The Birmingham Thrust Fault (indicated in red) in the bedrock exposed along Skytop Mountain Road in Patton Township (T. Giddings).

FROM THE CHAIR

In the 2015 State of the Water Resources Report we examine the region's geology and the connection to our water resources. We recognize it takes some imagination to understand the magnitude of the geologic events that occurred over the last 500 million years, and hope you'll enjoy thinking about these ancient events to connect with the present environment we live in and enjoy. This annual report is intended to assist the local community in better understanding the various water resource issues we face through understanding our region's geology.

The Water Resources Monitoring Project has been very fortunate to have Adrienne Gemberling as our Water Resources Coordinator for the last year. Adrienne's enthusiasm and professionalism in her first year has been nothing short of terrific and we'd like to recognize her efforts in maintaining our database and field stations, where she has the pleasure of collecting data in all sorts of weather conditions (good and bad!). Additionally Adrienne works with the community stakeholders on a variety of levels, so we hope you'll have the chance to work with her soon.

The 2015 WRMP committee members are listed in the back of this report. Together we would like to thank you all for your time and dedication to ensure this valuable project continues for many years into the future. The Water Resources Monitoring Project, which has been in place for 18 years, provides vital long-term data that can be used by local planning officials and engineers to make sound land use and water quality decisions. We could not conduct this valuable project without our volunteers, the landowners who provide us access to monitoring locations, and our project sponsors. On behalf of the committee I'd like to personally thank our participating landowners and project sponsors for the continued access and financial support the program receives on an annual basis. Your continued support will help maintain the program's ability to provide data needed to monitor water resources in the Spring Creek watershed, so as a community we can make well-informed decisions to ensure long-term stewardship for future generations. We hope you enjoy the report and always welcome the opportunity to discuss our efforts with you!

Warm regards,

David Yoxtheimer

Dave Yoxtheimer
Water Resources Monitoring Project Committee Chair

GEOLOGY OF THE SPRING CREEK WATERSHED

Introduction

Geology is literally the underlying reason we live in an area with abundant water resources and fertile soils. Understanding the relationship among geology, water resources, and land use is key to ensuring that long-term sustainable management of the region's natural resources occurs. The 2015 Annual Report looks at the Spring Creek watershed's fascinating geology through the lens of its history, structure, chemistry, and how this combination of factors created the setting we live in today. The report relates the water quality and flow data collected by the Water Resources Monitoring Project to the region's geology to facilitate a better understanding of Spring Creek's water resources and long-term conservation and stewardship.

Spring Creek Watershed's Geology

The Spring Creek watershed has its own very interesting geologic history. The parent materials for the bedrock we see today were sediments deposited from about 540 to 420 million years ago, during the Cambrian to Silurian periods of the Paleozoic era. During the early Paleozoic, Pennsylvania's land mass was near the equator, allowing the deposition of large carbonate (limestone and dolomite) formations in tropical lagoons, similar to the current Bahama Islands. These carbonate formations account for the limestone and dolomite bedrock formations found in Nittany Valley, over which Spring Creek flows. These carbonates were deposited in this tropical environment over the course of approximately 50 million years. Subsequently, the Taconic Mountains began to emerge to the east and carried clay mud deposits to the region, resulting in a thick shale over the carbonate deposits. This shale is known as the Reedsville Shale and forms the mountain side slopes around Nittany Valley, including the slopes of Tussey, Nittany, and Bald Eagle mountains. During the first half of the Silurian Period (approximately 440 to 430 million years ago), the Taconic mountains continued to erode and covered much of the state with coarser grained sandy deposits that eventually became the Bald Eagle and Tuscarora sandstones. Compared to the carbonates, these rocks are more resistant to weathering and form the tops of the ridges in the Spring Creek watershed. The Acadian Mountain Range emerged later during the Devonian Period, and caused transportation of silts, muds, and fine sand over the area within a westward migrating delta (Fail 1999). Eventually this thick sequence of sediments became interbedded shales, siltstones, and sandstones, but these rocks have long ago eroded away and are not found in the Spring Creek watershed.

Fail, Roger T. 1999. "Paleozoic", in *The Geology of Pennsylvania, Pa. Bur. of Topographic and Geologic Survey, Spec. Pub. 1*, pp. 418 – 434.

GEOLOGY OF THE SPRING CREEK WATERSHED

From a structural geology perspective, the Spring Creek watershed is located within the Appalachian Ridge and Valley physiographic province, where the bedrock is folded and faulted. These folds and faults are the consequence of great plate tectonic forces generated during the late Paleozoic Alleghenian Orogeny, when northern Africa collided with North America. As a result, Himalayan-sized mountains formed via a series of anticlines (upward arching folds) and synclines (fold troughs between the arches). Nittany Valley was formed by a major arch structure called the Nittany Anticlinorium, and it would seem intuitive that it should be a mountain rather than a valley; however, erosion and weathering played a major role in controlling the local topography. The edges of the valley are sandstone ridges which weathered slowly whereas the center of the valley consists of carbonates which weathered more rapidly. The highest parts of the Nittany Anticlinorium anticlines weathered first; hence, the sandstones (with the highest elevations) were removed first, exposing the carbonates. Once exposed the carbonates weathered more rapidly than the sandstone leading to a topography that is inverted, meaning that the structural high (anticline) became the topographic low because the core of the anticline was carbonate bedrock. **Figure 1** shows the topography of the region and outlines the Spring Creek watershed. Over geologic time the even-crested ridges we now see were formed by resistive sandstones, namely the Bald Eagle and Tuscarora formations that are roots of the ancient mountains and the valley is floored with carbonate rocks which form soils that

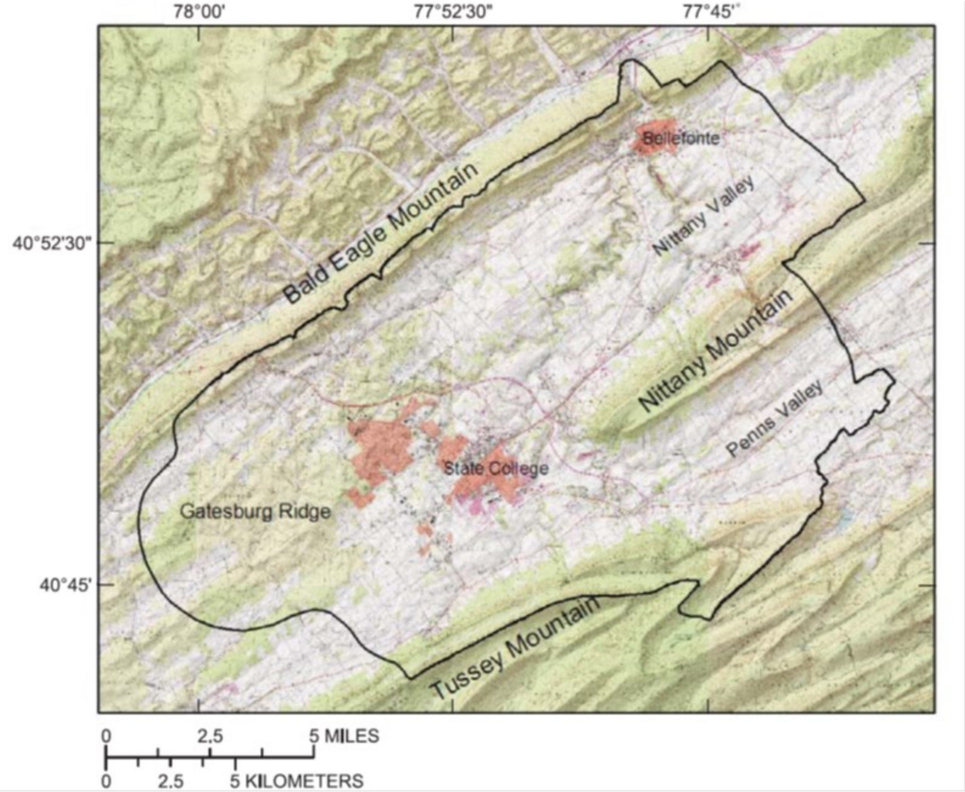


Figure 1. Topography of the Spring Creek watershed (Fulton et al., 2005).

Fulton, John W., et al. 2005."Hydrogeologic setting and conceptual hydrologic model of the Spring Creek basin, Centre County, Pennsylvania, June 2005."*US Geological Survey, Scientific Investigations Report* 5091.

make rich farmland. Despite all the erosion that has taken place, Nittany Valley is underlain by 6,000 to 8,000 feet (ft) of interbedded limestone, dolomite, and sandstone. **Figure 2** shows a geologic map of the Spring Creek watershed along with associated geologic cross sections as **Figures 3a** and **3b**.

It is worth noting that glaciers covered the northern portions of the state within the past 25,000 years; however, the ice did not reach as far south as the Spring Creek watershed. The glaciers were close enough to cause extreme freeze and thaw cycles (known as periglacial activity) in the area causing some rock beds near the surface to break into boulder size pieces as can be seen along the local ridges.

The rocks in the Spring Creek watershed have been fractured by many different forces, principally those that formed the Appalachian Mountains. Numerous faults within the watershed have offset rock layers and the Birmingham Thrust Fault is a major fault extending through much of the northern part of Nittany Valley from Scotia to Bellefonte. Some planar, vertical zones of concentrated fracturing are expressed topographically within the watershed. These features can be identified on

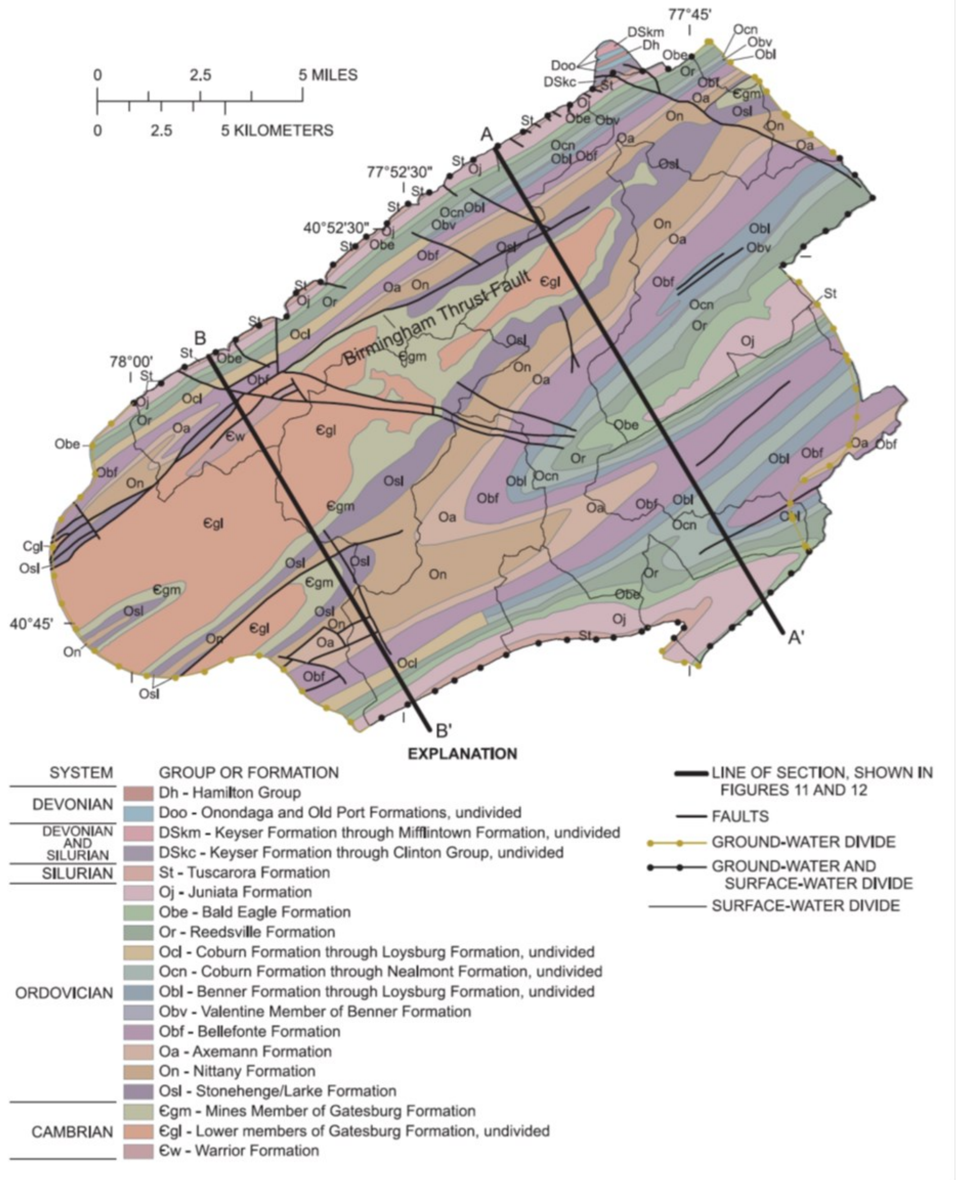
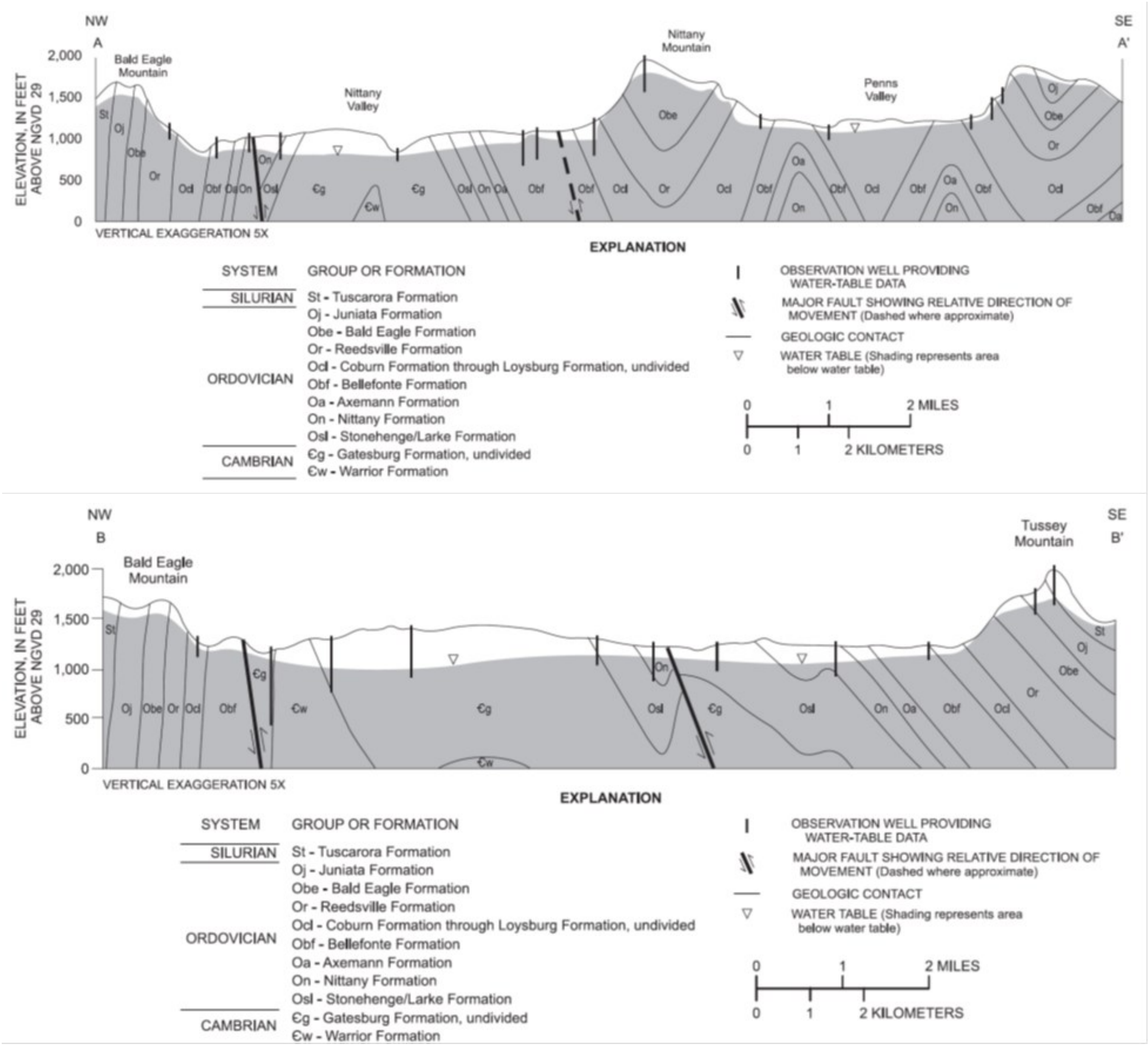


Figure 2. Geologic map of the Spring Creek watershed (Fulton et al., 2005).



Figures 3a and 3b. Geologic cross section of the Spring Creek watershed, A to A’ and B to B’, (Fulton et al., 2005).

aerial photos or satellite imagery as linear features on the landscape and are referred to as fracture traces. Fracture traces are expressed on the imagery as topographic, vegetation, or soil-tonal alignments greater than 1,000 ft, but less than 1 mile in length. Maps of fracture traces in the State College area by Lattman and Parizek (1964) and Parizek and Drew (1966) suggest they are abundant and tend to have north-south and east-west orientations, giving rise to large, irregular, rectangular blocks of bedrock. Their location is important because wells drilled on fracture traces and fracture trace intersections in the Spring Creek watershed generally have higher yields than those drilled off fracture traces (Lattman and Parizek 1964; Parizek and Drew 1966; Siddiqui 1969), and thus they may act as zones of enhanced groundwater flow. It is worth noting that Lattman and Parizek pioneered the fracture trace analysis method in Nittany Valley's carbonate geology and it has become a common geologic assessment tool practiced around the world for maximizing water well yield and assessing preferred pathways for contaminant migration in groundwater. As described in the next section, the carbonate bedrock of Nittany Valley has been geochemically modified to form Spring Creek's hydrogeologic setting.

Lattman, L. H., and Parizek R.R. 1964."Relationship between fracture traces and the occurrence of ground water in carbonate rocks." *Journal of hydrology* 2.2: 73-91.

Parizek, R.R., and Drew, L.J. 1966. Random drilling for water in carbonate rocks. Proceedings of a Symposium and Short-Course on Computers and Operations Research in Mineral Industries. Mineral Induestries Experiemtn Station. V3. The Pennsylvania State University, University Park, Pa. V3. (Special Publication 2-65), pp. 1-22.

Siddiqui, S.H. 1969. Hydrogeologic factors influencing well yields and aquifer hydraulic properties of folded and faulted carbonate rocks in Central Pennsylvania. Water Resources Research. V. 7, no. 5, pp. 1295-1312.

KARST GEOLOGY OF THE SPRING CREEK WATERSHED

When carbonate bedrock is exposed to slightly acidic water, the water has the potential to dissolve the bedrock. The dissolution of the bedrock occurs where carbon dioxide in soils mixes with rainwater moving downward from the surface and forms a weak acid (carbonic acid) that slowly dissolves limestone (calcium carbonate or $CaCO_3$) and dolomite (calcium magnesium carbonate or $CaMgCO_3$) bedrock. The slightly acidic groundwater moving through fractures and other spaces within the rock gradually enlarges small openings, creating passages and networks of interconnected conduits. This dissolution of the carbonate bedrock promotes the formation of cavities (known as vugs), sinkholes, conduits, sinking streams, springs, and caves; collectively known as karst features. Thus Nittany Valley is characterized as karst terrain. This combination of karst features can have a significant influence on surface water and groundwater flow.

The streams flowing off of the mountain slopes and into Nittany Valley encounter the permeable karst terrain. In some cases, this runoff is slightly acidic, which can contribute to the chemical weathering of carbonate rock on the valley floor. At this position on the landscape, some or all of a stream's flow may sink into the subsurface. This can be witnessed, especially during the drier months of the year, at Slab Cabin Run and Roaring Run, where some or all of the flow gradually, or even abruptly, sinks into the subsurface along permeable sections of the streambed or at sinkholes as the streams flow across the karst terrain.

It has been estimated that mountain runoff including the lost stream flow provides upwards of 50% of the Spring Creek watershed's aquifer recharge (Konikow 1969). **Figure 4** shows the various mechanisms for groundwater recharge in the watershed. Most groundwater is stored and transmitted through porosity formed by dissolution, which represents an average of one to two percent of the aquifer's volume, based on estimates by Giddings (1974). The aquifers in Nittany Valley are anisotropic and heterogeneous, meaning that groundwater flows preferentially in certain directions where geologic features provide the path of least resistance. Solution enlarged fractures, faults, and bedrock bedding planes often provide the key pathways for groundwater to flow on local to regional scales. In addition, zones of fracture concentration identified as fracture traces can provide avenues for significant groundwater flow on a local to regional basis. The nature of groundwater flow and well

Konikow, L.F.1969. Mountain runoff and its relation to precipitation, groundwater and recharge to the carbonate aquifers of Nittany Valley, Pennsylvania: University Park, Pa., The Pennsylvania State University, M.S. thesis, 128 p.

Giddings, M.T.1974. Hydrologic budget of Spring Creek Drainage Basin, Pennsylvania: University Park, Pa., The Pennsylvania State University, Ph.D. dissertation, 76 p.

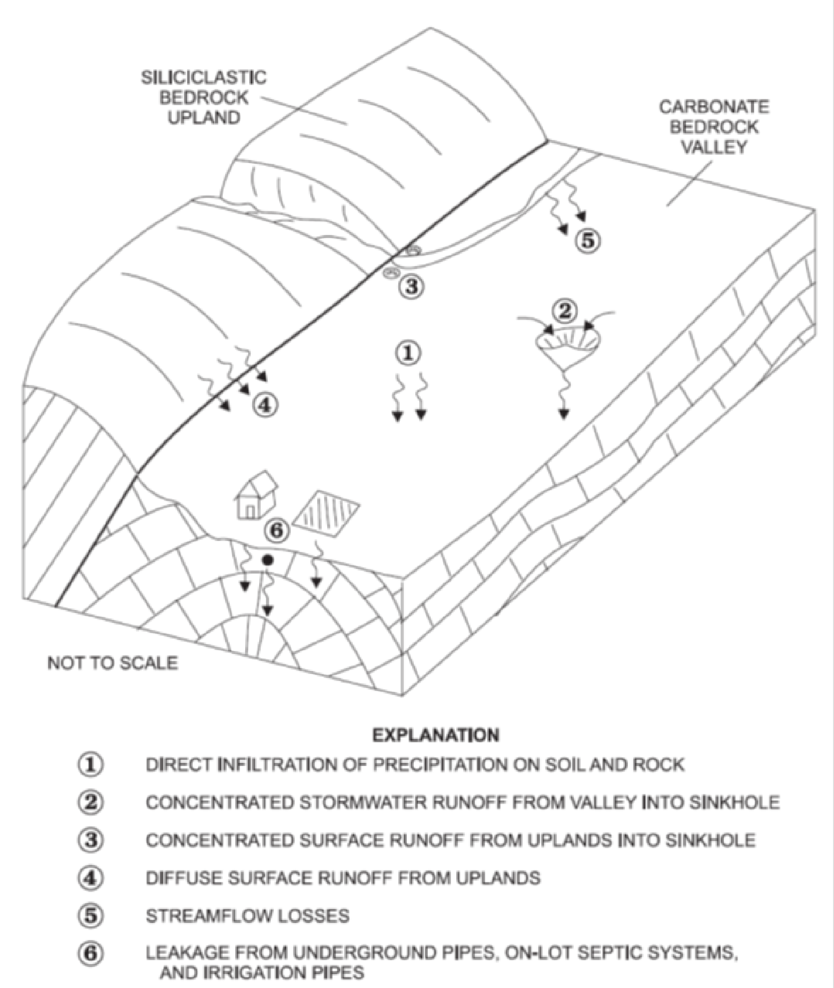


Figure 4. Groundwater recharge mechanisms in the Spring Creek watershed (Fulton et al. 2005).

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yields within Nittany Valley can be greatly influenced by the presence of fracture traces. Typically the limestone is very dense and mostly impermeable, except where solution processes have enlarged the bedrock fractures. This explains why a well's yield at one location may be quite high (in excess of 1,000 gallons per minute (gpm), while another nearby well's yield may be quite low (less than 5 gpm).

In some locations, faults have juxtaposed rock layers with different hydraulic properties and create impediments to groundwater flow. The same faults can have associated fracture zones that channel groundwater flow parallel to the faults, as described in the next section.

The Spring Creek watershed has two types of watershed boundaries as shown in **Figure 5'**s cross-section diagram. The surface-water boundary is on the left and the groundwater boundary on the right. The headwater area of the Big Spring in Bellefonte has its western boundary in the Spruce Creek surface watershed. When rainfall and snowmelt water infiltrate into some of the upper portion of the Spruce Creek surface watershed, shown by the blue drop of water above, this water percolates down to become groundwater recharge to the Spring Creek Groundwater watershed.

This groundwater recharge flows to the east and discharges from the Big Spring. The "stealing" of groundwater from beneath the Spruce Creek surface watershed in this manner is called groundwater piracy (Arrrrgh!). Groundwater piracy occurs due to the orientation of rock beds dipping beneath Spruce Creek toward Spring Creek and directing groundwater under the surface divide, and may be further accentuated by the orientations of faults. In most other areas of the watershed, the surface water and groundwater drainage boundaries are more or less coincident.

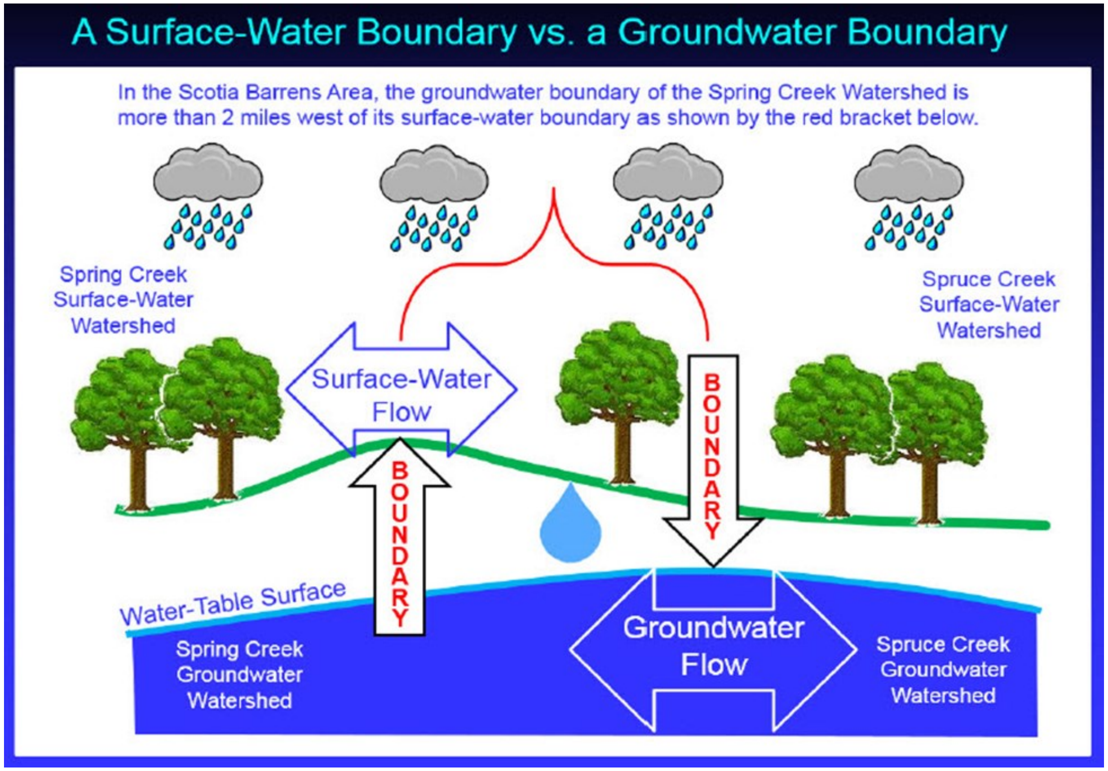


Figure 5. Types of watershed boundaries in the Spring Creek watershed (T. Giddings).

Figure 6 shows the groundwater boundary (red line) and the surface-water boundary (purple line) of the Spring Creek watershed. Where the two boundaries are coincident, there is a single red line shown. The blue dot in Bellefonte is the location of Big Spring, and the black dashed-line is the location of the Birmingham Thrust Fault in the

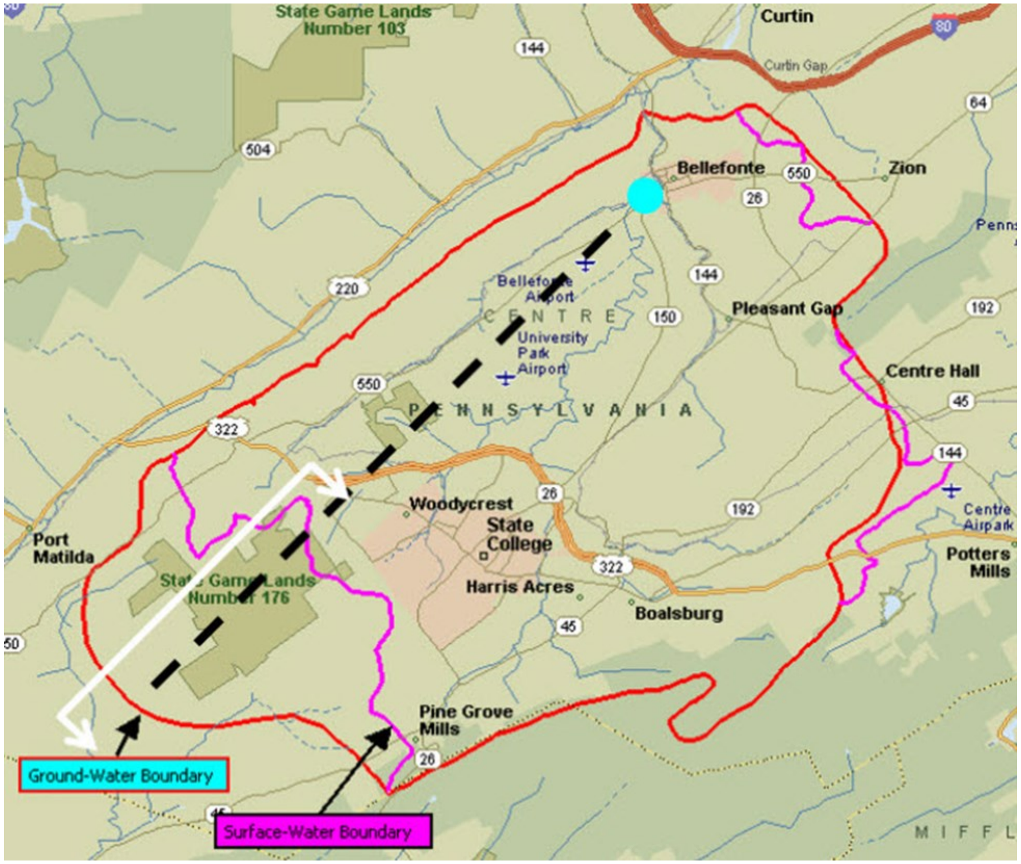


Figure 6. Map showing the difference in the groundwater and surface watershed boundaries (T. Giddings).

subsurface. The white line is the location of the cross-section shown in the diagram above, and the arrows show the direction of view. The land area between the surface-water boundary and the groundwater boundary is within the headwater area of the Big Spring in Bellefonte. Within the headwaters recharge area of Big Spring, State Game Lands 176 provides 6,423 acres (about 10 square miles) of undeveloped, natural oak forest and open meadows underlain by permeable soils that provide ideal groundwater recharge conditions. The area of the surface-water watershed of Spring Creek is 146 square miles, while its groundwater watershed extends another 29 square miles.

During the Appalachian mountain building event, layers of dolomite (carbonate) bedrock were ground against each other as the layers on the southeast side of the Birmingham Fault plane were pushed up and over the layers on the northwest side of the fault plane. The Birmingham Thrust Fault plane is exposed in an outcrop on the east side of Skytop Mountain Road in Patton Township as shown in **Figure 7** and on the cover of our report. The fault plane is indicated by the red dashed line between the red arrows in the photo of the rock outcrop. The white arrows show the direction of movement of the bedrock layers.

Over eons of geologic time, slightly acidic rainfall and snowmelt water became groundwater recharge, and this groundwater dissolved the ground-up bedrock along the fault plane at a faster rate than the adjacent intact bedrock. Today large open solution conduits that formed along the fault plane below the water table provide a preferential groundwater flow path to the pool of the Big Spring in Bellefonte. **Figure 8** shows an example of a very large solution conduit similar to those that would be found along the plane of the Birmingham Thrust Fault. The ease of groundwater flow to the Big Spring through the open solution conduits is the cause of the groundwater piracy from beneath the Spruce Creek surface-water watershed. The groundwater flow is taking the path-of-least-resistance to the Big Spring, some 15 miles to the northeast of the headwaters recharge area around and including State Game Lands 176. **Figure 9** shows an oblique view of the groundwater boundary for the Spring Creek watershed. Each red double circle represents a municipal water-supply

Figure 7. The Birmingham thrust fault along Skytop Road (T. Giddings).

Figure 8. A typical large, dry solution conduit similar to those found along the Birmingham Thrust Fault (T. Giddings).

well or well field. Each day all of the public and private groundwater wells supply approximately 16 million gallons of groundwater to the approximately 120,000 residents and visitors within the watershed. Each arrow shows the location of a mountain stream that flows off Bald Eagle Ridge, Nittany Mountain, or Tussey Mountain. The mountain ridges are green in this photo because they are forested and undeveloped, so the runoff water is of very high quality. At the point of each light-blue arrow there is a sinkhole or recharge zone at the edge of the carbonate bedrock valley floor that is shown by the yellow shading. When these mountain streams flow into sinkholes, their high-quality surface-water runoff becomes groundwater that continuously recharges the carbonate aquifers beneath the valley floor.

We are very fortunate that the Spring Creek watershed has these many mountain streams that continuously recharge the carbonate aquifers that are continuously supplying the 16 million gallons per day (gpd) of groundwater and are being pumped out for our use. On a daily basis the average annual flow of Spring Creek is 230 cubic ft per second (cfs), which equates to

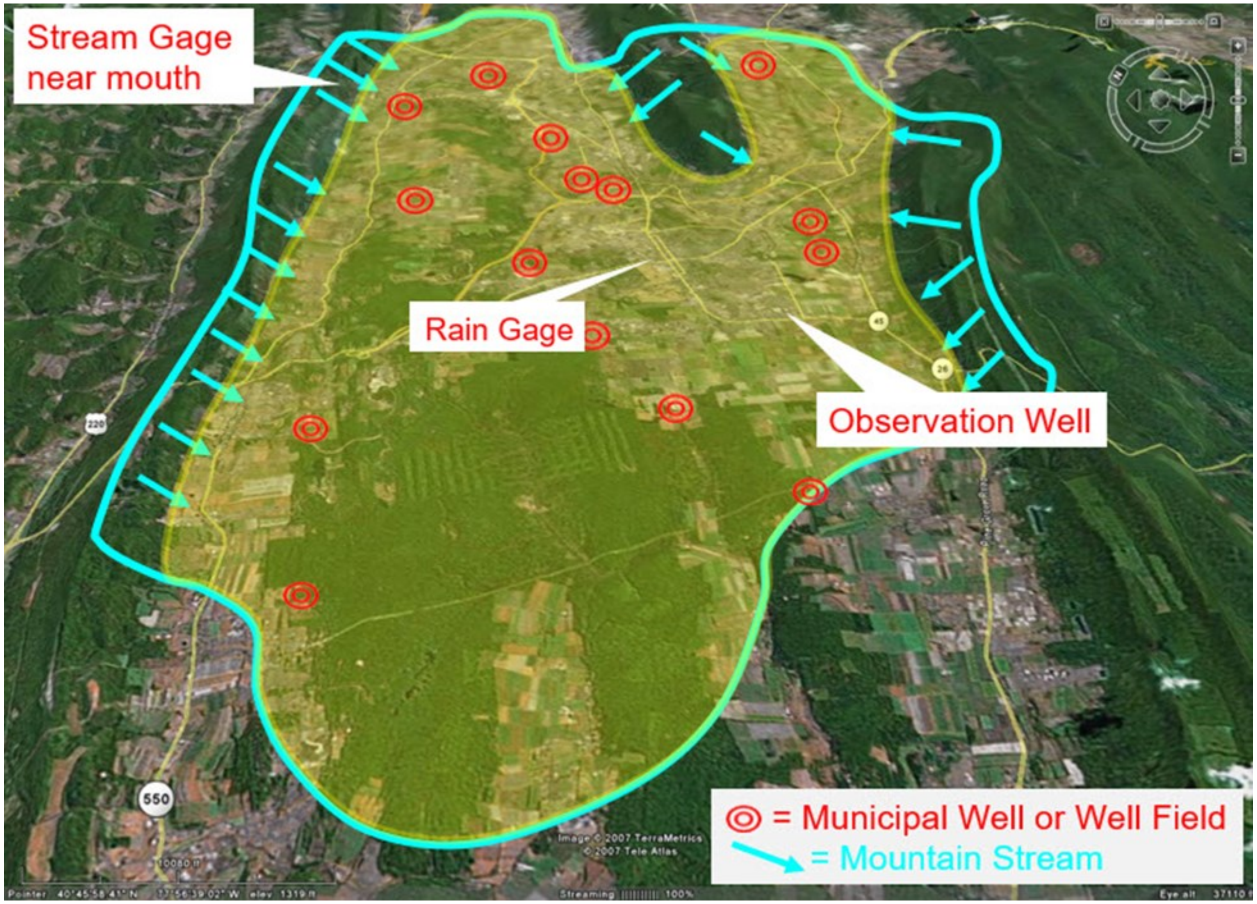


Figure 9. Oblique view (looking northeast) showing the Spring Creek watershed and the various public sources of groundwater supply (T. Giddings).

about 103,000 gallons per minute or nearly 150 million gpd of flow. Therefore, collectively slightly more than 10% of all of Spring Creek's water resources are withdrawn on a daily basis as our drinking water supply, with most of it returned to Spring Creek via municipal wastewater treatment plant discharges.

Approximately 85% of Spring Creek's annual average flow is comprised of groundwater that feeds into the stream via springs. During periods of no rainfall or snowmelt, 100% of the water in our streams is sourced from groundwater. The temperature and high quality of this groundwater flow provides an aquatic habitat that is ideal for trout and a flow quantity that is ideal for kayaking and canoeing in some downstream locations, even during a drought.

CORRELATING THE WMRP DATA TO THE GEOLOGY

In the Spring Creek watershed, karst geology creates a strong interconnection between surface water and groundwater and provides a setting that sustains consistent cold baseflow and high water quality. Using the data collected by the Water Resource Monitoring Project, we can better understand the influence of karst geology on our water resources.

The dataset collected by the Water Resource Monitoring Project provides an opportunity to understand how temperature, discharge, and water quality track with the underlying geology at each of our monitoring locations. We can also pair this data with land use in the watershed to understand how land use changes, such as urbanization, impact these parameters and why karst aquifers are vulnerable to contamination. In the following sections we explain how the geology of the watershed and land use affected water quantity and quality in 2015 and over the WRMP project period of record.

Stream Temperature

One of the most important aspects influencing stream ecology is water temperature. Temperature plays a role in nearly all biogeochemical processes including oxygen solubility, metal oxidation state, and metabolism of aquatic inhabitants from small invertebrates to large fish. Spring Creek is world renowned for the brown trout fishery it sustains despite its location within a relatively urbanized area. Water temperatures within the Spring Creek watershed remain below the threshold that adversely impacts trout populations (24°C or 75°F) in large part due to the significant groundwater component of its base flow. Groundwater temperatures are largely attributed to the springs that emanate from the karst geology of the watershed.

In general, stream temperature measurements collected from our monitoring stations reflect the underlying geology and the stations' proximity to groundwater inputs, such as springs or baseflow. Groundwater temperatures (and consequently spring temperatures) within the Spring Creek watershed typically remain around 11°C (51°F). As a general rule, tributaries in the watershed experience water temperatures that are more influenced by ambient air temperatures than that of the main stem of Spring Creek. Upper Spring Creek is fed by mountain streams and several springs on the basin floor. As Spring Creek moves downstream towards the confluence with Bald Eagle Creek, it is increasingly impacted by surface runoff and ambient air temperatures until it reaches Bellefonte where groundwater inputs from Logan Branch and Big Spring cool the stream in summer and warm the stream in winter. Tributaries such as Logan Branch experience very little temperature fluctuation across all seasons because of their close proximity to large springs. Stream reaches such as Buffalo

Run align more with ambient air temperatures because they are less influenced by groundwater inputs (**Figure 10**). Temperature variation can also be connected to stream height above the water table. Logan Branch Run and Thompson Run are sub-watersheds that have strong groundwater inputs and therefore have similar discharges and temperatures across all seasons. Within these sub-watersheds large nearby springs provide the majority of the baseflow and serve as the connection between groundwater and surface water. Buffalo Run and Slab Cabin Run sub-watersheds are perched above the water table. Being elevated above the water table means that during times of drought, the soil below the streambed is unsaturated. In these settings water in the streambed follows the natural flow path to the saturated zone and the stream disappears underground. For this reason, stream reaches of Buffalo Run, Slab Cabin, Upper Spring Creek, and Walnut Run often go dry during summer months, losing water to the underground karst system where it will later emerge downstream as spring water or baseflow. We can view this trend from pictures of Walnut Run during extreme drought, and during normal baseflow conditions (**Figure 11**).

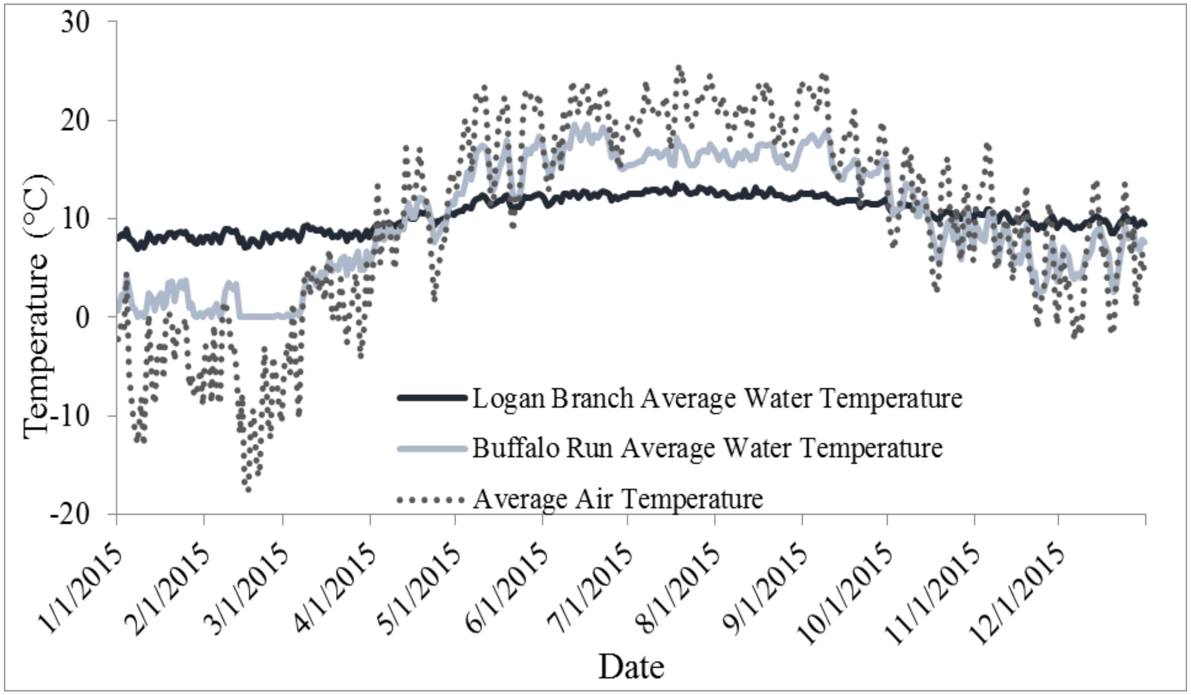


Figure 10. Average water temperature of Logan Branch and Buffalo Run compared to average air temperature in 2015.

Data from the WRMP in 2015 reflect the above observations about temperatures in the Spring

Figure 11. Walnut Run in fall 2014 (left) and during fall 2015 (right).

Creek watershed. Among our monitoring stations in tributaries and the main stem of Spring Creek, the lowest summer temperatures in 2015 were at Spring Creek in Oak Hall (the uppermost site on Spring Creek near the confluence with Cedar Run) and at Lower Logan Branch in Bellefonte. Both of these monitoring locations are in close proximity to high volume springs that provide consistent year-round cool baseflow. The station with the highest summer temperatures in 2015 was Walnut Run below Walnut Springs wetland. Walnut Run is perched above the water table and is a losing stream. During the summer, low flows enable the water to be warmed as it moves downstream from Walnut Springs Park.

Water Quantity

Looking at WRMP data from 1999 to present can tell us how the watershed, and more specifically its geology plays a role when our water resources become stressed. We learn during extreme drought conditions how karst bedrock yields groundwater baseflow to our surface waters and during periods of intense precipitation how the geology conveys stormflow and recharge. Groundwater levels can also be examined to understand how different geologic sections of the Spring Creek watershed respond to precipitation and water withdrawals.

Surface Water

One way to understand how geology affects a stream section is to look at the quantity of water the section produces during low and high flow conditions. To calculate this parameter (called basin yield), you can divide the given flow on a particular day by the area of tributary watershed. For example, at a monitoring station near the mouth of Spring Creek the average stream flow is 230 cfs and the upstream watershed area is 175 square miles (mi^2). Thus, average basin yield of the Spring Creek watershed is 1.31 cfs/mi^2 or about 590 gpm/mi^2. These data are useful because basin yield during low flows tells us how the bedrock yields groundwater baseflow to surface waters and during high flow how the landscape adds flow from precipitation as stormwater runoff and groundwater recharge.

Comparing basin yields across flow conditions and precipitation regimes helps us understand how Spring Creek and its sub-watersheds yield water. Using WRMP data we can examine how 2015 compared to 2001 and 2004, extremely dry and wet years, respectively. WRMP gage station data can be compared to the three USGS gage stations on Spring Creek because they monitor drainage from the largest contributing land areas. In 2015, the lowest flows at the USGS Spring Creek Milesburg gage occurred on February 21. Looking across all of our stations, we can see that those with the highest basin yields (and therefore the largest groundwater inputs) are Logan Branch and Thompson Run (**Table 1**). High basin yields at these locations may be due to the effects of natural subsurface geology or at Logan Branch by subsurface mining that takes places within the sub-watershed. Those streams with the lowest basin yields included Slab Cabin Run and Buffalo Run. These data also align with 2001 results from the WRMP and the understanding that Slab Cabin Run and Buffalo Run receive substantially less groundwater baseflow than Thompson Run and Logan Branch.

High flow data can demonstrate how the underlying geology of the watershed distributes stormflow. For example on July 18, 2015 the highest basin yield during stormflow conditions was at Thompson Run. Thompson Run drains the smallest area of all Spring Creek sub-watersheds and sits within a highly urbanized area with many impermeable surfaces, leading to increased surface runoff per unit land area. Underground conduits (both natural and man-made) connected to Thompson Spring convey the stormwater very quickly to Thompson Run. Upper Spring Creek, Slab Cabin Run, and Buffalo Run also showed significant basin yields during storm events. This could be attributed to runoff coming from the steep slopes of the mountains in these sub-watersheds. These data are also consistent with basin yields during Hurricane Ivan in 2004. Logan Branch basin yield is noteworthy during stormflow because it does not increase as significantly as other sub-watersheds or the main stem of Spring Creek, likely due to its subsurface geology (WRMP Annual Report 2003).

Groundwater

Since groundwater contributes the majority of streamflow in the Spring Creek watershed, we can use groundwater

Table 1. Comparison of basin yields at monitoring sites on Spring Creek and its tributary streams during high and low flow in 2015 compared to drought and high flow conditions in 2001 and 2004.

Stream Station	**Area mi^2**	**Basin Yield on 11/22/2001 cfs/mi^2 (drought)**	**Basin yield 2/21/2015 cfs/ mi^2 (lowest flow at Spring Creek Milesburg Gage in 2015)**	**Basin Yield 7/15/2015 cfs/ mi^2 (highest flow at Spring Creek Milesburg Gage in 2015)**	**Basin Yield 9/18/2004 cfs/mi^2 (Hurricane Ivan)**
Lower Buffalo Run	26.8	0.03	0.19	3.5	56.6
Lower Cedar Run	17.5	0.20	0.62	1.5	23.8
Lower Logan Branch	22.5	2.10	1.83	3.4	27.4
Lower Slab Cabin Run	16.7	0.0 (dry)	0.08	4.3	(no data)
Upper Spring Creek	13.1	0.52	0.51	4.7	96.9
Lower Thompson Run	3.94	1.50	1.70	9.7	(no data)
Spring Creek, Houserville	58.1	0.24	0.33	4.3	28.2
Spring Creek, Axemann	85.8	0.37	0.52	3.4	30.8
Spring Creek, Milesburg	145	0.69	0.85	3.8	29.9

levels within different areas to understand how groundwater is stored and discharged to surface waters. Groundwater level is controlled by several factors including precipitation, soil type and thickness, rock type and amount of fracturing, location of the well for water level monitoring, and proximity of the well to streams and sinkholes (WRMP Annual Report 2003).

The United States Geological Survey (USGS) maintains two monitoring wells within the Spring Creek watershed. USGS Well 686 (also known as CE 686) is located two miles southwest of downtown State College in the Nittany Dolomite geologic unit. This well is representative of the headwaters region of Spring

Creek. We can track the water level in this well using USGS data from 2001-2015. During the 15-year period, CE 686 had a net increase in groundwater level of 19.51 ft (**Figure 12**). Looking at **Figure 12**, you can see that water level fluctuates according to season, with groundwater recharge occurring in the spring and fall compared to the summer and winter when evapotranspiration by plants or snow cover decreases recharge. Additional decreases in discharge occur during times of drought when groundwater flows from the interconnected void space in the carbonate rocks that underlie the Nittany Valley are diminished.

The other monitoring well maintained by USGS is CE 118. This well is located within the Scotia Barrens area of Game Lands 176 and is installed within the Gatesburg Formation, which consists of dolomite bedrock and is a high-yielding aquifer. This area is critical for groundwater recharge within the Spring Creek watershed because it feeds recharge to Big Spring as described earlier. The deep, sandy soils of this area have an extremely high infiltration capacity and forest cover (as opposed to paved surfaces in more urban areas) which is important because it enhances the recharge capacity of the aquifer. The storage capacity of Gatesburg Formation dolomite is much higher than that of the Nittany Formation dolomite which

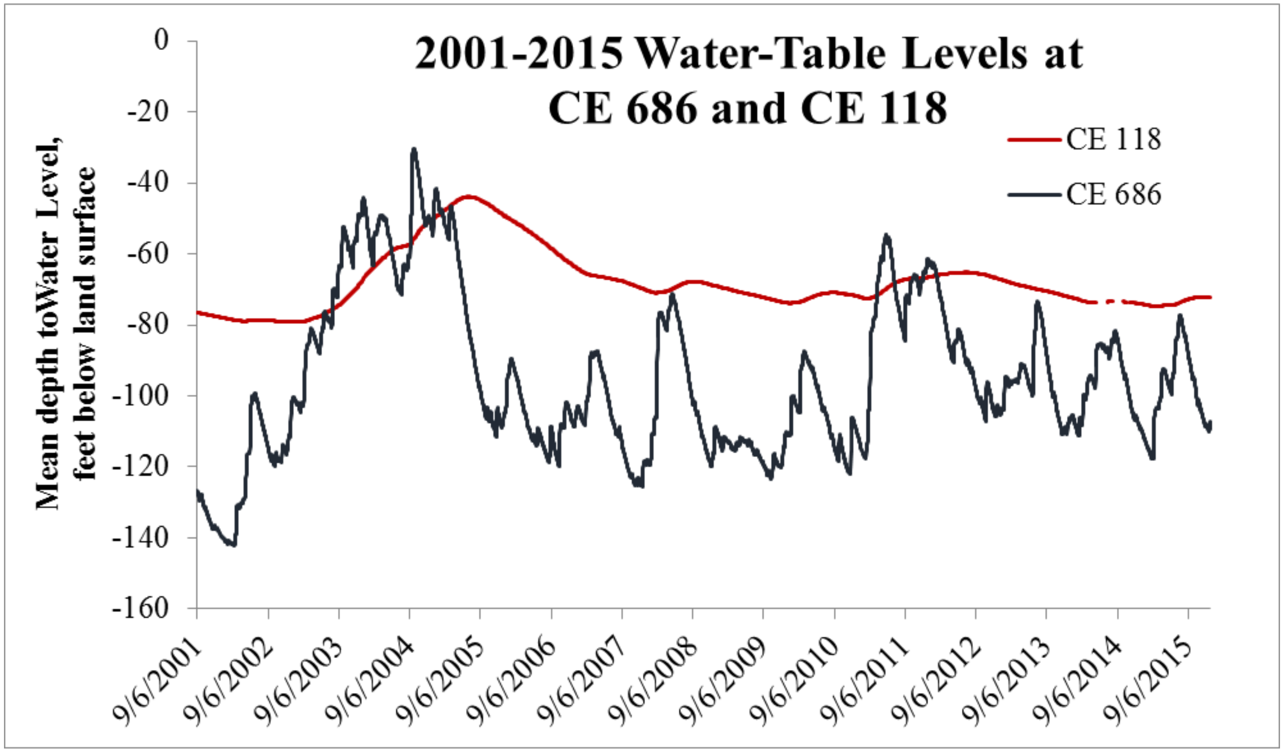


Figure 12. Comparison of mean depth to water level at the CE 118 and CE 686 groundwater wells from 2001-2015.

well CE 686 is drilled into, as demonstrated in the water-level trend lines of **Figure 12.** The water levels in the Gatesburg Formation dolomite bedrock aquifer near CE 686 react on a seasonal basis to recharge due to the deep water table and distant discharge point, 15 miles away at Big Spring. Other groundwater storage areas in the basin have much shorter flow paths to the water table and their discharge points and thus water levels rise more rapidly in response to recharge and drain more quickly during periods of drought. During the USGS 16-year period of monitoring, the Scotia well showed a 4.34 foot increase in water-level. Many municipal well fields as well as the borough of Bellefonte use the Gatesburg Formation (and Big Spring) as a source of drinking water. Therefore protecting the water quality and quantity of this critical recharge area and groundwater supply is necessary.

Water Quality

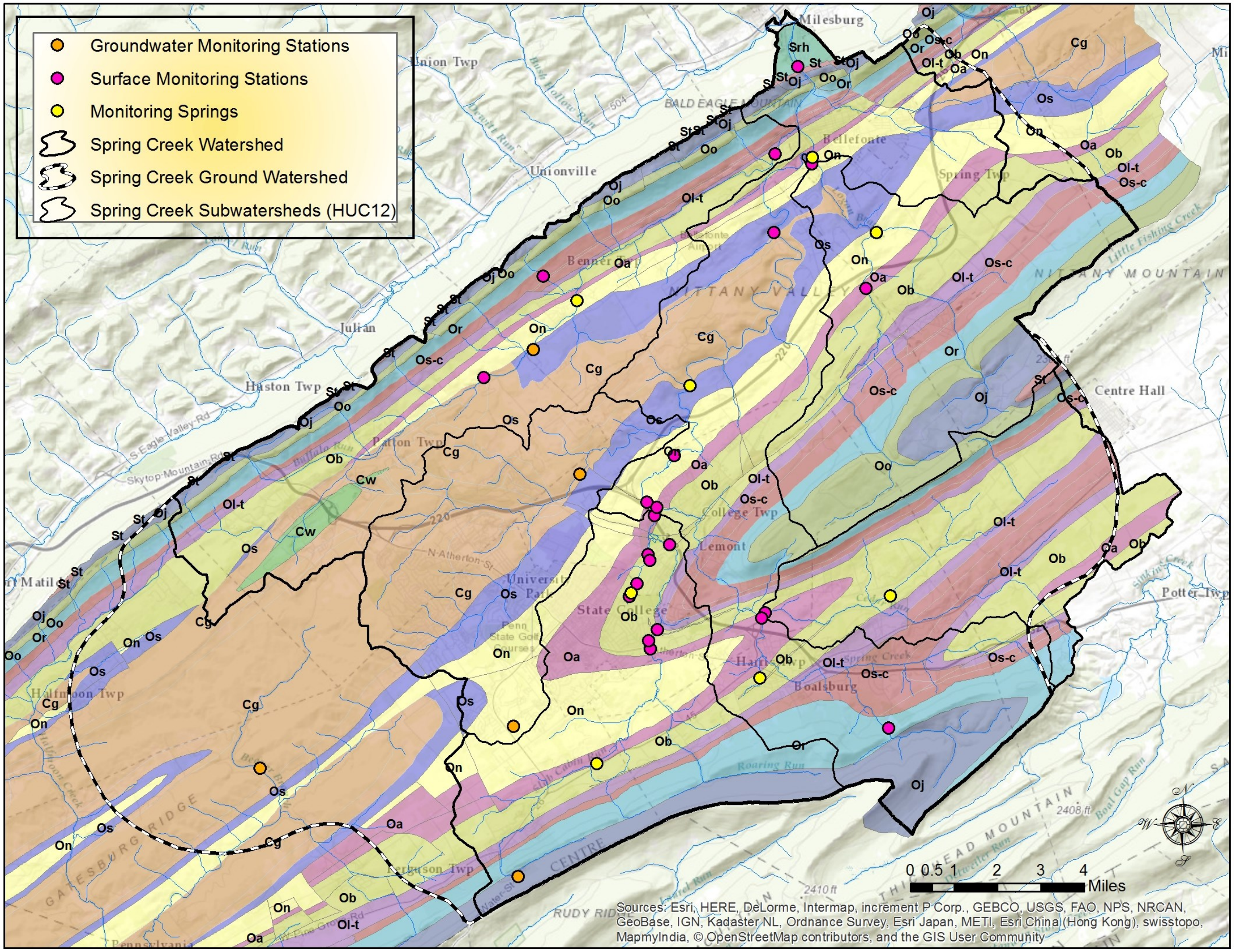
The water chemistry of Spring Creek surface and groundwater resources reflects the underlying geology of the watershed. **Figure 13** and **Table 2** on pages 21 and 22/23 respectively display the underlying geologic formations of the Spring Creek watershed. Mountain tributary streams coming from the sandstone and shale ridges have different water chemistry than those originating from the carbonate valley. Typically, carbonate streams have higher pH values and contain more dissolved calcium and magnesium; hence, these streams have higher hardness, and conductivity values .

In 2015, Galbraith Gap Run originating on Tussey Mountain had the lowest average pH (6.79), absolute conductivity value (37.8 µS/cm), hardness (14 mg/L), and calcium concentration (3.2 mg/L) compared to all surface (**Table 3** on page 24) and spring monitoring sites (**Table 4** on page 24). This sampling location is the only WRMP monitoring site within the watershed that receives the majority of its flow from a sandstone and shale aquifer (see map of Spring Creek geology with monitoring locations). Springs originating on the valley floor showed pH ranges between 6.98-7.37, conductivity values between 258.6-908 µS, hardness values between 123-360.5 mg/L, and calcium concentrations between 26.6-79.6 mg/L (**Table 4** on page 24).

Effects of Land Use

Almost any land use or cover change affects a watershed’s hydrologic regime, which is why comprehensive stormwater regulations have been developed in the region. Water resources in karst areas are potentially vulnerable to groundwater contamination because solution openings in the bedrock may provide pathways for rapid movement of contaminated water into underlying aquifers. This is especially true where soils are thin providing little buffering

CORRELATING THE WMRP DATA TO THE GEOLOGY



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 13. Surface geology of the Spring Creek watershed. **Table 2** on the following page includes the surface geology map key at WRMP monitoring locations.

Table 2. Key for surface geology at spring, surface, and groundwater monitoring locations labeled in the Spring Creek watershed map (Figure 12). Table cont. on page 23.

Location	**Monitoring Type**	**Formation Name**	**Surface Geology**
Axemann Spring (AXS)	Spring Monitoring	On	Nittany Formation
Big Spring (BIS)	Spring Monitoring	Oa	Axemann Formation
Benner Spring (BES)	Spring Monitoring	Cg	Mines Member of Gatesburg Formation
Continental Courts Spr* (COS)	Spring Monitoring	On	Bellefonte Formation
Windy Hill Farms Spring (WIS)	Spring Monitoring	Oa	Bellefonte Formation
Blue Spring (BLS)	Spring Monitoring	Ob	Bellefonte Formation
Linden Hall Spring (LIS)	Spring Monitoring	Ob	Bellefonte Formation
Walnut Spring (WAS)	Spring Monitoring	Ob	Bellefonte Formation
Buffalo Run Lower (BUL)	Surface Monitoring	Ob	Bellefonte Formation
Buffalo Run Upper (BUU)	Surface Monitoring	On	Nittany Formation
Buffalo Run Valley View (BVV)	Surface Monitoring	Os-c	Reedsville Formation
Cedar Run Lower (CEL)	Surface Monitoring	Ob	Axemann Formation
Logan Branch Lower (LOL)	Surface Monitoring	On	Nittany Formation
Logan Branch Upper (LOU)	Surface Monitoring	Oa	Axemann Formation
Millbrook Marsh (MIL)	Surface Monitoring	Oa	Axemann Formation
Slab Cabin Run Lower (SLL)	Surface Monitoring	Ob	Bellefonte Formation
Slab Cabin Run Upper (SLU)	Surface Monitoring	Ob	Bellefonte Formation
Spring Creek Axemann (SPA)	Surface Monitoring	Os	Stonehenge/Larke Formation
Spring Creek Houserville (SPH)	Surface Monitoring	On	Nittany Formation
Spring Creek Milesburg (SPM)	Surface Monitoring	Srh	Rose Hill Formation
Spring Creek Upper (SPU)	Surface Monitoring	Oa	Axemann Formation
Thompson Run Lower (THL)	Surface Monitoring	Ob	Axemann Formation
Galbraith Gap Upper (GGU)	Surface Monitoring	Or	Reedsville Formation
Lower Walnut Spring (WAL)	Surface Monitoring	Ob	Bellefonte Formation
Middle Walnut Spring (WAM)	Surface Monitoring	Ob	Bellefonte Formation
Upper Walnut Spring (Stormwater Channel) (WAU)	Surface Monitoring	Ob	Bellefonte Formation
Spring Creek Park (SPP)	Surface Monitoring	Oa	Axemann Formation
Spring Creek at PSU Sheep Farm (SPS)	Surface Monitoring	Oa	Nittany Formation

Table 2. Key for geology at surface and groundwater monitoring locations labeled in the Spring Creek watershed map (Figure 12) continued.

Location	Monitoring Type	Formation Name	Surface Geology
Slab Cabin Run at Country Club (SLC)	Surface Monitoring	Ob	Bellefonte Formation
Slab Cabin Run at Super 8 (SL8)	Surface Monitoring	Ob	Bellefonte Formation
Scotia 1 (USGS CE118)	Groundwater Monitoring	Cg	Lower members of Gatesburg Formation, undivided
USGS CE686	Groundwater Monitoring	On	Nittany Formation
Pine Grove 2 (DCNR 2)	Groundwater Monitoring	Oj	Juniata Formation
Fillmore 1	Groundwater Monitoring	On	Nittany Formation
Big Hollow (I99 MW1)	Groundwater Monitoring	Cg	Mines Member of Gatesburg Formation

Table 3. Calcium, hardness, pH, and conductivity values for surface water monitoring locations.

Site Name	Abbrev	Calcium (mg/L)	Hardness (mg/L)	pH	Conductivity (µS)
Galbraith Gap Run	GGU	3.2	14.0	6.79	37.8
Cedar Run - Lower	CEL	75.5	280.0	8.23	560.0
Slab Cabin Run - Upper	SLU	51.3	207.5	7.95	464.8
Slab Cabin Run - Lower	SLL	51.2	209.5	8.23	544.6
Slab Cabin Run - Millbrook	MIL	62.8	262.5	8.26	664.5
Thompson Run - Lower	THL	67.3	289.5	8.19	734.0
Buffalo Run - Upper	BUU	68.6	266.0	7.72	491.8
Buffalo Run - Valley View	BVV	44	130.0	8.03	246.3
Buffalo Run - Lower	BUL	62.3	255.0	8.29	514.0
Logan Branch - Upper	LOU	77.6	277.5	7.89	564.7
Logan Branch - Lower	LOL	54.4	213.5	7.79	485.5
Spring Creek - Upper	SPU	52.0	197.0	7.61	415.7
Spring Creek - Houserville	SPH	62.3	242.0	8.47	570.5
Spring Creek - Axemann	SPA	63.7	255.0	8.28	605.0
Spring Creek - Milesburg	SPM	57.5	235.0	8.23	558.0

Table 4. Calcium, hardness, pH, and conductivity values for groundwater water monitoring locations.

Site Name	Abbrev	Calcium (mg/L)	Hardness (mg/L)	pH	Conductivity (µS)
Axemann Spring	AXS	79.6	340.5	7.37	763.45
Benner Spring	BES	69.7	272.0	7.37	635.5
Big Spring	BIS	33.2	152.5	7.55	354.6
Blue Spring	BLS	26.6*	123.0	7.47	258.6
Continental Courts Spring	COS	58.2	246.0	7.61	520.0
Linden Hall Park Spring	LIS	77.2	321.5	7.20	625.5
Walnut Spring	WAS	78.7	360.5	6.98	908.0
Windy Hill Farm Spring	WIS	52.6	235.0	7.07	478.8

above shallow bedrock. Sinkholes can also provide direct injection sites for contaminants into groundwater, which may move rapidly to spring discharges and stream baseflow. Because groundwater is the main source of surface flow for many streams in the Spring Creek watershed, there is a close relationship between surface water contamination and groundwater contamination.

All development activities pose some level of risk to both surface and groundwater quality. Many of the stormwater management practices being advocated today by the State and Federal agencies focus on direct infiltration practices such as removing natural site soils and replacing them with gravels. These types of practices, while protective of stream waters, may result in more significant risks to groundwater. The key to protecting both surface water and groundwater resources is understanding a watershed's complex hydrologic system, and the renovation of pollutants as they are transported through the environment in water.

Urbanization often results in the construction of impervious surfaces resulting in higher rates or surface runoff, more frequent surface runoff events, degraded water quality, altered stream temperatures, stream channel instability and erosion, loss of aquatic habitat, and a loss of stream baseflow. One local example of these impacts can be seen in **Figure 14**, which shows the headwater of Thompson Run in the 1890s with no evidence of frequent surface water runoff occurring, such as channeling. Today, an inflow channel to the "duck pond" at the head of Thompson Run is apparent. This feature is approximately 15 ft wide and 3 ft feet deep and is derived from erosion below State College's storm drain outfall pipes. Surface water quality in Thompson Run, in response to precipitation events, has also degraded, and downstream nuisance flooding occurs frequently. Although the duck pond is known to have an adverse thermal impact on Thompson Run, it is an effective sediment removal feature.

Figure 14. Photograph of Thompson Spring in the Late 1890s showing the current Location of Penn State Wastewater Treatment Plant.

CORRELATING THE WMRP DATA TO THE GEOLOGY

While the State College area has developed significantly since the late 1800's, many local water resources experts would agree that it's likely that water quality in Spring Creek is better now than it has been since 1900. Additionally, data indicate that groundwater baseflows in the watershed have not decreased as one would expect due to development. The reason is that in karst areas stormwater can be directly recharged into the underlying aquifer via intended engineered infiltration structures or natural karst features. If new surface runoff created by development reaches a sinkhole, large closed depression, or highly influent drainageway it results in direct recharge to the underlying aquifer and in this manner the development may actually result in increased groundwater recharge. An excellent local example of this phenomena is the natural infiltration that is occurring in Big Hollow (a 17.1 square mile sub-watershed of Spring Creek), which only has surface water reach its outlet on average once every two years, even though the watershed has over 2.5 square miles of impervious area.

Induced recharge may unfortunately result in negative groundwater quality impacts if the surface runoff is not able to move through renovating materials, which consist primarily of the biological active soil horizons. Pollutants from surface runoff can carry petrochemicals, domestic and industrial chemicals, trash, fertilizers, pesticides, herbicides, animal decay products, as well as sewage effluent, therefore potentially providing a substantial risk of contamination to the groundwater supply. However, while the majority of significant local groundwater impairments in the watershed (ethylene solvents, mirex, and kepone) have historically been due to industrial or commercial activities, the watershed is currently experiencing an increase in chlorides and nitrates from human activities.

Additionally, if the surface runoff enters the ground in areas where karst conduit flow pathways dominate, the resulting apparent groundwater recharge water may rapidly exit the the aquifer as a discharge into a local stream. An example of this is the Memorial Field sinkhole, which causes rapid increases in discharge at the Thompson Spring during larger runoff events. There are large areas of some municipalities in the watershed that drain completely to sinkholes. In fact, it is estimated that approximately two (2) to three (3) square miles of impervious area within the Spring Creek watershed discharges into sinkholes or highly influent natural drainageways. Many of these discharges are directly adjacent to or up gradient of existing public water supply wells that produce water that does not require filtration, which speaks to the renovative capacity of the watershed's groundwater system.

The clearing and stabilization of land for buildings and roads can also be a threat to groundwater when sediments at the surface and below ground are destabilized and become entrained in runoff and groundwater. While this type of impact is usually temporary in nature, it can significantly affect unfiltered water supplies that need to be temporarily taken out of service.

In high-growth communities like State College, construction activities can also destabilize the delicate equilibrium between the surface and underground components of karst geology, causing altered drainage patterns that can lead to sinkhole collapse.

This report has presented a brief discussion of the complex hydrologic nature of the Spring Creek watershed. Protecting the community's water resources are a critical component for the long term sustainability of the region and its future growth. Spring Creek is not only blessed with an abundant supply of high quality water, but also a large number of experts in water resources working cooperatively on effective solutions to complex problems. In the Spring Creek watershed, if drainageways are preserved and protected, few negative effects will likely be experienced at the watershed scale if done in conjunction with appropriate planning and development practices.

WATER RESOURCES MONITORING PROJECT BACKGROUND

The Spring Creek Watershed Association (SCWA), a grassroots stakeholder group composed of concerned citizens and professionals, initiated the WRMP in 1997 as part of its strategic plan for the watershed. Their goal was to gather baseline information about the quantity and quality of the water resources in the Spring Creek watershed that could be used for the long-term protection of these resources as demands on them increase over time. A group of local environmental professionals formed the Water Resources Monitoring Committee in 1998 to develop and oversee the WRMP (see the listing of the current committee in **Table 5** on the following page). The first surface water monitoring stations were established in late 1998 through early 1999. Groundwater, surface water, stormwater and spring monitoring stations were added as the project gained momentum. Over the past fifteen years, the WRMP has strived to:

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

The WRMP field stations and database are maintained primarily by the Water Resources Coordinator, a full-time staff position housed at ClearWater Conservancy, and the assistance of volunteers. A number of local partners continued to provide funding to carry out WRMP data collection. Donors in support of the 2015 effort included:

- Bellefonte Borough
- Benner Township
- College Township
- Ferguson Township
- Graymont, Inc.
- Halfmoon Township
- Harris Township
- Patton Township
- Pennsylvania State University Office of Physical Plant
- Spring Township
- Spring Township Water Authority
- State College Borough

(CONTINUED ON PAGE 28)

- State College Borough Water Authority

Table 5. Active Water Resources Monitoring Committee Members in 2015.

WRMP Committee Member	Affiliation
David Yoxtheimer, P.G. **Committee Chair** Extension Associate	Marcellus Center for Outreach and Research, The Pennsylvania State University
Elizabeth Boyer, Ph.D. Associate Professor of Water Resources	Department of Ecosystem Science and Management, The Pennsylvania State University
Robert Carline, Ph.D. Aquatic Ecologist	Pennsylvania Cooperative Fish and Wildlife Research Unit, USGS-retired
Ann Donovan Watershed Specialist	Centre County Conservation District
Larry Fennessey, Ph.D., P.E. Utility Systems Engineer - Stormwater	Office of Physical Plant, The Pennsylvania State University
Chris Finton, P.G. Senior Hydrogeologist	ARM Group Inc.
Adrienne Gemberling Water Resources Coordinator	ClearWater Conservancy
Todd Giddings, Ph.D., P.G. Hydrogeologist	Todd Giddings and Associates, Inc.
Peggy Johnson, Ph.D. Professor of Civil Engineering	Department of Civil and Environmental Engineering, The Pennsylvania State University
Mark Ralston, P.G. Hydrogeologist	Citizen Volunteer
Hannah Stout, Ph.D. Aquatic Entomologist	Citizen Volunteer
Robert Vierck Communications Specialist	Citizen Volunteer
Rick Wardrop, P.G. Hydrogeologist	Groundwater & Environmental Services, Inc.

- Spring Creek Chapter of Trout Unlimited
- University Area Joint Authority

In addition to financial support, the WRMP received in-kind donations of professional services, water level and stream stage data, laboratory analyses and supplies, technical assistance, and transportation from the following in 2015:

- PA Department of Conservation of Natural Resources (PADCNR)
- Todd Giddings
- The Pennsylvania State University Office of Physical Plant (PSU OPP)
- United States Geological Survey (USGS)
- Pennsylvania Department of Environmental Protection (PADEP)
- University Area Joint Authority (UAJA)
- Volunteer field assistants

Stream Monitoring Stations

The WRMP measures conditions at six sites along the main stem of Spring Creek and sixteen tributary sites located throughout the stream's five major sub-basins (**Figure 15** on page 31). Twelve of the twenty-two sites currently included in the WRMP have been monitored since 1998. The WRMC chose the twelve original sites to be representative of land use practices across the watershed. Three of the original sites were chosen to coincide with existing USGS gaging stations. In 2004, the WRMP added two water quality monitoring sites on headwater tributaries to serve as reference (Buffalo Run Valley View and Galbraith Gap Run). A fifteenth WRMP stream monitoring station, located on Slab Cabin Run downstream of Millbrook Marsh, was added in 2005 to assess the marsh's ability to control stormwater impacts from downtown State College and University Park. Three additional sites were added in 2008 in the Walnut Springs sub-basin in State College Borough to monitor stormwater impacts. The last four site additions were added in 2015 to monitor temperature impacts. Two sites are located on Slab Cabin Run and two are located on the main stem of Spring Creek between State College and Houserville.

Groundwater Monitoring Stations

The WRMP monitored water levels at three wells in 2014 (**Figure 16** on page 32). These wells were selected because they are not subject to frequent fluctuations caused by external factors such as high-yield pumping, stormwater, artificial groundwater recharge, or surface water discharges. In addition, the WRMP analyzes publically available data from two USGS monitoring wells (**Figure 16** on page 32). When considered together, the five wells provide a picture of representative groundwater conditions across the Spring Creek Watershed.

Spring Monitoring Stations

Spring monitoring became part of the WRMP in 2005 with the addition of water quality monitoring at seven spring stations (**Figure 16** on page 31). Like the stream and groundwater sites, these springs were chosen to be representative of various land use, geologic, and hydrologic conditions encountered in the Spring Creek Watershed. With the addition of the Walnut Springs sub-basin monitoring in 2008, the Walnut Spring was added to the spring water quality monitoring in 2013, bringing the total to eight.

MONITORING STATIONS

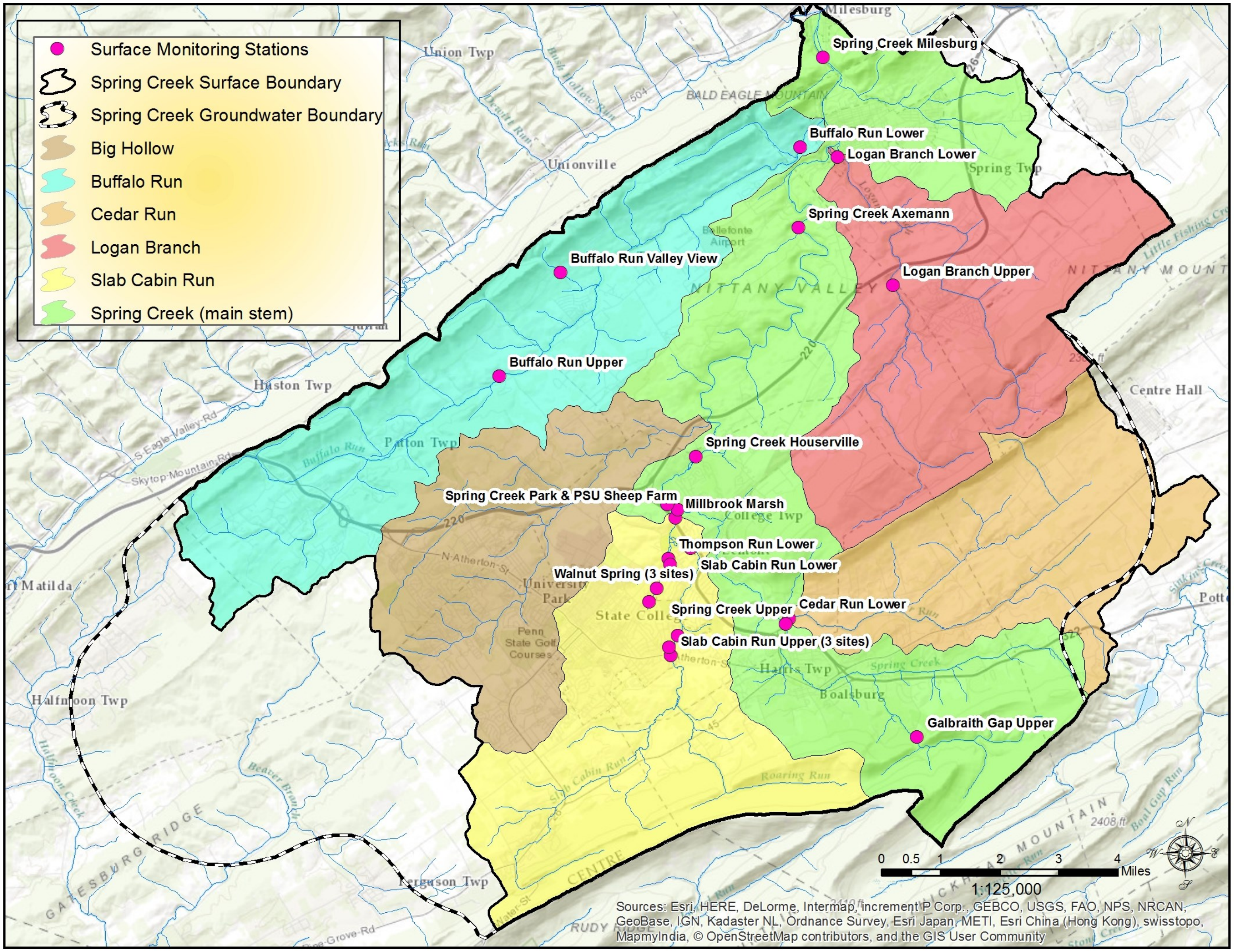


Figure 15. Stream sampling sites surveyed in 2015 as part of the Water Resources Monitoring Project and USGS stream gages.

MONITORING STATIONS

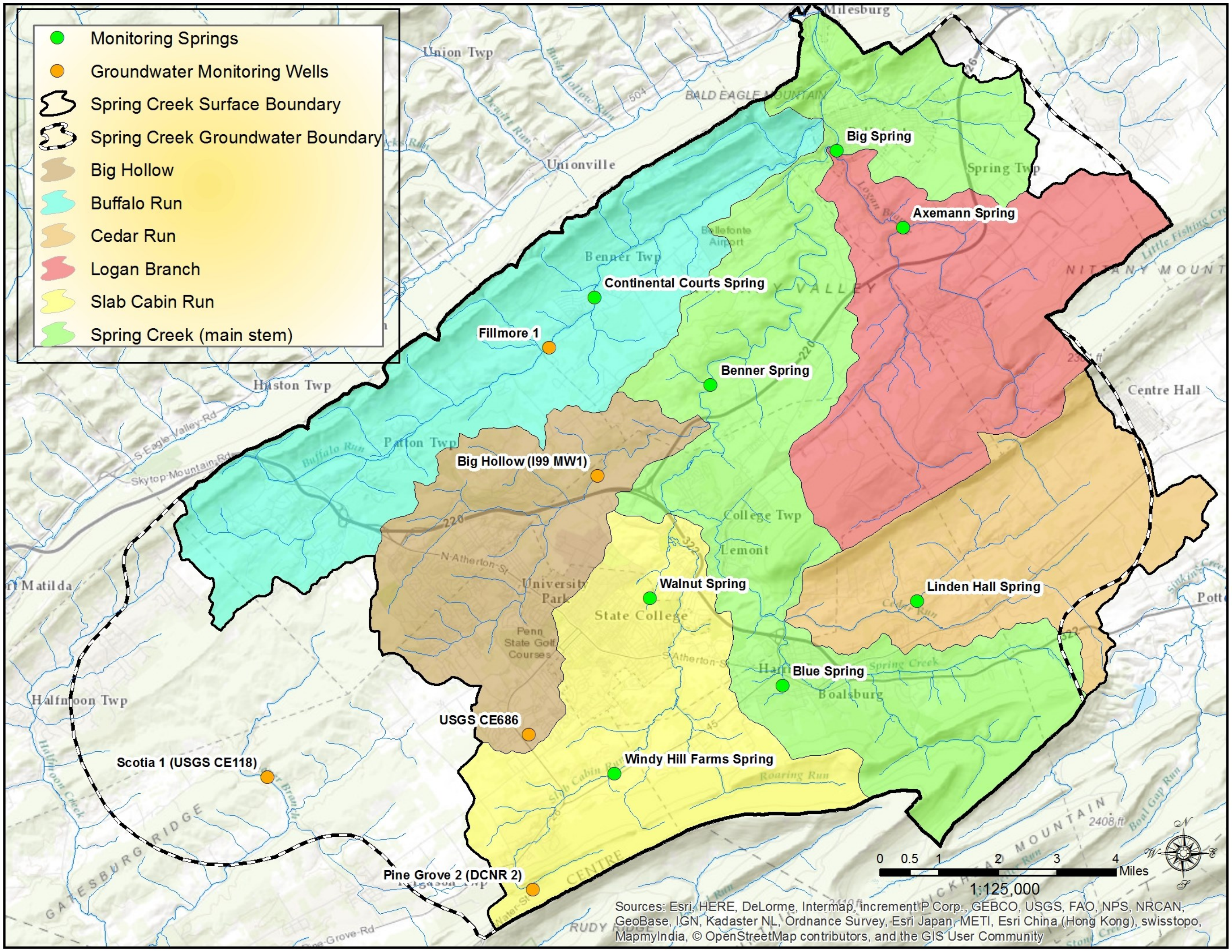


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Figure 16. Groundwater and spring stations surveyed in 2015 as part of the Water Resources Monitoring Project and USGS groundwater monitoring wells.

Water Quality Monitoring

WRMP staff and volunteers collected water samples from fifteen stream sites and eight springs in 2015. Sampling took place in April, August, October, and December when streams were at baseflow conditions. The water samples were analyzed for chemical and nutrient content by the PADEP Analytical Laboratories. Coliform analyses of spring samples were conducted by the University Area Joint Authority laboratory. **Appendices 4** and **5** summarize the results of the 2015 water quality analysis.

Continuous Measurements

Thirteen stream stations were equipped with instruments to continuously monitor stream stage. Stream stage stations were maintained by the WRMP and outfitted with one of two types of pressure transducer: Solinst, Inc. Levelogger Gold pressure transducer or Solinst, Inc. Levelogger Edge pressure transducer. Both types of Solinst transducer are non-vented and were coupled with a Solinst Barologger Edge or Barologger Gold to compensate for atmospheric pressure. Stream stage was recorded every 30 minutes for all stations except Lower Thompson Run and the three stations on Walnut Springs, where stream stage was recorded every 5 minutes. Readings were taken more frequently at these stations because past data have shown that the flow in Thompson Run and Walnut Springs can fluctuate rapidly in a short period of time during storm events. The other three stream monitoring stations are the stations maintained by the USGS.

Water temperature was measured hourly at eighteen stream stations using Onset Computer Corporation Optic Stowaway TidBitv2 data loggers. At the Thompson Run station and Middle Walnut Springs station, the temperature data logger was set to record temperature every 5 minutes instead of every hour. Again, readings were taken more frequently at these stations because, as with flow, past data have shown that temperatures in Thompson Run and Walnut Springs can fluctuate rapidly in a short period of time during storm events. Water temperature data summaries for 2015 are presented in **Appendix 7**.

Water surface elevation was recorded every 3 hours at the three wells comprising the groundwater monitoring network. These wells were equipped with InSitu miniTROLL pressure transducers. **Appendix 8** summarizes the groundwater elevation data for 2015.

Discharge Measurements

Data from the WRMP stream gages are collected as stream water level (or stage) data. In order to better understand the behavior of the streams, the data needs to be expressed as stream flow, or discharge. A rating table or curve is a relationship between stage and discharge at a cross-section of a stream. To develop a rating curve the Water Resources Coordinator and volunteers make a series of discharge measurements using a hand-held current meter (Marsh-McBirney FlowMate). These discharge points are plotted versus their accompanying stage, and a curve is drawn through the points (**Figure 17**). There can be significant scatter around this curve. Because of this, it is good to keep in mind that the discharge values provided by WRMP are estimates of the most likely discharge value. Also, wading into the stream to collect discharge measurements during high flows is not safe. Therefore, WRMP discharge values at high flows are calculated by extrapolating the rating curve to higher stages. As a result, there can be significant error in the rating curves at higher stages. Estimated discharges are indicated by the use of dashed lines in the graphs of WRMP discharge data.

Discharge measurements are made at each gaging station throughout the year to ensure the validity of the rating curves. Sometimes, stream channel dimensions at the gage site may change due to sediment erosion or deposition. The Water Resources Coordinator and members of the Water Resources Monitoring Committee periodically review the rating curves and revise them as needed.

The data for the USGS-operated stream gages were also collected as stage data. Rating curves for these stations are maintained by the USGS. The USGS is equipped to measure discharge at higher flows to produce more reliable rating curves at high stages. **Appendix 6** summarizes the stream discharge data for 2015.

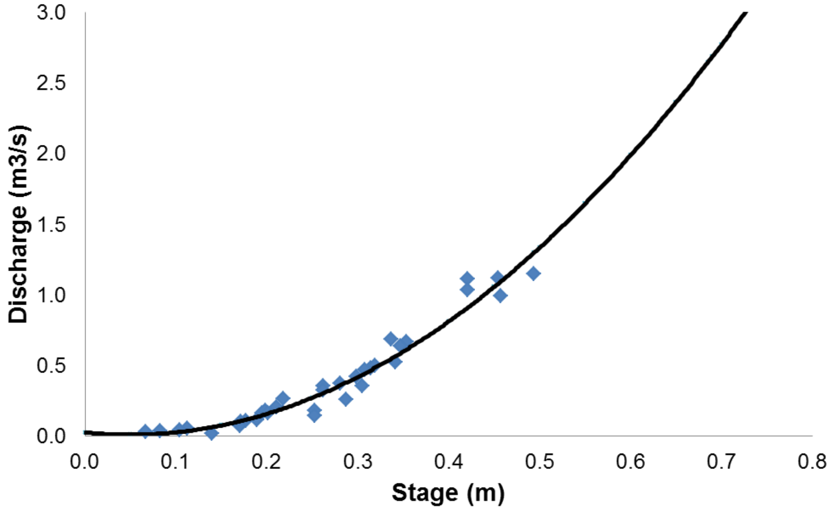

Figure 17. Stage-discharge relationship for WRMP site on Slab Cabin Run at East College Avenue.

Data Quality

To assure the consistency and quality of data collected as part of the WRMP, the Water Resources Monitoring

The WRMP rating curve transect location at Lower Buffalo Run.

Committee developed a set of standardized procedures for data collection, sample processing and database maintenance. A detailed description of these methods may be found in the Spring Creek Watershed Water Resources Monitoring Protocol. To review this document, please contact the Water Resources Coordinator at ClearWater Conservancy at (814) 237-0400.

In addition to periodic review of rating curves, the Water Resources Coordinator and the WRMC also review operational procedures and equipment used in the monitoring program. Due to increasing unit failures, the WRMP in 2011 discontinued the use of the type of pressure transducer used to record stream stage since the program's inception in 1998. By the end of 2011, all stream monitoring stations were equipped with Solinst, Inc. pressure transducers. These units have been considerably more reliable, and as a result the data logger reliability has greatly improved and operational costs have decreased.

Appendix 3 provides detailed summaries of the monitoring and data collected at each WRMP location.

Water Quality Monitoring

The WRMP water quality protocol is set up to collect samples on a quarterly basis throughout the year. Water Quality was assessed four times in 2015 in April, August, October, and December at 15 stream and 8 spring sites across the watershed during baseflow conditions. Water samples were evaluated for a number of common organic and inorganic pollutants (**Appendix 1**). **A summary of water resource management issues for each monitoring site can be found in Appendix 2.**

Appendices 4 and **5** show median 2015 concentrations of all parameters analyzed at each of the stream and spring sites, respectively. Results from the water quality monitoring were similar to results from past years.

- In 2015, the concentration of nitrate nitrogen at stream and spring sites were, as typically seen, higher in comparison to headwater concentrations at Galbraith Gap Run and Buffalo Run Valley View but below the drinking water standard of 10 mg/L. Median concentrations ranged between 0.10 and 4.17 mg/L at stream sites, with Galbraith Gap Run having the lowest and Cedar Run having the highest median concentration. Among the springs, Axemann Spring and Linden Hall Spring had the highest median concentrations at 5.94 and 4.80 mg/L, respectively. Cedar Run, Axemann Spring and Linden Hall Spring drain predominately agricultural areas.

- Orthophosporous is a pollutant commonly associated with agriculture. It is a limiting nutrient in fresh water, meaning elevated levels can cause adverse environmental effects such as algal blooms in streams and rivers. Orthophosphates were detected at low levels (<0.03 mg/L) at all stream sites. Orthophosphorous was also detected at low levels at all springs.

- The highest median chloride concentrations were observed at Thompson Run at East College (84.85 mg/L) and at Slab Cabin Run downstream of Millbrook Marsh (70.65 mg/L). These values are similar to historical values. Walnut Spring had the highest observed median concentration in the springs at 104.4 mg/L. Elevated chloride concentrations are generally associated with increases in urbanization such as impermeable surfaces and increases in road salt application.

- Median iron concentration was elevated at Windy Hill Spring (1918 µg/L) in 2013 but dropped to 217.5 µg/L in 2014. Levels in 2015 were again elevated to 1532 µg/L. This spring has historically seen occasional elevated levels of iron. Iron can occur from natural sources when water comes in contact with particular types of rock. The drying and wetting of rock surfaces has a tendency to increase iron concentration. This can occur when the water table fluctuates over a cycle of a dry period followed by a wet period. The observed elevated level of iron occurred in October (2534 µg/L) and December (3311 µg/L) of 2015.

- Conductivity is a fundamental water quality characteristic and is defined as the ability of the water to conduct an electrical current. Values of conductivity are directly related to the total major dissolved ion concentrations in water. There are seven major ions found in water and they include:
    - Calcium (Ca^{2+})
    - Magnesium (Mg^{2+})
    - Sodium (Na^{+})
    - Potassium (K^{+})
    - Bicarbonate (HCO_3^{-})
    - Sulfate (SO_4^{2-})
    - Chloride (Cl^{-})

The WRMP monitors five of these seven major ions. Based on the data collected, we can determine the percentage of the conductivity that can be attributed to each of these ions except bicarbonate and potassium, which the WRMP does not monitor. In 2015, conductivity was highest at Thompson Run at East College Avenue (734.0 mS) and Slab Cabin Run at College Avenue (664.5 mS) as it has been historically.

Stream Discharge

Stream discharge is defined as the volume of water in a stream passing a given point at a given moment of time. Large streams have higher discharge rates than smaller streams. A stream's ability to move sediment and dilute chemicals is proportional to discharge. Generally, the higher the discharge, the more effective a stream will be at moving sediment downstream and diluting pollutants. A stream's discharge determines the biological communities that will be found in it. Stream discharge also fluctuates with seasons and storm events, making it a measurement of interest when studying the effects of runoff and flooding.

The 2015 discharge profiles for the main stem of Spring Creek at Oak Hall and a representative tributary (Slab Cabin Run at South Atherton Street) are shown in **Figures 18** and **Figure 19**, respectively. In general, discharge stayed above median values for most of the year. From January until mid-March and then from May until mid-July, base flow was below median values. Base-flow conditions were above median values from mid-march until May and then from mid-July to December. These discharge profiles reflect a fairly wet year, with major storms peaking discharge in mid-March, late-April, and all of July. The largest discharges were recorded from a major storm event in late July.

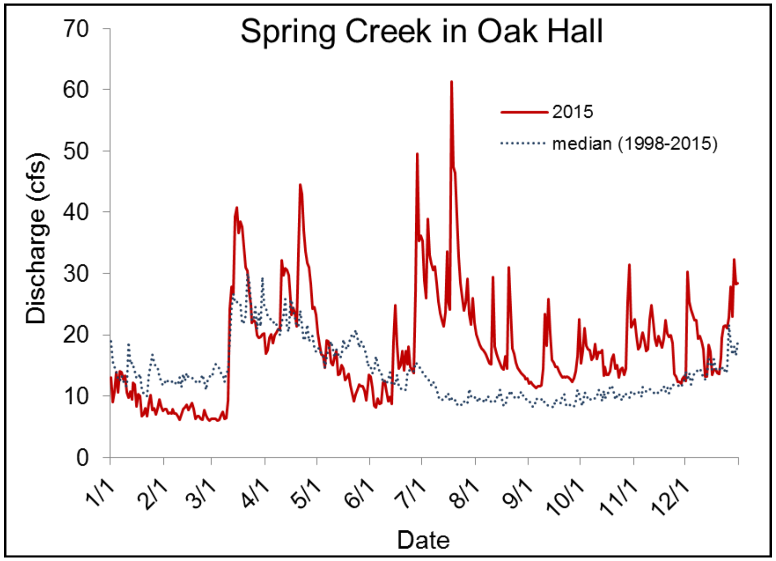

Figure 18. 2015 discharge and median discharge (cfs) for Spring Creek in Oak Hall.

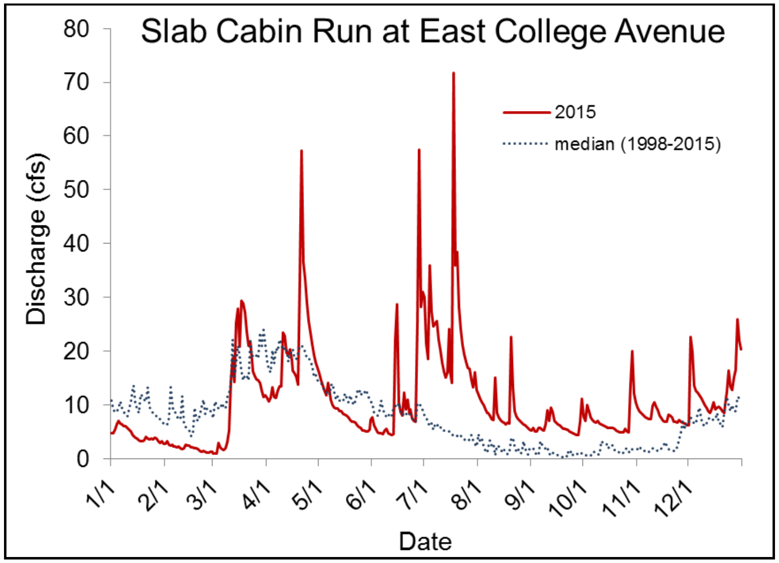

Figure 19. 2015 discharge and median discharge (cfs) for Slab Cabin Run at South Atherton Street.

The 2015 discharge profiles for all of the WRMP gages and the three USGS Spring Creek gages are included in **Appendix 6**.

Stream Temperature

Water temperature has a profound influence on aquatic life. It governs nearly every process that occurs in streams from regulating the solubility of oxygen and various chemicals to the metabolic functions of fish and other aquatic life. The significant inputs of groundwater throughout the Spring Creek Watershed protects the world-class trout fishery from the significant agricultural and urban impacts within the watershed. Brown trout's lethal temperature threshold is 76 °F (24 °C), and groundwater (10-11°C) inputs help maintain temperatures well below this threshold. Some portions of tributary streams lack significant groundwater inputs, such as lower Buffalo Run near Bellefonte and Slab Cabin Run in State College. These streams are perched above the water table minimizing the inputs of groundwater, especially during dry periods which typically occur in the summer and fall when air temperatures are generally greatest. The 2015 data from Slab Cabin Run downstream from Millbrook Marsh align well with historical data that predicts the highest stream temperatures between June and August (**Figure 20**). Walnut Springs near East College Avenue and Thompson Run downstream from East College Avenue were the only stream sites in which maximum daily temperatures exceeded Brown Trout's temperature

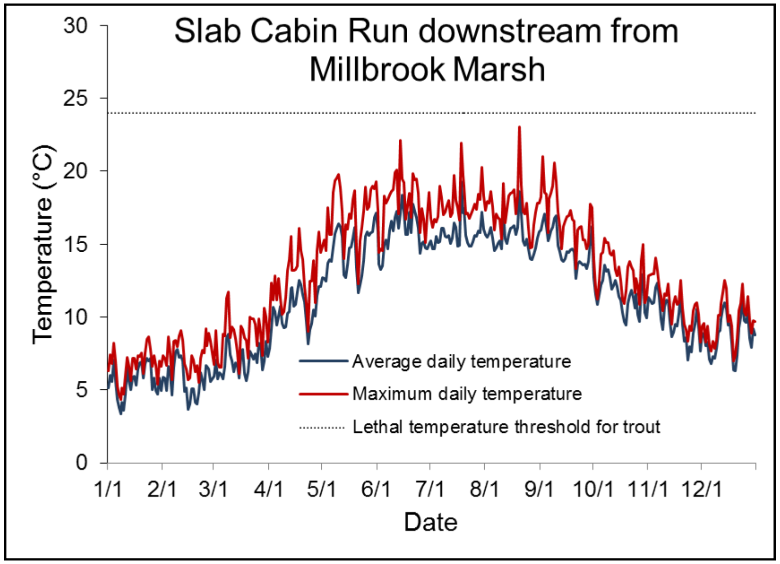

Figure 20. Temperature at the WRMP site at Slab Cabin downstream from Millbrook Marsh in 2015.

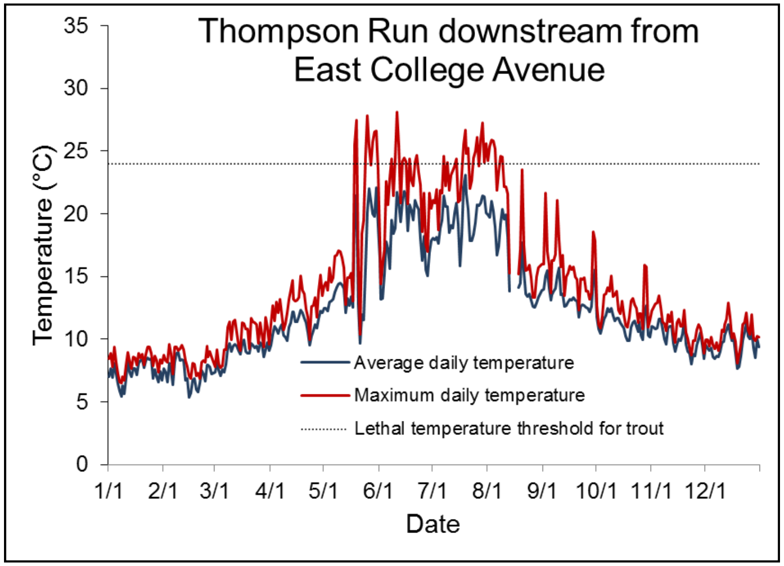

Figure 21. Temperature in 2015 at the WRMP site on Thompson Run.

threshold. Temperatures exceeding this limit were observed on 39 days at Thompson Run (**Figure 21**) and six days at Walnut Springs (**Figure 22**).

These two streams are subject to large urban storm water inputs which can cause these temperature increases. These waters can also exceed 76 °F during extreme heat or drought. The mean July temperature for State College, PA was lower in 2014 (70.3 °F) than in 2013 (73.8 °F) and 2012 (75.7 °F) when mean July temperature was the second and fourth hottest on record. Large-scale fish kills can occur when water temperatures rise above 76 °F for extended periods of time. In general, temperatures do not exceed trout's threshold, and when they do, it is only for

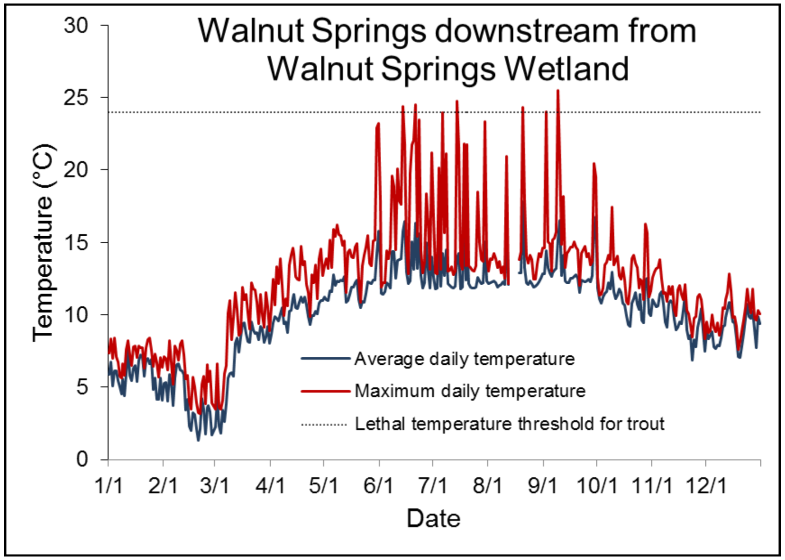

Figure 22. Temperature in 2015 at the WRMP site on Walnut Springs downstream from Walnut Springs wetland.

short (e.g., 1 day) periods of time. The 2015 temperature profiles for all WRMP monitored locations in the watershed are included in **Appendix 7**.

Groundwater

Groundwater supplies our streams with a constant supply of cold water that supports trout and other coldwater aquatic organisms. Most of the region's drinking water is also drawn from the many high volume springs and well fields. In 2015, the WRMP collected groundwater data from three monitoring wells and assessed data from two additional wells maintained by the USGS. Groundwater elevation profiles for 2015 are found in **Appendix 8**. Water surface elevation is used as the y-axis label and is equivalent to feet above mean sea level.

The groundwater hydrograph for the WRMP-maintained well near Pine Grove Mills is shown in **Figure 23**. As usually observed, groundwater recharge occurred in early spring. However, at the USGS CE118 well located in the Scotia Barrens, 2015 groundwater elevations were below the median, but generally rose over much of the year (**Figure 24**). The CE 118 well is located in the Gatesburg Formation, a large aquifer that drains to the Big Spring and several other large magnitude springs in the Bellefonte area. Due to the relatively deep saturated zone

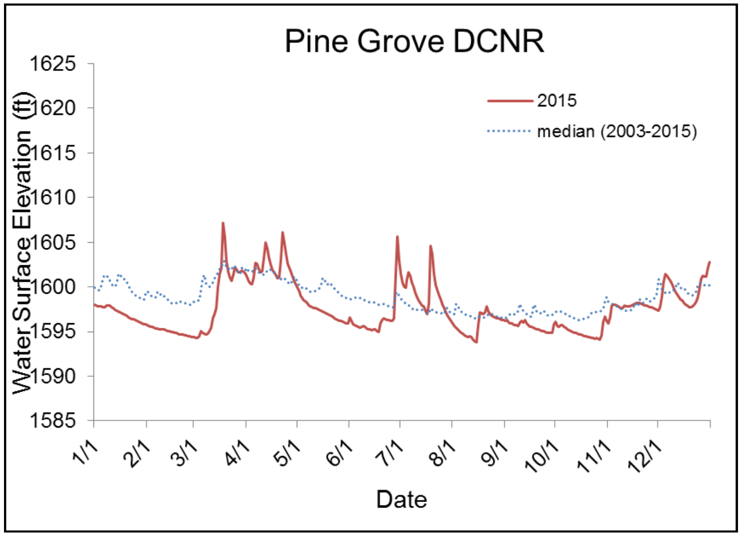

Figure 23. Water surface elevation (ft) in 2015 at the WRMP groundwater well located near Pine Grove Mills.

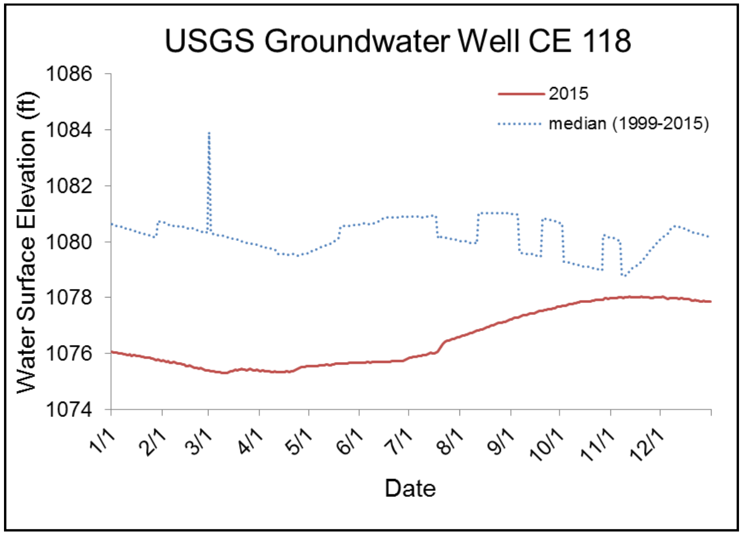

Figure 24. Water surface elevation (ft) in 2015 at the USGS CE118 well in Scotia Barrens.

in the Scotia Barrens area, the USGS CE118 well shows a lag in response to recharge events. Additionally, due to the aquifer's large size and permeability, it typically takes a large amount of persistent precipitation to result in a positive change in the groundwater elevation as observed in CE118. This particular well experienced a historic low in groundwater elevation in the fall of 2002 after an extreme dry period and a historic high in the spring of 2005.

In general, groundwater elevations at the WRMP and USGS wells were lower than median levels throughout the entire year during 2015.