs in colluvium at the base of the slope and piped to the homes. Many homes still use this type of water supply.

Figure 20: Blue Spring near Boalsburg is a substantial spring near the base of Tussey Mountain (Photo: G. Smith)

Springs

Big Spring : Icon of the watershed

Submitted by WRMP Committee Member Todd Giddings, Ph.D., P.G.

Big Spring is the second largest spring in Pennsylvania, with a flow of 19 million gallons per day. That's 13,200 gallons per minute, or in stream-flow terms, 29 cubic feet per second. During times of drought, the flow of Big Spring makes up about one-third of the total flow of Spring Creek where it joins Bald Eagle Creek. It is the source of public drinking water for the Bellefonte and Milesburg Boroughs' water systems, and it is also piped to a plant near Milesburg where it is bottled by CCDA Waters LLC, a division of Coca-Cola.

Figure 21: Big Spring in Bellefonte prior to installation of a protective covering (Photo: ClearWater Conservancy Archive)

In a James and Ann Dunlap Harris family legend, the exiled French statesman Charles Maurice de Talleyrand is given credit for naming Bellefonte in 1794 or 1795. Ann Dunlap Harris asked Talleyrand what he thought the name of the settlement he was visiting should be, and Talleyrand suggested that it be called "la belle fontaine" after the beautiful Big Spring. The legend has Ann changing and shortening the name to "Bellefonte".

Local folklore attributes the source of the 19 million gallons per day discharge of Big Spring to Lake Erie. However, the source area or "headwaters" of Big Spring is located 15 miles to the southwest, in State Game Land 176 in Ferguson, Halfmoon, and Patton Townships. This area is called the "barrens" due to the infertile, sandy soil that results in a unique Scrub Oak Shrubland plant community. This community type supports diverse and sometimes rare wildlife, including yellow-breasted chat, golden-winged warbler, and Appalachian cottontail. The sandy soil in the barrens has a high infiltration capacity, and the underlying Gatesburg Formation sandy dolomite bedrock has a high ground-water storage capacity. The amount of rainfall and snowmelt water that

Springs

Big Spring : Icon of the watershed

becomes ground-water recharge in the barrens is maximized by the forest land cover and the almost complete absence of impervious land uses such as roads, paved parking lots, and buildings.

Ground water flows from the recharge area in the barrens to the Big Spring through solution conduits that developed along the Birmingham Thrust Fault within the dolomite bedrock of the Gatesburg Formation. The sliding movement crushed the bedrock along this fault zone, and it dissolved more quickly (over eons of geologic time) due to the greater surface area exposed to slightly-acidic infiltrating rainfall. The Birmingham Thrust Fault is present across the entire length of the Spring Creek Watershed and is also present beneath the adjacent Spruce Creek Watershed to the southwest. The high permeability (ease of ground-water flow) of the solution conduits developed at depth along this fault zone drains ground water from beneath the barrens and from beneath the Spruce Creek Surface-Water Watershed.

The Spring Creek Ground-water Watershed area is approximately 20 percent larger than its surface-water watershed at the expense of the Spruce Creek Watershed. The ground water captured from the Spruce Creek Watershed flows through the solution conduits along the fault zone and discharges from the Big Spring. So in the headwater area of the Spruce Creek Watershed, the small tributary streams carry surface water southwest to Spruce Creek, while the ground water flows in the opposite direction toward Big Spring.

Ground-water piracy by the Spring Creek Watershed from the Spruce Creek Watershed was discovered by measuring water-table elevations in drilled residential and farm wells located in the southwestern area of the Spring Creek Watershed. The contour map of these water-table elevations showed that the southwestern ground-water boundary of the Spring Creek Watershed was as much as 6 miles beyond the surface-water boundary between the two adjacent watersheds. The contour map also showed that a deep trough in the water-table surface followed the Birmingham Thrust Fault zone to Big Spring. Successive rounds of water-level measurements during all four seasons confirmed the ground-water boundary location and the source area of Big Spring. Geochemical studies and area-discharge ratio analyses also have confirmed that the Spring Creek Ground-water Watershed area (175 square miles) is 23.2 percent larger than its surface-water watershed area of 142 square miles.

The mineral dolomite has the chemical formula $(Ca,Mg)CO_3$ where the comma between the Calcium and Magnesium indicates that their relative proportions vary. Dolomite bedrock, such as the Gatesburg Formation, can be predominantly Magnesium carbonate with very little Calcium carbonate (limestone) present. Because magnesium is less soluble than calcium in ground water, dolomite bedrock aquifers, such as the Gatesburg Formation, yield ground water to wells and springs (including Big Spring) that is significantly (as much as four times) less hard than ground water from limestone wells and springs. Therefore, while many homeowners have water softeners to reduce the hardness of their limestone aquifer water, softening is generally not necessary for dolomite aquifer ground water.

The Calcium/Magnesium Ratio graph shows that Big Spring water contains more magnesium than any of the other six springs and therefore its Ca/Mg ratio values are the lowest of all of the spring water values. The geochemical signature of ground water from wells drilled in the barrens area is the same as the geochemical signature of the ground water discharging from Big Spring.

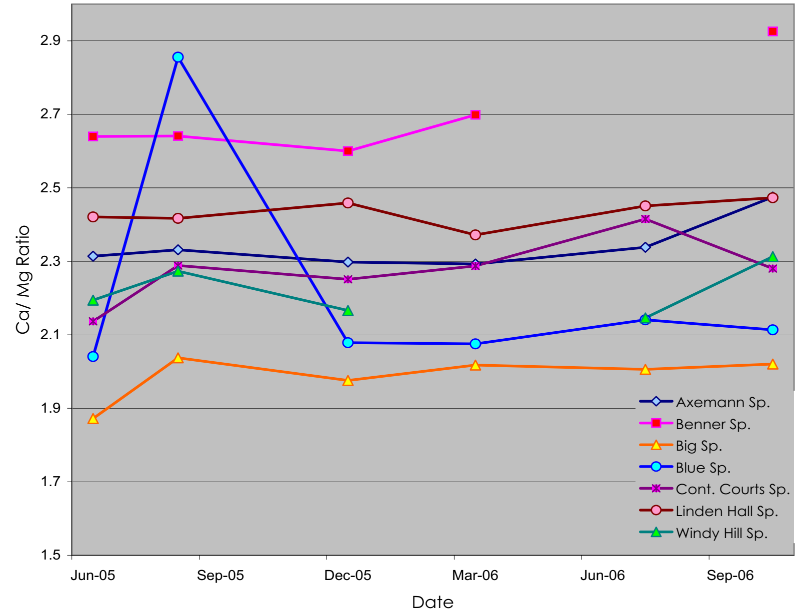

Figure 22: Comparison of Calcium/Magnesium ratios of all springs monitored as part of WRMP

Springs
Water Quality

Submitted by WRMP Committee Member John Sengle

Quarterly monitoring continued through 2006 at seven springs across the Spring Creek Basin identified on Page 12, in Figure 7. Quarterly grab samples are collected at all springs, and field testing is conducted for temperature, pH, specific conductance and dissolved oxygen at the time of sample collection. All laboratory analyses are conducted at the PA DEP Central Laboratory in Harrisburg, except for fecal coliform analyses which are performed by the University Area Joint Authority laboratory in State College, in order to meet the U.S. EPA 6-hour maximum holding time.

Figure 23: Bryce Boyer and Geoff Smith take a water quality sample from the Continental Courts Spring near Fillmore (Photo: B. Carline)

With initiation of quarterly spring sampling during 2005, most springs now have a 6-8 sample data set. The data set size precludes any definitive discussion of water quality trends over time; however, the data do reveal some key differences amongst Spring Creek springs. The small data set also precludes any discussion of seasonal trends or variability in groundwater quality across the basin that will be interesting to consider in the future.

Most samples from springs did not have detectable levels of fecal coliforms. October 2006 data did indicate some notably elevated results (>200 colonies/100mL PA DEP bathing standard) at Blue Spring and Windy Hill Spring. Fecal coliform bacteria can originate from any warm-blooded animal, and data are NOT specific to human versus animal fecal contamination sources.

Data for mean hardness span a two-fold range from 150-330 mg/L, and are strong indicators of the relative proportions of respective bedrock types (limestones and dolomites) that make up the recharge areas that feed the springs. Big Spring and

Blue Spring are both lower hardness springs at ~150 mg/L, while the remaining springs are all 250-330 mg/L hardness, suggesting largely limestone aquifers. Hardness data suggest that all the springs in the basin exhibit a significant degree of karst geology influence.

Chloride data for springs indicate a roughly five-fold range in mean chloride concentration, from a low of 8 mg/L at Linden Hall Spring to a high of 40 mg/L at Benner Spring. Within the Spring Creek basin, the source of chlorides are primarily anthropogenic; including chlorination of water/wastewater, roadway and pavement de-icing, and chlorinated components of agricultural or residential fertilizers and soil amendments. Big Spring, Blue Spring, Linden Hall Spring, and Continental Courts Spring all show mean chloride concentrations below 20 mg/L, while Axemann Spring, Benner Spring, and Windy Hill Spring show mean concentrations of 25-40 mg/L. The relative abundance of significant areas of roads and pavements and sources of chlorinated wastewater discharges to ground water are likely the largest sources of chlorides to the higher chloride springs.

Nitrate-Nitrogen data show two distinct groups of spring water quality. Big Spring, Blue Spring, and Continental Courts Springs all show mean nitrate-N data around 2 mg/L or less, while Axemann Spring, Benner Spring, Linden Hall Spring and Windy Hill Spring all show mean nitrate-N concentrations of 3.5-5.5 mg/L. Nitrate-N sources include a wide range of materials including domestic wastewaters, commercial and agricultural fertilizers, animal manures, and airborne deposition. All the higher nitrate springs lie within predominantly agricultural watersheds, but the influence of significant numbers

Figure 24: Geoff Smith taking dissolved oxygen measurement at Big Spring near Bellefonte (Photo: B. Carline)

of existing and new on-lot sewage disposal systems in rapidly urbanizing areas are difficult to assess.

Data for metals (Aluminum, Iron, Lead, Manganese, Nickel, Chromium, Copper, and Zinc) for all springs are dominated by results at less than detection limit. Where some metals concentrations are present as total metals, the dissolved component is typically only a small fraction of total metals. There are several instances where total and dissolved metals are present in detectable concentrations, but no consistent trend seems to emerge in which springs they are found or their trend over time. The most frequent metals detected, and the highest concentrations detected are for Iron (Fe) and Aluminum (Al). These are not unexpected given the widespread presence of iron and aluminum in host rock formations throughout the Spring Creek basin.

As spring sampling efforts continue into the future and the data set increases to a more statistically viable size, it will be interesting to conduct a more involved analysis to look at issues such as seasonal trends in water quality, correlations between related water quality parameters across basin springs, and correlations between water quality in springs and the surface water quality of basin streams.

Figure 25: Spring house located at Axemann Spring near Axemann (Photo: G. Smith)

Springs
Flora and Fauna

Submitted by WRMP Committee
Member Susan Buda

Flora and fauna of springs and seeps are unique due to the nature of these freshwater systems. Springs and seeps are interfaces between ground water and surface water; therefore, both subterranean and surface water organisms can be found in springs. Subterranean organisms display characteristics that are associated with their physical environment. Since groundwater environments often are dark, scarce in food sources, and low in oxygen, subterranean organisms often lack pigmentation, have reduced or missing eyes, develop enlarged sensory organs, possess long and numerous appendages, use highly developed chemical and mechanical receptors, and exhibit slower metabolic rates and less frequent reproduction (Gibert, et al., 1994).

Subterranean organisms often show highly efficient feeding and a resistance to starvation. The food webs in these environments are usually simple and organisms are not selective. Bacteria, fungi, and protozoans are the primary consumers in this system (Gibert, et al., 1994). Karst groundwater environments tend to be somewhat different due to a more direct link to surface water. These environments have more oxygen and nutrients, so the invertebrate communities may be more prolific (Gibert, et al., 1994).

The water found in springs has characteristics similar to groundwater such as low oxygen, low nutrients, and stable temperature; therefore, the flora that inhabits springs and the area around springs must be adapted to these conditions. Vegetation around springs is often similar to that found in wetland and stream riparian environments and can subsist in wet (hydric) soils. The vegetation type may also be dependent on the chemistry of the water coming out of the stream. For instance, vegetation near karst springs would be subject to high alkalinity and high minerals, whereas sandstone mountain springs more likely will have a low pH and soft water. Another unique characteristic of springs is that often they do not freeze over the winter due to the year-long influence of groundwater inputs. As a result, instream vegetation can subsist throughout the year.

Particular Species in Springs

A variety of animal species may be found in springs. Some freshwater fish such as slimy sculpin (*Cottus cognatus)* and blacknose dace (*Rhinichthys atratulus)* can be found around springs along with various salamanders such as the Spring salamander (*Gyrinophilus porphyriticus).* Other amphibians, such as frogs, may inhabit areas around springs and lay their eggs in them. Invertebrate species that inhabit springs are varied and include worms, crustaceans, snails, clams, and insect larvae. Particular species that can be found in Pennsylvania are listed in Table 2 from research by Glazier and Gooch (1987) in Blair, Centre, and Huntingdon Counties.

Table 2. Common spring macroinvertebrate taxa

TURBELLARIA (flatworms)	Plecoptera (stoneflies)
Tricladia	*Leuctra spp.*
OLIGOCHAETA (worms)	Trichoptera (caddisflies)
Lumbriculida	*Glossosoma intermedium*
Lumbriculidae	*Neophylax aniqua*
Haplotaxida	*Pycnopsyche gentilis*
Naididae	
Tubificidae	Coleoptera (beetles)
CRUSTACEA	Diptera (true flies)
Isopoda (sowbugs)	Chironomidae
Lirceus brachyurus	
Amphiopoda (scuds)	GASTROPODA (Snails)
Gammarus minus	Prosobranchia
	Fontigens nickliniana
INSECTA	Pulmonata
Ephemeroptera (mayflies)	*Lymnaea humilis*
Baetis tricaudatus	*Physa heterostrophia*
Epeorus sp.	
Odonata (dragonflies)	BIVALVIA (clams & mussels)
Gomphus sp.	Eulamellibranchia
	Pisidium casertaneum

Figure 26: The Northern spring salamander is a common spring inhabitant (Photo: PA Fish and Boat Commission)

Glazier and Gooch (1987) found that the type of macroinvertebrates in springs seemed to be dependent on vegetation, physical, and chemical conditions such as aquatic plant (macrophyte) coverage, substrate composition, and alkalinity. For instance, snails and crustaceans were more likely to be found in higher abundance in springs with dense plant coverage (algae and watercress) and high calcium. Caddisflies that use sand and gravel for cases are found in springs with sand, gravel, and cobble substrate. Stoneflies (in particular *Leuctra*) were found in lower pH soft water sandstone springs.

Vegetation in springs may vary due to the vegetation in the nearby area and what might be dispersed by animals and birds to the spring. Typical vegetation at springs may include green algae

(*Oedogonium sp.*), watercress (*Nasturtium officinale*), peat moss (*Sphagnum sp.*), golden saxifrage (*Chrysosplenium americanum*), violets (*Viola sp.*), skunk cabbage (*Symplocarpus foetidus*), highbush blueberry (*Vaccinium sp.*), Rhododendron (*Rhododendron maximum*), and other mosses, lichens, ferns, and flowering plants.

The Centre County Natural Heritage Inventory conducted by the Western Pennsylvania Conservancy identified Thompsons Meadow Spring, Galbraith Gap Headwaters, Shingletown Gap, and Linden Hall Park as springs or areas associated with springs in the watershed needing protection. At Thompsons Meadow Spring, a globally endangered invertebrate has been identified. Specific details are unknown about the extent of its distribution or abundance, and further study of this invertebrate is needed.


Figure 26: Adder's Tongue Fern is only found near the spring-fed areas of Roaring Run (Photo: B. Samuels)

Galbraith Gap Headwaters is a mountain seepage wetland that has been designated as a Biological Diversity Area (BDA) by the Western Pennsylvania Conservancy. Numerous plant species reside here including cinnamon fern or interrupted fern (Osmunda sp.), sphagnum moss, screwstem (*Bartonia virginica*), spikerushes (*Eleocharis* sp.), rushes (*Juncus* sp.), goldthread (*Coptis trifolia*), other sedges (*Carex folliculata*, *Carex trisperma*, *Scirpus cyperinus*), and green wood orchids (*Platanthera clavellata*).

Shingletown Gap is designated a BDA and includes numerous springs. The water coming out of the gap was previously used as drinking water supply for the State College area, so the springs remain fairly well-protected despite frequent hikers in the area. The spring-fed Roaring Run contains unique blackfly species, and the area also supports adder's-tongue fern (*Ophioglossum vulgatum*), which is the only known location in the county.

Linden Hall Park has unique flora, in particular the handsome sedge (*Carex formosa*) and Canada Lily (*Lilium canadense*). Both of these plants require wet, saturated conditions to grow, and the handsome sedge is the only known population in Pennsylvania. The, "Centre County Natural Heritage Inventory" is available online at www.co.centre.pa.us/planning/natural_heritage_inventory.pdf.

Threats to flora and fauna

Springs are unique habitats with unique organisms, so identifying threats and methods of protection are important. Unfortunately, it appears that springs have not been studied extensively, especially in Pennsylvania and Spring Creek; hence additional data is needed on the flora and fauna of Pennsylvania springs. Additional data collection in springs will help to identify areas warranting protection and also any springs that are adversely impacted. Subterranean species tend to have poor dispersal abilities and impacts to the population may be irreversible (Gibert et al., 1994). Therefore, protection of springs is critical. Since springs often do not freeze, they can be critical food and freshwater sources during winter. The temperature of spring water is important to the streams they feed; it is important that springs be sheltered and protected by natural vegetation. Sedimentation can be detrimental in springs due to the change in substrate and flow paths. Also, disturbance to the flow paths can result in areas that are wet during some periods, but dry up quickly. Specifically, this would be a problem for organisms that lay their eggs in water. Other potential threats to springs include fertilizers, pesticides, road salts, and any other pollutant that could impact groundwater. Guidelines for protecting springs are on the web at http://www.dcnr.state.pa.us/FORESTRY/sfrmp/water.htm#protecting.

Figure 28: The area around Linden Hall Spring is home to Canada Lily (Lilium canadense)(Photo: Fedricton Botanical Garden Assoc.)

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Glazier, D. S. and J. L. Gooch. 1987. Macroinvertebrate assemblages in Pennsylvania (U.S.A.) springs. Hydrobiologia 150:33-43.

Closing

We hope that you found this year's report on the State of the Water Resources both informative and entertaining. By focusing on springs, an often overlooked, yet vital component of the hydrologic system, we aimed to display the newest expansions in the Water Resources Monitoring Project and bring to light these interesting ecosystems. Your continued support will help this project maintain the integrity that it has shown throughout the last nine years and continue to grow with the ever-changing conditions that we face in the watershed. This upcoming year will be the program's tenth year of service to the Spring Creek Watershed. We hope to continue to provide state-of-the-science data collection in the Spring Creek Watershed for years to come.

Figure 29: Spring Creek upstream of Fisherman's Paradise (Photo: G. Smith)

Figure 30: Scenic view from Jo Hays Vista overlooking the upper portions of the Spring Creek Watershed (Photo: G. Smith)

Appendices

Appendix 1: Water Quality Parameters

Appendix 2: Stream Water Quality Results

Appendix 3: Spring Water Quality Results

Appendix 1: Water Quality Parameters included in the WRMP

Parameter	Description	Sources	Environmental Effects	Base-flow 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 when settled. Dissolved materials limit the osmoregulatory ability of aquatic animals	X	X
Copper	A heavy metal less common that 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 depeleted 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: Stream Water Quality Results (Nutrients & Physicochemical)

Site Name	Abbrev	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg/L)	Chlorides (mg/L)	Sulfate (mg/L)	Suspended Solids (mg/L)	Turbidity (NTU)
		Total	Total	Total	Total	Total	Total	
Buffalo Run - Upper	BUU	68.3	25.0	273.5	23.2	46.9	14.0	1.87
Buffalo Run - Valley View	BVV	25.8	4.5	83.0	21.6	16.2	6.0	1.76
Buffalo Run - Lower	BUL	61.2	24.5	253.5	18.1	35.3	7.0	1.89
Logan Branch Upper	LOU	67.2	17.2	239.0	18.3	55.3	12.0	4.26
Logan Branch - Lower	LOL	56.8	19.8	227.0	19.9	36.3	9.0	2.09
Slab Cabin Run - Upper	SLU	56.1	20.1	223.5	31.4	10.0	12.0	5.47
Slab Cabin Run - Lower	SLL	65.0	25.0	265.5	42.3	23.4	3.0	1.58
Slab Cabin Run - Millbrook	MIL	68.0	27.8	284.0	57.5	23.0	5.0*	1.69*
Spring Creek - Upper	SPU	56.0	17.8	213.0	18.7	15.3	5.0	0.79
Spring Creek - Houserville	SPH	66.0	22.6	257.0	34.3	25.3	6.0	1.83
Spring Creek - Axemann	SPA	62.7	22.3	245.0	45.7	24.4	12.0	1.37
Spring Creek - Milesburg	SPM	57.5	20.4	225.0	32.4	31.2	7.0	1.95
Cedar Run - Lower	CEL	80.2	23.7	297.0	15.7	15.5	7.0	2.15
Thompson Run - Lower	THL	71.8	30.0	303.0	57.4	20.9	7.0	1.30

Site Name	Abbrev	pH (units)	Diss. Oxygen (mg/L)	Temperature (°C)	Conductivity (mS)	Nitrate (mg/L)	Orthophosphorus (mg/L)
							Total
Buffalo Run - Upper	BUU	7.8	11.32	10.5	451.3	1.20	0.008*
Buffalo Run - Valley View	BVV	8.2	11.19	7.4[$]	197.3	0.23	0.023
Buffalo Run - Lower	BUL	8.4	12.40	12.9[~]	404.6	1.71	0.005**
Logan Branch Upper	LOU	8.2	10.65	10.8	382.4	2.87	0.036
Logan Branch - Lower	LOL	8.2	10.43	10.6	299.9	3.07	0.0135*
Slab Cabin Run - Upper	SLU	7.8	11.40	12.0	421.5	2.46	0.025*
Slab Cabin Run - Lower	SLL	8.2	12.01	12.2	509.0	2.57	0.017*
Slab Cabin Run- Millbrook	MIL	8.3	12.50	9.5[$]	515.5	3.34	0.016*
Spring Creek - Upper	SPU	8.2	9.59	10.1	322.3	2.24	0.005**
Spring Creek - Houserville	SPH	8.2	11.00	12.5[~]	428.4	3.06	0.013*
Spring Creek - Axemann	SPA	8.3	13.29	13.7[~]	504.0	3.62	0.022
Spring Creek - Milesburg	SPM	8.2	11.16	12.7[~]	416.6	3.12	0.019
Cedar Run - Lower	CEL	8.3	12.29	10.9	451.5	4.55	0.008*
Thompson Run - Lower	THL	8.2	11.42	11.6	496.0	4.04	0.017*

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

** All samples possessed concentrations below detection limit 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

$ Results from quarterly instantaneous samples

~ Median calculation inaccurate due to large volume of missing data

Appendix 2: Stream Water Quality Results (Metals)

Site Name	Abbrev	Aluminum (mg/L)		Cadmium (mg/L)		Chromium (mg/L)		Copper (mg/L)		Iron (mg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Buffalo Run - Upper	BUU	5.0*	71.7	ND	ND	ND	2.0**	2.0**	ND	10.0*	198.0
Buffalo Run - Valley View	BVV	5.0*	46.5	ND	ND	ND	3.2*	2.0*	ND	19.0	125.5
Buffalo Run - Lower	BUL	5.0*	44.7	ND	ND	ND	2.0**	2.0*	ND	10.0**	100.0
Logan Branch Upper	LOU	5.0*	83.9	ND	ND	ND	2.0**	2.0*	ND	10.0*	140.5
Logan Branch - Lower	LOL	5.0*	44.6	ND	ND	ND	2.0**	2.0*	ND	10.0*	87.5
Slab Cabin Run - Upper	SLU	5.0**	133.0	ND	ND	ND	2.0**	2.0**	ND	15.0	234.5
Slab Cabin Run - Lower	SLL	5.0*	39.0	ND	ND	ND	2.0**	2.0*	ND	10.0*	60.5
Slab Cabin Run - Millbrook	MIL	5.0**	42.7	ND	ND	ND	2.0**	2.0**	ND	10.0**	91.5
Spring Creek - Upper	SPU	5.0**	5.0**	ND	ND	ND	2.0**	2.0**	ND	10.0**	49.5
Spring Creek - Houserville	SPH	5.0*	44.9	ND	ND	ND	2.0**	2.0*	ND	10.0**	75.0
Spring Creek - Axemann	SPA	5.0**	24.6	ND	ND	ND	2.0**	2.0**	ND	10.0**	46.0
Spring Creek - Milesburg	SPM	5.0**	46.6	ND	ND	ND	2.0**	2.0*	ND	10.0*	82.0
Cedar Run - Lower	CEL	5.0*	41.9	ND	ND	ND	2.0**	2.0**	ND	10.0**	75.0
Thompson Run - Lower	THL	5.0**	32.2	ND	ND	ND	2.0**	2.0*	ND	10.0*	77.5

Site Name	Abbrev	Lead (mg/L)		Manganese (mg/L)		Nickel (mg/L)		Sodium (mg/L)		Zinc (mg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Buffalo Run - Upper	BUU	0.5**	ND	25.2	35.4	2.0*	2.0**	15.3	15.8	5.0**	5.0**
Buffalo Run - Valley View	BVV	0.5**	ND	13.0	20.8	2.0**	2.0*	12.5	13.1	5.0**	5.0**
Buffalo Run - Lower	BUL	0.5**	ND	5.8	11.7	2.0**	2.0**	9.7	10.2	5.0**	5.0**
Logan Branch Upper	LOU	0.5**	ND	3.7	8.5	2.0**	2.0**	8.9	8.9	5.0**	5.0**
Logan Branch - Lower	LOL	0.5**	ND	1.0**	4.1*	2.0**	2.0**	9.4	9.6	14.0*	11.0*
Slab Cabin Run - Upper	SLU	0.5**	ND	11.8	15.7	2.0**	2.0**	14.9	15.4	5.0**	5.0**
Slab Cabin Run - Lower	SLL	0.5**	ND	3.9	4.9	2.0**	2.0**	20.0	20.8	5.0**	5.0**
Slab Cabin Run - Millbrook	MIL	0.5**	ND	5.0	7.6	2.0**	2.0**	25.4	26.1	5.0**	5.0**
Spring Creek - Upper	SPU	0.5**	ND	1.5*	3.3	2.0**	2.0**	7.8	8.2	5.0**	5.0**
Spring Creek - Houserville	SPH	0.5**	ND	4.0	5.2	2.0**	2.0**	15.0	16.0	5.0**	5.0**
Spring Creek - Axemann	SPA	0.5**	ND	1.0*	4.3	2.0**	2.0**	23.3	24.9	5.0**	5.0**
Spring Creek - Milesburg	SPM	0.5**	ND	3.0	4.8	2.0**	2.0**	16.1	16.3	5.0*	5.0*
Cedar Run - Lower	CEL	0.5*	ND	1.6	4.2	2.0**	2.0**	6.0	6.1	5.0**	5.0**
Thompson Run - Lower	THL	0.5**	ND	5.0	8.2	2.0**	2.0**	23.7	24.6	5.0*	5.0**

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

** All samples possessed concentrations below detection limit 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: Spring Water Quality Results (Nutrients & Physicochemical)

Site Name	Abbrev	Calcium (mg/L) Total	Magnesium (mg/L) Total	Hardness (mg/L) Total	Chlorides (mg/L) Total	Sulfate (mg/L) Total	Suspended Solids (mg/L) Total	Turbidity (NTU)
Axemann Spring	AXS	77.7	33.6	332.0	29.7	27.9	1.0*	0.5**
Benner Spring	BED	59.1	22.5	239.0	39.7	10.0*	1.0*	0.5*
Big Spring	BIS	32.7	16.6	150.0	18.0	10.0**	1.0*	0.5**
Blue Spring	BLS	29.5	14.1	131.5	4.6	10.0*	2.5*	0.5**
Continental Courts Spring	COS	59.8	26.4	258.5	19.5	20.8*	1.0*	0.5*
Linden Hall Park Spring	LIS	77.5	32.0	324.5	8.3	22.8*	2.0*	0.5**
Windy Hill Farm Spring	WIS	60.0	27.7	264.0	23.8	10.0*	14.0*	1.04*

Site Name	Abbrev	pH (units)	Diss. Oxygen (mg/L)	Temperature (oC)	Conductivity (mS)	Nitrate (mg/L)	Orthophosphorus (mg/L) Total	Fecal Coliforms (#col/ 100mL)
Axemann Spring	AXS	7.6	9.32	10.5	572.0	5.74	0.005**	0.0*
Benner Spring	BES	7.8	10.26	10.6	397.2	4.01	0.005*	17.3
Big Spring	BIS	8.2	10.70	10.5	282.9	1.87	0.005**	0.0*
Blue Spring	BLS	7.9	8.7	10.1	278.5	1.50	0.005*	12.0*
Continental Courts Spring	COS	7.8	7.51	10.6	357.9	2.39	0.005**	2.3*
Linden Hall Park Spring	LIS	7.9	7.62	10.0	414.3	4.71	0.005**	2.0*
Windy Hill Farm Spring	WIS	7.6	7.62	11.7	397.6	3.24	0.011*	21.5*

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

** All samples possessed concentrations below detection limit 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: Spring Water Quality Results (Metals)

Site Name	Abbrev	Aluminum (mg/L)		Cadmium (mg/L)		Chromium (mg/L)		Copper (mg/L)		Iron (mg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann Spring	AXS	5.0*	5.0*	0.1**	0.1**	2.0**	2.0**	2.0*	2.0**	10.0**	10.0*
Benner Spring	BES	5.0**	22.9	0.1**	0.1**	2.0**	2.0**	2.0*	2.0**	10.0**	48.0
Big Spring	BIS	5.0**	5.0**	0.1**	0.1**	2.0**	2.0**	2.0*	2.0**	10.0*	10.0**
Blue Spring	BLS	5.0*	28.1	0.1**	0.1**	2.0**	2.0**	2.0**	2.0**	10.0*	37.0*
Continental Courts Spring	COS	5.0**	5.0*	0.1**	0.1**	2.0**	2.0**	2.0*	2.0**	10.0**	10.0*
Linden Hall Park Spring	LIS	5.0**	9.9*	0.1**	0.1**	2.0**	2.0**	2.0*	2.0**	10.0*	15.5*
Windy Hill Farm Spring	WIS	5.0*	42.4	0.1**	0.1**	2.0**	2.0**	2.0*	2.0*	10.0*	80.0

Site Name	Abbrev	Lead (mg/L)		Manganese (mg/L)		Nickel (mg/L)		Sodium (mg/L)		Zinc (mg/L)	
		Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Axemann Spring	AXS	0.5**	0.5**	1.0**	1.0**	2.0**	2.0**	10.3	10.8	5.0**	5.0**
Benner Spring	BES	0.5**	0.5**	1.0**	1.0**	2.0**	2.0**	16.0	10.0*	5.0*	5.0**
Big Spring	BIS	0.5**	0.5**	1.0**	1.0**	2.0**	2.0**	8.3	8.8	5.0**	5.0**
Blue Spring	BLS	0.5**	0.5**	1.0*	1.0*	2.0**	2.0**	2.41	2.45	5.0**	7.5*
Continental Courts Spring	COS	0.5**	0.5**	1.0**	1.0*	2.0**	2.0**	8.6	8.6	8.0*	5.0*
Linden Hall Park Spring	LIS	0.5**	0.5**	1.0*	1.0**	2.0**	2.0**	2.9	2.8	5.0*	5.0*
Windy Hill Farm Spring	WIS	0.5*	0.5*	4.1*	8.4	2.0*	2.0**	10.1	10.1	5.0*	5.0*

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