2007 State of the Water Resources in the Spring Creek Watershed

The Chesapeake Bay Tributary Strategy

Table of Contents

From the Chair

During the past few years, we have selected a water quality theme for our annual report. In so doing, we have tried to better inform our constituents on these vital issues and show how our monitoring project relates to contemporary water resource challenges in the Spring Creek Watershed. Judging from the responses of our readers, this approach seems to have been successful.

We chose the Chesapeake Bay Tributary Strategy for this year's theme, because the current state of the Chesapeake Bay is a national tragedy, and because the Tributary Strategy is well intentioned, but complex.

The Chesapeake Bay is the largest estuary on the east coast and was once the most productive one. Owing to the cumulative effects of pollution from Colonial times to present, the production of finfish and shellfish has plummeted to nearly inconsequential levels. Recovery of the Bay is predicated on the reduction of nutrient pollution – the goal of the Tributary Strategy.

Nitrogen and phosphorus, the nutrients of concern, enter our waterways via (1) point sources such as wastewater treatment plants and industrial discharges; and (2) non-point sources such as runoff from urbanized areas, suburban developments, and agricultural operations. Nearly all point sources are regulated through a permit system administered by the Department of Environmental Protection.

The Tributary Strategy consists of five elements designed to reduce nutrient pollution; the sixth element relates to fish passage. Perhaps the most stringent regulation is the imposition of a maximum permissible total load of nutrients that can be discharged by wastewater treatment facilities and other industries. While these permitted discharges can be readily regulated, we need to recognize that they represent only 19% of the total load of nitrogen entering the Chesapeake Bay and 22% of the phosphorus. Hence, to achieve substantial reductions in nutrient pollution, non-point sources must be addressed.

As the Tributary Strategy unfolds, many new questions will emerge. For example, how well are new regulations working and how can nutrient pollution be further reduced? Our water monitoring program has been in place for about 10 years, and we have good measures of nutrient output from the watershed. Perhaps more importantly, we will be able to track future changes in nutrient output and provide data needed to better manage our watershed.

The future of our monitoring program depends upon strong local support. As new information needs emerge, we will continue to respond to these needs.

Bob Carline

Introduction

A view of Spring Creek looking upstream near Fisherman's Paradise (credit: G. Smith)

Welcome to the Spring Creek Watershed Community's Water Resources Monitoring Project (WRMP) 2007 Annual Report. This year's report, entitled *The Chesapeake Bay Tributary Strategy and the Spring Creek Watershed* will focus on an issue that will affect some aspect of each of our lives in the coming year - the Chesapeake Bay Tributary Strategy (CBTS). In this year's report, we provide a brief overview of the history of the issues plaguing the Chesapeake Bay, give an explanation of the Chesapeake Bay Tributary Strategy, and describe some examples of ways local municipalities and institutions are dealing with the changes that will occur under the new program.

The monitoring data collected each year by the WRMP will be important in measuring the effects the Strategy will have in the Spring Creek Watershed. The type and quantity of information collected by the WRMP is unique for a watershed of this size and will be useful in evaluating the changes that take place in response to the CBTS. 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 addressing the CBTS, we will also review water quality and quantity for 2007 throughout the Spring Creek Watershed. This will cover both surface and ground water levels and surface water quality for the calendar year 2007. An addendum to this report provides a summary of the 2007 base flow data for in-stream stations, ground water wells, and springs . Also included in this year's addendum is a break down of monitoring sites by municipality so readers can relate their own municipalities to the results. These data are available upon request by contacting the Water Resources Monitoring Project Manager at (814) 237-0400.

Contributed by WRMP committee member Susan Buda (Susquehanna River Basin Commission)

The Chesapeake Bay has changed over the years due to alterations in land use and human activity in the watershed. The quality of the Chesapeake Bay has been impacted by pollution and loss of suitable habitat for many aquatic organisms, resulting in a decline in fisheries. These problems have been well documented and as a result, the Chesapeake Bay is receiving national attention.

As early as the 1700s, changes in water clarity were noted in streams and rivers feeding the Chesapeake Bay. During and after the American Revolution, changes in agriculture markets and technology resulted in increased sediment and nutrient inputs to the Chesapeake. This shift was a result of a change in demand away from tobacco to more demand for wheat, which required more land area and draft animals to pull plows and supply manure for fertilization. The amount of agricultural land in the watershed increased from approximately 2% in 1720 to 40% in the early 19th century. Increased erosion that resulted from cleared and tilled land caused sedimentation in streams and began causing navigational problems, in some instances even leaving some ports inoperable. The Susquehanna Flats, the confluence of the Susquehanna River and the Chesapeake Bay, accumulated 6 to 10 feet of sediment from 1760 to 1860. Scientists studying sediment cores from this area believe hypoxic or anoxic (little or no dissolved oxygen, respectively) conditions first occurred in the Chesapeake after 1760, corresponding to changes in agricultural practices and increased sedimentation. In addition to reduced dissolved oxygen and navigational problems, sedimentation also reduces suitable habitat for a variety of aquatic organisms and limits the number and size of suitable spawning areas for fish.

Satellite imagery of Chesapeake Bay taken May 22, 2002 (credit: Liam Gumley, Space Science and Engineering Center, University of Wisconsin-Madison)

In the early 1800s, the need for fertilizer to support the agriculture market increased and farmers began to import guano and nitrogen deposits from South America, thereby increasing nutrient inputs to the bay. In the mid-1800s, many towns in the watershed installed sewer lines to pipe domestic and industrial waste directly into streams and rivers. During this time, the Chesapeake Bay also began to receive more industrial waste and toxins from coal burning and petroleum refining as we entered into the heart of the industrial revolution. This was compounded by even further land clearing, resulting in more extensive erosion to support the wood and wood product demands created by a growing economy and population. Construction of wastewater treatment plants did not begin until the early 20th century. Locally, Penn State University built the first treatment plant in the watershed in 1913. During the late 1930s and 1940s, chemical fertilizers, pesticides, and herbicides began to be manufactured and widely used, adding to the toxins to the Chesapeake Bay as disposal of these materials was unregulated at this time.

In 1972, the United States Congress passed the Clean Water Act, followed by a ban on phosphate detergent by states in 1985. These legislative actions were extremely important in improving water quality in the bay. However, the Chesapeake continues to suffer as human population grows and pollutants continue to be transported to the Bay by its tributaries. In the 1990s, harmful algal blooms that resulted in massive fish kills and even affected humans were discovered in the tidal area. A 1995 study estimates that nitrogen inputs to the bay increased 4 to 8 times and phosphorus increased 10 to 30 times since the pre-colonial period. Clearly, regulatory and non-regulatory efforts to reduce nutrient inputs to the bay have not been effective, and hypoxic and anoxic conditions have become more widespread in recent decades.

These pollution events, along with overfishing practices, have had a marked effect on the fisheries of the Chesapeake Bay. Records of fisheries first appear in the late 18th century, but issues with over fishing and dam construction appeared in the laws of the Commonwealth of Virginia as early as 1634. Records indicate that 25 million American shad and 750 million river herring were caught in the Potomac River in 1833. By 1878, those catches plummeted to less than 1% of the 1833 numbers. Similarly, there have been massive declines in oyster populations. In the early 19th century, fishing pressure for oysters began to increase in the Chesapeake as a result of declines in New England. The increase of pressure, catch efficiency due to advanced technology, and demand due to new preservation techniques coupled with pollution and disease resulted in dangerously low oyster populations by the year 2000. Efforts have been made to restock oyster populations; however, levels still remain at historic lows. Efforts have also been made to reintroduce American shad fry and fingerlings to increase populations but returns of adults have been limited. Striped bass, locally known as rockfish, have benefitted recently due to moratoriums on harvests enacted in the 1980s. However, concerns still exist over dwindling habitat and forage fish supplies as rockfish populations increase.

In recent decades, numerous Chesapeake Bay protection groups have been organized, legislation has been passed, governmental partnerships and goals have been set, many projects have been initiated, and a lot of work has been directed at restoring the bay. Despite these efforts, conditions in some areas are remaining the same or even declining. The situation becomes more complicated as the human population of the watershed exceeds 16.6 million. Multi-state efforts such as the Chesapeake Bay Tributary Strategy are hoped to be effective in reaching restoration goals.

To address the serious issues being encountered in the Chesapeake Bay, the states within the watershed signed the original Chesapeake Bay Agreement in 1983. This original agreement acknowledged a cooperative approach was needed to address the pollutants entering the Chesapeake Bay. In doing so, the signatories agreed to share the responsibility for management decisions and resources to make this goal a reality.

On June 28, 2000, the Chesapeake Executive Council signed *Chesapeake 2000* - a comprehensive and far-reaching Bay agreement that will guide Maryland, Pennsylvania, Virginia, the District of Columbia, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency (EPA) in their combined efforts to restore and protect the Chesapeake Bay. To meet the new goals established in the agreement, the Commonwealth developed the Chesapeake Bay Tributary Strategy (CBTS). The goals of the strategy focus on reducing additional nitrogen loads to the Bay by 37 million pounds, phosphorus loads by 1.1 million pounds, and sediment loads by 116,000 tons annually.

The strategy identifies 6 initiatives that will be used to help meet the goals of the Chesapeake 2000 Agreement. Below are the initiatives as listed in the executive summary of the strategy and how Pennsylvania will address theses initiatives.

Limiting Wastewater & Industrial Discharges: Stringent new regulations will require some 150 significant sewage and industrial dischargers in Pennsylvania to substantially reduce their nutrient loads. The new regulations are among the toughest in the Bay watershed because they use actual flows rather than design flows to determine loads and ensure real results. Specifically, Pennsylvania's 8 mg/L nitrogen concentration requirement based on actual flows compares favorably to a 4.5 mg/L requirement based on design flows as calculated by other Bay states. These requirements will be implemented and enforced through the permitting process.

Upgrading Sewer & Water Infrastructure: Governor Rendell has successfully worked with the Legislature to secure $250 million in new grants and loans to upgrade, rehabilitate, and expand wastewater and water supply systems. Up to $150 million of these funds support nutrient reduction upgrades at wastewater treatment facilities.

Enhancing Storm-water Management: Pennsylvania is requiring enhanced storm-water management efforts, and in particular infiltration of storm-water, by municipalities, developers and design professionals to reduce pollutant loadings to streams. These new requirements are being implemented and enforced through the permitting process.

Preserving Agriculture, Communities and Rural Environments (ACRE): This initiative establishes extensive new farm management regulations and some of the most comprehensive farm-based water quality protections in the nation. In addition to new regulatory requirements that became effective in April 2005, the plan includes a new effort to analyze and take action on water quality problems in all "agriculturally impaired" waterways. This is the first time any such effort has been undertaken. The initiative is backed by as much as $13 million in new and existing resources to achieve real results.

Accelerating Dam Removals & Building Fish Passageways: Pennsylvania has removed more dams than any other state, eliminating 50 structures and supporting construction of nearly a dozen fish passages in the Susquehanna River Basin since 1994. The work has restored 384 miles of free-flowing rivers and streams. An additional 270 miles were slated to open in 2006, enabling Pennsylvania to meet its first fish passage goal and restoring habitat critical for the spawning of American shad.

Removal of dams is one of the focal points identified in the Chesapeake Bay Tributary Strategy (credit: K. Ombalski)

Expanding the Conservation Reserve Enhancement Program (CREP): Pennsylvania has become the leading participant in the nation's important CREP program. With 265,000 acres in 59 of the state's 67 counties enrolled, CREP will be among the state's most effective tools for preventing polluted farm runoff from fouling streams.

Submitted by WRMP Committee Member John Sengle (PA Department of Environmental Protection)

In January of 2005, the Pennsylvania Department of Environmental Protection (PADEP) released its current Chesapeake Bay Tributary Strategy (CBTS). The purpose of the CBTS was to address Pennsylvania's commitment for nutrient and sediment reductions to the Chesapeake Bay Watershed under the 2000 Chesapeake Bay Agreement. The goal of that agreement, signed by the governors of each state who are in the Chesapeake Bay watershed, is to remove the Chesapeake Bay from the federal Clean Water Act's list of "impaired waters". The Susquehanna River, to which Spring Creek is a tributary, is the largest single source of fresh water and nutrients to the Chesapeake Bay. Nutrient enrichment of the Chesapeake Bay has resulted in eutrophication of large portions of the Bay and detrimental changes in the aquatic communities in the estuary, and has been identified as the major (but not only) cause of the impaired status of the Chesapeake Bay waters. Nutrient pollutants (generally understood to be various forms of nitrogen and phosphorus compounds) to the Chesapeake Bay come from a wide range of sources, including "non-point sources" such as agriculture, silviculture and forestry activities, urban and suburban storm-water runoff, mining activities, atmospheric deposition, residential development and earthmoving activities, as well as "point sources", including effluent from municipal sewage treatment facilities and industrial wastewater discharges.

University Area Joint Authority is one of the NPDES permitted dischargers in the Spring Creek Watershed

As a group, Pennsylvania's 213 "significant" point-source nutrient dischargers contribute approximately 14% of the total nitrogen and 22% of the total phosphorus that leaves Pennsylvania's waters to the Bay. All point source discharges to any surface waters in Pennsylvania are required to hold a National Pollution Discharge Elimination System (NPDES) permit, which establishes allowable concentrations and loads of a wide range of regulated pollutants, including but not limited to, nitrogen and phosphorus. Allowable concentrations and loads of various pollutants are determined based upon effluent discharge levels that will not interfere with the "designated use" of the receiving stream. Designated receiving stream uses could include cold water fisheries, recreation, warm water fisheries, and public water supplies.

The PADEP is implementing its nutrient reduction through a phased approach by issuing new or renewed

NPDES permits to nutrient dischargers. The phased approach will assign annual nutrient load limits or nutrient monitoring requirements over a number of years from the most to the least significant nutrient discharges on the Chesapeake Bay Watershed. These permits will include enforceable limits for maximum total annual loads (in pounds per year) of nitrogen and phosphorus in the effluent discharge. The highest priority was assigned to Phases 1, 2, and 3, which are made up of the most significant nutrient (nitrogen and phosphorus) loads on the Bay watershed. Phases 1, 2, and 3 generally include all significant nutrient discharges over 400,000 gallons/day. Phase 4 facilities are nutrient discharges from 200,000 to 400,000 gallons/day, and Phase 5 nutrient discharges are 200,000 to less than 2,000 gallons/day.

The Bellefonte Wastewater Treatment Facility was the third municipal wastewater treatment plant in the Spring Creek Watershed

The allowable total annual loads (in total pounds per year) for nitrogen and phosphorus that are assigned to each significant NPDES discharger are calculated by assigning a total nitrogen concentration of 6 mg/L and a total phosphorus concentration of 0.8 mg/L in the effluent discharge at the facility's annual average design flow, which results in a total pounds per year load limit (referred to as a "cap load") for each significant nutrient discharger. Achieving compliance with the annual cap load limits can be accomplished through upgrades and/or modifications to existing wastewater treatment facilities, construction of new and more advanced nutrient removal technologies, purchase of nutrient trading credits, or a combination of plant modifications and purchase of nutrient trading credits. An innovative component of Pennsylvania's program to meet Bay nutrient commitments is a new system for the sale and purchase of nutrient credits in a market-based trading system. More stringent nutrient concentration and loading limits may also be assigned to NPDES dischargers where specific water quality uses in the receiving stream, downstream uses, or special protection waters need to be protected, and that has been the case for NPDES discharges on the Spring Creek basin for many years.

The two major municipal wastewater treatment facilities located on, and discharging into Spring Creek, are the Bellefonte Borough wastewater treatment plant (located just north of Bellefonte Borough on SR-150 in Spring Township), and the University Area Joint Authority Spring Creek Pollution Control Facility, (located southwest of the Shiloh Road/I99 interchange in Benner Township). Both of these facilities are Phase 1 priority facilities and have been issued new NPDES permits in early 2008 that include maximum allowable annual nutrient load limits for nitrogen and phosphorus. The Bellefonte Borough facility serves the Borough of Bellefonte and developed areas in Spring, Benner and Walker townships. The University Area facility serves portions of State College Borough, and developed areas in College, Harris, Patton, and Ferguson townships. Annual average design flow for the Bellefonte Borough facility is 3,220,000 gallons/day. Annual average design flow for the University Area facility is 9,000,000 gallons/day. Penn State University and some adjacent portions of State College Borough are served by the Penn State University wastewater treatment plant located near the junction of East College Avenue and University Drive. All of the treated effluent from the Penn State facility (which has a current annual average design flow of 4,000,000 gallons/day) is spray irrigated on two spray-field sites totaling approximately 520 acres on both agricultural and forested lands to the east and north of the Toftrees development, north of the University Park campus. The Penn State University facility does not discharge directly to surface water and, as such, is not regulated by an NPDES permit. PA DEP does regulate the Penn State University facility through requirements of a number of Water Quality Management (WQM) permits, which are currently under significant revision and consolidation.

The long-term base flow water quality and stream flow data collected beginning in 1998-1999 through present day by the Spring Creek Water Resources Monitoring Project (WRMP) will be an invaluable resource in determining the actual nutrient load reductions to Spring Creek that will occur when Chesapeake Bay nutrient load limits become effective. The current basin-wide base flow water quality and stream flow network includes monitoring stations both upstream and downstream of the Bellefonte Borough and University Area facilities. The coupling of pollutant concentration and stream flow data from those monitoring stations will permit an accurate calculation of in-stream nutrient loads and a real-time assessment of the effectiveness of Chesapeake Bay nutrient reduction efforts on the Spring Creek basin.

Contributed by Tom Smith, Plant Superintendent, Bellefonte Wastewater Treatment Plant

Bellefonte Wastewater Treatment Plant (BWWTP) provides wastewater treatment service to Bellefonte Borough and parts of Spring, Benner and Walker Townships. A new NPDES Permit issued by PADEP in February, 2008 imposes annual maximum nutrient limits (called cap loads) regulating the amount of total phosphorous and total nitrogen BWWTP may discharge to Spring Creek and ultimately Chesapeake Bay.

Current treatment technology in place at BWWTP enables the plant to comply with the total phosphorous cap load without any modifications to the existing treatment processes. The total nitrogen cap load, on the other hand, poses a problem for BWWTP because the existing treatment processes are not able to remove nitrate, a component of total nitrogen. To remedy this problem BWWTP is upgrading to a process for biological nitrate removal using Continuous Backwash Upflow Filters. The upgrade, designed by Nittany Engineering & Associates, is underway with a projected completion date of September, 2009.

Funding for the project comes from a combination of grant and low interest loan money from Pennworks, and an increase in local sewer user rates.

Contributed by Cory Miller, Executive Director, University Area Joint Authority (UAJA)

UAJA and the Centre region anticipated the requirements of the Chesapeake Bay Tributary Strategy as early as 1997 when the water reuse project was first conceived. The plant expansion included biological Nitrogen (N) and Phosphorus (P) removal, as well as chemical precipitation of Phosphorus. Under the tributary strategy, plants are allocated a mass of N and P based on their permitted capacity. UAJA's treatment capacity is 9.0 million gallons per day (MGD), however, discharge to Spring Creek is limited to 6.0 MGD. Since we discharge less that the permitted capacity of 9.0 MGD, our concentration limits for discharge are much higher than the 6.0 mg/l N and 0.8 mg/l P that are specified in the strategy. UAJA has also evaluated the addition of a Carbon source to enhance Nitrogen removal. While there is no need to lower our N discharge this way, depending on the value of N credits, it may be cost effective for UAJA to generate credits for sale.

Pennsylvania State University Wastewater Treatment Facility (credit: Bob Carline)

Submitted by WRMP Committee Member Larry Fennessey, Ph.D. P.E. (PSU—OPP)

As part of the Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) Phase II Program, municipalities, or municipal like entities, within designated urban areas are required to have Small Municipal Separate Storm Sewer System (MS4) permits. In Pennsylvania, the Pennsylvania Department of Environmental Protection (PA DEP) administers the NPDES permit program. Operators of small municipal separate storm sewer systems are required by the EPA/PADEP to design programs to reduce the discharge of pollutants in stormwater to the "maximum extent practicable," to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act. Although the minimum control measures of the MS4 permits do not directly address the requirements of the Chesapeake Bay Tributary Strategy, the stormwater management practices that are recommended through the MS4 permit likely provide ancillary benefits in helping to achieve nutrient reduction goals of the Strategy.

In the Centre Region - College, Ferguson, Harris, and Patton Townships, the Borough of State College, and the Pennsylvania State University's University Park Campus hold MS4 permits. The initial permits were 5-year permits that ran from March 10, 2003 to March 9, 2008, but were automatically extended for another year through March 9, 2009 at which time PADEP will issue new permits.

The MS4 stormwater management program is comprised of six elements that, when implemented in concert, are expected to result in significant reductions of pollutants

Debris collector constructed downstream of a storm water conveyance in State College Borough (credit: G. Smith)

discharged into receiving water bodies. The six program elements, termed "minimum control measures" are:

1. **Public Education and Outreach on Stormwater Impacts-**Distributing educational materials and performing outreach to inform citizens about the impacts polluted stormwater runoff can have on water quality.
2. **Public Involvement/Participation -** Providing opportunities for citizens to participate in program development and implementation, including effectively publicizing public hearings, meetings, and/or encouraging citizen input.
3. **Illicit Discharge Detection and Elimination (IDD&E) -** Developing and implementing a plan to detect and eliminate illicit discharges to the storm sewer system including developing a system map and informing the

community about hazards associated with illegal discharges and improper disposal of waste.

4. **Construction Site Stormwater Runoff Control -** Developing, implementing, and enforcing an erosion and sediment control program for construction activities.

5. **Post Construction Stormwater Management in New Development and Redevelopment -** Developing, implementing, and enforcing a program to address discharges of post-construction stormwater runoff from new development and redevelopment areas.

6. **Pollution Prevention/Good Housekeeping for Municipal Operations -** Developing and implementing a program with the goal of preventing and reducing pollutant runoff from municipal operations.

The permits require annual reports to be submitted indicating how each minimum control measure was achieved. College, Ferguson, Harris, and Patton Townships, the Borough of State College, and Penn State University work cooperatively on several initiatives under minimum control measures 1 and 2.

Stormwater Channel in State College Borough
(credit: G. Smith)

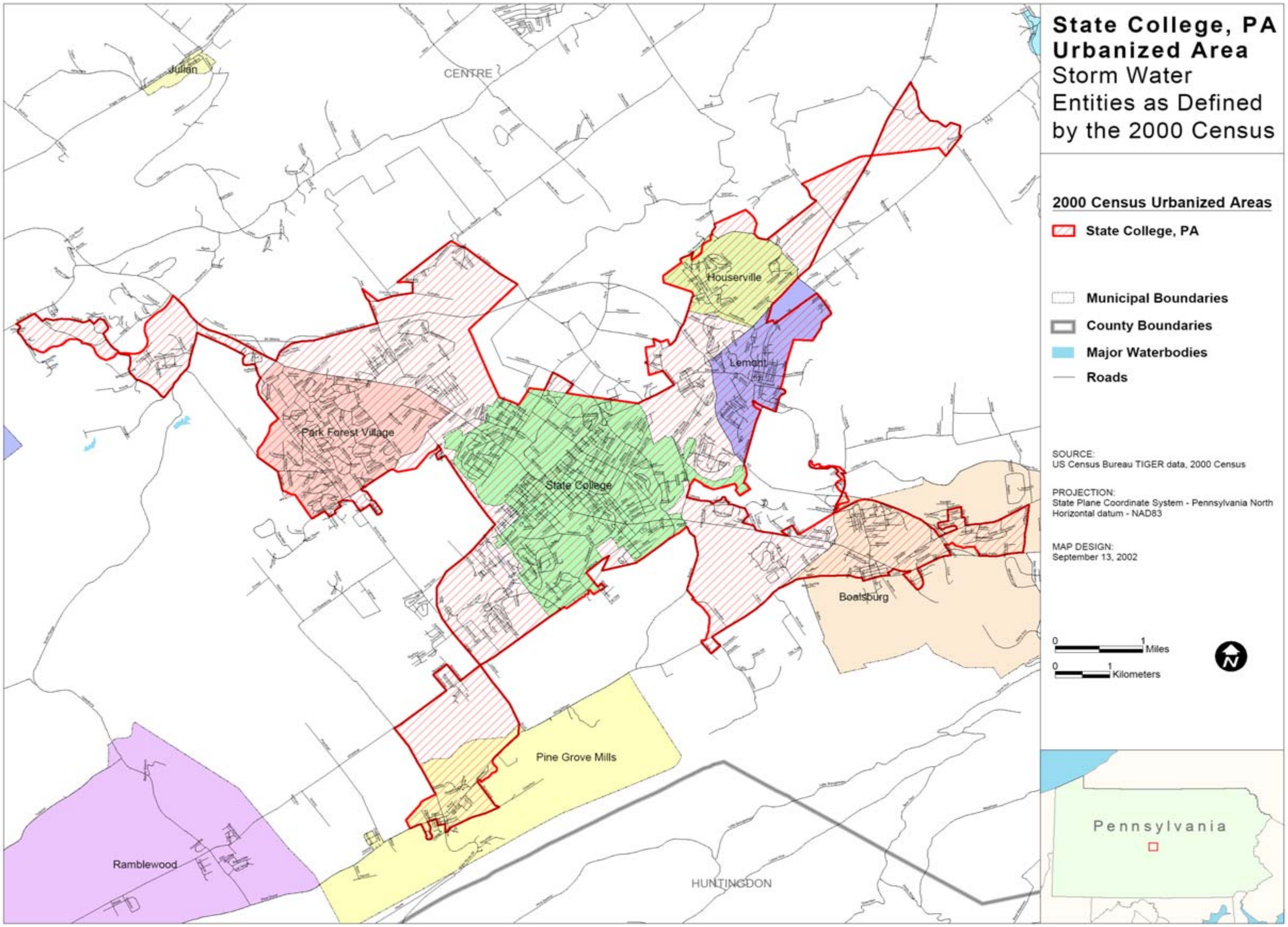

Figure 17: Urbanized storm-water entities in the State College area represented by the MS4 permit system

Living Filter System

Submitted by Penn State University Office of Physical Plant Staff John Gaudlip, P.E.

Research on land treatment of wastewater at the Pennsylvania State University began in 1962. A group of scientists were attempting to find solutions to two local water problems: (1) the pollution of Spring Creek, the area's only surface water, by discharge of ever increasing amounts of sewage effluent from the wastewater treatment plant that serves both the University and State College; and (2) a dwindling supply of ground water due to a seven-year drought. In those seven years there was a deficit of 50 inches of precipitation, which was almost equivalent to 1.3 years of normal precipitation. During the same time period, millions of gallons of sewage effluent were discharged daily into Spring Creek and were not available for reuse as a water resource in the immediate area.

Penn State University Living Filter System spray irrigating treated wastewater on University cropland (credit: John Gaudlip—PSU OPP)

The need to find solutions to these problems led to a full-scale investigation into the feasibility of applying large volumes of wastewater on the land. In 1963 a research facility was constructed to spray irrigate 20 percent (0.5 MGD) of the University's chlorinated secondary effluent to cropland and forest areas. From these initial investigations evolved the living filter concept. The idea embodied in this concept is to apply treated wastewater on the land in a manner that utilizes the entire biosystem-soils, vegetation, and microorganisms-as a living filter to renovate the wastewater to potable water quality for direct recharge to the ground-water reservoir. (Sopper 1985)

Implementation of the full scale living filter concept began in 1983 when 100 percent of the Penn State University wastewater treatment plant effluent was applied to 606 acres of farm fields and forest areas at a rate of 2" per acre per week. To date no Penn State University wastewater treatment plant effluent has been released on a continual basis to Thompson and Slab Cabin Run's tributaries of Spring Creek since 1983. Approximately, one billion gallons of treated wastewater is being recharged into the ground water per year. (Parizek 2008)

Some areas of the spray field receive 100 inches of wastewater, plus an annual average precipitation of 38.74", resulting in a total hydraulic load of almost 140" per year (rainforest minimum normal annual rainfall = 68 -78 inches per year). Over the years, this has resulted in development of a unique dynamic management plan based on research conducted on the operating facilities. The plan includes the following actions that have been taken to date:

- Penn State Farm Operations uses double-crop combinations to optimize year-round nutrient uptake. Crops are planted with a pattern of water and nutrient use that corresponds well with the variations in campus population. Supplemental fertilizer needs are closely monitored to ensure that only the minimum is used to achieve economical production. The harvested crops are used within the University to feed or bed animals.
- The application of water on the spray sites has been re-designed from a rigid chronological schedule originally implemented in 1983 that required each lateral to operate the same time each week on a year-round basis to one that is biologically based. This biologically based schedule provides more efficient management of water providing it where and when it is needed based on growing season, cropping, weather conditions, and other factors, while operating within the permit application rate. This schedule is determined monthly.
- Much of the original forest areas consisted of upland tree species that are not acclimated to wet conditions. Some of these communities have been replaced with a variety of tree species that thrive in the wet conditions creating food and cover for wildlife while improving the infiltration capacity of the soil.
- Total nitrogen in the effluent of the wastewater treatment plant has been significantly reduced. The existing activated sludge units were converted with no major capital cost to reduce nitrogen by modifying the process flow pattern utilizing existing infrastructure. Similar reductions in nitrogen were accomplished on the trickling filter effluent by using existing tanks and adding only anoxic tanks with appurtenances.
- Since phosphorus (P) is the nutrient limiting algal growth in most freshwater systems, a major benefit of Penn State's effluent irrigation system is avoidance of P discharge to surface waters. Annually about 30,000 pounds of P are applied to the living filter site. For the agricultural fields, approximately 50% of this amount is taken up by crops with the remainder accumulating in the top few inches of soil. Since P leaching does not occur for these soils and the system is designed to preclude effluent runoff, the living filter system prevents wastewater P from impacting local surface water quality.

The results have proven that spray irrigation of treated wastewater is a viable, sustainable method to use this water beneficially. University water well UN14, the nearest University production well has proven to be an extremely good quality/quantity producer even with heavy pumping during recent drought years

CBTS agricultural implications

Submitted by WRMP Committee Member Ann Donovan (Centre County Conservation District)

The Centre County Tributary Strategy, also referred to as the County Implementation Plan, is a working document developed by the Centre County Conservation District to illustrate the County's level of commitment to Pennsylvania's Chesapeake Bay Tributary Strategy.

As part of the County Implementation Plan, the Centre County Conservation District carries out projects that will reduce nutrient and sediment loads in the Chesapeake Bay Watershed. The District provides cost share funding and technical assistance for the installation of Best Management Practices on farms and for the development of nutrient management plans. Farmers who wish to participate in the County's cost-share programs are required to develop a Nutrient Management Plan for their property based on the recommendations of the County Implementation Plan. The District has a PA Certified Nutrient Management Specialist on staff to support landowners in the creation of property-specific nutrient management plans that meet the recommended guidelines.

Fenced stream bank along Cedar Run in Harris Township. Fences limit access of animals to streams and allow riparian areas to remain vegetated and reduce erosion (credit G. Smith)

Support is also provided for volunteer organizations and non-profit groups focused on agriculture to aid in activities that help meet the nutrient and sediment goals of the strategy. Two of the major agricultural initiatives that the District supports are Centre County Grazers and Project Grass. Technical and administrative support are given to these two local volunteer efforts that support alternative agricultural land practices. The District recognizes grazing as a practice that both maximizes environmental benefits and improves farm economy. The District also works with Project Grass and the Centre County Grazers to secure funding through Project Grass and the Pennsylvania Association of Conservation Districts to help with grazing activities in this county. The District encourages farmers to develop rotational grazing systems and District staff work with farmers to create grazing plans for local farms.

In addition to the agricultural land-use support, there are several other initiatives that are supported by the county. One exciting project that is presently in development is a partnership with the Pennsylvania Department of Environmental Protection Energy Harvest Grant program to install a methane digester in the county. This will help the landowner better handle excess manure as well as provide energy for use on the farm.

In addition to the previously mentioned initiatives, the district is continually seeking funding that will assist local watershed groups, farmers, and other landowners with invasive species control and programs that encourage no-till farming and cover crops. We host no-till/cover crop workshops in order to promote those programs. The District also supports the local foods initiative, since sustainable agriculture is environmentally sound farming.

The Centre County Conservation District supports numerous Centre County watershed groups, assisting them with their implementation plans and contributing to their restoration projects. Watershed groups throughout Centre County identify agriculture as a significant contributor of sediment and nutrients in each of their respective watersheds. Numerous studies state that stream-bank stabilization and riparian protection on agricultural land are highly effective methods that reduce sediment and nutrient loads to the stream, which is why the District aids these groups in their restoration and stream stabilization efforts. There are recommendations in the Centre County Tributary Strategy for buffer establishments on farmland as well as the installation of Best Management Practices (BMPs) that will reduce sediment and nutrient runoff from farms. There are three active watershed associations within the Spring Creek Watershed that have partnered on restoration projects in the watershed: Spring Creek Watershed Community, ClearWater Conservancy, and the Spring Creek Chapter of Trout Unlimited. The District has assisted these groups with stream bank stabilization projects that will reduce the sediment loads to our local streams. Last August, the District participated in the Spring Creek Chapter of Trout Unlimited sponsored PSU Sheep Farm restoration project and will also participate in the upcoming fish habitat enhancement efforts that will be taking place in 2008 on lower sections of Spring Creek. The Spring Creek Watershed Community Water Resource Monitoring Program and the Centre County Pennsylvania Senior Environmental Corps (PASEC) both monitor water quality within the Spring Creek Watershed, and their data can be used to track the progress

Fish habitat enhancement and stream bank stabilization structure at the PSU Sheep Farm (credit: G. Smith) of restoration efforts within the watershed.

The Centre County Conservation District continually seeks funding to fulfill the goals of the County Implementation Plan. Currently, the District is working with funds from the National Fish and Wildlife Foundation, the Centre County Growing Greener Initiative, the Growing Greener Grant Program, the DEP Energy Harvest, and the Chesapeake Bay Program, as well as with financial support from Senator Corman and Representative Hanna. The District develops partnerships with many organizations and agencies in order to be more efficient in the achievement of our goals. These groups include local watershed associations, ClearWater Conservancy, Trout Unlimited, Pennsylvania Fish and Boat Commission, US Fish and Wildlife Service, Natural Resource Conservation Service (NRCS), PSU Center for Watershed Stewardship, Western Pennsylvania Conservancy and the Centre Region Council of Government. The District always welcomes new partners and new ideas that will help us in our efforts to reduce the sediment and nutrient loads to our local streams and to the Chesapeake Bay.

For more information please call the Conservation District office at 355-6817. The Centre County Tributary Strategy can be found in its entirety on the CCCD web site at www.co.centre.pa.us/conservation .

Submitted by WRMP Committee Member Kristen Saacke Blunk.

The Spring Creek Watershed and Agriculture: Considering Both Sides of the Equation on Preferred Land Uses.

The nutrients (nitrogen and phosphorus) measured in the Spring Creek Watershed's streams come from a variety of sources including municipal wastewater treatment plant discharges, septic systems, fertilizers used by home owners, golf courses, and park fields, and agricultural croplands and pasturelands. Increasingly, scientists are recognizing that atmospheric deposition of nutrients is also a significant source in the Chesapeake Bay Watershed.

Agriculture's influence on the Spring Creek Watershed, and its overall output of nutrients and sediment that contribute to the impairment of the Chesapeake Bay depends partly upon weather conditions. In wetter years, movement of nutrients and sediments to the area's streams and eventually to the Bay is greater. During dryer years, there is less movement of nutrients and sediments because less water is filtering through the soils and flowing over land. Herein lies the reason why managing our stormwater and maintaining and improving our natural or "green" infrastructure like open space, wetlands and floodplains within Spring Creek Watershed is so critical.

Agriculture's working lands are part of the natural infrastructure in place for the Spring Creek Watershed. As such, it is essential that we understand and quantify the full suite of ecosystem services that farms can provide in the Spring Creek Watershed. It is especially important to

understand these ecological benefits, because they are in sharp contrast with what alternative land uses – such as urbanization – can provide.
Nationwide, and particularly in areas like the Spring Creek Watershed, where the quality of life and quality of environment converge favorably, conversion of agriculture to other land uses is rapidly changing the local landscape. Every citizen of the 14 municipalities that make up the Spring Creek Watershed can mark their time of entry to the community by a memory of a no-longer-existing farm that was once on the landscape – but is now an apartment building, shop, church, or currently hosts a "for sale – zoned commercial" sign. This land conversion brings with it a significant increase of impervious surfaces which can exacerbate the volume and energy of stormwaters that carry pollutants from our watershed to downstream rivers and eventually to the Chesapeake Bay.

Fenced stream bank along Spring Creek at the PSU Sheep Barn property (credit: Katie Ombalski)

But what else is lost when a farm is converted to urban land uses? Here's the short list of ecosystem services that agricultural working lands provide our community:

Open space. While often valued for its aesthetic qualities, agricultural lands also provide open space that performs the critical function of absorbing and filtering rain waters to replenish ground- and surface water supplies. In a karst (limestone) stream environment, there are intricate connections and limited barriers between groundwater and surface water. Agricultural areas, including pasturelands, croplands, and the riparian corridors traversing them, maintain land in open space and preserve the land's ability to serve as a living filter system. This slows the energy of stormwater across land by drawing water into the soil capillaries and filtering out contaminants that rain may pick up as it falls through the atmosphere.

Habitat protection. Habitat as an ecosystem service is typically undervalued until it is no longer available. Many of the farms in the Spring Creek Watershed actually enhance habitat through the increase of what conservation biologists call "edge habitat" or the transitional area between croplands or pasturelands and forests. Large and small mammals, amphibians, song birds, and birds of prey have specialized habitat requirements that are uniquely provided in agricultural settings through the diverse mixture of crop edges, pastures, meadows, forests, wetlands, and springs and creeks. There are some places in Pennsylvania where farmers participate in "habitat banking" to preserve species of concern through use of protective conservation easements and offsets that re-direct development to areas that do not host the specialized habitat.

Reduction of carbon dioxide in the atmosphere. Crop and livestock farmers, along with forest owners, now have an opportunity to manage their land for improved capture and sequestration of carbon that result in the generation of carbon credits. Carbon credits can be sold through a voluntary carbon market on the Chicago Climate Exchange. From carbon capture of methane from manure on livestock operations to soil-based carbon sequestration using no-till practices, to improved forest management, agricultural operations can reduce the emission of carbon dioxide into the atmosphere, helping to offset one of the major greenhouse gases attributed to global climate change.

Water quality. Agriculture plays a meaningful role in the nutrient credit – or water quality credit trading program in Pennsylvania. By additional reductions of nutrients released from farm practices, agriculture can help municipal- and industrial wastewater treatment plants meet stringent permit requirements. To generate a credit, the farm must implement practices above and beyond baseline requirements. To the farmer, nutrients are not pollutants, they are resources best retained and used on the farm and not lost to the environment. The price of fertilizer has risen dramatically coinciding with the increase in price of gasoline, resulting in the need for farmers to conserve and better utilize the valuable nutrient resources available to them. The core conservation practices that agriculture can employ such as riparian buffers, streambank fencing, nutrient management planning, precision feeding, cover crops, and no-till farming, particularly when used in tandem, will ensure that agriculture is providing maximum protection to local water resources.

These ecosystem services are possible in an agricultural landscape because the land is under the private ownership of a few. Imagine these thousands of acres instead parceled out to hundreds or thousands of homeowners, businesses, and other commercial endeavors. What would it take to preserve these ecosystem services if many different landowners, many different land uses, and the added constraints of increased impervious surfaces were added to the equation?

Because of the diverse ecosystem services that working lands can provide, agriculture in the Spring Creek Watershed is a preferred land use. As such, it is essential that farms continue to work diligently to implement best management practices that will further reduce the potential for crop and pasture nutrients from being released to the environment. This is accomplished through cooperative conservation initiatives that partner the farm with technical services and resources like the Centre County Conservation District, Penn State Cooperative Extension, local governments, and watershed associations. Through this level of cooperation, the working lands that provide the agricultural products that sustain communities and the ecosystem services that enhance the quality of the local environment will not be lost to less productive and possibly more environmentally deleterious land uses.

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 ground-water 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 ground-water levels in critical areas
D. Provide the means to detect changes in quantity and quality of surface waters under base flow conditions, storm-water runoff, and ground-water reserves
E. Provide sufficient measurement sensitivity through long term monitoring to permit the assessment of the previously mentioned parameters.

The WRMP receives funding to carryout the data collection activities from several municipalities and organizations. For 2007, more than $64,000 was donated to support the work of project. Donors in support of the 2007

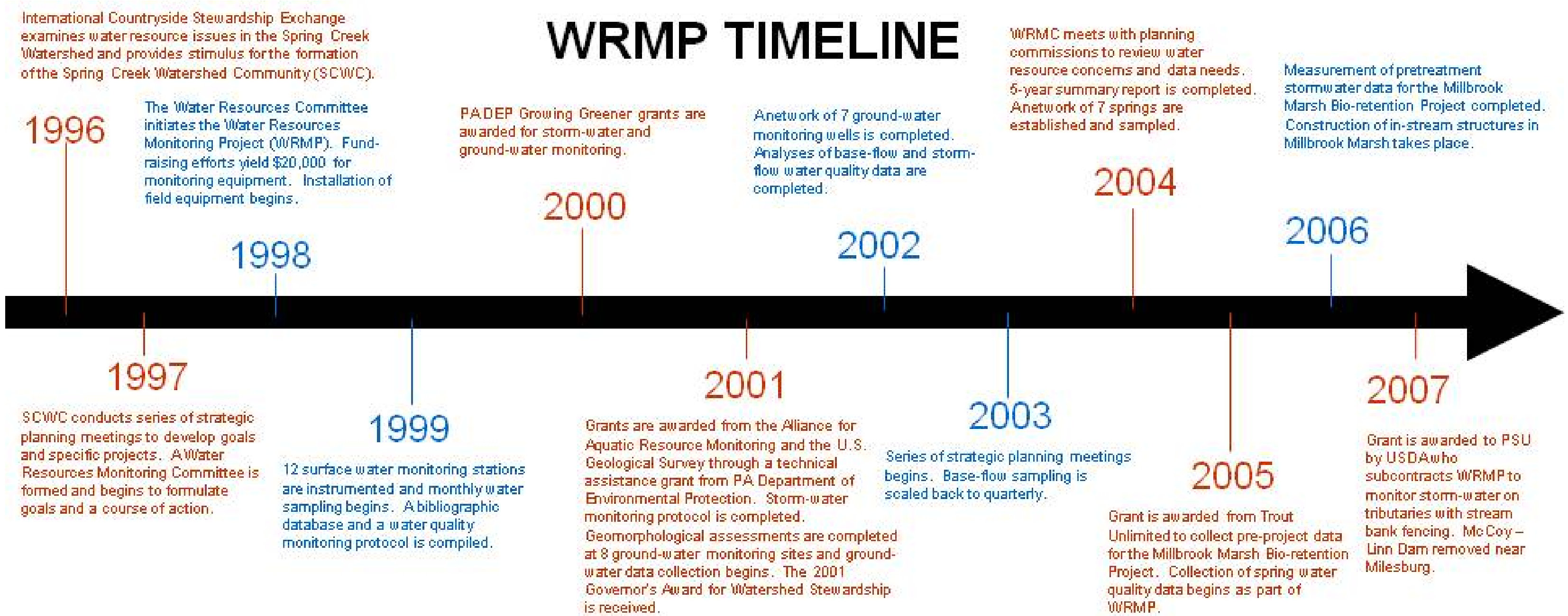

Figure 1: Timeline of activites associated with the Water Resources Monitoring Project

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 supplies, technical assistance, and transportation from the following:

Ground-water well owners

Corning Asahi
Howard Dashem
PA Department of Conservation of Natural Resources (DCNR)
Todd Giddings
Penn State University – Office of Physical Plant (PSU-OPP)
United States 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

WRMP Committee Member	Affiliation	WRMP Committee Member	Affiliation
Robert Carline, Ph.D. ***Committee Chair*** *Retired*	Pennsylvania Cooperative Fish and Wildlife Research Unit, USGS	**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	**Mark Ralston, P.G.** Hydrogeologist	Converse Consultants
Jason Brown Project Manager	University Area Joint Authority	**Kristen Saacke-Blunk** Director	Agriculture and Environmental Policy Center College of Agricultural Sciences, The Pennsylvania State University
Susan Buda Aquatic Ecologist	Susquehanna River Basin Commis-sion	**John Sengle** Water Pollution Biologist	Pennsylvania Department of Environmental Protection
Hunter Carrick, Ph.D. Assistant Professor of Aquatic Ecology	School of Forest Resources The Pennsylvania State University	**David Smith** Assistant Executive Director	University Area Joint Authority
Ann Donovan Watershed Specialist	Centre County Conservation District	**Geoffrey Smith** Water Resource Coordinator	ClearWater Conservancy
Rebecca Dunlap Project Manager	Trout Unlimited	**Rick Wardrop, P.G.** Hydrogeologist and Industrial Contamination Specialist	Shaw Environmental & Infrastruc-ture
Larry Fennessey, Ph.D., P.E. Utility Systems Engineer - Stormwater	Office of Physical Plant , The 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.** Senior Hydrogeologist	ARM Group, Inc.

Table 1: Water Resource Monitoring Project Committee Members for 2007

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 14 stream sites at base flow conditions quarterly throughout 2007 (Figure 2). Twelve of these stations were sites that were originally established at the inception of the project in 1998. These sites were aimed at capturing run-off from representative land use practices as well as covering each of the Spring Creek Watershed subbasins. Other sites were chosen to coincide 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 to serve as a reference to track any impacts associated with acid drainage 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.

WRMP monitoring site Buffalo Run Upper (BUU) (credit: G. Smith)

Ground-water Monitoring Wells

The ground-water reservoir in the Spring Creek Watershed is monitored with a network of seven wells equipped with water-level monitoring devices (Figure 3). The wells were established at locations representing different ground—water conditions across the watershed and that were not subject to frequent fluctuations caused by external factors such as high-yield pumping wells or well fields, storm water, artificial ground-water recharge, or surface water discharges.

Becky Dunlap preparing to download ground-water data from the Fillmore well (credit: G. Smith)

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. Figure 3 shows the seven spring sites sampled by the WRMP.

Volunteer Bryce Boyer and Water Resources Coordinator Geoffrey Smith sample Continental Courts Spring (credit: R. Carline)

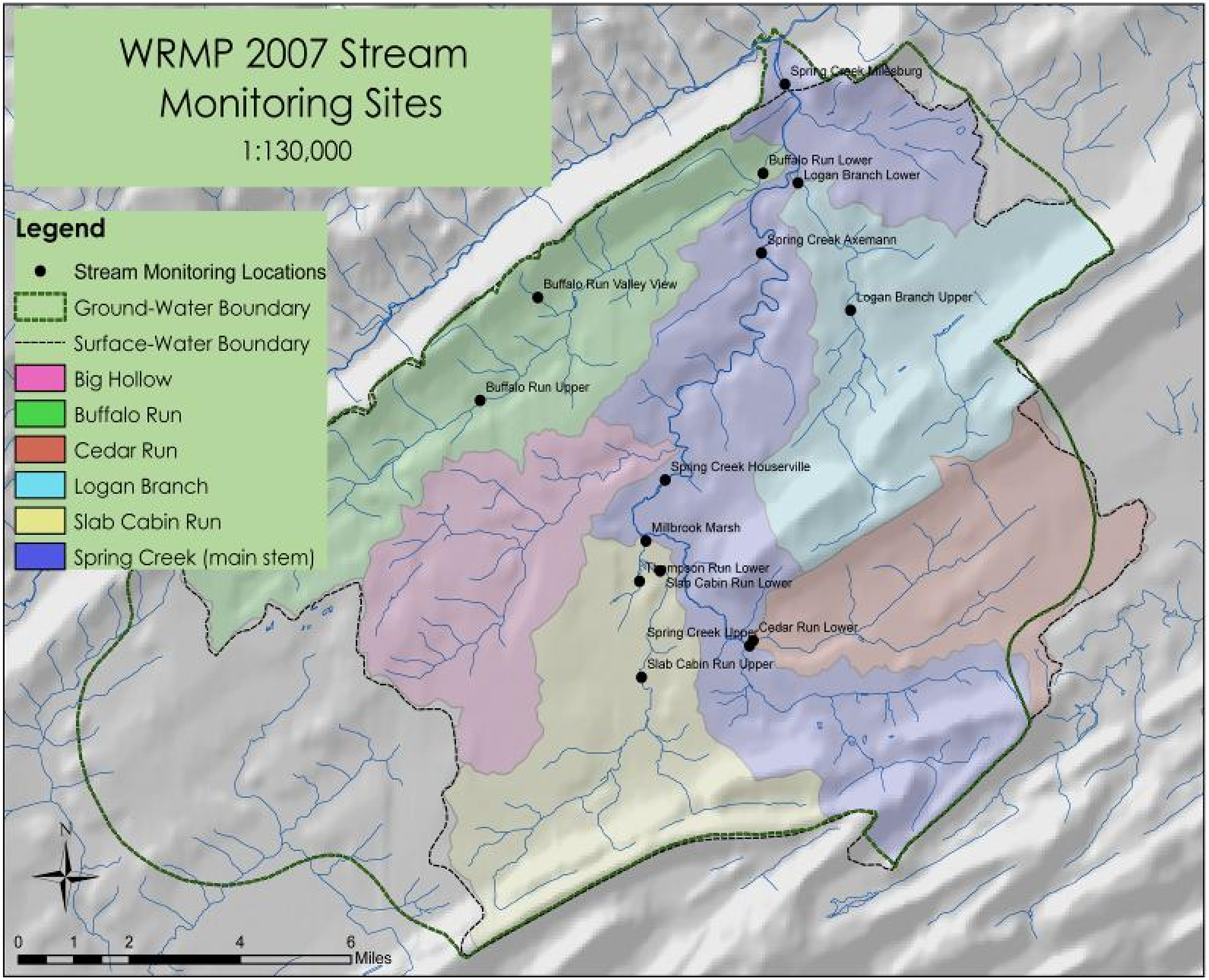

Figure 2: Stream sampling sites surveyed during the 2007 Water Resources Monitoring Project

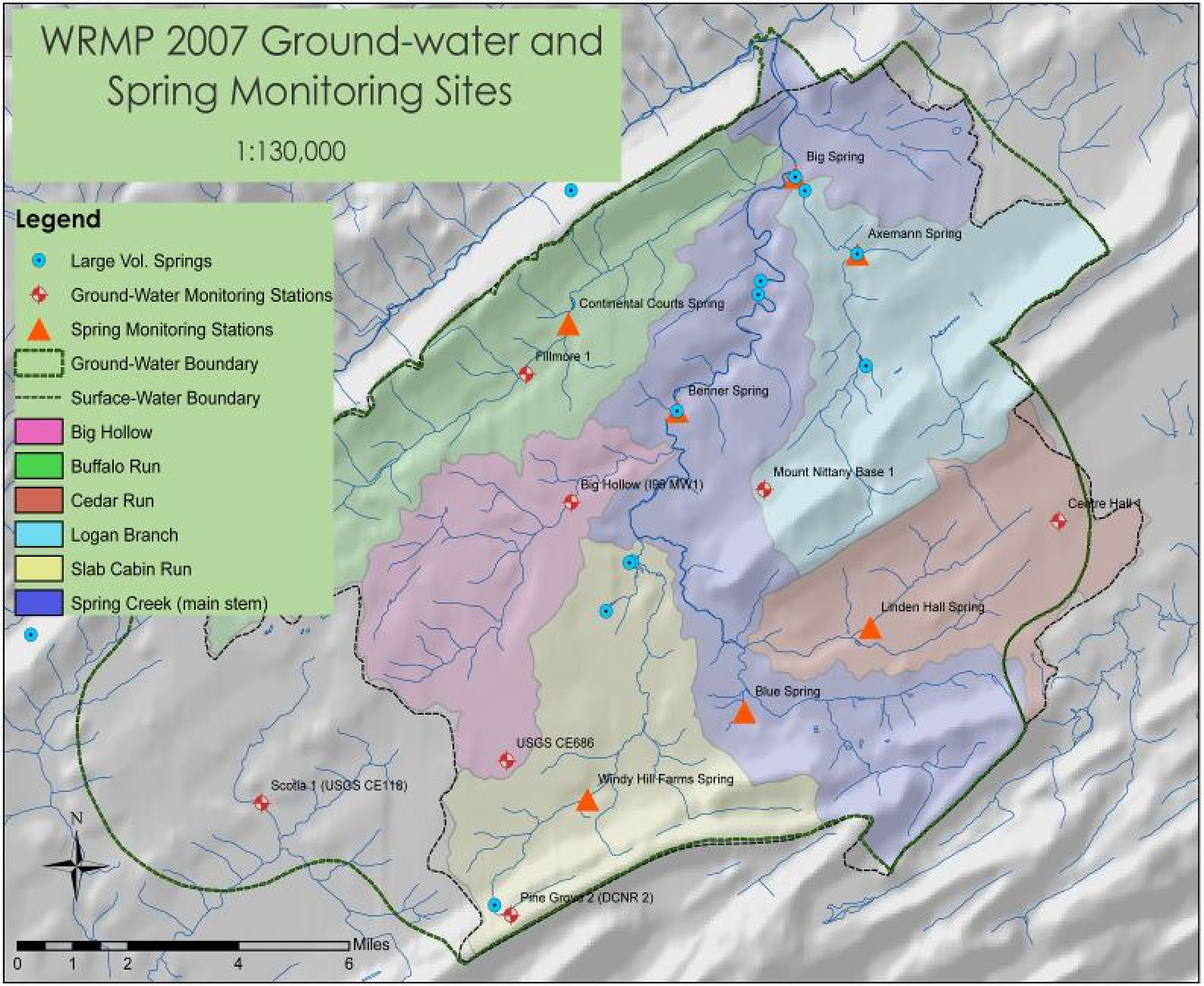

Figure 3: Ground-water and spring stations surveyed during the 2007 Water Resources Monitoring Project

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 Geoffrey Smith 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, and an analysis of the results for each parameter can be found in Appendix 3.

Continuous Measurements

Stream stage was continuously measured at thirteen of the stream monitoring stations covered as part of the WRMP during 2007. Ten stations were equipped and maintained by the WRMP using Design Analysis Associates, Inc. DH-21 pressure 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 at 15-minute intervals.

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 were recorded at 3-hour intervals. Five of the seven were maintained by the WRMP, with the other two (CE118 and CE686) being 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 to develop 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.

Water Resources Technician Nicole Rhodes takes a discharge measurement at the Buffalo Run Upper site (credit: G. Smith)

The WRMP collected quarterly base flow samples at 14 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 2007. Trends in concentrations of the various parameters analyzed were similar to previous years' samples despite drought conditions. Appendix 3 shows median concentrations of all parameters analyzed at each of the stream sites sampled as part of the 2007 WRMP.

Generally,

- The concentration of nitrate nitrogen, a common pollutant associated with agriculture, is found at relatively high levels at all sites, however concentrations are unchanged from previous years. Spring sampling locations had elevated nitrate levels showing that ground water serves as a considerable source of nitrates under base flow conditions.
- Total orthophosphorus concentrations, another common pollutant associated with agriculture, hovered around the lower detectable levels and remain relatively unchanged in comparison with previous sampling efforts. Orthophosphorus concentrations were largely below detectable levels in spring samples indicating that ground water is not a primary source of orthophosphorus under base flow conditions.
- 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 elevated in the Buffalo Run watershed showing some contamination as a result of leaking pipes that were part of the pyritic waste material treatment for the Interstate 99 project.
- Total aluminum concentrations were slightly lower at all sites than those measured in 2006.
- Total iron concentrations were slightly lower at all sites with the exception of Logan Branch when compared to 2006 data. Dissolved iron levels were higher at Buffalo Run Upper and Buffalo Run Valley View. However, total recoverable concentrations were lower. These elevated concentrations are most likely the result of faulty pipes that are part the Interstate 99 treatment process.
- Manganese concentrations were slightly lower or unchanged at all sites compared to 2006 data.
- Zinc was undetectable at all sites except the lower site on Logan Branch and is probably a legacy of factories in that area. Concentrations are similar to previous years indicating no change. Analysis of permitted discharges show contributions are not from present operations of the permitted dischargers.
- Dissolved oxygen, pH, and conductivity are similar to previous years.

The prevailing drought conditions faced during summer and fall 2007 resulted in dry or stagnant conditions in Blue Spring, Windy Hill Spring, and Linden Hall Spring and either made sampling impossible or created conditions that were uncharacteristic of base flow conditions. The other springs in the network did not seem to be as adversely affected. Results of 2007 WRMP spring monitoring can be found in Appendix 4.

Monitoring *results*

Surface Water

The hydrology of 2007 was not typical compared to most years. Summer and fall 2007 were times of near-record drought in the Spring Creek Watershed. This resulted in a period between August and November in which some spring and stream reaches were completely dry. Slab Cabin Run near South Atherton Street, Blue Spring in Boalsburg, Windy Hill Spring along Route 45, and Linden Hall Spring did not see sustained flow return again in late November and did not return to normal conditions until March 2008.

Figures 4 – 8 are graphs portraying discharge values for the sites covered by the WRMP during 2007 based on data collected from U.S. Geological Survey and WRMP stream gages. Figure 4 is a comparison of discharge values at four sites along the mainstem of Spring Creek during calendar year 2007. Figure 5 is a comparison of discharge values for five tributary sites monitored by the WRMP during 2007.

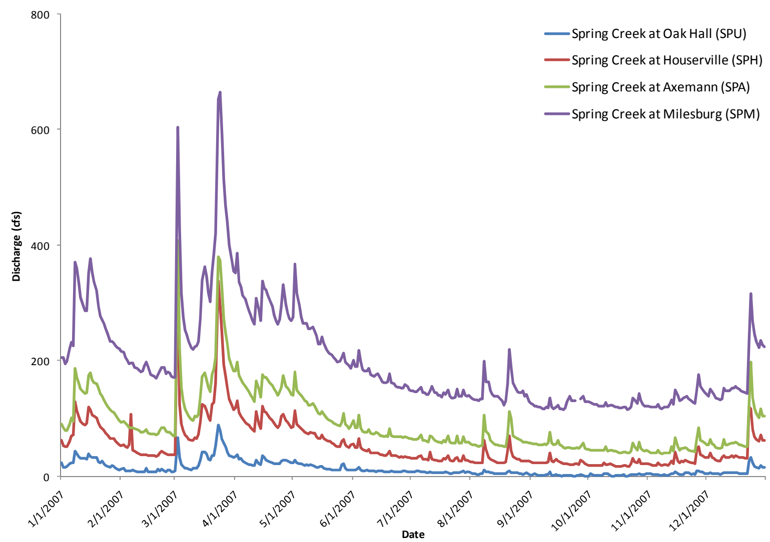

Figure 4: Discharge at four locations on Spring Creek during 2007

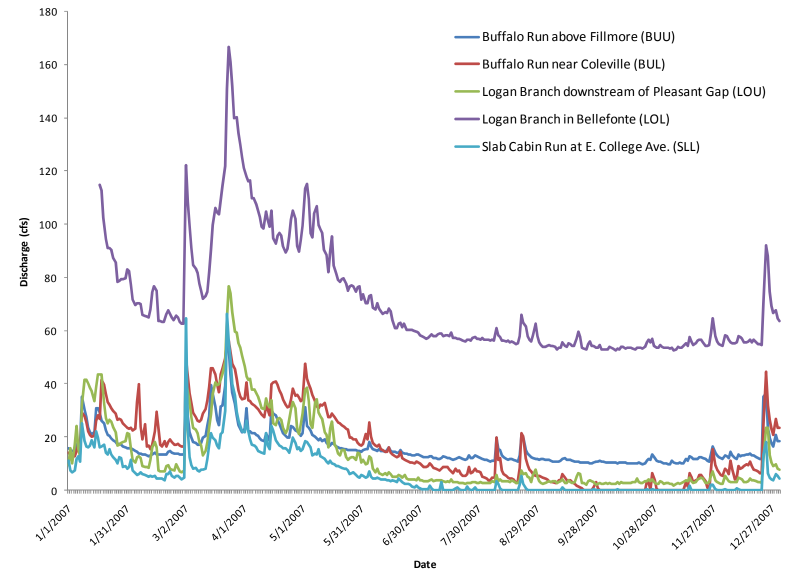

Figure 5: Discharge at five tributary locations in the Spring Creek watershed during 2007

While Spring Creek maintained flow throughout this time period, values were below normal for much of this time. Figure 6 compares historical daily discharge data with discharge data from 2007 for Spring Creek at Oak Hall (SPU) and Spring Creek downstream of Fishermen's Paradise (SPA). Discharge for 2007 at both locations dipped below the median daily values beginning in August and remained below those levels until late December, with the exception of brief periods of relief caused by rain events. Although discharge was below median values, it remained above historic minimum levels on Spring Creek downstream of Fisherman's Paradise (Figure 7).

Like Spring Creek, Buffalo Run also exhibited discharges below historic levels for much of the late summer and

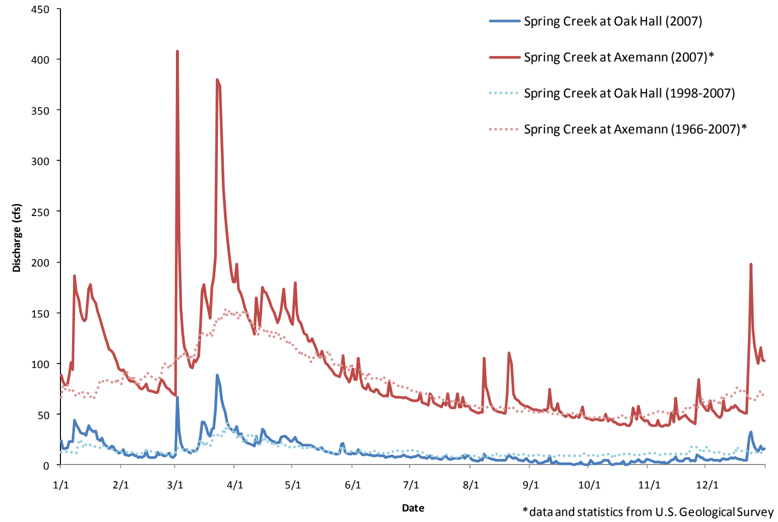

Figure 6: Comparison of 2007 discharge of Spring Creek at Oak Hall and Axemann against historic discharge values

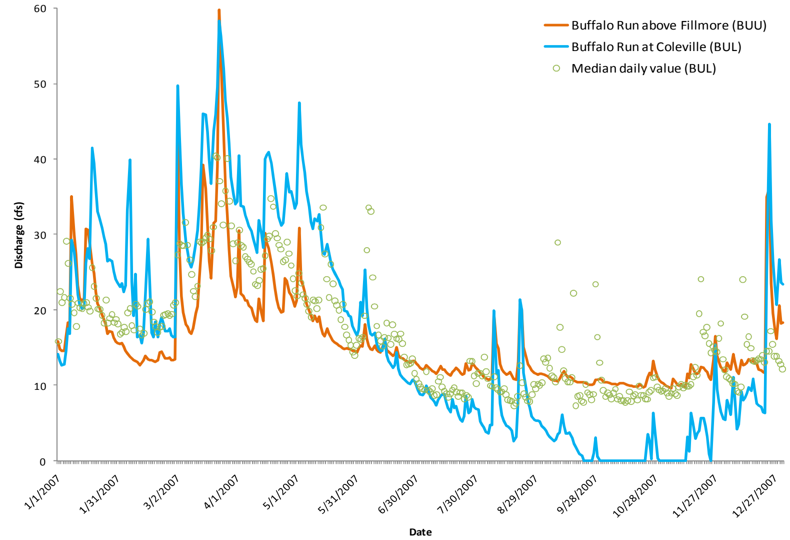

Figure 8: Comparison of 2007 discharge of two sites on Buffalo Run and historical data.

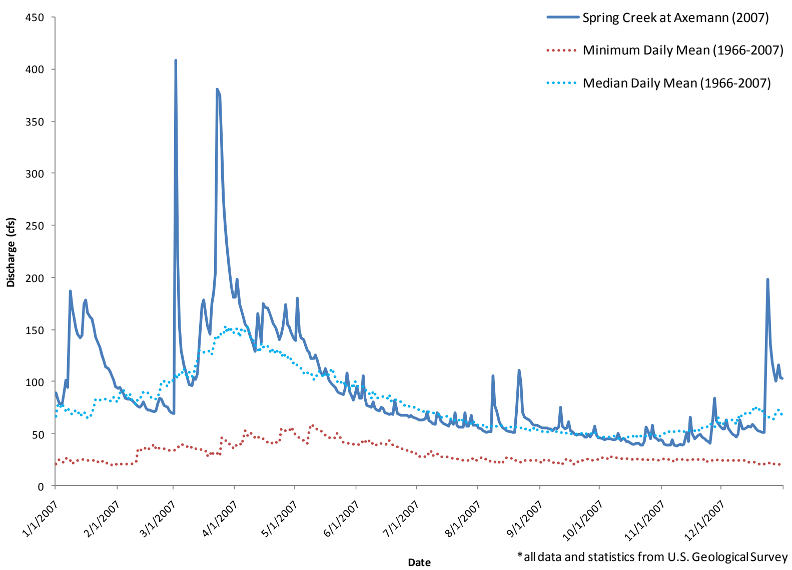

Figure 7: Comparison of discharge data from Spring Creek at Axemann versus historic data

early fall. Figure 8 compares daily discharge data from 2007 from Buffalo Run upstream of Fillmore (BUU) with historical daily discharge data and 2007 daily discharge data from Buffalo Run near Coleville (BUL). Although Coleville is downstream of Fillmore on Buffalo Run, the downstream section is perched above the water table and loses water to the water table during low-flow conditions. Discharge at the lower Buffalo Run site actually fell below historic levels as early as mid-June and did not rebound again until late-December.

Temperature

Temperature is arguably the most important characteristic 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

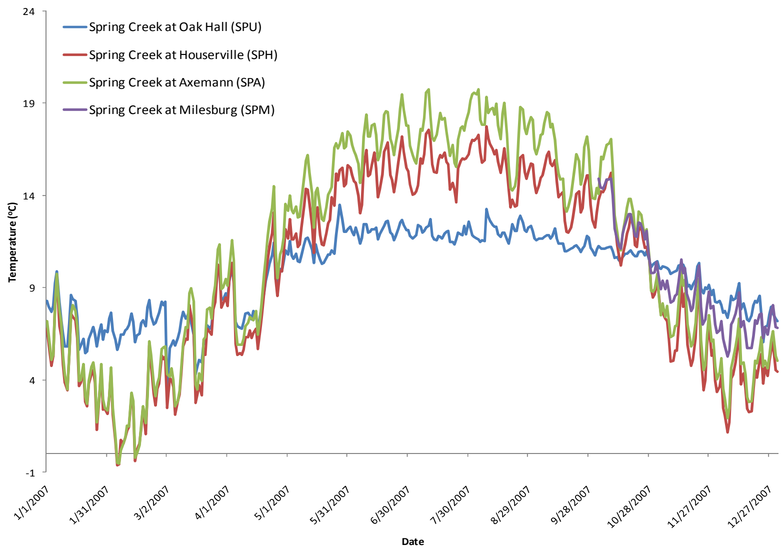

Figure 9: Median daily temperature at 4 locations on Spring Creek

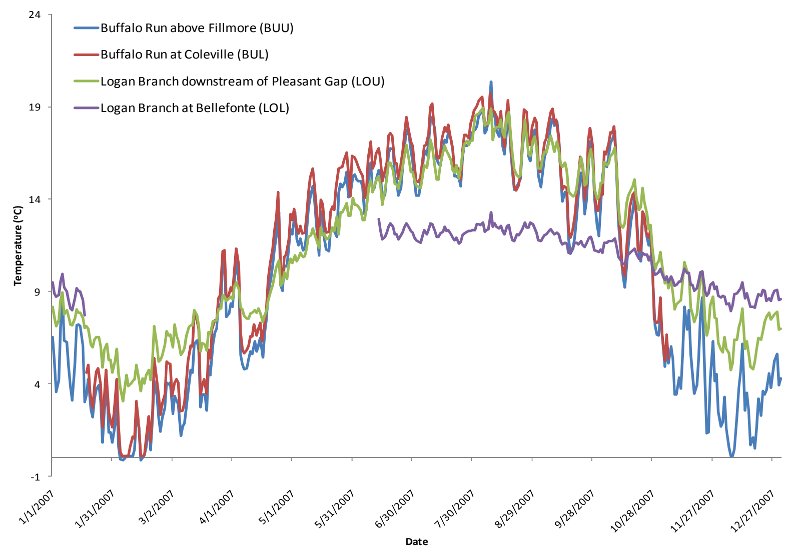

Figure 11: Median daily temperature from tributaries in the lower portion of the Spring Creek watershed

Spring Creek Watershed is directly attributable to sustained low temperatures, which is why so much attention is 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.

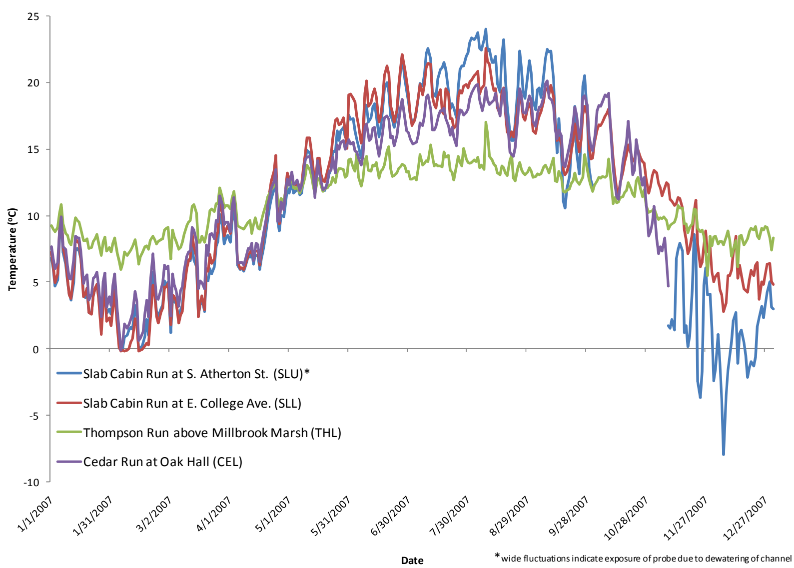

Figure 10: Median daily temperature from tributaries in upper portion of the Spring Creek watershed

Despite the extreme hydrologic conditions during 2007, the temperature of stream reaches that remained wetted during this time did not reach levels critical to resident brown trout populations. Only during very brief periods of time did temperature near this threshold, and then only at one site, lower Slab Cabin Run near East College Avenue in State College (Figure 10). Figures 9 – 12 show average daily temperatures for all sites monitored

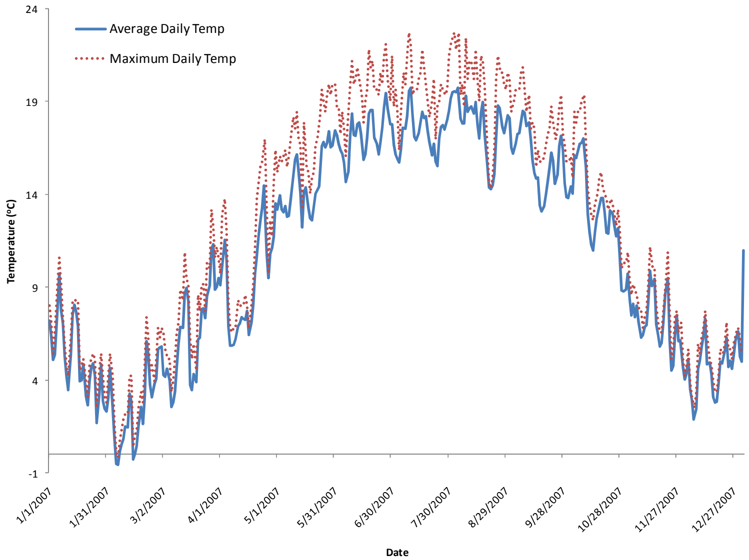

Figure 12: Comparison of average daily temperature and maximum daily temperature at Spring Creek at Axemann during 2007

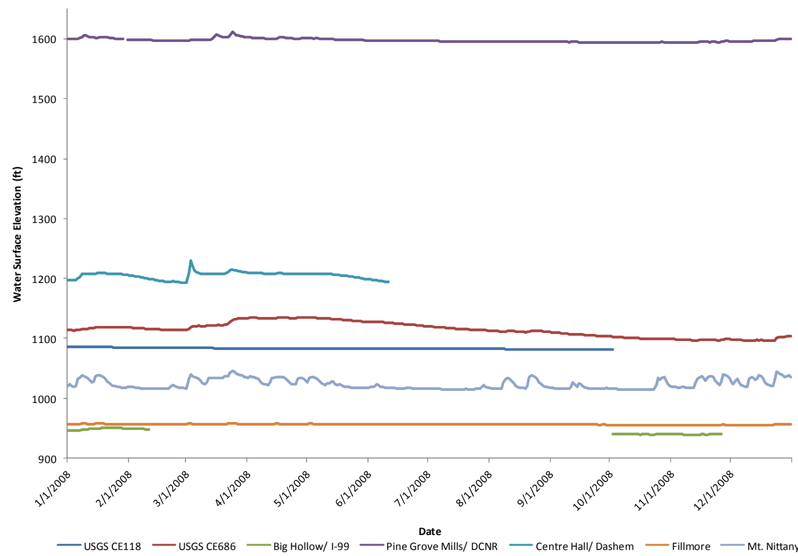

Figure 13: Comparison of water surface elevations of seven wells monitored by the WRMP during 2007

by the WRMP during 2007. Figure 12 shows the difference between average daily temperature and maximum daily temperature at Spring Creek at Axemann (downstream of Fisherman's Paradise). Maximum daily temperature during 2007 never reached critical levels at this site, and the departure from the maximum was only a few degrees in each instance.

Ground water

During 2007, 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 3 is a map showing the location of the seven wells where elevation data was recorded during 2007.

Ground-water elevations declined throughout 2007. Normal fluctuations as a result of wet/dry periods were present early in the year, but as we approached summer, a steady decline occurred that only began to rebound in December, much like surface water conditions. A comparison of all wells monitored as part of the WRMP during 2007 can be found in Figure 13. USGS monitoring well CE686 began 2007 near median levels but fell below and remained below median levels throughout 2007. Although 2007 levels were below median levels for well CE686, they only neared record low levels for a given date during late August (Figure 14). Water surface elevation of the Fillmore well, which is closely related to surface water conditions of Buffalo Run, fell below median values in late August and remained below the median value throughout the remainder of 2007 (Figure 15).

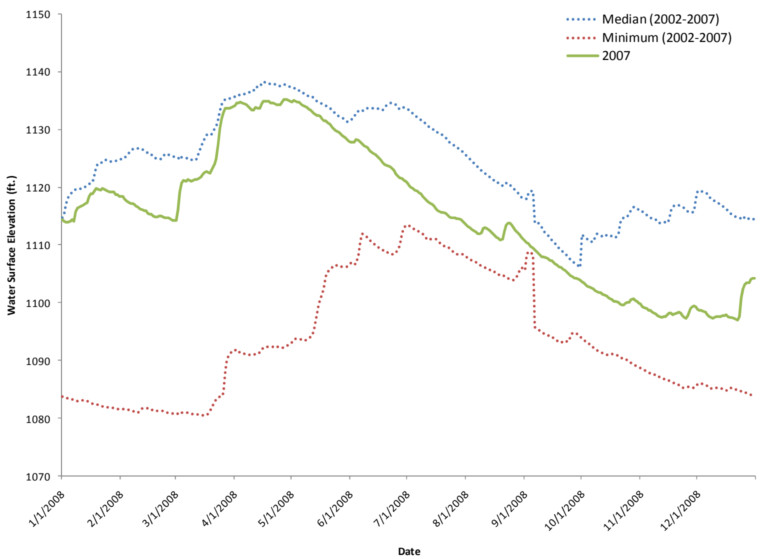

Figure 14: Comparison of 2007 water surface elevation at USGS monitoring well CE686 versus historical median and minimum daily elevations

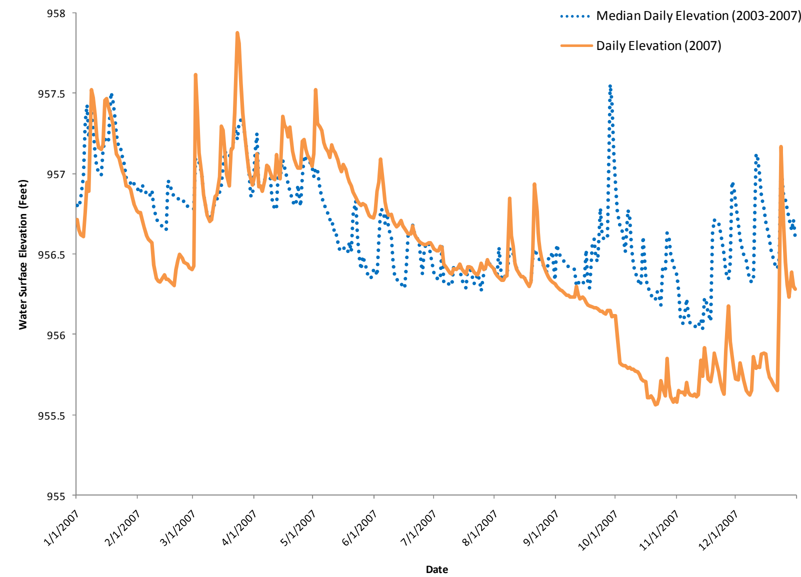

Figure 15: Comparison of 2007 water surface elevation of Fillmore Well versus historical median daily data

Figure 16 depicts ground-water elevations for USGS 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 and 2007 from record high levels of July 2005. However, present levels are 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.

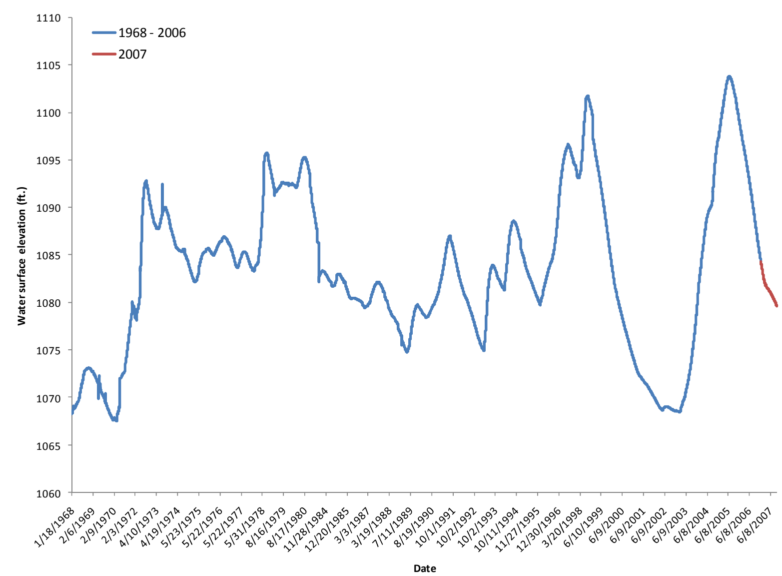

Figure 16: Water surface elevation of USGS monitoring well CE118 throughout period of record

We hope that you found this year's report on the State of the Water Resources very informative. The current state of the Chesapeake Bay is a national catastrophe and each one of our lives will be in some way be affected by the Chesapeake Bay Tributary Strategy. The Water Resources Monitoring Project, which has been in place for nearly 10 years, will provide vital data to help better manage our watershed and ultimately help restore the Chesapeake Bay. Your continued support will help this project maintain our ability to respond to new information needs and provide credible data to monitor the future changes within the watershed due to new Chesapeake Bay Tributary Strategy regulations.

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 included in the WRMP

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)	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 2007

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**	40.2	ND	ND	ND	ND	ND	2.0**	35.5*	72.0*
Buffalo Run - Valley View	BVV	5.0*	49.8	ND	ND	ND	ND	ND	2.0**	43.0*	128.0
Buffalo Run - Lower	BUL	5.0**	57.5	ND	ND	ND	ND	ND	2.0**	10.0*	80.5
Logan Branch Upper	LOU	5.0**	73.7	ND	ND	ND	ND	ND	2.0**	10.0**	196.0
Logan Branch - Lower	LOL	5.0**	13.1	ND	ND	ND	ND	ND	2.0**	10.0**	18.5*
Slab Cabin Run - Upper	SLU	5.0*	63.8	ND	ND	ND	ND	ND	2.0**	10.0*	109.0
Slab Cabin Run - Lower	SLL	5.0**	55.3	ND	ND	ND	ND	ND	2.0**	10.0**	82.5*
Slab Cabin Run - Millbrook	MIL	5.0**	42.5	ND	ND	ND	ND	ND	2.0*	10.0**	60.0
Spring Creek - Upper	SPU	5.0**	14.5*	ND	ND	ND	ND	ND	2.0*	10.0**	45.0*
Spring Creek - Houserville	SPH	5.0**	31.2	ND	ND	ND	ND	ND	2.0**	10.0**	48.5
Spring Creek - Axemann	SPA	5.0*	43.6	ND	ND	ND	ND	ND	2.0**	10.0**	48.5
Spring Creek - Milesburg	SPM	5.0*	41.0	ND	ND	ND	ND	ND	2.0*	10.0**	74.0
Cedar Run - Lower	CEL	5.0**	58.5	ND	ND	ND	ND	ND	2.0**	10.0*	69.5
Thompson Run - Lower	THL	5.0**	39.8	ND	ND	ND	ND	ND	2.0**	10.0**	62.0

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
Buffalo Run - Upper	BUU	ND	ND	10.5	14.5	ND	ND	15.5	16.0	5.0**	8.5*
Buffalo Run - Valley View	BVV	ND	ND	24.1	32.6	ND	ND	19.4	19.1	5.0**	5.0**
Buffalo Run - Lower	BUL	ND	ND	4.4	8.5	ND	ND	9.3	9.7	5.0*	5.0*
Logan Branch Upper	LOU	ND	ND	3.5	5.3	ND	ND	11.9	11.8	5.0*	5.0*
Logan Branch - Lower	LOL	ND	ND	1.0*	1.0*	ND	ND	10.3	10.7	16.5*	30.0
Slab Cabin Run - Upper	SLU	ND	ND	8.1	15.3	ND	ND	10.5	11.2	5.0**	12.0*
Slab Cabin Run - Lower	SLL	ND	ND	3.2*	5.1	ND	ND	23.4	24.1	5.0**	5.0**
Slab Cabin Run - Millbrook	MIL	ND	ND	5.5	7.2	ND	ND	24.8	24.7	5.0**	5.0*
Spring Creek - Upper	SPU	ND	ND	1.0*	1.0*	ND	ND	8.6	8.8	5.0**	8.5*
Spring Creek - Houserville	SPH	ND	ND	3.9*	5.6	ND	ND	15.0	15.1	5.0*	5.0**
Spring Creek - Axemann	SPA	ND	ND	1.6*	3.2	ND	ND	26.0	26.9	5.0*	5.0*
Spring Creek - Milesburg	SPM	ND	ND	3.6	5.4	ND	ND	18.2	19.1	11.0*	15.5
Cedar Run - Lower	CEL	ND	ND	1.0*	4.2*	ND	ND	5.4	5.6	5.0*	5.0**
Thompson Run - Lower	THL	ND	ND	2.7	7.5	ND	ND	24.4	24.2	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: Median Stream Water Quality Results (Nutrients & Physicochemical) for 2007

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)
Buffalo Run - Upper	BUU	72.4	27.5	294.0	25.8	102.5	2.8*	1.21*
Buffalo Run - Valley View	BVV	29.1	4.1	89.0	19.1	21.8	4.0*	2.17*
Buffalo Run - Lower	BUL	63.2	25.4	263.0	17.4	52.5	4.5*	0.83*
Logan Branch Upper	LOU	82.7	26.4	316.0	26.6	103.1	12.0*	2.12
Logan Branch - Lower	LOL	50.0	19.0	207.0	21.9	35.6	3.0	0.50**
Slab Cabin Run - Upper	SLU	55.6	22.4	231.0	22.9	26.5	4.0*	3.32
Slab Cabin Run - Lower	SLL	65.0	28.9	281.5	53.5	31.9	1.0*	1.74*
Slab Cabin Run - Millbrook	MIL	67.3	28.8	287.0	59.0	17.1	1.0*	1.39*
Spring Creek - Upper	SPU	61.5	19.8	235.0	19.7	22.5*	1.0*	0.82*
Spring Creek - Houserville	SPH	67.4	24.8	269.5	36.3	34.4	4.6*	0.05*
Spring Creek - Axemann	SPA	63.2	24.3	255.0	52.9	38.6	7.0*	0.96*
Spring Creek - Milesburg	SPM	57.4	22.0	230.8	37.3	35.5	3.5*	0.86*
Cedar Run - Lower	CEL	71.6	22.9	273.5	14.4	25.4	1.5*	2.13*
Thompson Run - Lower	THL	66.2	28.8	284.5	59.4	22.4	2.5*	0.96*

Site Name	Abbrev	pH (units)	Diss. Oxygen (mg/L)	Temperature (°C)	Conductivity (mS)	Nitrate (mg/L)	Orthophosphorus (mg/L) Total
Buffalo Run - Upper	BUU	8.2	12.44	9.8	407.1	1.36	0.008*
Buffalo Run - Valley View	BVV	8.1	12.28	6.0$	229.4	0.27	0.022
Buffalo Run - Lower	BUL	8.5	13.78	11.9	339.4	1.99	0.005**
Logan Branch Upper	LOU	8.3	12.24	11.1	437.1	4.58	0.029
Logan Branch - Lower	LOL	8.2	11.62	10.9	330.7	3.21	0.010*
Slab Cabin Run - Upper	SLU	8.2	11.38	10.6	402.1	3.15	0.016
Slab Cabin Run - Lower	SLL	8.4	12.74	11.6	468.9	2.77	0.005*
Slab Cabin Run- Millbrook	MIL	8.3	12.12	9.3$	491.0	3.91	0.010*
Spring Creek - Upper	SPU	7.9	11.05	9.7	325.6	2.62	0.005*
Spring Creek - Houserville	SPH	8.4	11.98	9.4	404.3	3.49	0.005*
Spring Creek - Axemann	SPA	8.4	15.10	10.5	431.8	4.38	0.033
Spring Creek - Milesburg	SPM	8.5	12.54	9.3	370.2	3.48	0.025
Cedar Run - Lower	CEL	8.5	13.35	12.1	360.8	4.58	0.005*
Thompson Run - Lower	THL	8.3	12.24	11.1	497.0	4.16	0.015

* 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

Appendix 4: Median Spring Water Quality Results (Metals) for 2007

Site Name	Abbrev	Aluminum (mg/L) Dissolved	Aluminum (mg/L) Total	Cadmium (mg/L) Dissolved	Cadmium (mg/L) Total	Chromium (mg/L) Dissolved	Chromium (mg/L) Total	Copper (mg/L) Dissolved	Copper (mg/L) Total	Iron (mg/L) Dissolved	Iron (mg/L) Total
Axemann Spring	AXS	5.0**	5.0**	ND	ND	ND	ND	ND	ND	10.0**	10.0*
Benner Spring	BES	5.0**	15.8	ND	ND	ND	ND	ND	ND	10.0**	16.5*
Big Spring	BIS	5.0*	5.0**	ND	ND	ND	ND	ND	ND	10.0*	10.0**
Blue Spring	BLS	5.0**	20.9*	ND	ND	ND	ND	ND	ND	10.0**	28.0*
Continental Courts Spring	COS	5.0**	5.0**	ND	ND	ND	ND	ND	ND	10.0**	10.0**
Linden Hall Park Spring	LIS	5.0**	5.0**	ND	ND	ND	ND	ND	ND	10.0**	10.0**
Windy Hill Farm Spring	WIS	5.0**	31.2	ND	ND	ND	ND	ND	ND	10.0**	973.5

Site Name	Abbrev	Lead (mg/L) Dissolved	Lead (mg/L) Total	Manganese (mg/L) Dissolved	Manganese (mg/L) Total	Nickel (mg/L) Dissolved	Nickel (mg/L) Total	Sodium (mg/L) Dissolved	Sodium (mg/L) Total	Zinc (mg/L) Dissolved	Zinc (mg/L) Total
Axemann Spring	AXS	ND	0.5**	1.0**	1.0**	ND	ND	11.2	11.5	5.0*	9.5*
Benner Spring	BES	ND	0.5**	1.0**	1.0**	ND	ND	17.5	17.8	5.0**	5.0*
Big Spring	BIS	ND	0.5**	1.0**	1.0**	ND	ND	8.6	8.8	5.0**	5.0**
Blue Spring	BLS	ND	0.5*	1.0*	17.3*	ND	ND	2.8	2.8	5.0*	10.0*
Continental Courts Spring	COS	ND	0.5**	1.0**	1.0**	ND	ND	8.5	9.1	5.0**	5.0*
Linden Hall Park Spring	LIS	ND	0.5**	1.0**	1.0**	ND	ND	3.2	3.2	5.0**	5.0*
Windy Hill Farm Spring	WIS	ND	0.5**	1.0**	4.3	ND	ND	10.9	11.2	5.0**	46.0*

* 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 4: Median Spring Water Quality Results (Nutrients & Physicochemical) for 2007

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	77.5	35.3	330.0	32.4	32.5	7.0	0.5**
Benner Spring	BED	61.7	22.7	248.0	41.5	15.8	1.5	0.5**
Big Spring	BIS	31.3	15.8	143.5	18.2	10.0*	1.0*	0.5**
Blue Spring	BLS	34.3	6.1	156.0	4.8	23.2	1.0*	0.5*
Continental Courts Spring	COS	58.7	26.6	256	19.4	15.3	13*	0.5**
Linden Hall Park Spring	LIS	76.7	31.7	322.5	8.0	23.1	1.0*	0.5**
Windy Hill Farm Spring	WIS	60.5	28.8	269.5	22.3	18.3	5.5*	0.5**

Site Name	Abbrev	pH (units)	Diss. Oxygen (mg/L)	Temperature (^{o}C)	Conductivity (mS)	Nitrate (mg/L)	Orthophosphorus (mg/L) Total	Fecal Coliforms (#col/ 100mL)
Axemann Spring	AXS	7.4	9.35	10.3	486.0	6.64	0.005**	1.2223
Benner Spring	BES	7.6	9.35	10.3	388.6	3.84	0.005*	145.0825$
Big Spring	BIS	8.1	10.54	10.4	253.4	1.80	0.005**	5.3333
Blue Spring	BLS	7.7	9.08	9.3	211.1	1.96	0.005*	93.1111$
Continental Courts Spring	COS	7.7	7.26	10.3	359.6	2.33	0.005**	0.6667
Linden Hall Park Spring	LIS	7.5	7.31	9.8	428.2	4.68	0.005**	2.5000$
Windy Hill Farm Spring	WIS	8.1	7.54	9.3	461.6	3.86	0.005**	2.0000$

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