PennState

Penn State Stormwater

2019

Penn State Stormwater is published by the Office of Physical Plant's Division of Energy and Engineering, Engineering Services Department at The Pennsylvania State University. The magazine is part of the University's outreach program for its Municipal Separate Storm Sewer System (MS4) permit. Use of trade names implies no endorsement by Penn State.

Publisher: Engineering Services
Editor: Larry Fennessey
Assistant Editor: Andrew Gutberlet

PennState

The intent of this magazine is not to be a stand alone stormwater document but rather to allow University faculty, students, and researchers to have a better understanding of the types of stormwater facilities that are used at the University Park Campus.

Special thanks to Mike Turns Photography for the use of photographs indicated © Mike Turns.

Table of Contents

Background Information

1 Sustainable Water Resources
2 The Big Picture
4 University Park Watersheds
5 Cisterns, Drywells and Sinkholes

Non-Structural Facilities

6 Critical Land Areas
8 Karst Critical Land Areas
9 Water Resource Preservation Areas

Structural Facilities

10 Dams
11 Surface Ponds
12 Subsurface Detention Facilities
13 Bioswales and Rain Gardens
14 Green Roofs
15 Infiltration Facilities
18 Wetlands
19 Storm Drains
20 Conveyance Swales
21 Water Quality Inlets and Oil/Water Separators
22 Pervious Parking
23 Energy Dissipaters and Level Spreaders

Research Activities

24 Surface Water Gaging
25 Thermal Studies
26 Water Quality Testing
27 Surface and Groundwater Interactions
28 Demonstration Projects

Policies, Permitting and Outreach

29 Stormwater Master Plan
30 MS4 Permit
31 Stormwater Oversight Committee
32 Community Support and Cooperation
33 Penn State Water Resources Outreach

On the cover: The University's Bathgate Dam. Constructed in the early 1990's, the dam has a drainage area of 237 acres and controls peak runoff rates and water quality of stormwater prior to being discharged to the Millbrook Marsh. The back cover photograph is of the Bathgate Dam outflow swale draining into Millbrook Marsh.

Sustainable Water Resources

Penn State is a large landowner with extensive facilities and responsibilities. At University Park alone, we supply approximately 2,000,000 gallons of potable (drinkable) groundwater annually to over 50,000 customers. Treatment and monitoring is provided for all wells at a central water treatment plant to ensure that water delivered to customers meets all regulatory requirements. Protection of the groundwater is one of the primary reasons the University has developed such high standards for water resources management and holistically evaluates stormwater, wastewater, and potable water together.

The University owns and operates a wastewater collection, treatment, and disposal system that serves the University Park Campus and parts of the Borough of State College. It treats on average 1,600,000 gallons per day. In the 1960's, Penn State began researching the potential to spray renovated wastewater over farm crops and forests north of campus, rather than discharging it to streams. The University found this approach beneficial and since 1983 has replaced stream discharge with this method, which is known as the Land Treatment Area or more commonly as the Living Filter. The soils in the land treatment area vary in depth to over 100 feet, thereby filtering the water as it seeps down and recharges the groundwater.

Photo: Lydia Vandenbergh

From a stormwater management perspective, the University promotes the use of conservation design practices that preserve and use natural critical hydrologic areas. The Office of Physical Plant extensively monitors all of its watersheds. The University's four primary drainage basins are all differently managed based on the density of development, tributary basin, soils, and geology. For example, the Fox Hollow Drainage Basin, while over 25% impervious, generates surface runoff equivalent to less than 3% of the annual precipitation. This occurs because the University has protected critical natural recharge areas that act like sponge areas, which infiltrate large quantities of surface runoff.

Stormwater is the surface hydrologic response from an area due to a precipitation event, or meteorological event such as a snowmelt event, and does not include baseflow. Development activities create changes in the hydrologic response of an area; however, in a carbonate watershed the effects are not always clear-cut. The University Park Campus is underlain by carbonate geology. The one thing that is clear is that poorly controlled stormwater runoff, or the use of general rules of thumb developed in other areas, has the potential to significantly impact both surface water and groundwater quantity and quality. Penn State, in addition to providing education, research and service to Pennsylvania, is a large landowner with extensive facilities and responsibilities. The University's holistic water management strategy in a karst terrain includes the wise use and reuse of this valuable resource, while providing an opportunity for experimental or demonstration projects to prove their worth.

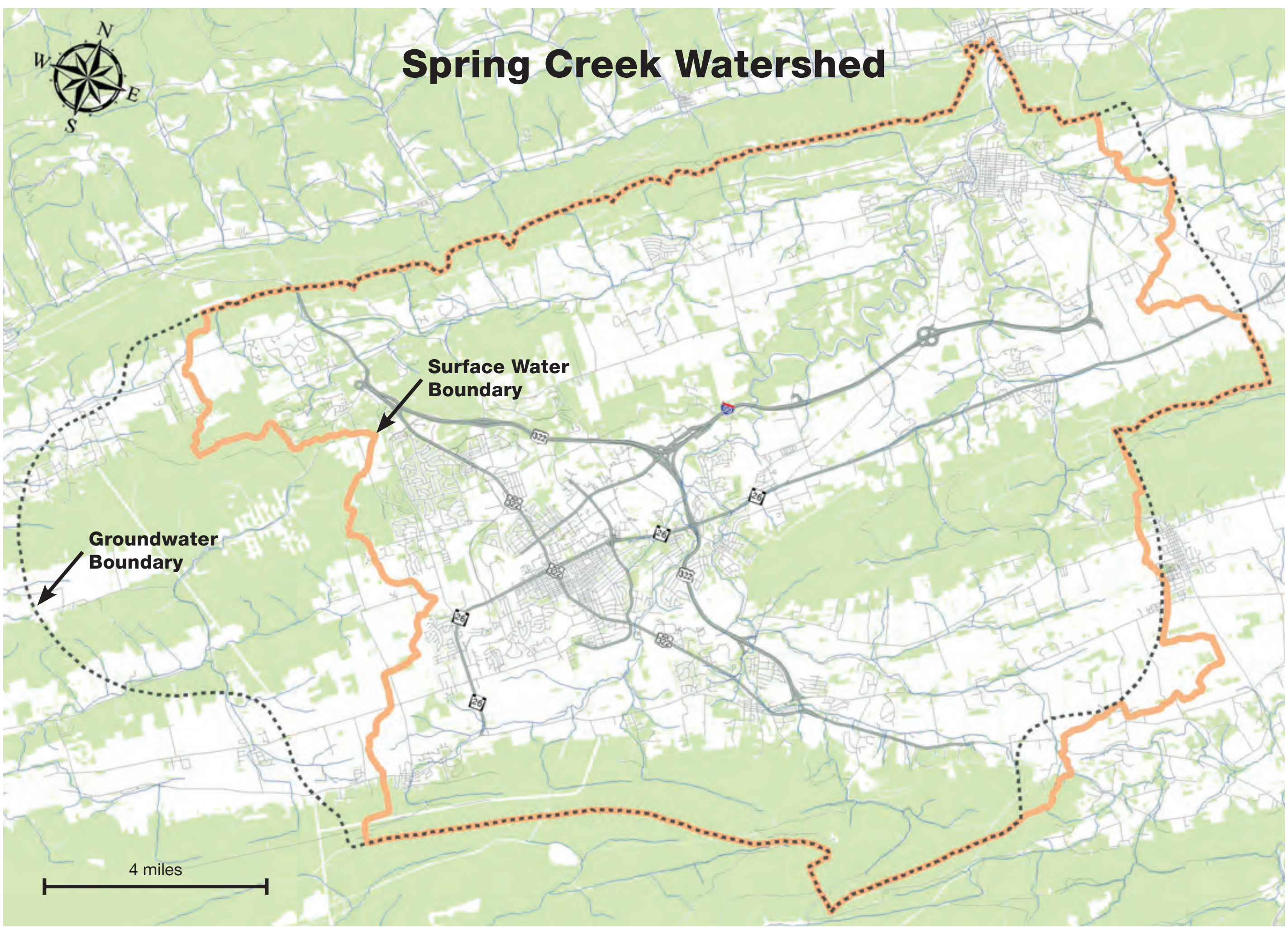
The Big Picture

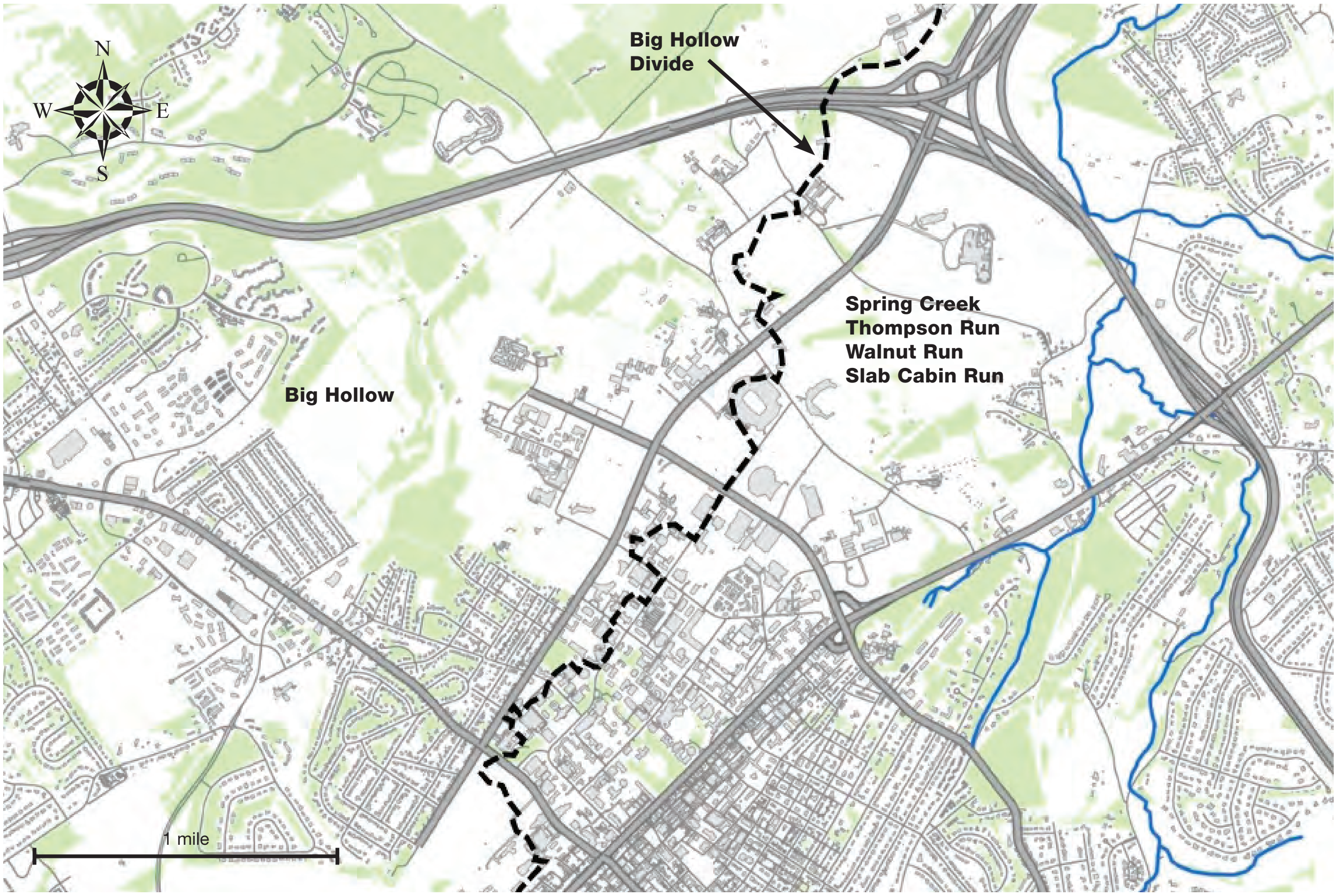
The University Park Campus is located within the Spring Creek watershed, which lies in the Ridge and Valley Physiographic Province of the Appalachian Mountains. The topography is characterized by a prominent northeast-southwest alignment of a succession of steep-sided narrow ridges and valleys. Karst features are present in valleys, where they are underlain by carbonate formations. The surface water basin of Spring Creek watershed is 142 square miles (sq mi); however, the groundwater basin is considered to be approximately 175 sq mi (23% larger). The groundwater divide is temporally and spatially dynamic; and therefore, the groundwater basin may be larger or smaller at any point in time. Part of the adjacent Spruce Creek surface watershed is tributary to the Spring Creek groundwater basin. Spring Creek is the major perennial stream within the watershed with Buffalo Run and Slab Cabin Run as two major intermittent tributaries to Spring Creek.

Large springs are located at the head of and along the course of Spring Creek. These large springs are fed primarily by diffuse groundwater flow, with some sinkhole and closed depression recharge. Some water reaches the springs through well-developed conduit-flow-dominated karst aquifer, or a combination of diffuse flow and conduit flow. Most of the small tributary valleys on the carbonate rocks of the valley floor are dry except during significant storms and snow melt periods. Sometimes during low-flow periods, many stream segments naturally go dry.

The University's primary potable well field lies within a portion of the Big Hollow watershed, which has a total surface water drainage area of 17.1 square miles at its mouth. The Big Hollow watershed, a tributary to Spring Creek, is an under-drained carbonate valley identified as a perennial stream on USGS maps. However, the Big Hollow does not have baseflow anywhere along its length and there are no large springs. Surface runoff is primarily generated only by overland flow from impervious areas during rainfall events, with the exception of extreme runoff events or major snow melt or rain on frozen ground conditions. Since 2007, the University has monitored surface runoff in the Big Hollow. At a point 15.8 square miles in size, with 2.5 square miles of imperviousness, runoff was observed only eight (8) times in 11 years. The reason this phenomenon occurs in the Big Hollow is that it and its tributaries generally act as influent streams. In other words, the streambed loses water to the ground. The figure on page 3 shows the drainage divide between the Big Hollow and other tributaries in the watershed. Note the absence of drainageways on the Big Hollow side.

These same phenomena also occur in most natural minor karst drainageways in the area. However, ultimately a threshold is reached where the rate of loss within the drainageways, or infiltration, is exceeded by





the peak runoff rate generated during large runoff events. Development of impervious cover can result in surface runoff occurring more frequently and traveling farther down the watershed, and closer to the University's well field.

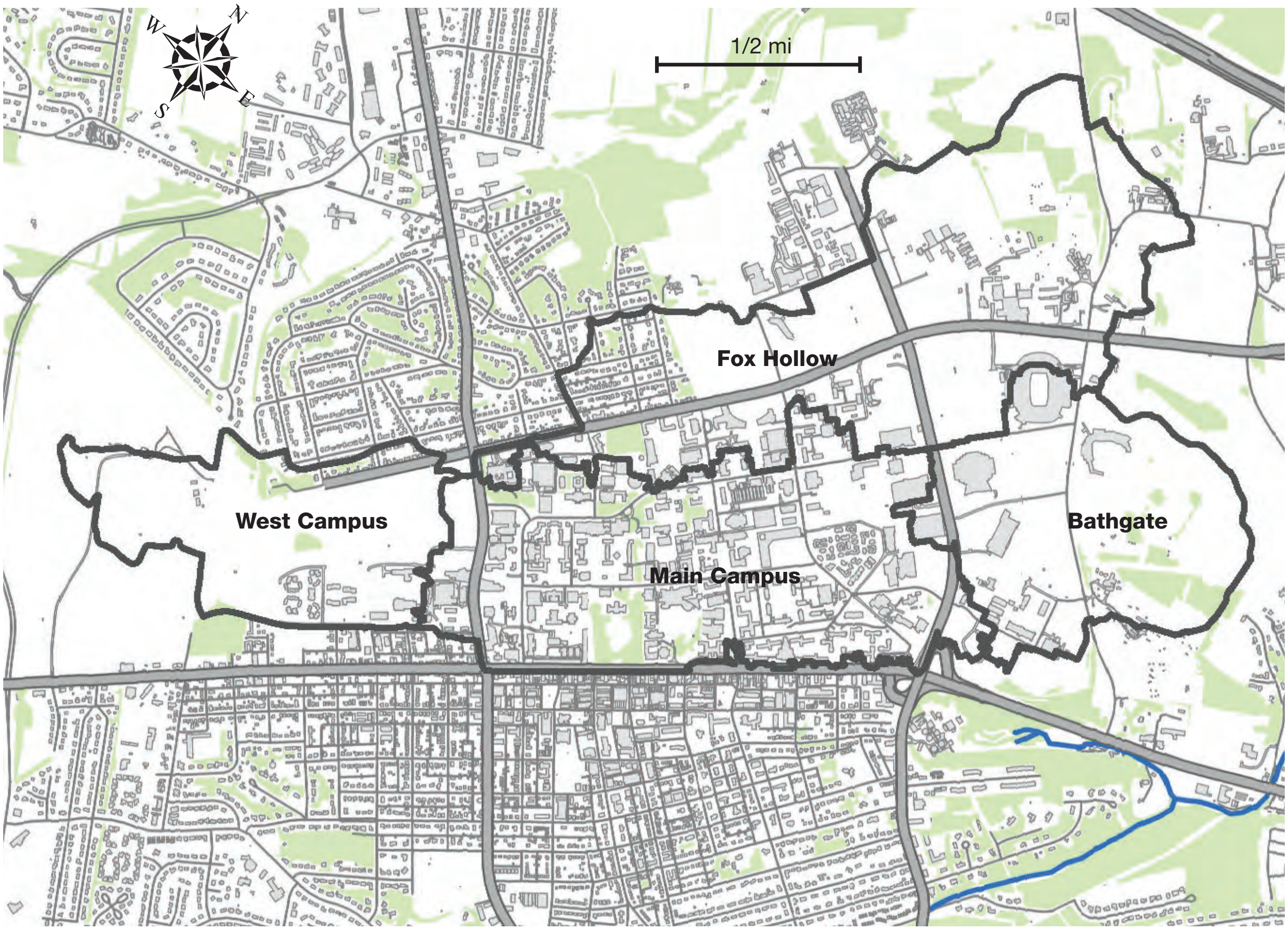
Pervious areas rarely, if ever, generate surface runoff; and therefore, even cornfields can have as low of runoff rates and volumes as wooded areas or meadows. Because of the lack of surface runoff, peak runoff rates and the frequency of runoff historically have been significantly overestimated in carbonate watersheds, especially for undeveloped pervious areas. This occurred because engineers applied models developed for non-carbonate areas without adjustment or calibration. This resulted in nuisance flooding immediately below most developments in the past. However, if drainageways downstream are preserved, little if any negative effects are experienced at the watershed scale. While these facts make hydrologic changes in a carbonate watershed very different from a non-carbonate watershed, the greatest differences may be related to groundwater impacts.

In carbonate areas, while the evapotranspiration (ET) component or local site recharge potential may be reduced by development activities, if the new surface runoff then reaches a sinkhole, large closed depression, or highly influent drainageway that results in recharge, the development may actually result in an increase of usable groundwater. This can occur because the ET component that was converted to surface runoff as a result of development can become potential recharge. In fact, a review of the USGS's Axemann stream gage on Spring Creek (downstream of the Big Hollow watershed) shows that while imperviousness, the population, and groundwater consumptive use have all significantly increased since the 1940's, the stream low flows have not decreased and indicate an increasing trend. This volume buffering effect is also supported by the fact that the USGS's gage at Axemann shows that no significant increase in the annual peak runoff rates have occurred in the past 70 years.

This induced "recharge" may unfortunately result in negative water quality impacts if the surface runoff is not able to move through renovating materials, which consist primarily of the biological active soil horizons. Additionally, if the new surface runoff enters the ground in areas where conduit flow pathways dominate, the resulting apparently recharged water may actually rapidly exit the usable groundwater, resulting in a case where development still results in reducing usable groundwater.

Because of our inability to fully know how groundwater is moving, the University assumes that groundwater controlled by conduit flow may exist more predominantly in areas of large geologic sinkholes or in areas of known fracture traces, and that a portion of surface runoff, whenever possible, should be allowed to recharge in closed depressions or known recharge areas that may be underlain by a more diffuse groundwater flow area. In order to successfully consider these more complicated processes it must be understood that large-scale groundwater recharge of the usable aquifer occurs in discrete areas of the basin and not equally across all types of lands with similar land covers or uses.

University Park Watersheds



The majority of the developed portions of the University Park Campus are within one of four major drainage basins and several smaller drainage areas. The four major basins are: 1) the Fox Hollow Drainage Basin, 2) the Bathgate Dam Basin, 3) the Main Campus Basin, and 4) the West Campus Drainage Basin. The Fox Hollow and West Campus Drainage Basins are tributaries to the Big Hollow watershed, the Bathgate Dam Basin is tributary to Slab Cabin Run and the Main Campus Basin is tributary to Thompson Run. Other smaller University drainage basins include the Foods Building Detention Pond, the Parking Lot 43 Detention Pond, the Corl Drywell, and the Grad Circle Parking Bioswales.

Peak runoff rate control, volume control, and water quality control are conducted in the University Park area to varying degrees in each of the four basins. While minor structural stormwater management systems exist in each of the basins that were developed for specific land development projects, major systems have also been constructed to function at the basin scale. The Fox Hollow and West Campus Drainage Basins are considered to effectively control peak runoff rates, volume, and water quality. The Bathgate Dam Basin is considered to effectively control peak runoff rates and water quality. The Main Campus Basin relies on two downstream stormwater management areas to offset any impacts. These two areas are the Duck Pond, which is located immediately downstream, and Millbrook Marsh. The Bathgate Dam Basin has additional planned storage capacity for future imperviousness.

The Office of Physical Plant has collected continuous flow data every five minutes for the four drainage basins shown above since 2007. The University uses these data to guide stormwater management decisions in the basins.

Not all of the imperviousness shown in the below table is owned by the University. Borough properties account for approximately 15 acres in the Fox Hollow and West Campus basins.

Drainage Basin	Basin Area (acres)	Impervious Area (acres)	Percent Impervious
Bathgate	237.2	91.3	38.5%
Fox Hollow	453.4	134.9	29.8%
Main Campus	383.5	213.4	55.6%
West Campus	189.7	31.8	16.8%

Cisterns, Drywells and Sinkholes

Because the entire University Park Campus is underlain by carbonate geology, sinkholes are an operational way of life. Sinkholes can form due to the addition or removal of water, from utility leaks, as a result of development or just naturally. Most sinkholes on Campus are surficial sinkholes, where soils have been flushed out from previously developed cavities. The dissolution of the carbonate bedrock units in the area occurs in geologic time. A sinkhole that occurred in front of one of the entrances to the Forum Building in 2011 can be seen to the left. While sinkholes may occur fairly frequently on Campus, the University is sensitive to their development and practices that may make them occur more frequently. At the University Park Campus a sinkhole occurs on average every couple of weeks.

Old Main photograph courtesy: Annemarie Mountz, Penn State Live.

Prior to the construction of the University's wastewater treatment plant in 1913, raw sewage was frequently discharged into sinkholes, or cesspools. All of these types of discharges have been removed in the region. Because of this early practice, water 150 years ago would have been consumed from cisterns. The University occasionally will uncover an old cistern from this period. In fact, for the first 20 years of the University's existence, the potable water source was from a cistern located behind Old Main, which was fed by roof runoff.

Additionally, some buildings such as Old Main (at left) discharge all the rain water from the roofs into drywells, which result in no roof runoff from these buildings entering the storm drain system or the wastewater system. Because of the density of Campus buildings and the number of existing utilities in the ground that can act like trench drains directing water into buildings or inducing sinkholes at the utilities, only in some very special areas can such dry wells be safely employed.

Despite the most intensive geophysical investigations, uncertainty will always exist in how water moves once it becomes infiltrated into soils in a carbonate watershed. On the left is a photograph of the excavation for the Dickinson School of Law that was constructed north of Park Avenue. As can be observed, the bedrock can change from pinnacled rock formations to solid bedrock planes in a very short distance.

Critical Land Areas

In order to minimize stormwater impacts, land development activities need to avoid impacting and encroaching upon areas with important natural stormwater functional values. These areas include floodplains, wetlands, riparian areas, and drainageways as seen in this photograph of Millbrook Marsh.

Karst Critical Land Areas

In karst areas, critical land areas can include sinkholes, closed depressions, minor draws or drainageways, or what are commonly referred to as sponge areas.

In karst areas, if these additional critical landforms or areas are not identified or recognized, significant stormwater problems may occur following development. If any of the critical areas are developed, not only would they generate additional surface runoff from non-snowmelt events, but most likely all of the upslope runoff that is now being infiltrated would also become effective downstream, resulting in a double impact. In the Spring Creek Watershed, it has been recognized that land areas that may have only had a marginal impact on stormwater in the past, may now be playing a critical role by buffering downstream areas from runoff generated on upslope impervious areas.

In order to identify these types of areas, extensive data collection are required. The University has been a leader in defining these areas in the region. Three examples of such normally indiscrete areas are shown to the right. The top right is a photograph of the White Golf Course drainageway, which consists of a series of closed depressions. These depressions infiltrate all surface runoff discharged from West Campus and part of the Borough of State College. The depressions only allow surface runoff to leave the University's property during extreme meteorological conditions, the last time being during Hurricane Ivan in 2004.

The middle photograph is the Mitchell Tract closed depression, prior to the Arboretum's development, which is documented to infiltrate all runoff events, even a 100 year runoff event from approximately 70 acres of residential area. This depression also acts as an overflow area from the Park Avenue drainage system during larger runoff events. The bottom photograph is the Big Hollow drainageway on the north side of Campus. This drainageway is one of the University's most critical water resource areas for protecting its well fields.

Karst: a landform term related to blind valleys, sinkholes, closed depressions, or caves due to the dissolution of the underlying limestone or dolomite geology.

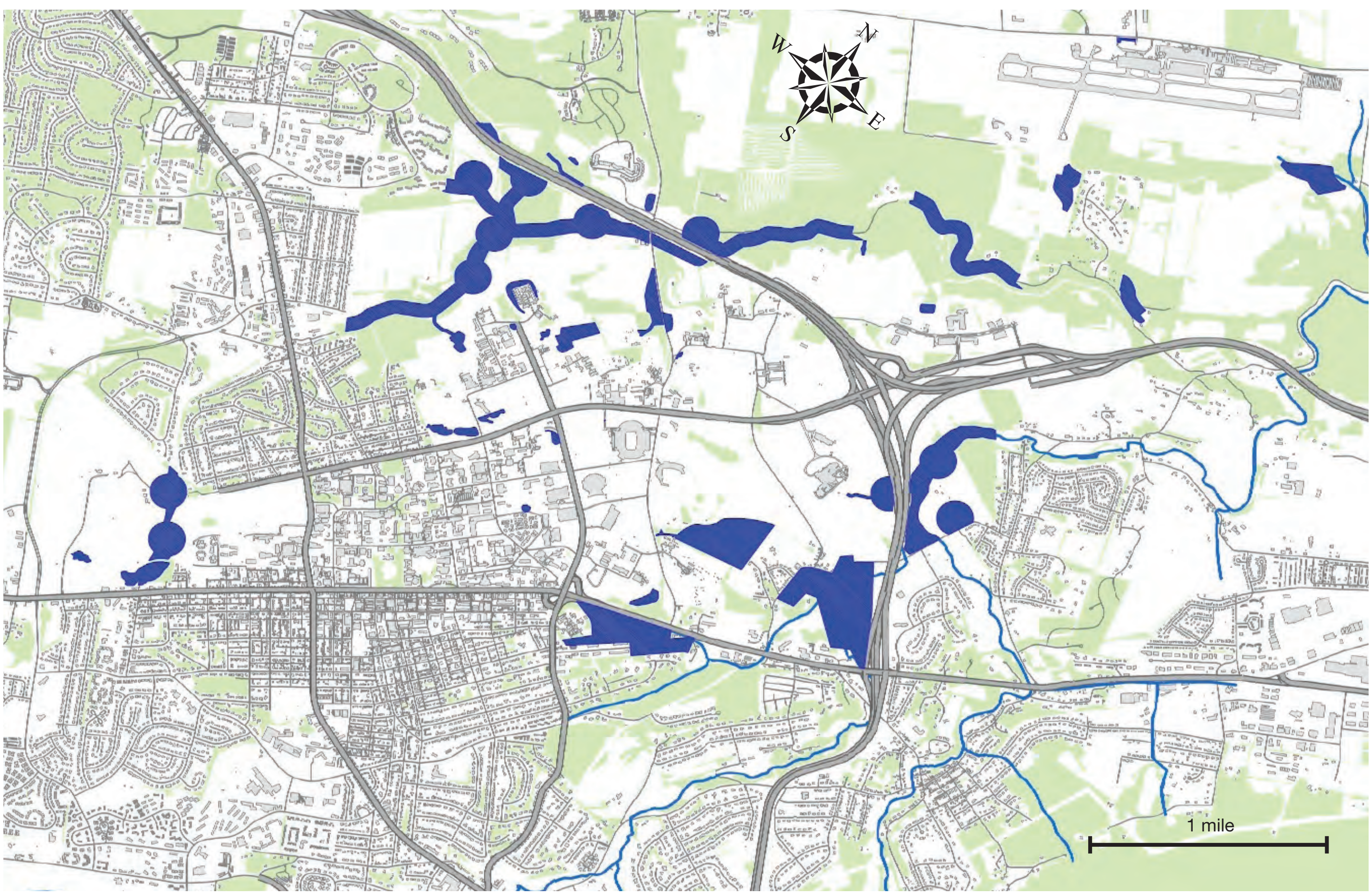
Water Resource Preservation Areas

From a wellhead perspective, the most important stormwater considerations for the University are to promote practices that allow the highest degree of renovation of stormwater and to keep any possible negative influences far removed from the wells so that adequate dilution occurs. No matter how bad a pollutant is, if it is not hydrologically active it may pose no real threat to the groundwater. The key is to understand the physical processes of how water actually moves in the area in addition to how each contaminant moves.

To protect its water resources, the University has defined critical areas on its property as Water Resources Preservation (WRP) areas, which are drainageways, streams, Zone 1 wellhead protection areas, natural infiltration areas, major sinkholes and depressions, detention basins, and other lands that have a significant impact on the University's water resources. Development, grading, clearing, grazing, or compaction are not permitted in these areas. The map below shows the extent of the WRP areas (in blue) that have been designated on University property. Abrupt areas where drainageways protection ends are where they leave University property. The University works with local groups to advocate the protection of areas not owned by the University.

The photograph above is the Mitchell Tract critical recharge area, which is located within the Arboretum and is now named the Marsh Meadow. The ponded water seen in the photograph was from 3.38 inches of rainfall that fell in 6 hours and the runoff was completely infiltrated by the next day. To date many of the critical recharge areas have been found to be drainageways with local alluvial soil.

The University promotes first the protection and use of the natural areas for stormwater management; however, the University still has numerous structural stormwater best management practices.



Dams

Dams are large impoundments that are regulated by the Pennsylvania Department of Environmental Protection (PaDEP) in order to protect the health, safety, and welfare of the public. The University owns six dams, four of which are located at the University Park Campus. Most dams require annual inspections and emergency action plans that are updated every 5 years. The University's largest dam is the Shavers Creek Dam, which is a 540 foot long earthen fill dam approximately 46 feet deep, shown to the right during the winter. The Shavers Creek Dam has a surface area of approximately 70 acres and holds about 1,100 ac-ft of water at normal pool. The dam was constructed in 1959 at a cost of $205,000.

Five of the University's dams are classified as High Hazard dams by PaDEP. The Shavers Creek Dam is designed to pass a full probable maximum flood (PMF), while the others are designed for a 1/2 PMF event. A probable maximum flood in this area considers what would happen during a rainfall event of approximately 36 inches occurring over a 72 hour period.

The Bathgate Dam (below left) is the University's only other dam with a permanent pool of water. This dam has a water quality forbay that reduces pollutant loading downstream and is lined to prevent sinkholes. The Bathgate Dam discharges to Thompson Run in the University's Millbrook Marsh. Because the Bathgate Dam is located on the edge of campus (on the northeast side of Porter Road), classes can visit this dam fairly easily by contacting the Office of Physical Plant.

The dam shown below at right is a typical dry dam, which functions primarily as a large stormwater management pond. Three of the University's dams are dry dams, two of which are located at the University Park Airport and one that is located on the Hershey Medical Center Campus in Hershey, PA.

The Airport Dam below at right is also lined due to being located in carbonate geology. This dam has approximately 65 ac-ft of storage capacity for a drainage area of 341 acres and discharges less than 15 cfs for all but the most extreme runoff events due to discharging in close proximity to Spring Creek.

The Duck Pond located along College Avenue is a class C-4 dam constructed in the late 1920s as an ice skating rink.

Surface Ponds

The University owns over two dozen stormwater management ponds and several ponding areas that simply flood during large runoff events. The Duck Pond seen at the left was originally constructed as part of the "Pennsylvania State College" Class Gift of 1927 to 1930, which was called the Winter Sports Park Complex at Thompson Springs. The pond's size and shape, the spring flow paths, and the water feed locations to the pond have been changed several times over the years. Today, the pond is approximately 2 acres in size. While many people consider the duck pond a stormwater pond, it was never intended to be one or have that function. However, the pond does work as an excellent settling pond for suspended solids in storm flows, but does create a thermal impact to Thompson Run.

Most stormwater management ponds at University Park were designed as traditional detention ponds. However, because of the carbonate geology, many of these still infiltrate a significant amount of surface runoff from impervious areas resulting in discharging runoff only from larger rainfall or snow melt events. The pond at left, designated Parking Lot 43 Pond, is an under-drained infiltration basin. In the last 10 years of monitoring, the largest peak rate discharged was less than 0.5 cfs, even though it's drainage area is over 5 acres of impervious parking area.

The University collects 5 minute data continuously from its larger stormwater ponds. Some of the ponds are structurally lined, but most are not. In the Centre Region, as many lined ponds as unlined ponds have developed surficial sinkhole problems. Ponds that were originally designed using models that did not account for the carbonate geology during the pre-development analysis are being reanalyzed and as funds become available are converted to discharge smaller peak runoff rates.

Some areas, such as the softball field pond shown on the left provide dual uses. The Pond is not regulated, but rather is controlled by the University. This area is a remnant of the original Fox Hollow drainageway and is designed to flood approximately once a month. This flooding plays a critical role in protecting downstream facilities. In the Spring Creek basin, if peak runoff rates are delayed or extended, downstream drainageways can safely infiltrate more stormwater.

Subsurface Detention Facilities

As the University constructs new facilities to keep up with the demands of being an educational, research, and service institution, it finds that infilling in core campus is often deemed more desirable than expanding on the fringes. Because of this, land on the core campus area is continuously becoming more valuable. Because the University has determined that peak runoff rate control is a significant requirement to protect its resources in addition to community resources, additional subsurface stormwater detention facilities are being constructed.

Currently the University has 42 subsurface units. These units are designed to provide temporary storage volume of runoff so that the peak rate of discharge leaving is reduced to some pre-determined level. Generally, this level is based on protecting a downstream conveyance system from flooding. The photograph to the right is the Sarni facility under construction, which is the University's largest subsurface detention system holding well over 1,000,000 gallons.

The University currently has subsurface units that are constructed of corrugated metal pipe (CMP), high density polyethylene (HDPE), and reinforced concrete pipe (RCP), with reinforced concrete being required for all new facilities. Plastic built up storage systems are prohibited at University Park.

These systems are constructed with accessible entry points and are inspected annually. Vacuum trucks are used to clean out debris that collect in these systems. Because of the potential of sinkholes and the fact that the majority of the soils are removed, none of these facilities are permitted to infiltrate or leak greater than a prescribed amount. In fact, designs at University Park Campus are required to have a separation between pipes because if one leaks and forms a sinkhole, it should not render the entire unit useless.

The University has instituted a multi-phased research project where all of the subsurface units are monitored and analyzed for performance. The below left photograph shows the inside of a pipe where the normal water storage level and the apparent high water mark can be observed. These systems discharge water using multi-stage orifices as seen in the photograph on the lower right. Trash racks are incorporated over the low flow orifices.

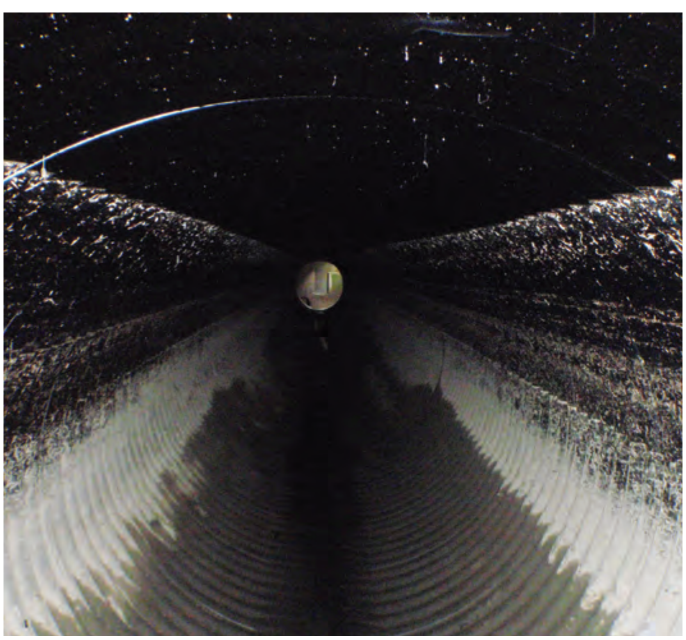
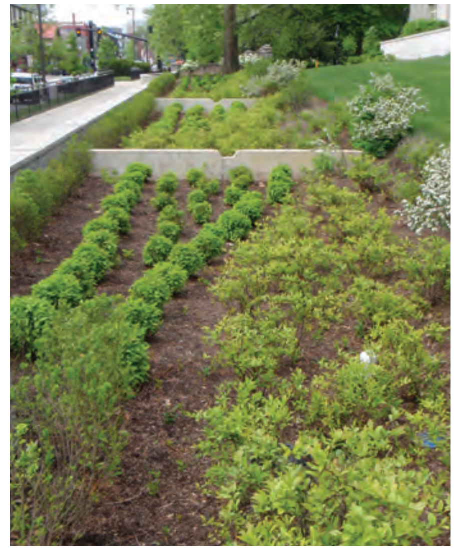


Photo: Mark Saville

Bioswales and Rain Gardens



Bioretention is a method of treating stormwater by ponding water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Rain gardens, bioswales, or bioretention techniques are primarily used to accomplish water quality improvement and water quantity reduction. Because bioswales and rain gardens generally use a manufactured urban soil complex, they are not considered as beneficial as other campus green stormwater best management practices that use undisturbed in-situ soils.

The University currently has about three dozen bioswales or rain gardens around campus. Approximately two thirds of the systems at the University Park Campus are structurally lined so that they do not infiltrate water into the subsoil. The primary reason many of these facilities are lined is because they are frequently criss-crossed by existing utilities that can move water into buildings via the utility's trench and bedding. Sinkholes are not a significant concern and only one bioswale has developed a sinkhole so far. The bioswale at top left is one of a pair constructed for a large parking area. Not only was the area of the bioswale previously constructed fill, but they were both placed in the basements of demolished buildings; and therefore, these two are lined and under drained such that the only volume control is from seasonal evapotranspiration.

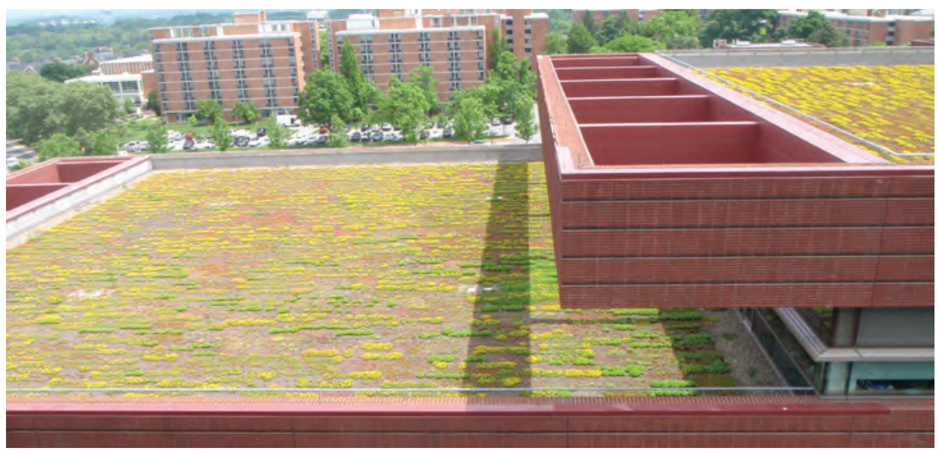
Bioswales or rain gardens, if designed properly, can also be used for peak runoff rate control from smaller areas similar to a detention structure; however, most at the University are not specifically designed for that function.

The bioswales (above right) are an example of four bioswales in series along the College Avenue corridor. Only one of the four was used to meet regulatory requirements for redevelopment. The lower left photograph is at the Intramural Building and had plantings and hardscape used that are non-traditional including trees, which were planted over the liner. The lower right photo shows a small rain garden adjacent to a building. Maintenance concerns have resulted in restricting the use of multiple small rain gardens for most projects.

Green Roofs

Plant-covered roofs have been built in many U.S. and German metropolitan areas for decades. Green roofs have been touted to provide multiple environmental benefits including mitigating summer heat because plants cool the air; insulating the building, keeping it cooler and reducing summer electricity bills; increasing the life of the roof up to twice as long as a traditional shingle roof; and increasing the evapotranspiration from the roof to that of a naturally vegetated area on an annual basis.

Some people also advocate that green roofs can be used for stormwater management to control peak runoff rates following development. While this may be the case in some areas, any under drained green roof cannot generally match the pre-development runoff rates from carbonate-derived soils. The University generally assumes that a 4” deep extensive green roof can attenuate approximately 1” of rainfall. Therefore greens roofs are not used for peak runoff rate control at the University.



The first full-scale green roofs on campus were constructed in 2006. The University currently has 14 buildings with green roofs with a total coverage of approximately 3.3 acres. The Katz Building has the only sloped green roof on campus and can be seen in the upper right. The Millennium Science Building has over 1 acre of green roofs as see on the right. This roof still exhibits its distinct row planting scheme after eight years. While sedums are typically planted on the roofs, some deeper intensive soils can sustain other vigorous plant growth as seen below.

Infiltration Facilities

Stormwater runoff can be a source of pollution that in some cases could be catastrophic to a groundwater supply such as if the University's Best Management Practices (BMP) are improperly designed, installed or maintained. The University believes stormwater runoff in carbonate areas should be directed to natural critical areas that provide renovation of stormwater in undisturbed well-vegetated in-situ soils. If the artificial recharge of stormwater is attempted on small individual sites, such as what is being promoted with the land development industry, it must be done very carefully and not using pre-defined criteria or "rules of thumb" developed in non-carbonate areas. Adequate pretreatment must be accomplished prior to stormwater runoff being injected into an engineered infiltration BMP. Water quality pretreatment facilities must be visible and accessible to provide a means to monitor their efficiency and replace if necessary in the event of failure.

The University has developed its own ranking of volume control stormwater facilities from best to worst. They are: 1) discharge low velocity surface runoff to existing undisturbed, stable, closed depression areas, 2) discharge low velocity surface runoff to existing undisturbed areas that have engineered berms to induce shallow surface ponding, 3) create small low-head bioswales (engineered vegetated depression areas) where temporary ponding is acceptable, 4) use porous materials over soils in which only the topsoil or organic upper soil horizon has been removed, 5) use green roofs or other methods that allow ET to occur, but are essentially lined or under drained, 6) use low velocity pervious swales to convey surface runoff to storm drains, 7) use engineered infiltration methods such as infiltration beds, where the tributary area to the bed is equal to the area of the actual bed or treatment area, 8) use unlined surface ponds, and lastly 9) use engineered infiltration methods such as infiltration beds where the tributary area to the bed is greater than the area of the actual bed or treatment area.

The University has examples of all of these at the University Park Campus including the Fox Hollow Recharge Facility shown above during a winter runoff event. The Fox Hollow facility was the first constructed Low Head Weir (LHW), a method pioneered by the University in 2003. Below left shows an example of a protected closed depression with an overflow grate that prevents roadway overtopping. The photograph below right is the only low head weir constructed to date on historically altered soils. The University Park Campus currently has nine low head weirs.

By protecting its critical land areas, such as the Big Hollow drainageway and Millbrook Marsh, the University is able to recharge millions of gallons annually from off-site properties that discharge surface water onto these natural land areas.

Photo © Mike Turns

Wetlands

Wetlands play an important role in protecting and renovating water quality. One excellent example is the Millbrook Marsh, which has a Nature Center operated by Centre Region Parks & Recreation.

The 62 acre site, seen in the photograph to the right, consists of a 12 acre farmstead area, plus an adjacent 50 acre wetland area. The 50 acre wetland area also hosts a conservation easement between Penn State and ClearWater Conservancy of Central PA. Both tracts were leased from Penn State to the Centre Region Recreation Authority starting in 1997 for $1/year. The center provides an opportunity to present to Centre Region residents three important themes from the site: environmental, agricultural, and historical.

The 50 acre wetland includes several important types of wetland areas, including natural springs and a calcareous fen. The forested areas draw a wide variety of wildlife. The meadows contain wildflowers, tall grasses, and sedges.

Millbrook Marsh is located at the confluence of Slab Cabin Run and Thompson Run. The Marsh is located approximately 1,000 feet upslope of the Spring Creek confluence and has a large buffering influence on water quality and peak runoff rates seen downstream. While large wetlands such as Millbrook Marsh are rare in the carbonate valley, the University has other small artificial wetlands that attempt to mimic the treatment characteristics. Seen in the lower right photograph is the Fox Hollow filtration area, which was constructed just upslope of the Fox Hollow recharge facility. This area incorporates both structural and non-structural methods of pollutant removal. Because the soils in the area are prone to sinkholes and are highly infiltrative, constructed wetland such as these usually require a clay or structural liner.

Other examples of constructed wetlands are the water quality forbays that are located on some of the surface ponds. The largest such forbay can be seen on the cover page of the magazine, which shows the Bathgate Dam's forbay that was added to the dam during a 2001 expansion project.

Storm Drains

Storm drains are pipes under the ground designed to convey runoff downstream. The University Park storm drain system is currently a 100% gravity flow system consisting of approximately 73 linear miles of storm drain pipes varying from 6 inches to 72 inches in diameter, and thousands of inlets and manholes. The lower figure shows the storm drains at University Park as blue lines.

The oldest storm drains that have been in continual use are approximately 100 years old and are made of reinforced concrete (RCP), which tends not to degrade in the area. At left is a photograph from 1948 along College Avenue, during which a major storm drain project was undertaken through the core Campus area. Seen in the photograph is a 33" reinforced concrete pipe being replaced with a 66" bituminous coated corrugated metal pipe. Other types of storm drain material at the campus are galvanized or aluminized corrugated metal pipe (CMP), high density polyethylene (HDPE), polyethylene (PE) terra-cotta (TC), ductile iron (DI), cast iron (CI), or polyvinyl chloride pipe (PVC).

The University has surveyed the major lines and has hydrologic and hydraulic models of the main portions. Because sinkholes are a real concern, none of the storm drains are designed to leak water into the ground and all pipes are desired to be water tight. Storm drains are inspected and repaired as required. The University no longer attempts to increase pipe size because stormwater is managed from new developments at each site.

Conveyance Swales

Conveyance swales are traditional swales that are designed to move water downstream, with little regard to improving water quality. While the University owns numerous grass lined swales, such as seen below, these swales cannot adequately provide long term stability for high flow or slope channels. In these conditions, swales need to be able to resist the velocity and shear stress of the flowing water. At University Park, numerous hard armored conveyance swale types have been used around campus. Interlocking concrete block swales, concrete swales, fabri-form concrete mats, gabion basket and reno mattresses, and the more common rip rap stone are seen in the photographs on this page, which are all located at the University Park Campus. The most recent major armoring project was conducted at the duck pond channel seen in the lower right photograph. This project has significantly reduced sediment loads to Thompson Run.

Water Quality Inlets and Oil/Water Separators

The University has several types of water quality inlets to remove specific pollutants from stormwater runoff. At the left two large continuous deflection separators can be seen during their installation. At University Park, several types of hydrodynamic storm structures are used. However, water quality inlets that require regular replacement of filters are prohibited except in special circumstances where their need is specifically documented. All of these facilities, in addition to regular inlets and subsurface detention units are on a regular inspection and cleaning schedule.

Oil/water separators are also used to remove contaminants from runoff. The photograph at middle left shows a 15,000 gallon oil/water separator being installed in the Fox Hollow drainage basin. The University has about a dozen oil/water separators located around campus.

Below right a University employee can be seen conducting an annual inspection of an oil/water separator located at the University Park Airport, and below left shows the cleaning of a storm inlet and the surrounding pavement with the University's vacuum truck. The University has found over the last decade that anti-skid material used for winter safety is one of the largest pollutant loads being transported in the storm drain system.

Pervious Parking

The University has been using porous or pervious parking areas for as long as cars have been driven. Many sports events use grass parking areas as seen in the lower photograph during a football game. Unparked grass areas in the photograph are athletic fields or critical water resource preservation areas.

The University is well aware of the problems associated with the construction of large impervious parking lots; however, it is also aware of the problems related to pervious parking areas. While occasional parking on pastures is preferred during temporary events, parking on these areas frequently or when wet can be extremely problematic. Some areas, such as the Beaver Stadium north end zone grass parking lot seen to the right are specially engineered grass areas that can be parked on in any weather condition without rutting or other problems. Several pervious parking areas exist around campus that use commercially available products that reinforce the soils for when more frequent parking is required. However, at University Park, porous pavement (asphalt) is prohibited because of two failures on campus and the fact that the technology does not meet the University's expectations regarding water quality.

Photograph of Beaver Stadium courtesy: Greg Grieco, Penn State Live.

Energy Dissipaters and Level Spreaders

Energy dissipaters are used at the outlet of swales or storm drains to reduce the energy and velocity of runoff so erosion does not occur. Likewise, level spreaders are used to both slow down and spread out the runoff. Whenever possible, natural level spreaders are preferred, such as the one seen to the left; however, when this is not possible engineered systems are used.

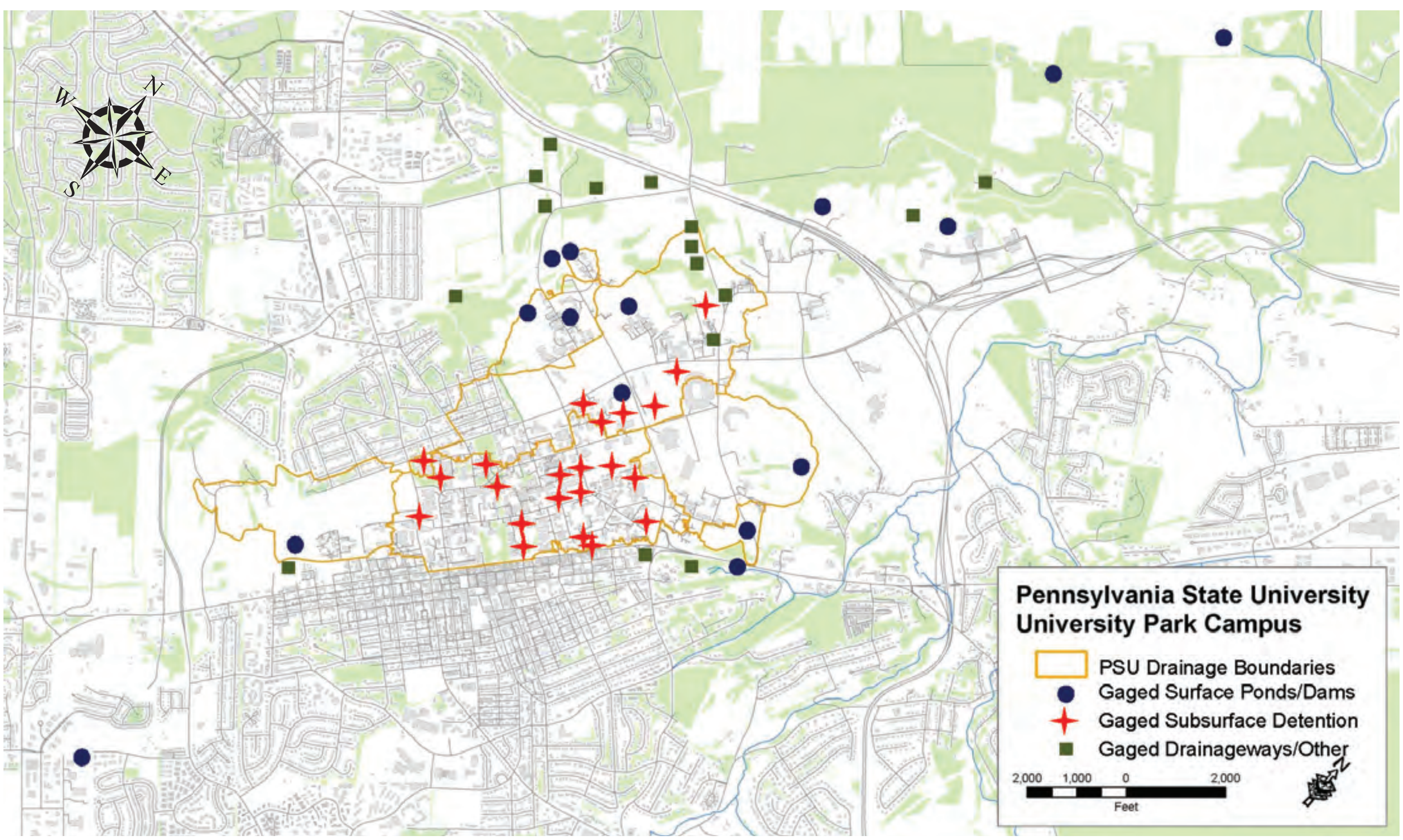
At University Park, several types and designs of energy dissipaters are used including large impact basins, drop chutes, preformed scour holes, and the traditional riprap outlet. The preference at University Park is that pipe outlets are sumped, when hydraulic conditions allow, which results in runoff spilling out at a low velocity from the edges of the sump.

Surface Water Gaging

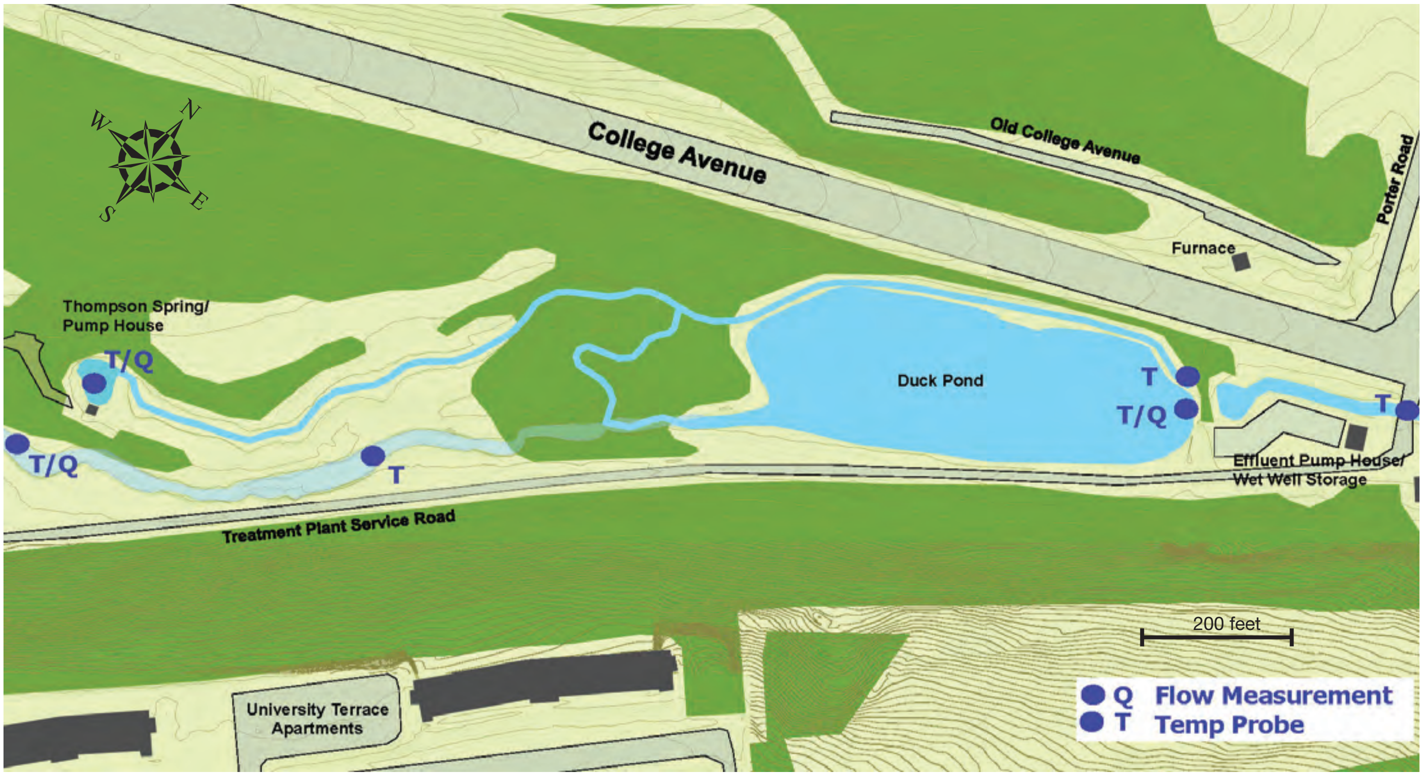
The University's Office of Physical Plant has instituted an extensive surface water monitoring project with over 25 permanent gages located throughout the University Park Campus in an effort to better understand the local hydrology and protect its water resources. The lower map shows where some of these gages are or have been located. All the regulated dams, major stormwater detention facilities, and watershed outlets are currently gaged or planned to be gaged in the future.

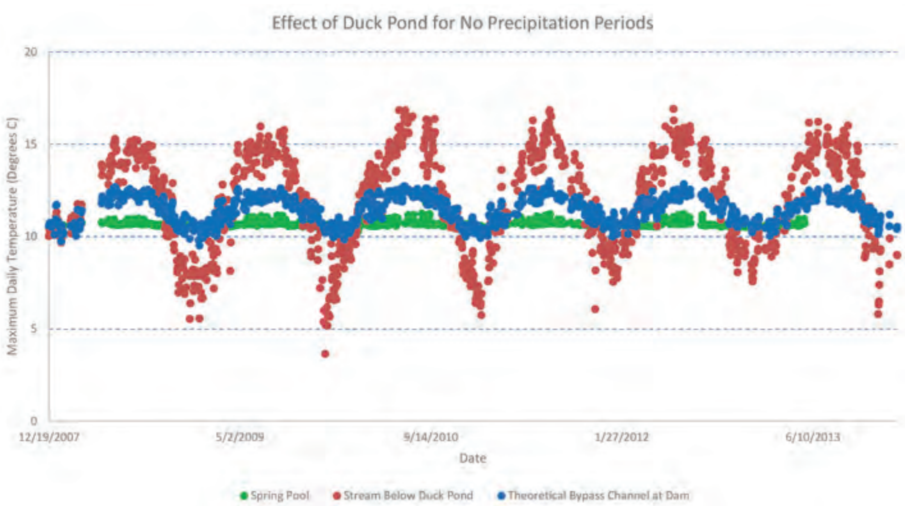
Data are continuously collected in 5 minute or 15 minute intervals depending on the size of the watershed. Some of the gages are calibrated v-notch weirs or flumes as seen in the photographs above, or other control sections, which are accurate at determining runoff peaks and volumes. Some gages are earthen control sections that still need to be calibrated, which has not yet been finished because of the lack of surface runoff in many areas. Data are available to University faculty for research or class projects, and data summaries are published as Water Resource Publications, which are available to the public.

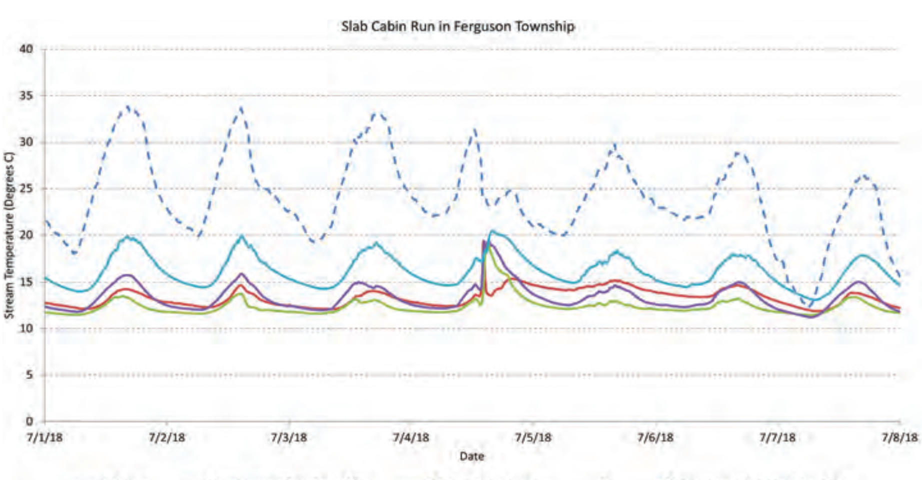
Additionally, the University's Office of Physical Plant supports local non-profit groups with data collection efforts off University property.



Thermal Studies





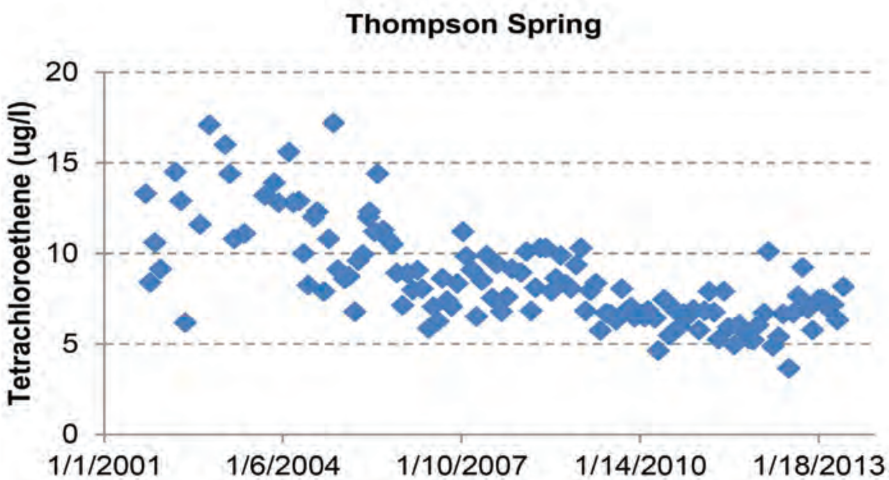


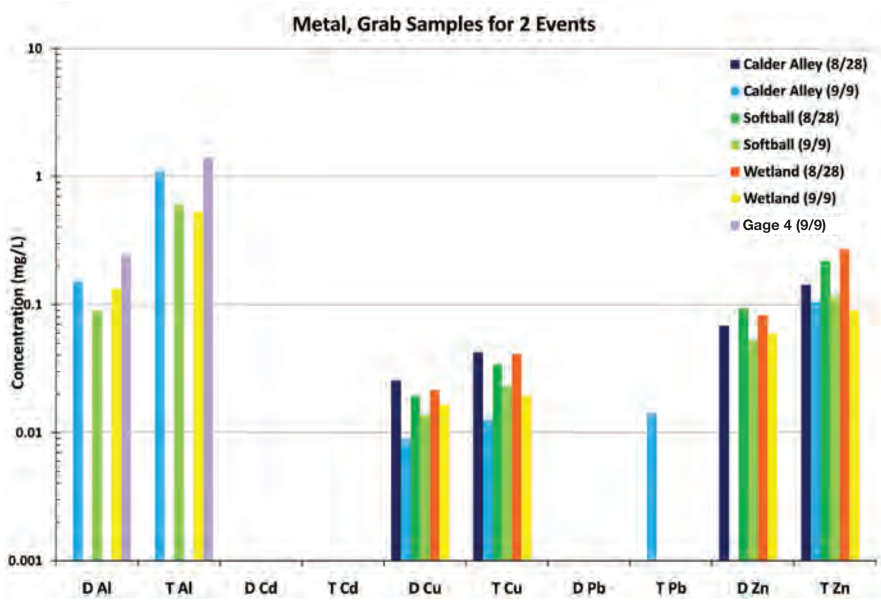
Groundwater discharge to a stream is at a relatively constant temperature, whereas stormwater runoff from developed areas may be very hot in the summer months and cold in the winter months. These temperature extremes can have a significant effect on aquatic organisms, from bacteria and fungi to larger species. Many fish, especially native trout, can be harmed by a temperature increase of a few degrees.

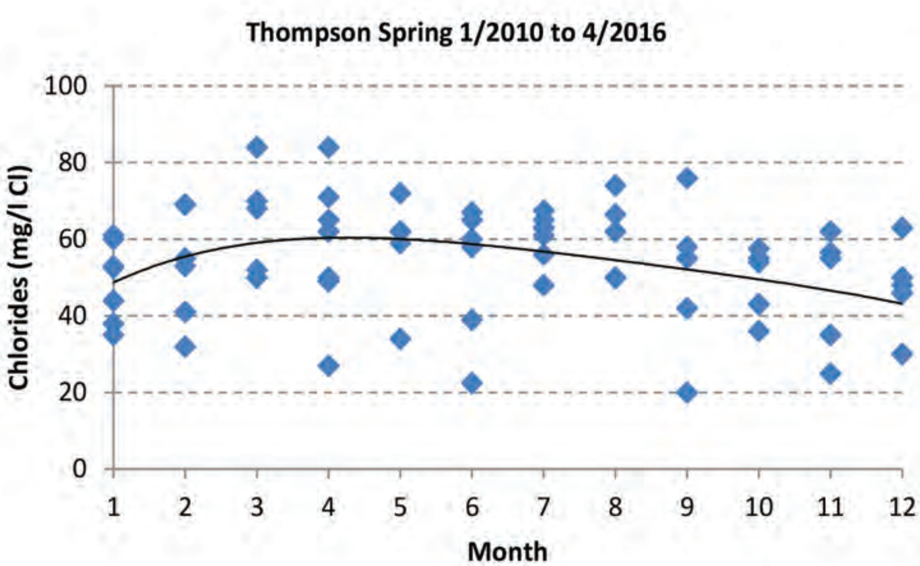
As part of a larger research effort, the Office of Physical Plant monitors the temperature of stormwater discharges in several areas. The largest study was conducted at the Thompson Spring and the Duck Pond. The above map above shows where flow and thermal data were collected over a six year period to determine the effects of stormwater inflows and the Duck Pond itself. As seen in the middle left graph, during no rain periods the duck pond can significantly affect the stream temperature.

The lower left graph shows data from Upper Slab Cabin Run in Ferguson Township and how the temperature changes as flow moves downstream through the Township. This thermal study is being conducted as a joint education and outreach project by the University and the Township. The graph represents a one-week period during which a 1.5” storm event occurred on July 4th during one of the hotter periods of the year.

Water Quality Testing





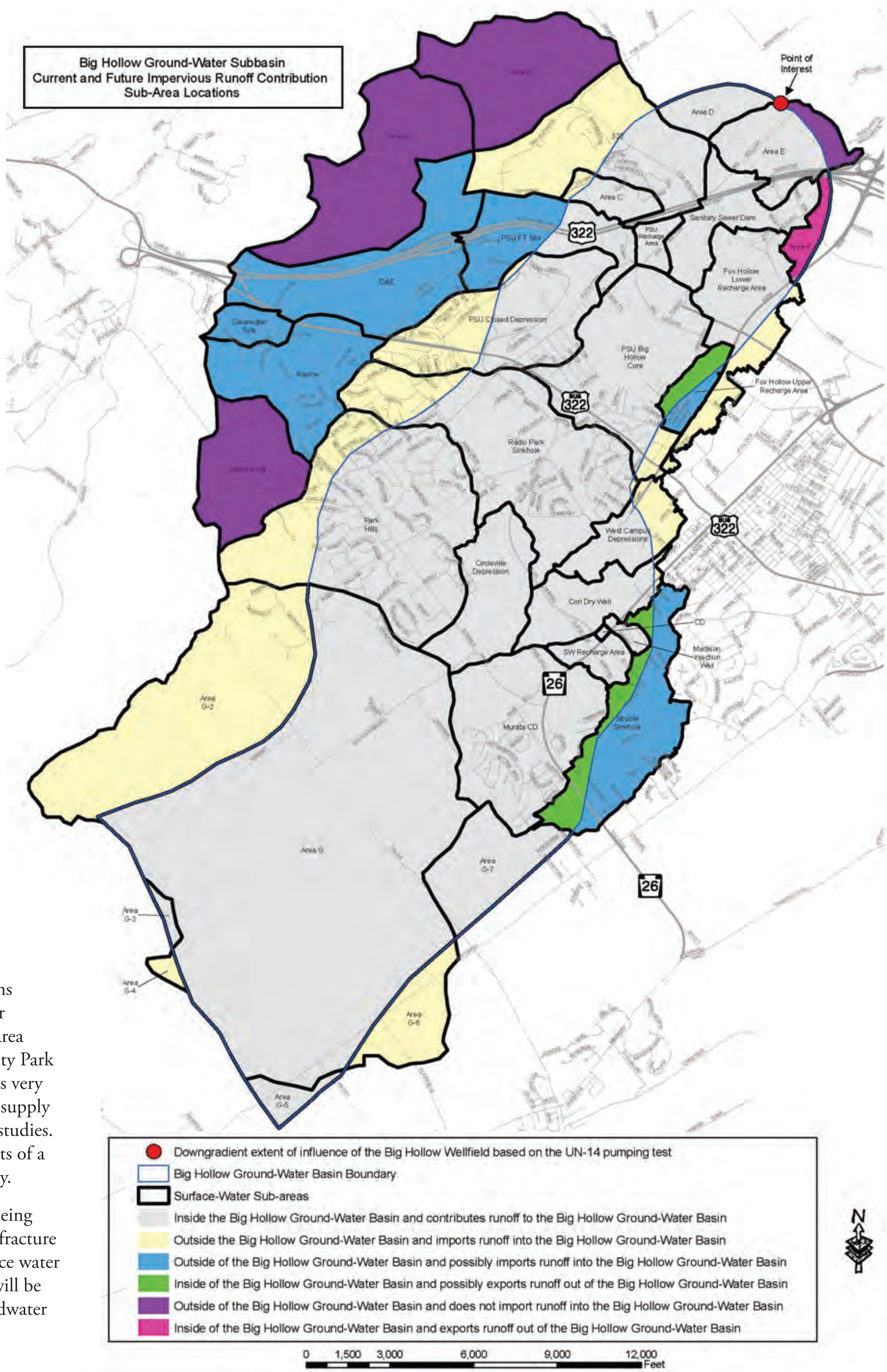


Pennsylvania's Department of Environmental Protection uses a narrative or Best Management Practice approach to address water quality and does not require effluent testing. Nonetheless, the Office of Physical Plant (OPP) conducts water quality testing of stormwater runoff as needed.

As part of the University's annual inspection program during dry weather periods, any flows that are observed can be tested on site by staff for detergents, chlorine, pH, temperature, copper, and phenol. Past sampling indicates that the quality of stormwater runoff from the University is fairly good and runoff is significantly less than most urbanized areas.

In addition, the University's lab at the wastewater treatment plant routinely tests springs and other significant surface water for pH, hardness, turbidity, chlorides, conductivity, alkalinity, and perchloroethylene (PCE). Additionally, testing is done as part of other permits, or purely from a research perspective such as the three graphs seen to the left, which represent sampling being conducted of the University runoff in addition to runoff from other properties that discharge onto the University's property. Periodically, OPP funds graduate students to monitor water quality data as part of their research studies.

Surface and Groundwater Interactions



Because of the interactions between the surface water and groundwater in the area surrounding the University Park Campus, the University is very concerned with its water supply and conducts numerous studies. This map shows the results of a study on water availability.

Other studies currently being conducted are dye trace, fracture trace mapping, and surface water monitoring. These data will be used with existing groundwater well data.

Demonstration Projects

Penn State, in addition to providing education, research and service to Pennsylvania, is a large landowner with extensive facilities and responsibilities. The University's holistic water management strategy in a karst terrain includes the wise use and reuse of this valuable resource, while providing an opportunity for experimental or demonstration projects to prove their worth.

Seen at top left is a cross vane recently constructed as part of a demonstration project along Slab Cabin Run in Millbrook Marsh. These vanes improve fish habitat and reconnect the flood plain with the stream. A 10 year assessment of the vanes was conducted in 2017, which determined the vanes were largely intact and still functioning as designed.

The University recently worked cooperatively with the Pennsylvania Fish and Boat Commission, Trout Unlimited, and ClearWater Conservancy to move the stream bank fencing farther away from Spring Creek along its Sheep Farm property. Fish habitat structures were also created as well as riparian planting by volunteers as seen below.

Not all demonstration projects are successful. Porous pavement constructed at the Centre County/Penn State Visitor Center as seen in the middle left failed soon after installation. While we frequently learn more from our failures than successes, this experience helped prohibit the further use of porous asphalt pavement on campus. Today porous pavement is only used on sports surfaces such as basketball courts.

Stormwater Master Plan

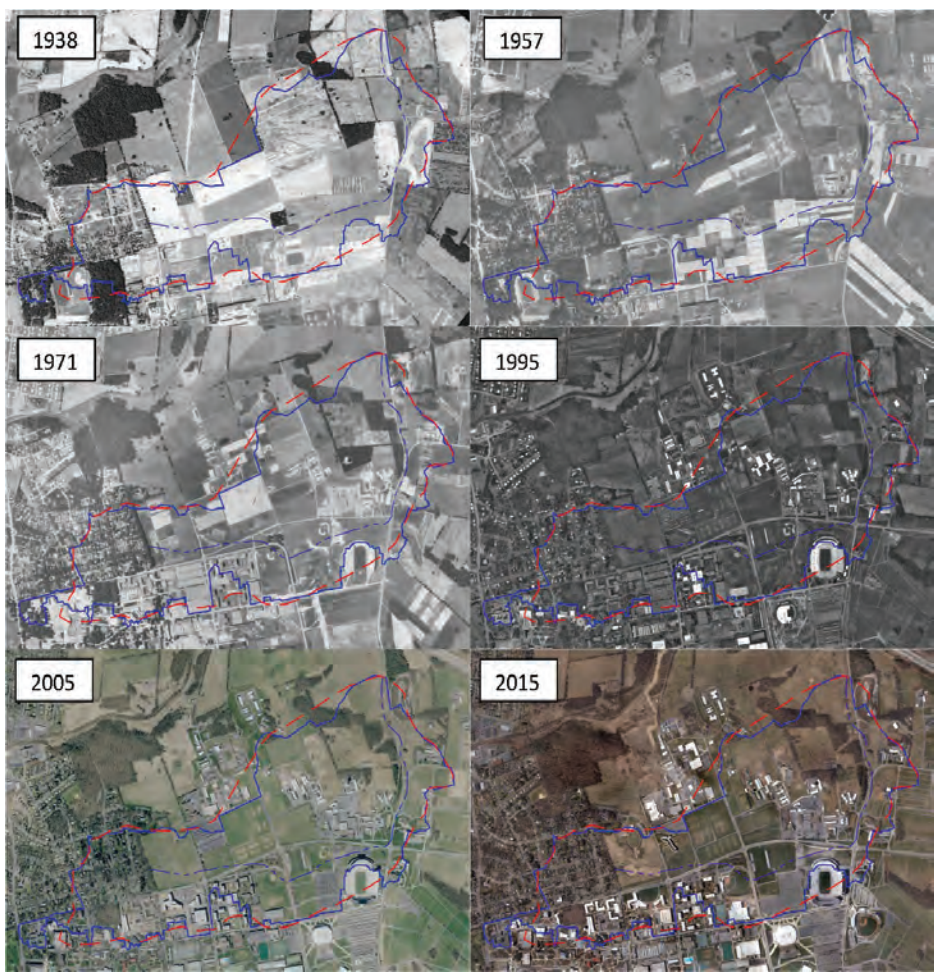
The University has developed a Stormwater Master Plan that is published online which provides a comprehensive view of stormwater management at the University Park Campus. The plan covers the history of development on campus, the overall stormwater philosophy, maintenance and financial responsibilities, and special design requirements. The plan also provides guidance for future repairs and corrective actions required in the four main drainage basins.

Drainage basin mandates are currently instituted across the board and supersede and are in excess of all other municipal, State, or Federal requirements. For example, in the entire Main Campus drainage basin, all redevelopment projects over 0.5 acres of total disturbance are required to assume that 100% of the existing impervious areas are meadow in good condition for the consideration of peak runoff rate computations. This applies to extended detention storage requirements, when there is a land use/cover change proposed.

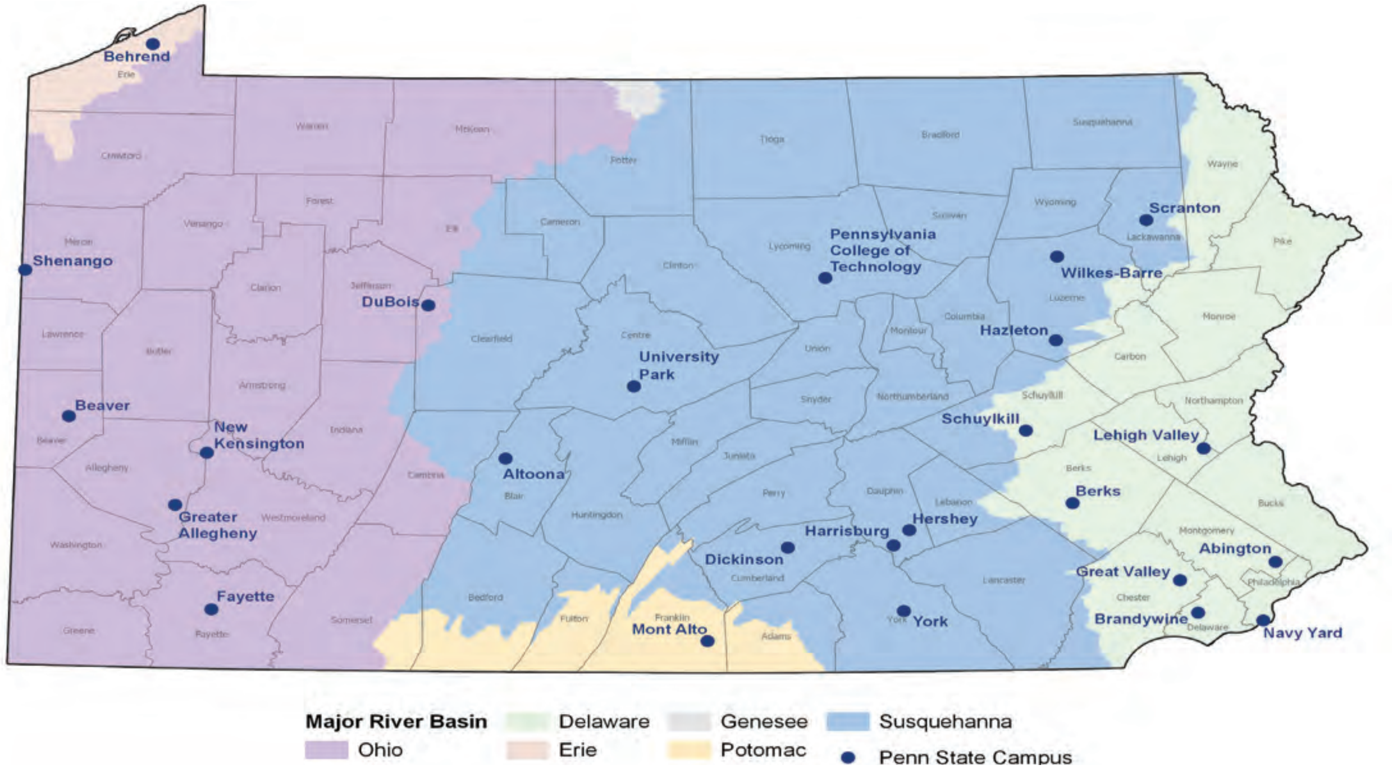
Another fairly unique aspect of the University's policies is how it deals with existing flooding. While some flooding is due to storm drain conveyance systems that are undersized, the University will not simply increase pipe sizes to solve the problem, because such actions are counterproductive to the goals of the University and result in pushing more flooding downstream (flood transference) to both University and non-University properties. Rather, all new development and redevelopment projects at the University have the goal of reducing peak runoff rates downstream to eventually reduce peak flows to the existing pipe capacities.

Additional publications called Water Resource Publications have been developed with specific information on certain storm drain networks where major problems exist. These studies can sometimes provide even stricter design guidance than the master plan requirements.

While the University recognizes it will likely never get back to the environment that existed here in the 1800's, as seen in the above right 1895 photo of the Thompson Run Valley, the University does attempt to understand how the land use and cover had changed over time affecting stormwater.



MS4 Permit



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 (PaDEP) 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.

In the Centre Region, College, Ferguson, Harris, and Patton Townships, the Borough of State College, and Penn State's University Park Campus have had MS4 permits since 2003. Penn State works cooperatively on several initiatives with the local municipalities and takes care of all of its own MS4 permit requirements and pollutant loads, which is something no other land owner does.

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

In 2013 the MS4 permits also included additional requirements for impaired waters, watersheds with a Total Daily Maximum Load (TMDL), and watersheds that drain to the Chesapeake Bay. These new requirements are significantly increasing costs for MS4 permittees, which is resulting in municipalities instituting stormwater fees in some areas.

There are approximately 950 municipalities in the State of Pennsylvania with MS4 permits. In 2013, of the 19 non-municipal MS4 permits in the State held by universities and colleges, Penn State accounted for 15 of the permits/waivers. The other four were State owned universities.

Stormwater Oversight Committee

The University is aware of the key role that proper management of stormwater plays on the health of watersheds in which our campuses are located. Proper stormwater management can be a challenge that is complex, multi-faceted, and involve best management practices that implement cutting edge technology. It will be important to use the vast resources of the University to meet this challenge.

To that end, a group of key faculty and operating staff help guide the University strategy for stormwater management. The group's goals include developing standards for watershed and stormwater monitoring, data gathering, modeling and analysis. Exploring educational and external funding opportunities are also pursued. All campuses and projects can request input by the committee or its members, who are experts in their field. The Committee's membership currently includes University Park faculty and staff from the following Departments:

- Department of Agricultural and Biological Engineering
- Department of Agricultural Economics and Rural Sociology
- Department of Civil and Environmental Engineering
- Department of Crop and Soil Sciences
- Department of Geography
- Department of Geosciences
- Department of Horticulture
- Department of Landscape Architecture
- Office of Physical Plant
- School of Forest Resources

University faculty and students have been studying the surroundings, including its watersheds, since the University's founding as seen in the 1890's photograph above of Civil Engineering students measuring stream velocities on Thompson Run.

The University has protected special value areas such as Hort Woods seen to the left, which is located in core Campus and receives stormwater runoff from surrounding areas.

Community Support and Cooperation

University faculty and staff work consistently with conservation groups to improve the region's water resources and quality of life. For example, in 2016 University staff worked with Trout Unlimited to remove fallen trees and brush from the Thompson Run bypass channel as seen in the photograph below. In 2014, the University worked with the community and built the Musser Gap Greenway & Trail bike path and bridge on its Mellon property as seen in the photograph at the bottom.

Additionally, because of the University's extensive land holdings, the surrounding municipalities and land owners discharge hundreds of millions of gallons a year of stormwater runoff onto protected land areas of the University where it's infiltrated.

Penn State Water Resources Outreach

The University's Office of Physical Plant conducts numerous stormwater management outreach initiatives including working with students and faculty, as well as local community groups and State committees. Additionally, Penn State has other departments and programs that teach water resource topics or conduct research. A partial list is:

- Agricultural and Biological Engineering Extension
- Agriculture and Environment Center
- Center for Dirt and Gravel Road Studies
- Center for Sustainability at Penn State
- College of Agricultural Sciences Natural Resource Extension
- College of Agricultural Sciences Water Resource Extension
- Penn State Center for Green Roof Research
- Penn State Riparia, Cooperative Wetlands Center
- Penn State Department of Meteorology Weather Station
- Penn State GIS Technical Support Center
- Penn State Institutes of Energy & The Environment
- Pennsylvania Housing Research Center
- Pennsylvania Water Resources Research Center at Penn State
- Shavers Creek Environmental Center
- Rock Ethics Institute

Additionally, the University faculty and staff participate on local conservation committees such as the Spring Creek Watershed Association, and the Water Resources Monitoring Project in addition to numerous other committees.

The University also has cooperative agreements with State and Federal programs such as the Pennsylvania Cooperative Fish and Wildlife Research Unit and the United States Department of Agriculture's Agricultural Research Station.

In part because of the University's efforts at addressing stormwater on Campus, it is likely that water quality in Spring Creek is better now than it has been at any time since 1900.

Photo © Mike Turns

Stormwater management education is an important component of protecting our water resources. This magazine is provided free of charge with the hope that students, faculty, and researchers will have a better understanding of the types of stormwater management facilities that are located at the University Park Campus.

PennState