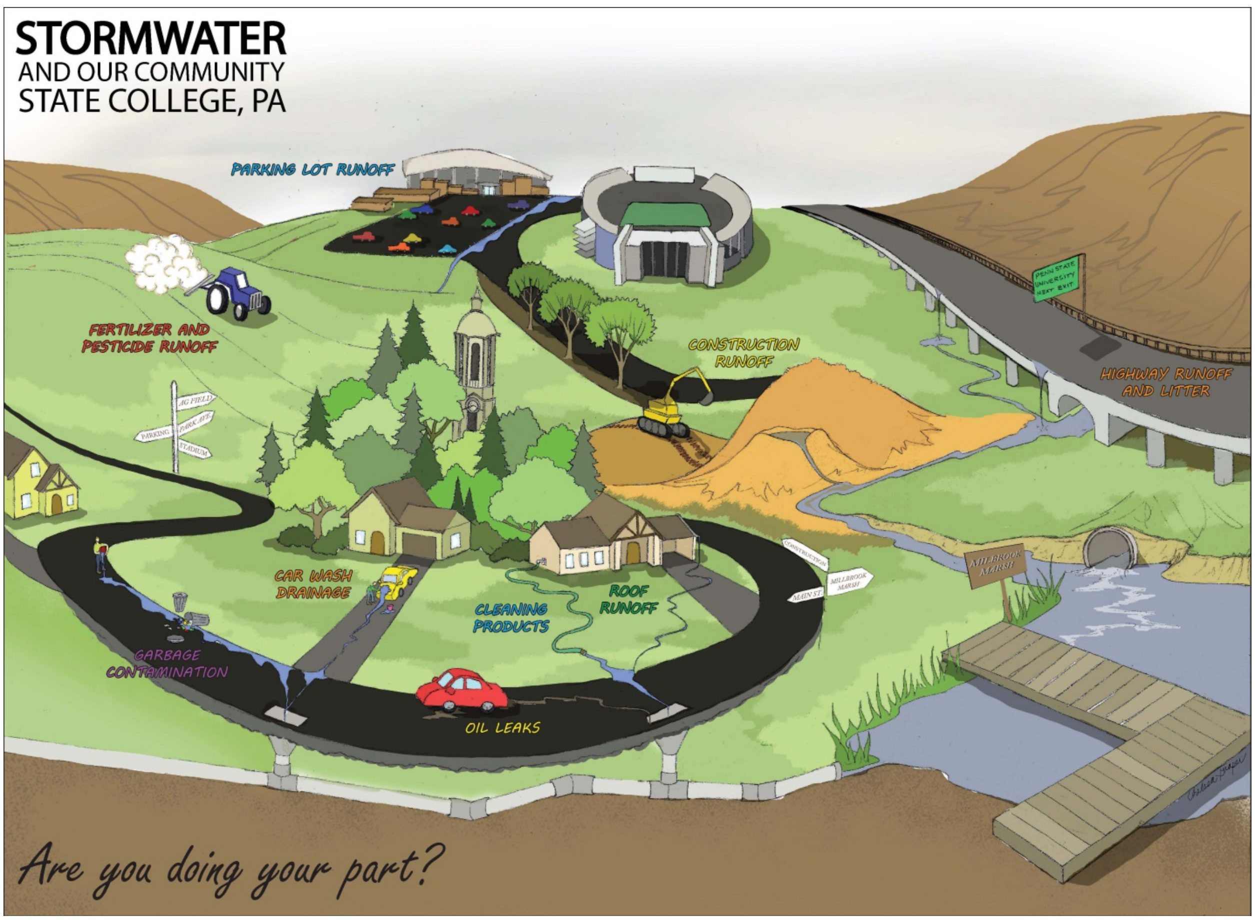
Penn State

University Park Campus

Stormwater
Guidance, Policies,
and Master Plan



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Penn State University Park Campus Stormwater Guidance, Policies, and Master Plan
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Section 1. Purpose and Limitations of the Document

This document has been created to define where current stormwater problems exist at the University Park Campus and where upgrades will be required in the future to correct these problems. Additionally, the document suggests ways to meet the ever increasing stormwater regulations that will be required, even where many people think no problems exists. This document also presents the University's objectives and methods that will be used to correct existing problems and prevent future problems and covers issues related to new development, redevelopment, and where stormwater facilities will be required in their own right. This document also provides a summary of existing stormwater related policies. **The reader is cautioned that the information is not updated continuously; and therefore, a meeting with Engineering Services should always be held prior to starting projects. Additionally, the University has special stormwater design requirements in some drainage basins that supersede existing regulations as indicated on page 3-2. The reader is strongly advised to review and understand these requirements, which can have significant project cost implications.**

During a large high intensity storm, one can observe uncontrolled surface runoff running down sidewalks and lawns with no evidence of a functioning stormwater collection and conveyance system. These issues, while clearly stormwater problems are related more to landscaping site design failures and are currently considered beyond the scope of this document. The section on problems addresses these issues and how they occur; however, at this point in time large scale site plans that address all areas of Campus are not included in this document.

Another reason these smaller area issues are not addressed in this plan is that the University is undergoing continuous change and modification, and contrary to what some people would claim, plans change at someone's whim. Therefore, at the current time it's unrealistic to propose small distributed stormwater site features. Future versions of this document may incorporate block by block improvements.

Additionally, this document is not intended to be all-inclusive of the stormwater information for the University Park Campus. Rather, multiple documents already exist and are published or produced by the Office of Physical Plant (OPP). The reader is advised to review these additional sources of information to gain an understanding of the University Park Campus' stormwater system, problems, and challenges. Some of these documents are:

The Pennsylvania State University Watersheds Report contains background information on the larger regional area and also sub-watersheds as defined to University points of interest. The document provides general information for each watershed. The document also indicates if Water Resource Publications are available. The document can be found at:
http://www.opp.psu.edu/services/stormwater/Watershed%20Document-2015.pdf

Water Resource Publications (WRP) are documents that provide detailed information and results of data collection within a sub-watershed. While not all data are contained in these reports, they allow one to see what types of data are collected. WRPs are updated based on need and additional data may be available. The documents can be found at:
http://www.opp.psu.edu/services/stormwater/presentations-publications

The 2009 **Stormwater Management Magazine** is a good source of background information on the watershed, general practices used by the University and stormwater issues at University Park Campus. The document can be found at:
http://www.opp.psu.edu/services/eng-resources/Stormwater%20Magazine.pdf

A general **PowerPoint Presentation of Stormwater Management** at University Park Campus can be found at:
http://www.opp.psu.edu/services/stormwater/images/stormwater-long

Public Domain **maps of stormwater management facilities** can be found at:
http://www.opp.psu.edu/services/stormwater/major-stormwater-facilities-2014

The University hosts two **stormwater websites** with additional information on stormwater practices and policies with large amounts of information and data. These websites are:
http://www.opp.psu.edu/services/stormwater

http://www.ms4partners.org/

University Stormwater Design Standards (33.40.00) can be found at:
http://www.opp.psu.edu/planning-construction/design_and_construction_standards/division-33-utilities

Additionally, the University has created multiple special reports and presentations, and has data and policies, which are not always in the public domain. Over the course of the last approximately 160 years, several significant local issues have been created for which very little public information exists. These types of information can only be found by meeting with Engineering Services or Environmental Health and Safety.

Section 2. Introduction

Campus Setting

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. The Spring Creek Watershed is tributary to Bald Eagle Creek, which flows to the West Branch of the Susquehanna River and then ultimately to the Chesapeake Bay. Spring Creek is a head-watershed stream with a surface drainage area of approximately 146 square miles; however, the groundwater basin is considered to be approximately 175 square miles (23% larger than the surface water). Development within the watershed is approximately 14% impervious, but the town center which includes downtown State College and a large portion of Penn State is approximately 50% impervious.

The majority of the developed University Park Campus lies within either the Slab Cabin sub-watershed or the Big Hollow sub-watershed as shown in Figure 2.a. Within the Centre region, the University's property is located within the State College Borough, and Benner, College, Ferguson, Harris, and Patton Townships. For a complete discussion, refer to the Pennsylvania State University Watersheds Report.

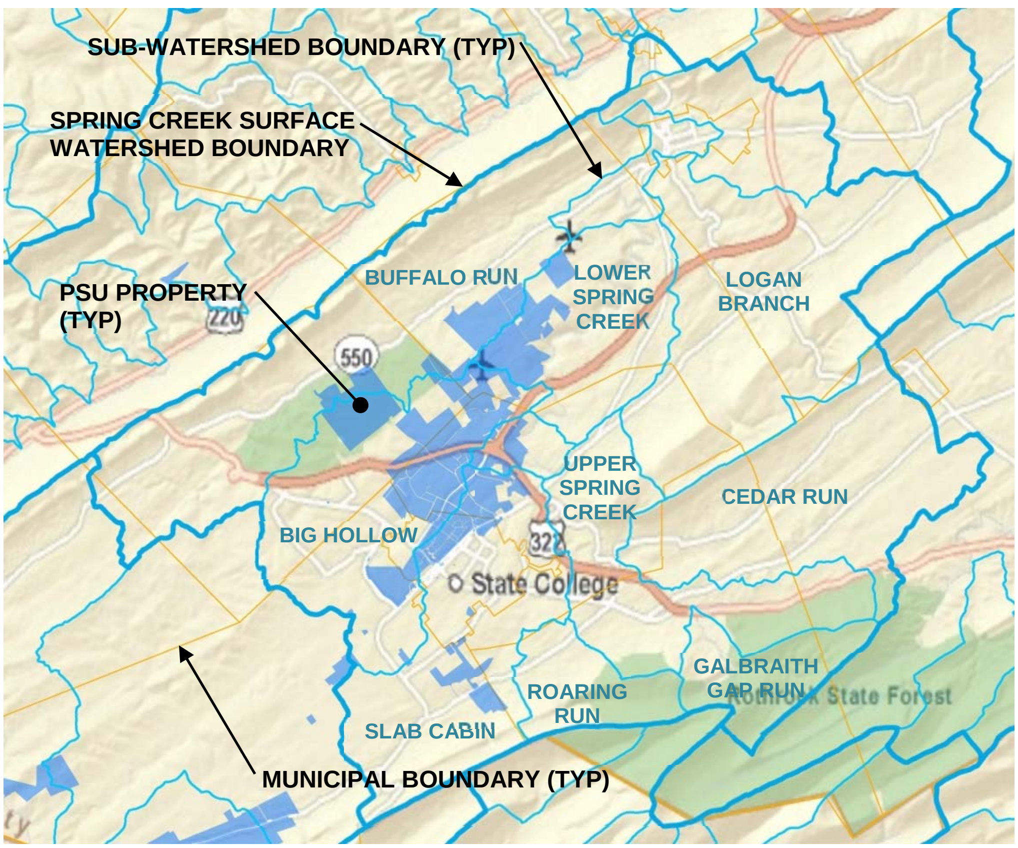

Figure 2.a. Spring Creek Surface Watershed and Subbasins Showing University Owned Lands

Local Geology and Its Effect on Stormwater

The Campus is underlain entirely by carbonate geology, which has resulted in karst features such as blind valleys, sinkholes, closed depressions, or caves. Many other karst watersheds in the State act very different from a stormwater perspective than the Spring Creek Watershed, which precludes making generalizations with other karst watersheds. Additionally, two distinctly different types of carbonate geology split the Campus area resulting in significantly different hydrologic responses, soils, and stormwater issues.

The vast majority of perennial or intermittent stream reaches in the Spring Creek watershed are perched above the groundwater table in the region. 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 aquifers, 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.

One extreme example of this is the Big Hollow watershed which is a sub-watershed of Spring Creek. The University owns a large portion of the undeveloped area of the Big Hollow's drainageway. The Big Hollow watershed, which has a total surface water drainage area of 17.1 square miles at its mouth 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; and therefore, it is really an ephemeral stream. 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.

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. 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 in other areas. If drainageways are preserved, little if any negative effects are experienced at the watershed scale if done in conjunction with smart development.

One extreme example of this can be seen in Figure 2.b, which shows the Thomson Spring Valley in the 1890s with no evidence of frequent surface runoff occurring, which would have resulted in channelization. The photograph is taken from the current day wastewater treatment plant's primary settling tanks located up on the hill. Today, the duck pond inflow channel is located in this valley having been created from erosion below the three town storm drain outfall pipes and currently the channel is approximately 15 ft wide and 3 ft feet deep.

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. The 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. There are large areas of some municipalities that drain completely to sinkholes. In the Spring Creek watershed, it is generally accepted that baseflow has not declined due to development, but rather shows an increasing trend.

The geology and the resulting soils are significantly different from one side of Campus to the other, which also creates different stormwater opportunities or challenges across the Campus. For example, the University overall is a net zero discharger of runoff in the Spring Creek Watershed. In other words, more runoff from University and non-University areas is recharged (infiltrated) on the University's property than runoff from the University that is discharged off University areas to surface waters. While some people may read this to state that the University promotes currently popular engineered infiltration systems, nothing can be further from the truth. The University in general has a prohibition against engineered infiltration systems in the majority of areas within the University Park Campus. For these reasons, many general rules of thumb or stormwater best management practices employed elsewhere may not be the most practical in the Spring Creek Watershed. These apparent contradictions are why the reader must fully understand the local physical hydrologic processes around Campus.

Figure 2.b. Thompson Valley Looking Over Current WWTP Site in 1890s
with Thompson Spring in the Foreground.

Historical Changes of Stormwater at the Campus

The University was founded in 1855, graduating its first class of 13 Baccalaureate degrees in Agriculture in 1861. What few people realize is that the original 200 acre gift from James Irvin of Bellefonte that became the Campus was located on a barren hilltop with no trees or water. Early University records indicate that the only source of water for bathing, drinking, or the support of livestock or crops was from rainwater collected in cisterns. The University has always struggled with potable water, wastewater, and stormwater, which has resulted in one of the most unique and holistic water systems in the country.

Prior to the 1930's all buildings that were constructed either had cisterns or drywells and none are known to have to discharged surface runoff downstream. When Old Main was rebuilt in 1930, the drainage system was converted from a cistern to four (4) drywells, which are still in service today. Approximately 50 buildings on Campus still drain all, or a portion, of the buildings to drywells or sumps (which are very different than similar structures today). The first major storm drain conveyance systems were constructed in the early 1930's along College Avenue and later Shortlidge Road. Another major storm conveyance project was then undertaken in 1947 and 1948, which resulted in the construction of the major trunk lines through the core Campus area. Other major expansions of the storm conveyance system occurred in the 1950's and 1960's. As the storm drain system was developed, many of the existing building stormwater drywells were abandoned, possibly due to building water problems.

The oldest storm drains on Campus were constructed primarily of terra cotta pipe (TC), reinforced concrete pipe (RCP), and cast iron (CI). Corrugated metal pipes (CMP) installed on Campus, such as the 1947/48 pipes, were constructed from high grade boiler plate pipe that was generally bituminous coated on both sides with paved inverts. For the most part, the larger storm drains on Campus were well designed and had adequate reasonable future capacity. These larger storm drains are defined as University trunk lines, most of which have been fully surveyed and modeled by the University. In the 1970's thin gauge uncoated CMPs became popular on Campus from a value engineering perspective. The era of the 1970's through the 1990's pipe installation is generally the worst on Campus. Today, pipes are required to be RCP, high density polypropylene (HDPP), high density polyethylene (HDPE), poly vinyl chloride (PVC), or in some cases ductile iron (DI). All subsurface detention systems are required to be made from RCP. CMP pipes are only used for maintaining existing CMP systems.

Historically, up until the 1960s, small surface swales were a normal feature on Campus. These swales have been mostly removed for maintenance or aesthetic reasons relying now completely on the subsurface conveyance system. Unfortunately, what many lay people don't realize is that the storm drain conveyance system is actually only classified as the "minor conveyance system," which by design will be exceeded in capacity based on some defined risk (risk is usually defined by return periods in years). When this minor conveyance system is exceeded, the overflows are conveyed by the major conveyance systems which are made up of the natural drainageways or surface conveyance systems. Since these no longer exist, when the minor conveyance system is now exceeded, the roads, curbs, or buildings themselves serve this function. Today, one of the biggest problems on Campus is grades sloping directly into new buildings entrances resulting in building flooding, which is simply a result of poor architectural or landscape design.

Older storm drains on campus were backfilled with the same material that came out of the trench; and therefore, backfill generally consists of cohesive soil materials around the pipe envelope. Where fill was placed in wet areas, wood planking can frequently be seen installed below the pipes. Topsoil was also frequently filled over resulting in multiple topsoil layers in fill areas. Modern construction practices on Campus fill the trench with stone and for decades this practice was done without the use of trench plugs on storm drains or other utilities. These differences in construction practices result in significant differences in how the pipes act when they begin to leak or decay. Water has been found to move hundreds of feet down pipe trenches where they can develop sinkholes at points of weakness in the underlying geology. Since the utilities serve buildings, water moving along utility trenches frequently can end up inside the buildings.

The first traditional stormwater management facilities were constructed at the University to control peak runoff rates in the late 1980s in response to local municipal ordinances. Many of these facilities were subsurface detention units because of the need to have usable land around the core Campus area. Surface stormwater management ponds were primarily constructed on the fringe areas of Campus. Large regional stormwater facilities were constructed in the 1990's including the Bathgate Dam, which is the largest stormwater facility at University Park. In early 2000, the University pioneered the use of the Low Head Weir for peak runoff rate, water quality and volume control to further protect its Big Hollow well fields. In 2006 the University designated approximately 450 acres of its land as Water Resources Preservation areas, which are defined as 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. These areas can be seen in Figure 2.c represented in blue.

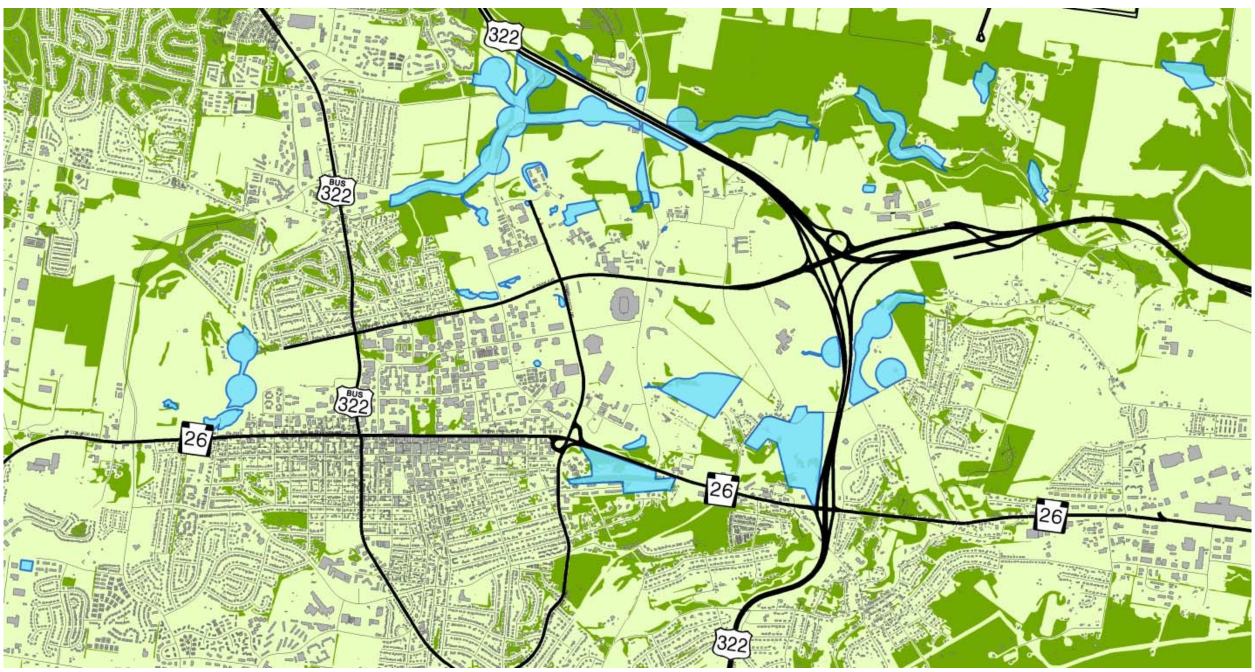

Figure 2c. Water Resource Preservation Areas on the University's Property

The University promotes the use of sound science and engineering for effective stormwater management and control. Recommended stormwater management practices used at the University balance the protection of groundwater and surface water. Today, the University promotes foremost the use of conservation design practices that preserve and use natural critical hydrologic areas (non-structural methods); however, the University still has numerous structural BMPs as seen in the following section.

University Stormwater Infrastructure

The University owns more stormwater infrastructure than the surrounding municipalities or any other single property owner in the Centre Region. In the University Park area, the University has approximately 73 miles of storm drain pipes ranging in size from 6” to 72” in diameter. This number does not include smaller under drains, foundation drains, or building internal plumbing. The University also owns several thousand inlets and manholes.

The University also owns numerous other types of stormwater facilities or best management practices (BMPs). Many of the most advanced and progressive stormwater BMPs, and most of the conveyance system were constructed by the University to protect itself without being required as a result of regulation. More recently, this is not the case and facilities are constructed as part of a regulation or ordinance and are required to be maintained such that they function properly for perpetuity, or the life of the facility they were constructed for.

Since 2010, any development that triggers an NPDES Erosion and Sediment Control Permit, has stormwater requirements that last even after the earth disturbance permit is terminated. Additionally, because the University has a Municipal Separate Storm Sewer System (MS4) Permit that covers part of Campus, it’s required to maintain records, conduct inspections, and maintenance for all stormwater facilities constructed under the permit requirements since 2003. However, the University generally applies these same practices across all of its property and for all of its facilities. The University has created multiple policies, some of which can be found online at:

http://www.opp.psu.edu/services/stormwater/ms4

The University owns the following stormwater BMPs in the Centre Region as of the end of 2014:

Regulated Dams: 4
Surface Stormwater Ponds: 28
Subsurface Detention Facilities: 33
Green Roofs: 9 (101,000 sf area)
Bioswales and Rain Gardens: 33
Low Head Recharge Weirs: 7
Stormwater Reuse Cisterns: 3
Hydrodynamic Water Quality Structures: 11

The general locations of these facilities can be seen in Figures 2.d through 2.g. Additionally, the University has numerous natural protection areas that are in the Water Resource Preservation Areas (WRPAs) as shown previously in Figure 2.c. These WRPAs are defined in both OPP GIS and AutoCAD mapping formats. Contact Engineering Services for more information on WRPAs.

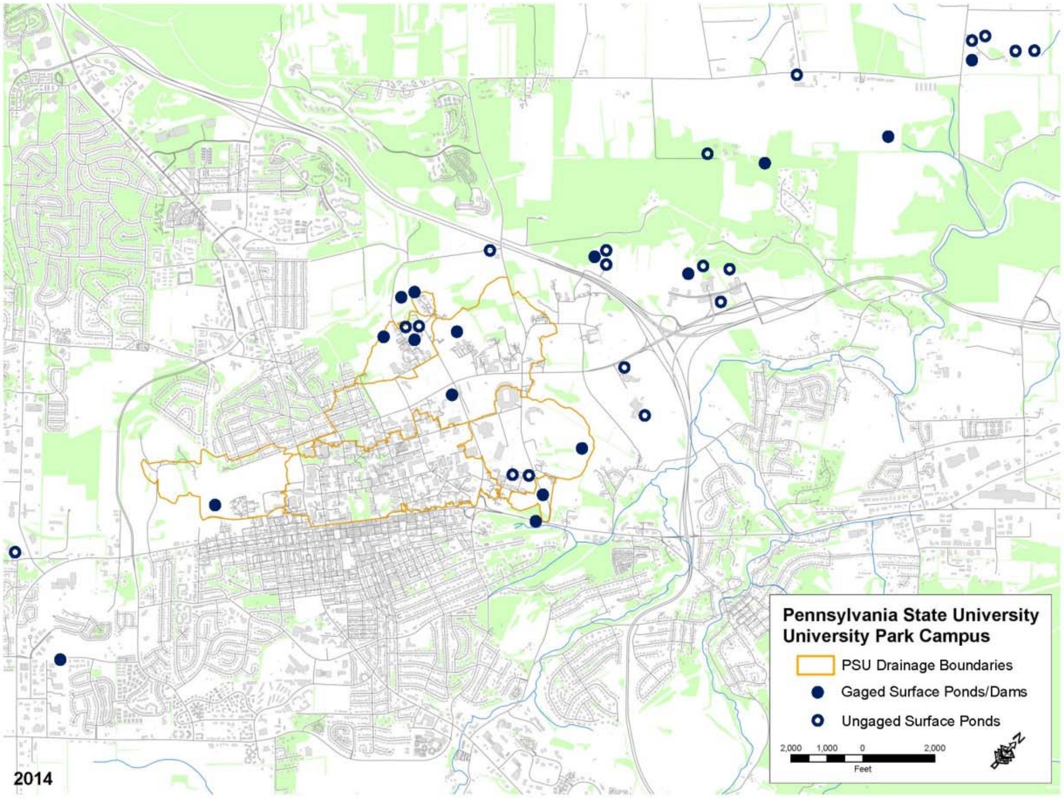

Figure 2.d. Penn State Surface Ponds and Dams in the Centre Region

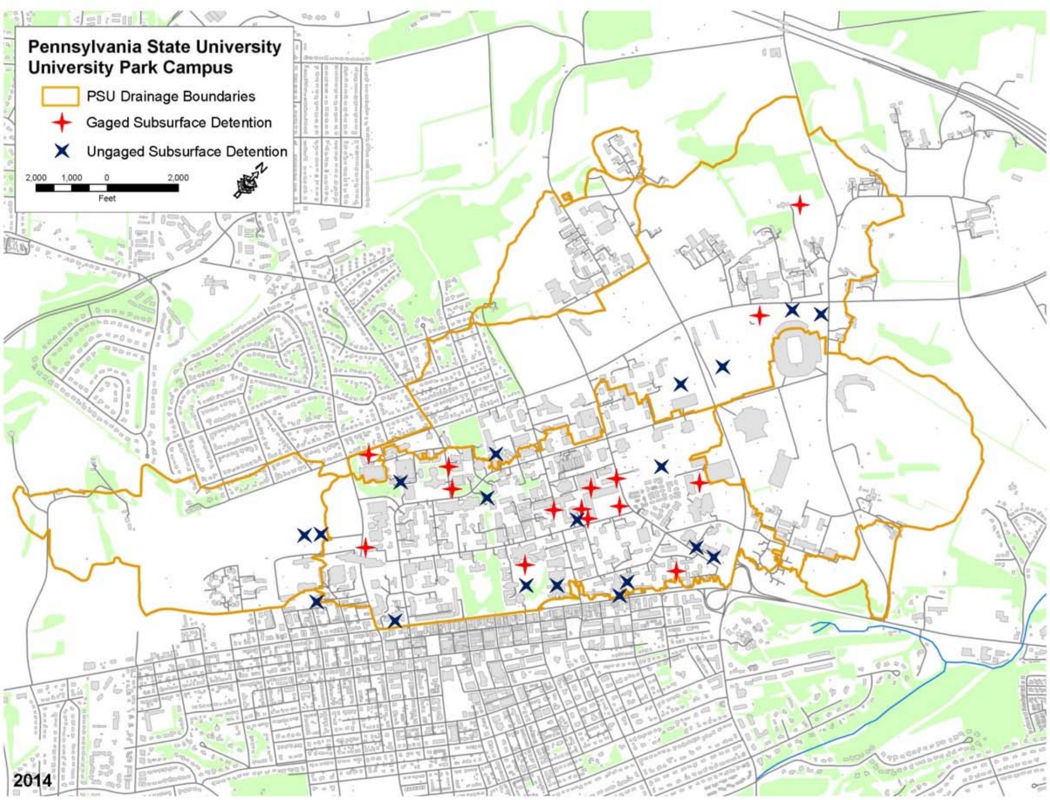

Figure 2.e. Penn State Surface Ponds and Dams in the Centre Region

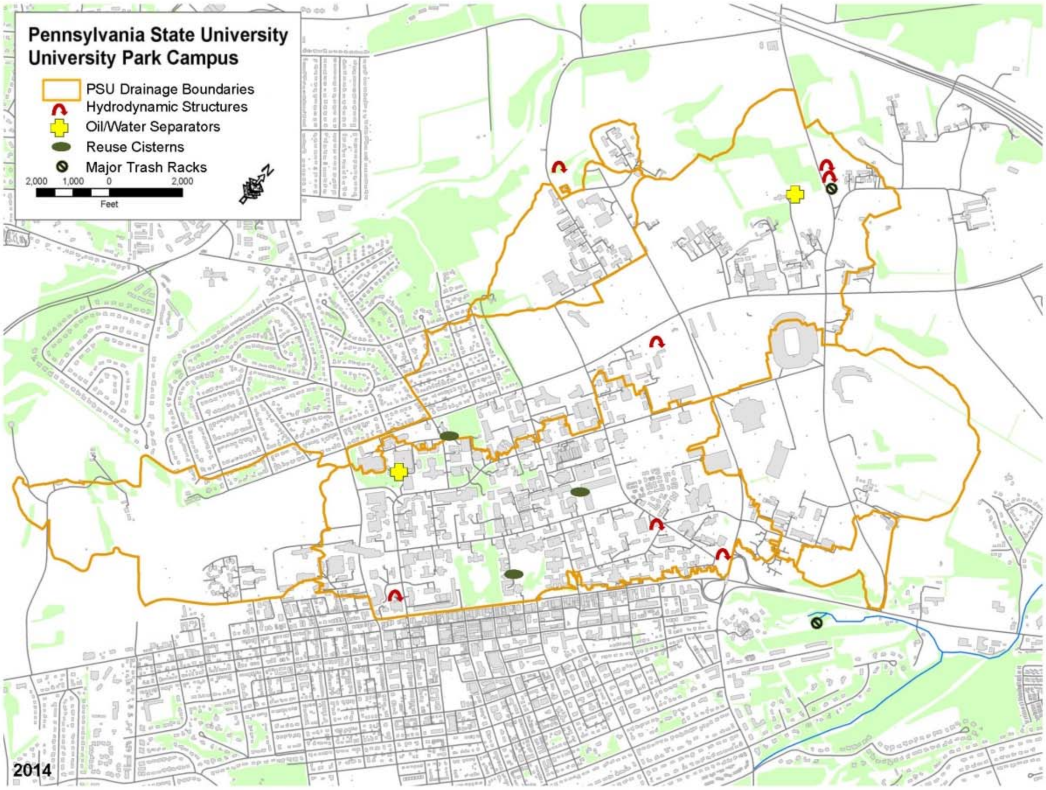

Figure 2.f. Penn State Structural BMPs in the Centre Region

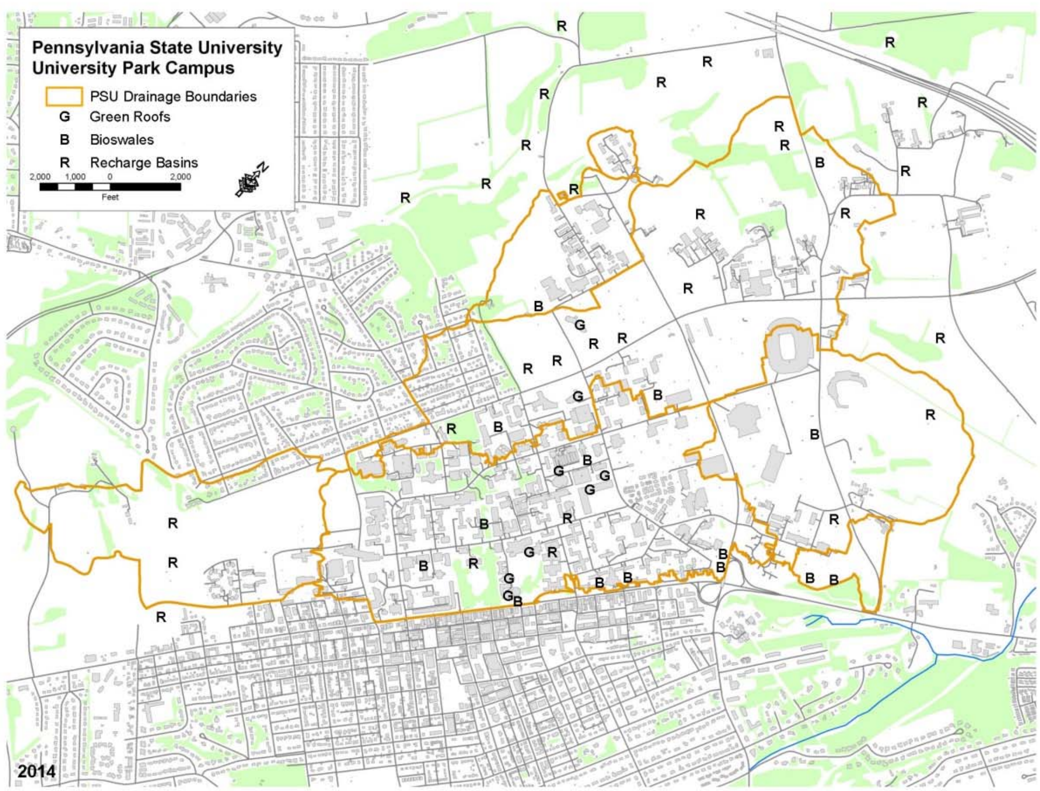

Figure 2.g. Penn State Recharge and Green Facilities in the Centre Region

Section 3. Policies

Overall Stormwater Philosophy

The University promotes foremost the use of conservation design practices that preserve and use natural critical hydrologic areas, including, but not limited to, floodplains, wetlands, streams, minor drainageways, natural recharge areas, carbonate closed depressions and sinkholes. It also promotes the use and application of sound science in our stormwater management practices and does not believe that any best management practice (BMP), Low Impact Development (LID), or Green Infrastructure (GI) method can be used anywhere, or that we can engineer replacements to complex natural hydrologic areas. Therefore, site designers shall make every effort to preserve these areas, and any disturbance of a Water Resource Preservation Area (WRPA) is only permitted at the approval of Engineering Services.

The University's recommended practices for land development activities at shall be based on a thorough understanding of the watershed, soils, geology, site density, existing conditions, and the local regulatory requirements. Examples of recommended practices are available for the University Park Campus from Engineering Services.

The University owns the wastewater, potable water, and stormwater systems at the University Park Campus and holistically considers all three together from a planning and operations perspective. Historically, stormwater best management practices used on Campus were selected to protect the potable water system to the most practicable extent possible. While this practice still exists today, the University does not believe that currently popular BMPs or practices, or regulatory criteria meet these goals by default.

While some storm drain conveyance systems are undersized, the University will not simply increase pipe sizes to solve the problem. 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. The only exception to this rule is where the storm drain system is currently so undersized that it poses a significant life safety issue and the upgrade has been shown to have a negligible impact downstream. Currently, there are only two such areas on Campus; lower Bigler Road, and Trunk Line D in the vicinity of Pattee Library and Pond Lab.

Increasing storm line sizes of minor system pipes is permitted and will generally not result in flood transference. An example of this is where several buildings tie into historical 6" to 12" storm drains. When new work is being conducted in the area of these buildings, these lines will generally be increased to 12" to 15" pipes even if the remaining pipes downstream are smaller, because the larger pipes are less prone to clogging inside the inlets. Additionally, the construction of new conveyance systems is permitted in areas being developed or where it may not have previously existed.

All new development and redevelopment projects at the University will have the goal of reducing peak runoff rates downstream. While most people will argue this has always been done by stormwater management, this is simply not true. Engineers and regulations overreliance on overly conservative design methods frequently resulted in having a minimal effect on common or short duration extreme precipitation events. For this reason, in some cases Engineering Services will dictate allowable discharges for new or major projects and these discharges may be significantly less than required by current regulations. However, the ultimate goal is to prevent flooding downstream and to protect University infrastructure.

All new development and redevelopment projects at the University will consider and control water quality. Water quality considerations are to be based on the actual site conditions. In the event that inlet type water quality facilities are recommended, the designer should consult with Engineering Services. Using water quality inserts that require frequent changes of material or products are discouraged and may only be installed at the direction of Engineering Services.

The use of engineered infiltration methods on core Campus is prohibited without the approval of Engineering Services. Ponds, bio-swales and rain gardens will be structurally lined with underdrains. The removal of these liners will be determined by risk to University infrastructure by Engineering Services. The University has numerous examples of artificially infiltrated water moving hundreds of feet down gradient where it emerges in other facilities including buildings.

Where infiltration is permitted, adequate treatment must be accomplished prior to stormwater runoff being injected into an engineered infiltration BMP or areas where infiltrated runoff can rapidly bypass the soils and enter fractures or the groundwater. Water quality pretreatment facilities must be visible and accessible to provide a means to monitor their efficiency, and replace if necessary in case of failure. Every effort should be made to insure that the quality of stormwater that is to be artificially recharged is of equal or better quality than the existing groundwater. If sinkholes or rapid infiltration does occur, limited water quality impacts may occur if the water is of high quality.

Construction practices must be utilized so as to minimize the compaction of existing soils. In addition, a) soil at grade should be managed and b) vegetative cover and organic amendments should be utilized to enhance the restoration of infiltration capacity of disturbed soils.

As a nationally recognized institution of higher learning, the University reserves the right to request comprehensive computations that defends a designs function above and beyond those required for regulatory approval in order to protect health, safety, and welfare. The claim that LID or GI development methods are always better and do no harm is unacceptable propaganda.

Role of Regulations

The University as a large land owner is a developer and permitee. All University projects will comply with Federal, State, and local laws and regulations, as required, and University special requirements listed in the next section. Any project that triggers Federal water regulations will be closely coordinated with Engineering Services.

Projects that are located within the University's EPA NPDES Phase II Municipal Separate Storm Sewer System Permit area, will comply with existing stormwater regulations, but in general will not require any additional work by the design team beyond those requirements listed below. Projects done specifically for the MS4 permit will be directed by Engineering Services.

Projects that trigger PaDEP NPDES earth disturbance permits will need to comply with the Post Construction Stormwater Management (PCSWM) requirements. However, the design team will not simply comply with all the requirements/regulations related to volume control. The University had representation on the State' technical committee for the Pennsylvania Stormwater Best Management Practices Manual dated 2006, which was later used as the basis for the NPDES PCSWM design criteria. Requirements regarding the volume control criteria's use of the 2-year event were not based on sound science and were never reviewed, discussed, or approved by the technical oversight committee. These regulations were simply adopted due to the threat of litigation by environmental groups. The end result is that engineered infiltration facilities are failing in mass across the State and University properties, due to a lack of fundamental considerations regarding soils physical properties. For this reason, the University will not atomically comply with State volume regulations, especially in the core Campus area.

Instead, the University endorses primarily the use of extended detention systems that do not place runoff volume into the ground. Where State reviewers demand compliance with volume reduction criteria, evapotranspiration, reuse methods, or accounting for different impervious areas will be explored. State (NPDES) water quality and peak discharge criteria will be met without exception.

All projects over the municipal development threshold (generally 2,500 sf or 5,000 sf of new impervious area) will also comply with the local Act 167 plan requirements. The Act 167 and the NPDES criteria are significantly different and both need to be addressed. All regulatory requirements of the Act 167 plan must be met. Projects that do not trigger a NPDES permit, will still comply with municipal regulations as required.

Special Design Requirements in Excess of Regulations

Engineering Services may require any project to meet more stringent requirements than Federal, State, or municipal requirements to reduce existing flooding or to prevent additional future problems in certain areas. Engineering Services will define these additional requirements in Scoping Documents or project kick off meetings. In areas of flooding, Engineering Services may define maximum permitted discharges. Drainage basin mandates that are currently instituted across the board and supersede and are in excess of all other municipal, State, or Federal requirements are listed below:

Main Campus Drainage Basin:

In the entire Main Campus drainage basin, all redevelopment projects over 0.5 acres of total disturbance shall assume that 100% of the existing impervious areas are meadow in good condition for the consideration of peak runoff rate computations for determining extended detention storage requirements, when there is a land use/cover change proposed. Computations for water quality or volume shall use existing impervious areas. Any project that increases imperviousness by 1,000 sf shall provide peak runoff rate control for the new imperviousness. Using impervious area credits in the Main Campus drainage basin are prohibited.

Fox Hollow Drainage Basin:

Any project upslope of storm manhole #252 (STMH252) located at the intersection of Park Ave and Shortlidge Road in the Fox Hollow drainage basin over 1.0 acre of total disturbance shall assume that 100% of the existing impervious areas are meadow in good condition for the consideration of peak runoff rate computations for determining extended detention storage requirements, when there is a land use/cover change proposed. Computations for water quality or volume shall use existing impervious areas.

West Campus Drainage Basin:

No future major development is permitted within the pond's drainage area without the West Campus Pond being improved or reconstructed. Major development is defined as any "new" building, building addition, parking lot, or road. Only minor sidewalk work or maintenance activities will be permitted without triggering this requirement.

Bathgate Drainage Basin:

The Bathgate dam was designed as a drainage basin peak runoff rate and water quality control facility and currently has reserve capacity. All increases will be tracked by Engineering Services and proposed impervious area must first be approved in writing by Engineering Services.

Maintenance Responsibility

The proper functioning of stormwater infrastructure requires regular maintenance. The Office of Physical Plant (OPP) is generally responsible for all stormwater management with some exceptions. Auxiliary Service areas are responsible for all stormwater maintenance activities in their areas, examples are the University Park Airport, Stone Valley Recreation, Shavers Creek Environmental Center, Rocks Springs, etc. Commonwealth Campuses are responsible in entirety for their Campuses. Engineered stormwater facilities in Ag Areas surrounding Core Campus are the responsibility of OPP.

Utility Services is responsible for maintaining roadway inlets, manholes, conveyance systems and stormwater BMPs not considered part of a building. They will also conduct mowing, trash removal, inlet vacuuming, and facility cleaning.

Inlet grates located within lawn areas or landscaped areas will be inspected and cleaned by Landscaping.

Plants on green roofs and bioswales/rain gardens will be maintained by Landscaping.

Plant control or removal in ponds will be by Utility Services.

Stormwater irrigation systems, including cisterns will be maintained by Landscaping.

The repair of sinkholes on Campus will generally be the responsibility of Utility Services. Financial responsibility can vary, i.e. a sinkhole caused by a building utility may be the financial responsibility of Major Maintenance. Sinkholes in Auxiliary areas are the responsibility of Auxiliary Services. A sinkhole in an Inter-Collegiate Athletics (ICA) controlled area is the responsibility of Utility Services; however, a sinkhole in an ICA specialized area such as a synthetic turf field is the responsibility of ICA.

The cleaning of building area drains, gutters, downspouts, and rain water conductors will be by the Area Shops.

Because of the complexity of the University, exceptions to these responsibilities exist. In cases where disagreements occur, Engineering Services will provide background information to OPP's vice president who will make the final determination.

Because of the limitations of equipment owned by the different groups or expertise, Engineering Services may request involvement of other groups outside their area of responsibility. In these cases, the financially responsible group will provide a budget to the other group.

Regulated annual physical inspection of stormwater facilities will be by Engineering Services. Deficiencies or maintenance requests will be sent to the responsible group.

Financial Responsibility

One of the first things asked regarding any stormwater or utility upgrade or repair is who is responsible for funding. Over the years, OPP has created policies on the financial responsibility of the storm system, because the system is technically unfunded. The following case studies are used.

Case No 1 - A new land development project. All stormwater costs for new land development projects within the project area should be paid for by the project. The reason is the project is creating a new impact. These new facilities must also include designs to intercept upslope runoff and safely/adequately convey it through the project area to an existing storm facility (stable swale, storm drain, or detention pond, etc.).

If the existing downstream facilities are adequate, no downstream/offsite improvements will need to be made by the project. If there are no close adequate stormwater facilities (example a large building with high imperviousness in the middle of a field), the project will need to design adequate storm facilities, which could be offsite. If the downstream facilities are already inadequate (such as Bigler Road), then downstream facilities will need to be made by the responsible owner. For all storm drain pipes, inlets, manholes, ponds, subsurface units, site stormwater BMPs, etc. the responsible owner is the Utility Group.

Case No 2 - Redevelopment/site improvements. If a project proposes to modify existing drainage patterns or land cover, then the project needs to install adequate storm drains. This may include modifying existing inlets or installing new inlets and pipes to safely/adequately convey surface runoff to an existing storm facility. Under no circumstance is a project permitted to alter the surface condition and not adjust the storm drain/drainage system because it was not in their original budget estimate. If the existing storm drains that run "through" the site (conveying upslope runoff through the site) are inadequate or in poor condition, then the Utility Group needs to upgrade the existing inadequate utilities. However, adequate time must be provided to the Utility Group for securing funding. Doing surface improvements without upgrading utilities underneath is highly discouraged.

Case No 3 - An existing stormwater problem where no site improvements are made. If the stormwater problem is due to a lack of surface inlets, conveyance, or controls, those costs should be paid for by Major Maintenance funds or special budgets. If the stormwater problem is due to an inadequate existing system (generally a hydraulic grade line problem such as water coming out of inlets), those costs should be paid for by the Utility Group.

Stormwater facilities that are not considered a Utility responsibility include: green roofs, building cisterns, building sumps, foundation drains, building area drains, and building rain water conductors. Building rain water conductors can be inside the building or run along the outside of the building to pick up down spouts. Until they reach an outside major structure (manhole or inlet) they are part of the building. If a building installs a surface pond, bioswales, or subsurface detention facility, these become the responsibility of the Utilities Group after the contractor warranty period, even if it serves a single building, as long as they were constructed to the University’s design standards.

Stormwater installed by an Auxiliary Unit is the responsibility of that Unit. This is especially true in the event they did not follow University standards due to funding constraints or grants from Federal or State agencies that may have had different (lesser) requirements. In these cases, the facilities will remain that Unit, group, or areas responsibility for perpetuity and the facilities will not be transfer to the Utility Group.

Future Funding Models

Stormwater management requirements nationally are becoming more onerous and expensive. Currently, each responsible party allocates funds for stormwater activities by their own method. Capital Renewal projects funded through Old Main may be used for larger University Stormwater Projects, but where specific groups have paid for facilities with extra capacity, that extra capacity belongs to that group. With the exception of the Engineering Services Stormwater Utility Engineer, there are no dedicated University stormwater employees.

Because of these issues, Engineering Services has in the past proposed a new funding model based on impervious area, which is a typical model used in many parts of the country. Because this would significantly increase costs to some University groups the idea has not been well received. However, eventually the University may need to determine a new system for funding and maintaining stormwater facilities, but as of now, while not ideal, the current systems still works.

Prohibited BMPs at University Park

During project kick off meetings or scoping documents, Engineering Services provides the design team with information regarding their specific area or project in excess of information that may be found in this document. Engineering Services also provides suggestions regarding what regulatory goals should be established for the project. However, with the exceptions noted below, Engineering Services will not dictate specific BMPs the design team will be limited to, but rather what needs to happen if certain BMPs are proposed.

The use of multiple small rain gardens or bioswales on a single project are discouraged. The reason is that these areas are too difficult to control and maintain. For example, small rain gardens in the past have simply been removed by different work groups not realizing they were special features.

Rain gardens or bioswales shall always initially be assumed to be lined. Removing the liner shall be at the direction of Engineering Services based on an assessment of risk.

The general use of engineered infiltration trenches or beds is prohibited on Core Campus. Engineering Services determines on a case by case basis what is considered Core Campus. In some instances, Engineering Services will permit engineered infiltration facilities for use, testing, or research purposes.

Subsurface detention facilities must be water tight and will not be permitted to infiltrate. All storm drain pipes and joints are to be water tight. BMPs such as the ADS stormTech system, or equivalents, are prohibited without the approval of Engineering Services.

The use of combination drains (combined surface water and foundation drains) are prohibited.

The use of plastic egg shell or built up shelf type subsurface detention facilities such as Rainstore or equivalent are prohibited, even if they include liners.

The use of porous asphalt pavement is prohibited for roads or parking lots.

Facilities or practices that require specialized equipment or maintenance are discouraged since it is not reasonable to expect University operations staff to change their ways of conducting business.

During the design and permitting process, only those stormwater BMPs specifically required to meet the permit will be included in the permit paperwork even if the University plans on constructing more BMPs than required. This allows the University as a premier research institution to remove/alter some BMPs at their discretion.

Section 4. Defining Stormwater Problems

Typical Stormwater Problems at the Campus

Much of the storm drain conveyance infrastructure is at, or beyond, its serviceable design life and in some cases is no longer adequately sized. Simply replacing old pipes is frequently not an option because in many areas trees or other infrastructure were built adjacent to, or directly over, the storm lines, which then are not permitted to be cut down or disturbed. Other storm pipes have been hemmed in so much that replacement is not possible without becoming major projects. Therefore, reinforced concrete pipe (RCP) has been found to be the most cost effective long term pipe so far and RCP installed nearly 100 years ago are still generally in excellent condition. For this reason RCP is the preferred material for main trunk lines and road crossings.

Several areas of Campus have undersized storm drains where water can frequently be observed surcharging structures exasperating or causing additional flooding. Some of the existing flooding problems are related to development activities that did not adequately evaluate the existing downstream storm drain capacity; however, some problems are related to the increase in significant rainfall events in the last several decades. For example, where a storm drain capacity may have originally been designed using statistics for a 25-year event, due to the increase in significant events in the last several decades, the capacity may now have been downgraded to a 10-year or less rainfall event.

Additionally, several storm lines have adverse slopes (run up hill for some distance), which are very difficult and costly problems to fix because of utility conflicts or the distance one needs to go downstream to establish adequate positive slopes. Flooding along Park Ave is due to an adverse pipe installed and owned by PennDOT. However, most of the stormwater problems that exist on Campus were easily preventable, but were simply caused by poor design considerations or by the multiple conflicting activities required by a University this size. A comprehensive presentation of these problems was developed in 2013 and may be available for review from Engineering Services upon request. Many of the University policies are a direct result of trying to prevent stormwater problems from occurring.

Unfortunately, because of the overselling of LID or GI methods in some communities in the last several years, many groups of people now believe that existing stormwater problems can simply be fixed by installing stormwater best management practices such as bioswales, green roofs, and engineered infiltration systems. However, much of this information is unsubstantiated or oversold to the engineering and lay communities. Once significant stormwater flooding and water quality issues have been created, generally no amount of green best management practices will completely fix the problems, but rather they will only slightly reduce the problems and many times only in a negligible manner. For this reason, the University has also developed this Plan and its policies counter too many of the popular trends seen in some areas of the Country.

There are numerous stormwater problems at the University and different people have different ideas of what constitutes a problem. Regulatory agencies are generally concerned with water quality and impacts to waterways or larger water systems. The University is concerned with these issues too, but also with population safety, localized flooding impacts to facilities and buildings, nuisance flooding, and manpower concerns. University faculty, staff, and students can also be concerned with building dampness in basement or research spaces, or custodial cleanups.

The following sections highlight larger stormwater problems and repairs within each subwatershed; however, there are many general stormwater issues on Campus, which are simply a result of poor practices. Contractor related issues are not generally a major concern at University Park, with the exception of a few poorer than average construction firms. The University as a nationally recognized institution of education, research, and service is always expanding/altering/improving Campus to best serve its mission. Unfortunately, this results in almost weekly alterations to the storm system by multiple groups across Campus that may not fully understand a change's implication. Common types of problems found on Campus are:

- Inlet bypass flow generally neglected by designers and projects,
- Project punch lists generally neglect drainage inspections, especially subsurface facilities,
- Not understanding that minor details can create major problems,
- Lack of people reporting historical flooding,
- Undersized pipes,
- Adverse pipe slopes (run up hill due to construction error or conflict),
- Major conveyance systems removed historically,
- Minor swales minimized for aesthetics/mowing,
- Pipe failures routine due to limited maintenance or sinkholes,
- Large developed areas with no inlets/drainage,
- Heel proof inlets placed in incorrect areas,
- Inlets buried for aesthetics by landscape staff,
- Inlets removed without permission,
- Lack of flanking inlets in flood prone or clogging areas,
- Inlets installed too high in lawn areas due to perceived tripping hazards or aesthetics,
- Inlets installed too high in roadways due to pavement settlement or biking standards,
- Inlets and pipes not adjusted when landscape changed,
- Inlet protection left in place long after the project ended,
- Inlet protection used poorly in flood prone areas,
- Buildings at low spots without positive drainage away from the building,
- Building basements with water issues converted to occupied spaces,
- Main storm drains routed under or through buildings,
- Underground or complex building leakage,
- Overuse of mulch resulting in mulch entering the storm system,
- Mulch placed in incorrect areas, which washes away
- Erosion associated with steep gravel roads,
- Raised islands used instead of depressed islands,
- Sidewalks drains to roads instead of lawns,
- Construction compaction of soils,
- Neglecting historical fill issues,
- Incorrect land cover around inlets resulting in frequent clogging,
- Ramps creating artificial low spots forming puddles/ice hazards,
- Ramps and crosswalks can divert flow to unintended areas.

Some people would argue that these types of problems can all be prevented; however, from an operation perspective this is unrealistic. Therefore, many of the standards/methods/policies the University has developed are to keep designs fundamentally simple and less prone to alteration/failure.

In instances where existing main storm lines go under buildings, at such a time when a major project occurs in that area, the line will be rerouted if physically possible. This will be paid for by the project.

Fundamental Types of Problems in Karst and Why it's Critical To Understand the Differences

Many people have different ideas of what a stormwater problem is, as indicated in the previous section. However, more important is understanding the type of problem and how it can actually be fixed. The Campus generally experiences what is defined as "nuisance flooding" due to multiple different reasons. Nuisance flooding is defined as flooding, which although not normally life threatening, is a temporary inconvenience and causes financial burden on community residents. In addition, nuisance flooding can induce negative morphological changes downstream causing erosional problems and can also significantly affect water quality. Of course, people that have nuisance flooding occur can certainly feel severely impacted, especially if it occurs frequently. An example of nuisance flooding can be seen in Figure 4.a.

Figure 4.a. Example of Nuisance Flooding on Campus

There are three distinct types of nuisance surface flooding cases on Campus. Case 1 is flooding with no major effective storage, and the overland flow simply acts as another conveyance system. A classic example of this type of flooding can be seen in Figure 4.b. The flooding occurred on Bigler Road because the existing conveyance system was so significantly undersized. Because Bigler Road has a steep grade, the surface runoff moved as quickly overland as it would have in the pipe. This problem was fixed in 2015 by installing a larger conveyance system. Case 1 examples are one of the few times when the major conveyance system can be upgraded and still have a negligible impact downstream. Another common example is where surface flooding occurs along sidewalks and roads because of insufficient inlet placement. In these instances surface flooding may occur while there is available capacity in the underground storm drain system.

Figure 4.b. Case 1 Type Flooding along Bigler Road

Figure 4.c. Case 2 Type Flooding along Atherton Street

Case 2 Type flooding is where flooding occurs with major effective storage (ponding) but the area has a limited outflow possibly because of an undersized conveyance system or frequency clogging. This type of flooding acts like a stormwater detention pond in the wrong place. Many engineers would address this type of problem by increasing the conveyance system capacity; however, this would simply result in flood transference, which could cause new problems downstream. An example of Case 2 type flooding can be seen in Figure 4.c, which is a photograph of the sag in Atherton Street directly adjacent to the Campus water tunnel.

While Case 2 is considered from an urban perception on Campus, it could also be considered equivalent to flooding in the floodplain. It's generally understood that developing floodplains and removing floodplain storage is not a good idea. In both cases, serious consequences can occur unless the volume and downstream conditions are considered. Since this can intuitively be considered a stormwater pond in the wrong place, the University's objective is to replace the function of the ponding in the correct, or better suited, place.

Case 3 type flooding is generally limited to carbonate areas or karst topography and is considered flooding with effective storage and no, or negligible, surface outflow. In other words, this is a recharge area. Figure 4.d shows an example of this type of flooding on Campus. If these areas are developed and the flooding is either forced into a smaller recharge areas, or worse yet, the water is pushed downstream, significant adverse impacts should be expected. For this reason, all such areas ponding areas, including natural or artificial closed digressional areas, are protected at the University.

Figure 4.d. Case 3 Type Flooding at the Arboretum's Mitchell Tract Recharge Area

Because the University owns thousands of acres in the University Park area and the areas are under the direct control or supervision of multiple different University groups or Departments, conflicts can arise due to the desired use for land that may not be in the best long term interest of the University's water resources. This occurs because employees believe they're acting in the best interest of the University from their personal perspective. For this reason, Engineering Services attempts to review all projects and planning. Figure 4.e gives an example of what some people may consider flooding that's disruptive to their operations. However, the photograph is simply a drainageway doing what drainageways are supposed to do, convey runoff during larger meteorological events. Flooding can later become a problem in these areas after being developed.

Figure 4.e. Flooding Example that is not a Problem

Other types of flooding can occur that are more related to temporary measures or problems; and therefore, they are not considered in this document. Examples are flooding due to leaves or debris clogging inlets or headwalls, slush and snow issues, and clogging due to the use of temporary erosion and sediment control products (such as siltsack inlet filters), All of these problems can be fixed by proper staff education and maintenance. However, sometimes this type of localized flooding cannot be avoided due to timing. An example would be a high intensity rainfall event occurring with high winds late in the fall when leaves can easily be knocked off trees resulting in inlet clogging. For this reason, positive flow should always drain away from buildings or other critical infrastructure.

<u>**Available Methods to Fix Flooding Problems**</u>

Unfortunately in the last several years many people when asked about fixing stormwater problems reply that we simply need to incorporate Green Infrastructure or Low Impact Development. However, generic answers such as this are a disservice to the community and people attempting to fix existing problems. It needs to be understood that there's a significant difference between fixing existing problems and making new ones or existing problems worse.

For the latter two, Green Infrastructure or Low Impact Development can be used successfully if the dominant hydrologic processes of an area are understood and accounted for in the design.

For example, the Bigler Road flooding problem was frequently used in classes and evaluated by the University to determine if the problem could be remediated without the replacement of the conveyance system and the answer was always a resounding “no.” When significant flooding already exists, the use of green infrastructure will generally have a minor effect on real stormwater problems. These concepts are currently being explored in many cities including Philadelphia and the City of Lancaster, both of which discharge massive amounts of raw sewage into their waterways every year, in addition to having significant flooding problems. Currently both programs, which are spending significant resources and have instituted substantial stormwater user fees, are promoting success, but the real answers lie more than 20 years in the future. Until that time, raw sewage will continue unabated into their waterways.

So how do we fix stormwater existing problems? This may better be asked as how “can” we fix stormwater problems. There are many variations on the same old methods, which are always being given new and “sexy” names, but in reality there are really on six (6) things that can be done. These six are: increase the size of the conveyance system (push downstream), put water deep into soils (recharge), use soils and plants to evapotranspire water (ET), detain the stormwater for a period of time (detention/retention), store and reuse stormwater for potable water type functions, or improve the hydrologic conditions (ex. removing imperviousness).

This document has already discussed the issue of increasing conveyance size, and in general the practice is discouraged unless integrated with other practices. One common accepted use of upsizing conveyance is when it’s integrated with a significant detention facility. Recent examples of this are the West Campus development, the Bathgate Dam watershed, the Fox Hollow facilities, and the Sarni subsurface detention facility, and most new building projects.

Some people may argue using unlined bioswales, etc. induces infiltration; however, this type of BMP is really just a combination of recharge, evapotranspiration, and detention. While many groups including the PADEP and the EPA promote the use of engineered infiltration BMPS; in Pennsylvania and in particular on Campus, water introduced unnaturally into soils does not simply go downward becoming groundwater recharge. Rather, in general infiltrated water should be assumed to move laterally parallel to the ground surface where it can frequently reemerge as exfiltration into tunnels, buildings, and utilities, or as seeps. Runoff generation in humid regions is complex and oversimplification of infiltration processes can cause problems. Figure 4.f depicts the common hillslope hydrologic processes for the humid northeast, which is where the Campus is located. In only a very few areas of Campus, and none in Core Campus area, can it be generally assumed that infiltrated water moves primarily downward to become recharge. For this reason, known existing recharge areas are highly protected on Campus.

Evapotranspiration (ET) is comprised of Evaporation and Transpiration. The discussion of ET for stormwater management facilities has evolved due to the discussion of the annual hydrologic budget. In the humid northeast part of the US, ET is considered to be between 55% and 60% of the annual rainfall. Green roofs and other green infrastructure can generate equivalent ET to natural conditions on an annual basis. However, flooding and stormwater management issues most people are concerned with have little to do with annual conditions, except from a regulatory perspective. During design type precipitation events, ET is generally negligible when using native plants. In general, while the University understands the benefits and needs of ET from stormwater facilities, from a practical perspective it is considered negligible for the control of design events.

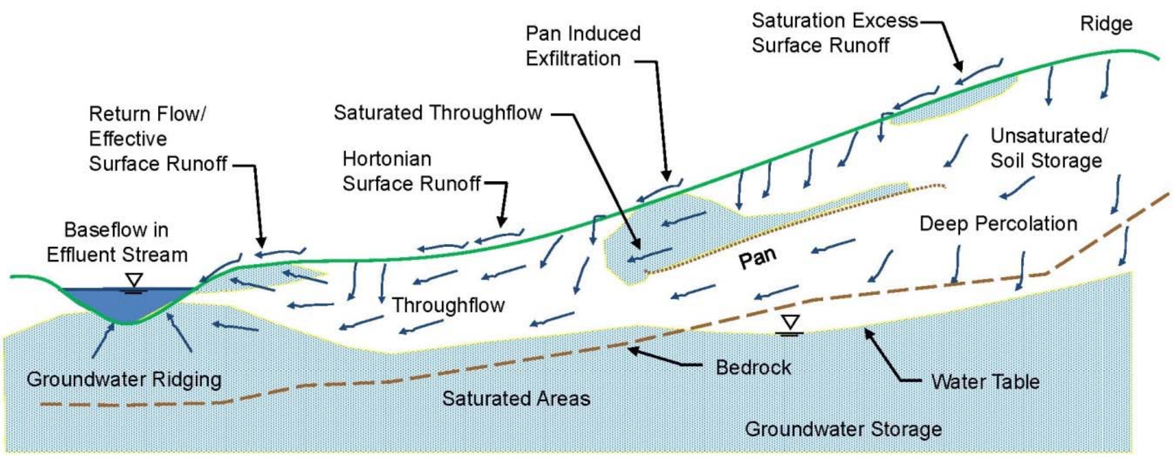

Figure 4.f. Hillslope Hydrologic Process in Humid Climates including Campus

Detention typically consists of simply holding runoff temporarily and then releasing it slowly at some engineered rate. Detention storage using surface ponds, subsurface detention ponds, bioswales, and rain gardens is considered the most effective stormwater control method for Core Campus. If new development and redevelopment projects include facilities that significantly reduce peak runoff rates to negligible levels (super extended detention), then downstream conditions will likely be protected or improved. Unfortunately, most regulatory standards allow or promote the use of conservative design methods that historically have resulted in little if any peak runoff rate benefit from these facilities.

Another Detention option available primarily outside Core Campus, is the integration of recharge. Most Campus surface stormwater ponds are unlined; and therefore, result in some infiltration losses even when not specifically designed for that function. Small unlined bioswales or rain gardens can provide the same volume control function. If the surface discharge component is completely removed from detention facilities, they end up becoming purely recharge facilities. The University pioneered the use of the low head weir recharge facility to mimic natural closed depressions. Some people may argue that the use of infiltration trenches, or infiltration beds also integrates detention and recharge; however, the University does not generally use these types of facilities because they remove the most renovative soils and replace them with gravel, which has little to no water quality benefits.

Detention type facilities hold runoff for later slow release or recharge. If instead we hold the runoff for some later potable water use, then we have created a stormwater reuse cistern. Cisterns were very common at the University in the 1800s and rural Pennsylvania farms before drilling wells for private property became popular. The University currently owns four stormwater reuse cisterns, two of which are used for irrigation, and two which are used for flushing toilets. In general, reuse facilities are dismissed on Campus because of the high cost to construct and maintain compared to the low current cost of potable water. Nonetheless, in 2015 the University began conducting a stormwater reuse study for the University Park Campus. One of the current barriers is the fact that the University has an extensive long range plan for Campus wide wastewater reuse.

The USDA Soil Conservation Service was established after the western dust bowls of the 1930s to explore the use of agricultural practices on soils and hydrology. Today's it's understood that land use practices can have a significant effect on runoff and watershed health. Imperviousness is frequently cited as the main culprit for stormwater woes, and there is a degree of truth to the generalization. Therefore, on many projects the University promotes the removal of imperviousness. For projects that remove substantial impervious areas, the

University will create impervious credit documents that are used to replace the impervious covering at a later date without being penalized as significantly from a regulatory perspective. However, at the University Park Campus, imperviousness is never truly "reduced", but rather simply moved somewhere else. Since 1995 the University Park Campus has added approximately 150 acres of impervious area and the trend seems to be continuing by infilling Campus green space.

Past Improvements

Frequently people tend to forget about problems once they're repaired; and therefore, this section has been added as a reminder of past problems. Additionally, if changes are made without understanding fully how the hydrologic systems works in each area, these problems can easily start again. Only larger flooding problems that were fixed are included as examples. Figure 4.6 shows a photograph of the Bathgate Dam that discharges to Millbrook Marsh. When the dam was originally constructed in 1991, the 10-year design discharge was approximately 250 cfs, which resulted in significant downstream flooding and limited attenuation in the dam. In the year 2000, the University expanded the dam, altered how it functioned, and reduced the design 10-year discharge to approximately 56 cfs. Today flows from the dam are minor and fairly high in quality.

Figure 4.g. Bathgate Dam after 2000 Upgrades

Prior to 2002, the intersection of Park Avenue and Fox Hollow Road flooded frequently during high intensity rainfall events as seen in Figure 4.h. The University Installed over 2,100 lf of 42" storm drain piping in conjunction with a $3,000,000 storm drain project downstream, which included water quality, and quantity controls. In 2003, Phase 3 of this project repaired and replaced the 10 ft wide and 8 feet deep eroded gulley below the Office of Physical Plant (OPP) and Fleet Services, which can be seen in Figure 4.i.

Figure 4.h. Flooding of the Intersection of Fox Hollow Road and Park Avenue

Figure 4.i. Fox Hollow Gulley below OPP and Fleet Services

In 2015, the University installed approximately 1,000 lf of 42" and 48" storm drains to remedy flooding along the lower portion of Bigler Road, which was a significant life safety issue as seen in Figure 4.j. It's anticipated that the second Phase of the project will continue up McKean Road extension going towards East Area Locker Room.

Figure 4.j. Flooding of Lower Bigler Road

Figure 4.k shows an example of a Case 3 Type of flooding issue at the Corl Street Underpass, which drains to the Corl Drywell. Past planning efforts looked to remove the function of the drywell and route the water downstream because the roadway flooded approximately 3 to 4 feet deep several times a year. However, the University conducted extensive monitoring of the drywell and in the end protected it since it currently is the end point (closed depression) for an approximately 2 square mile area. The end result was abandoning the roadway for public use and returning the property to the University where it now serves only as a service road for golf course maintenance activities. For more information on the Corl drywell, refer to:

http://www.opp.psu.edu/services/eng-resources/OPP-WRP-SW-CD-2-2010.pdf

Hundreds of smaller repairs have been conducted across the University on the stormwater systems, which are not included here. Therefore, it cannot be stressed enough that a meeting is conducted with Engineering Services to ensure an understanding of areas is gleaned.

Figure 4.k. Flooding of the Corl Street Underpass in West Campus

Section 5. Drainage Basins Covered in this Plan

As previously seen in Figure 2.a, the University Park Campus has extensive land holdings in the State College area. This Plan currently covers the majority of the developed portions of the University Park Campus, which are primarily located within one of four major drainage basins. The four major basins are: 1) the Main Campus Drainage Basin, 2) the Fox Hollow Drainage Basin, 3) the Bathgate Dam Basin, and 4) the West Campus Drainage Basin as seen in Figure 5.a. The Fox Hollow and West Campus Drainage Basins are tributaries to the Big Hollow watershed, the Bathgate Dam Basin is tributary to Thompson Run/Slab Cabin Run and the Main Campus Basin is tributary to Thompson Run.

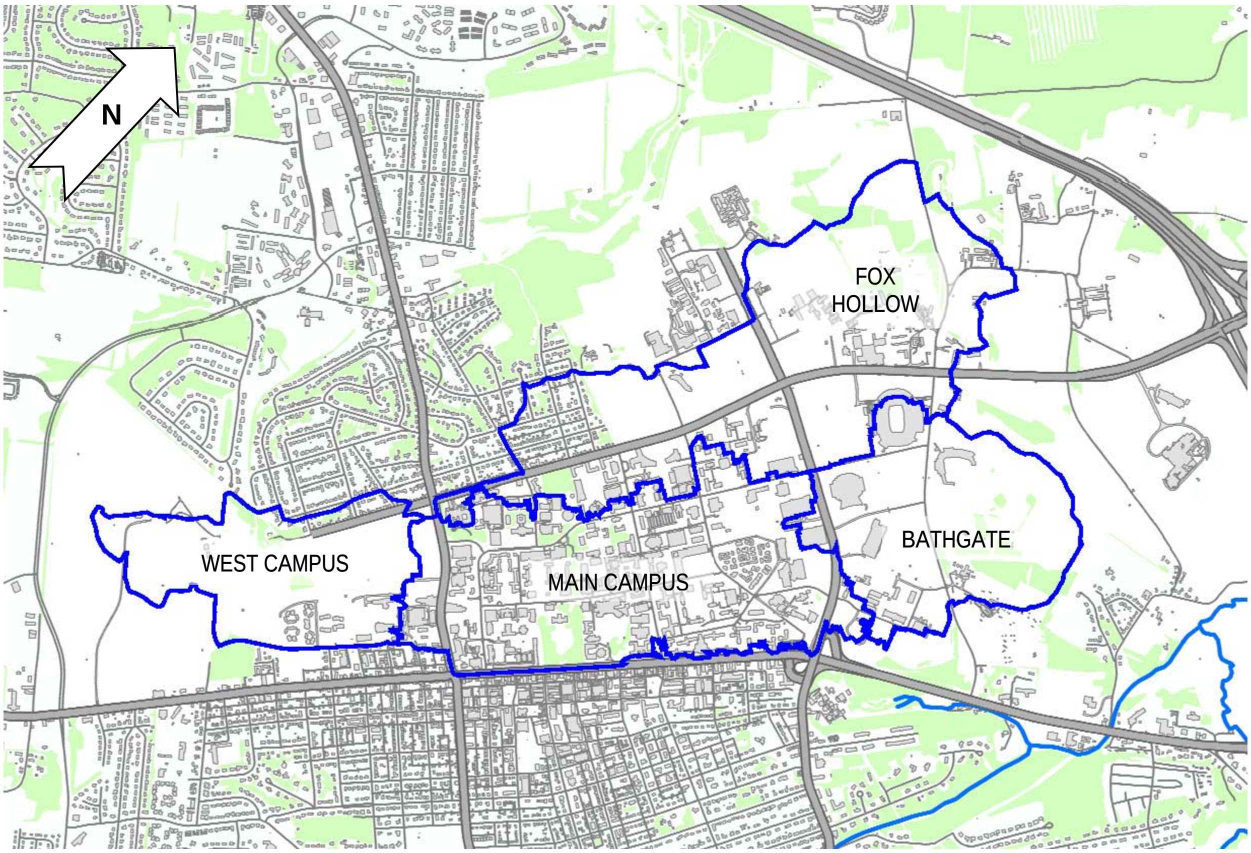

Figure 5.a. University Park Campus Primary Four Subwatersheds

While all four of these University subwatersheds experience most of the typical stormwater problems identified in the previous section, each one is different in how it responds hydrologically. Peak runoff rate control, volume control, and water quality control are conducted in the University Park area to varying degrees in each of the subwatersheds. 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 watershed scale. How quickly pollutants could reach a surface stream or the groundwater is highly dependent on the subwatershed.

Minor or negligible changes are always occurring to the University subwatersheds. Additionally, new information or better mapping is also a continuous process; and therefore, minor variations may exist for these subwatersheds at any time.

The use of the term watershed is generally only used for regulatory defined drainage areas or large basins. The University subwatersheds are also considered local drainage basins and from here on the term “drainage basins” or “basins” will be used for these four areas.

Section 6. Main Campus Drainage Basin

Background Information

The Main Campus Drainage Basin cannot be separated easily from the larger Duck Pond watershed. The Duck Pond is owned by the University and is located near the Centre Furnace just south of College Avenue in the Borough of State College (refer to Figure 6.a). The Duck Pond has a contributing drainage area of approximately 867 acres (1.35 sq mi) of which approximately 50% is impervious. The imperviousness is highly connected and the Borough and the University own the storm drain systems. The watershed area is comprised of approximately 51% of University lands and 49% of urban and residential areas of the Borough. Three main storm drains (72", 66", and 48" CMPs) discharge into a drainage swale approximately 1,200 ft above the Duck Pond. The Duck Pond does not have baseflow; however, a portion of the Thompson Spring flow is routed to the pond so that it does not become stagnant. Additional information on the relationship between the Duck Pond and the Thompson Spring, Thompson Run, and other drainage areas to the Duck Pond can be found in the Watersheds Report. A complete history of the Thompson Run Watershed can be found at:

http://www.opp.psu.edu/services/stormwater/opp-wrp-sr-tr-2013

The Main Campus Drainage Basin boundary changes slightly with projects and is currently approximately 384 acres in size and 50% impervious. The Drainage Basin is defined as the tributary area to the University main storm line outfall without consideration to bypass flow. Some University property along College Ave drains to the Borough's Calder Ave system.

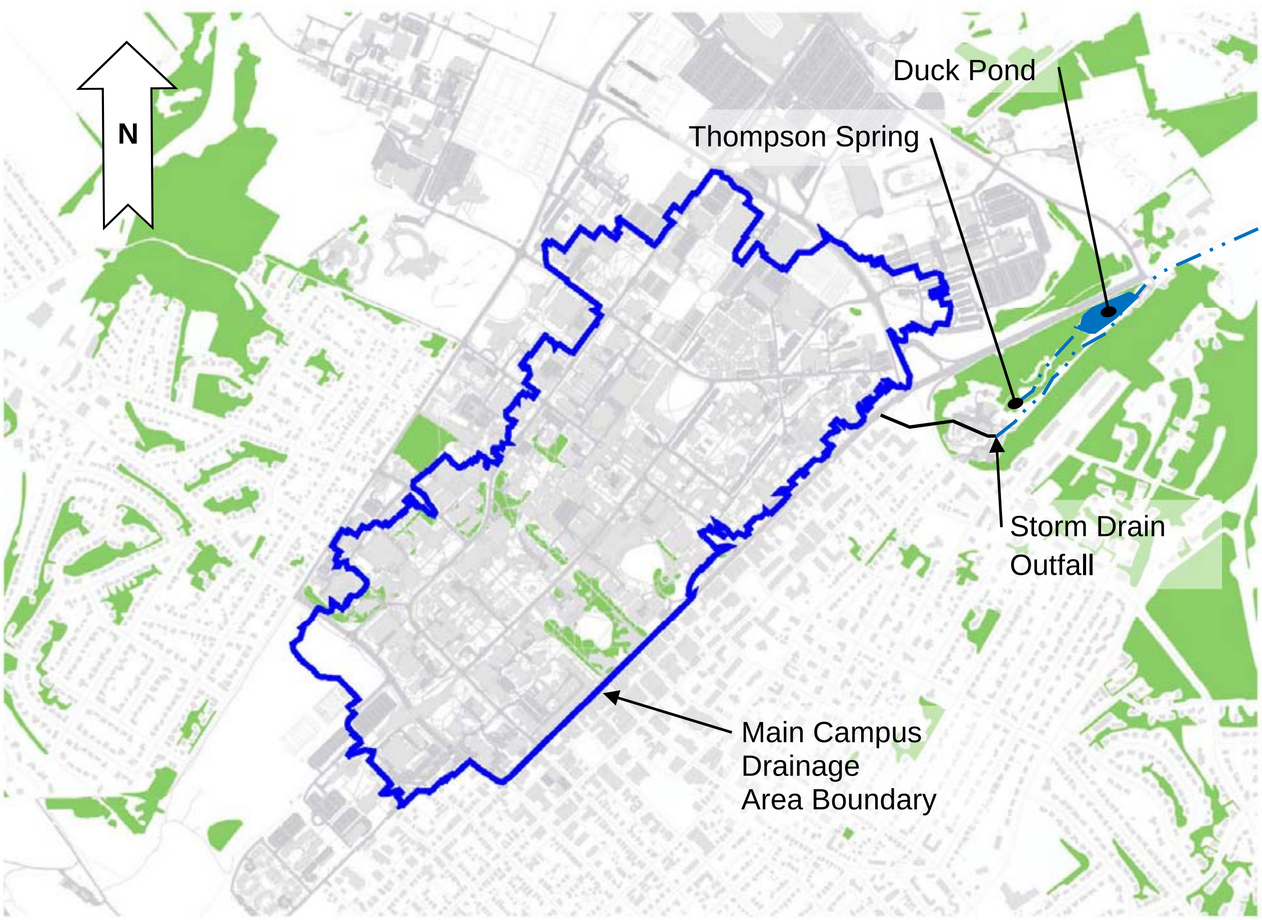

Figure 6.a. Main Campus Drainage Basin

There are approximately 36.6 miles of storm drains in the Main Campus basin ranging in size from 6” to 72”, which does not include underdrains, foundation drains, or building plumbing. Storm drains and best management practices can be seen in Figure 6.b represented in blue.

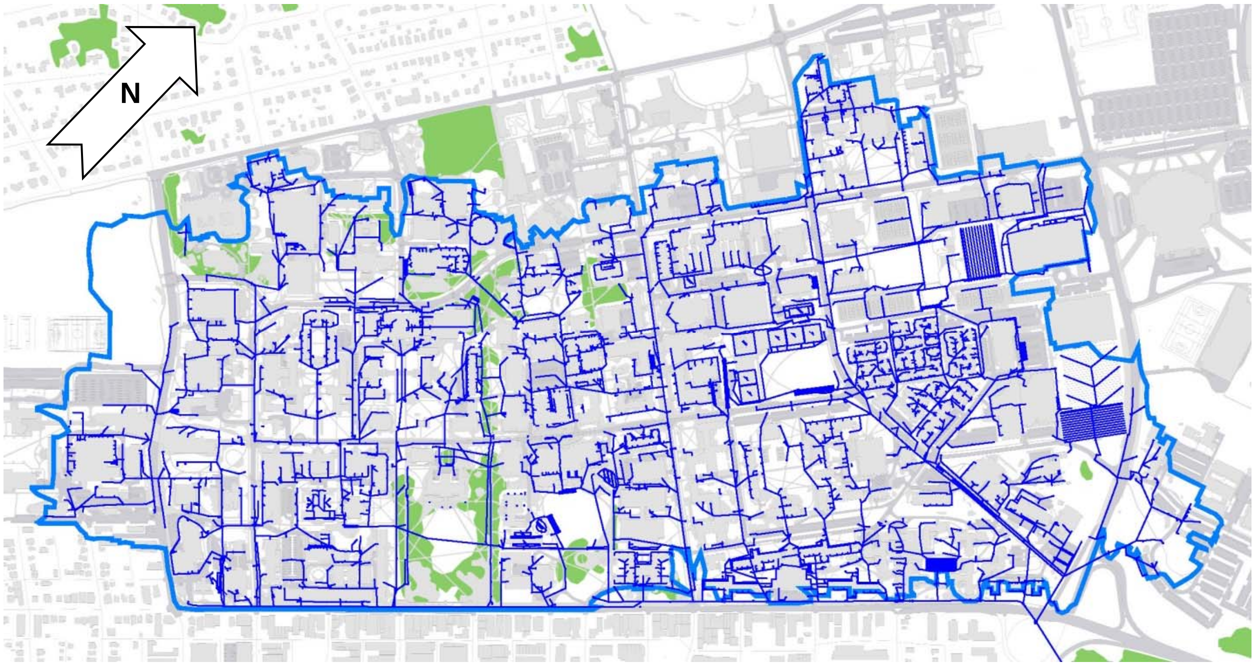

Figure 6.b. Stormwater Management Facilities in the Main Campus Drainage Basin

Occasionally, there’s flooding along College Avenue and Calder Alley during larger runoff events (refer to Figure 6.c). The June 27th 2013 event seen in the figure resulted from 3.38” of rainfall, of which 2.05” fell in one hour (recorded by the Walker Building Weather Station), which is approximately equivalent to a 25-year IDF rainfall event. During these types of events, bypass from the Main Campus Basin can occur.

Figure 6.c. Flooding Along College Ave on June 27th, 2013

The discharges to the duck pond are limited by the hydraulic capacity of the University and Borough's 66" and 72" storm drains. While hydrologic estimates for the duck pond watershed would typically be in excess of 1,000 cfs for runoff events greater than a 10-year return period, data so far indicates that the maximum discharge may be on the order of 800 cfs. The reason is that when University Drive was constructed in the 1950's approximately 40 ft of fill was placed in the original drainageway. Today, all flooding from Calder Alley, College Ave, and Main Campus would be stopped at the University Drive clover leaf, which acts like a detention pond.

If catastrophic failure of the University's and the Borough's storm drains under University Drive occurred, ponding could then potentially occur until water spilled over the bank east of the clover leaf. This ponding could cover an area approximately 6.3 acres in size, or three times the size of the duck pond. The maximum depth would be approximately 12 feet deep. The area that would flood is shown in Figure 6.d.

However, while some flows have gone across the or down College Ave as seen in Figure 6.e, there is no known time that the cloverleaf or the roadway actually flooded to any significant depth. Nonetheless, because of these pipe limitations, maximum discharges are regulated from the center of State College. If the University or the Borough upgraded the sizes of the storm drains under University Drive, it could significantly increase flooding down along College Ave at the current location of Blaze Alexander and Your Building Center (refer to Figure 6.f).

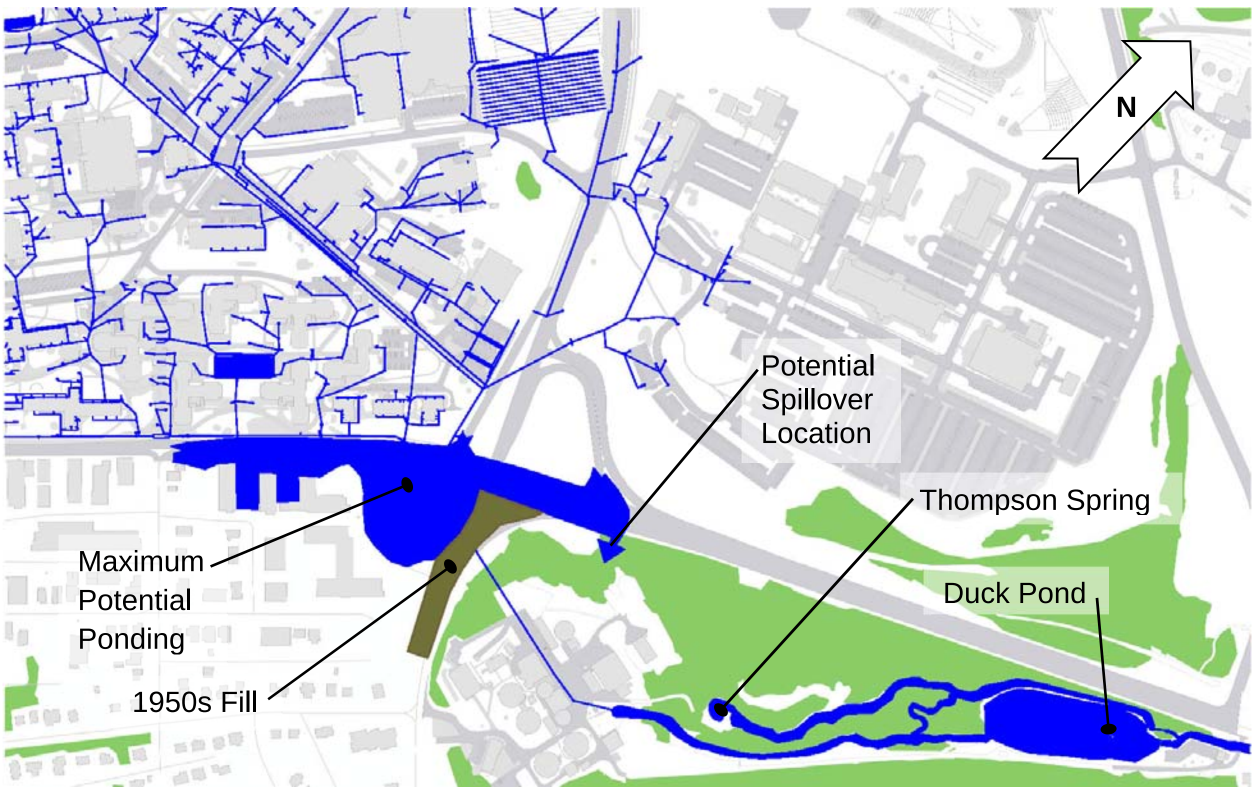

Figure 6.d. Potential Maximum Ponding at Cloverleaf if Both University and Borough Storm Drains Failed

As indicated in the policy section, the University has no plans to increase these pipe capacities and all Main Campus activities are aimed at reducing peak flows to the clover leaf.

Additional information on the Duck Pond drainage basin and Thompson Spring can be found at:
http://www.opp.psu.edu/services/stormwater/water-resource-publication-duck-pond-drainage-basin-2014
http://www.opp.psu.edu/services/eng-resources/OPP-WRP-SW-TS-2-2010.pdf

Figure 6.e. Flooding of College Ave at the University Cloverleaf from Bigler Road Runoff

Figure 6.f. Flooding at Blaze Alexander on June 25th, 2014

Current Problem Areas – General Description

Because the Main Campus drainage basin contains the oldest parts of Campus and has the highest density of development, it naturally also has the most stormwater problems. Additionally, because the basin discharges directly to surface waters, it can also have the most significant impact on downstream waterways including surface water quality. The general areas that flood routinely (less than a 5-year return period) due to the storm drain system capacity are shown in Figure 6.g. Note that this figure does not include localized building flooding or small ponded area problems resulting from the landscape design. Additionally, flooding can frequently be observed along Bigler Road between Pollock Road and Hastings Road; however, that problem is due to poor road grading which prevents water from going into the roadway inlets rather than insufficient storm drain capacity. This same problem exists campus wide with most sidewalks where runoff moves down the sidewalk as if it were a shallow channel.

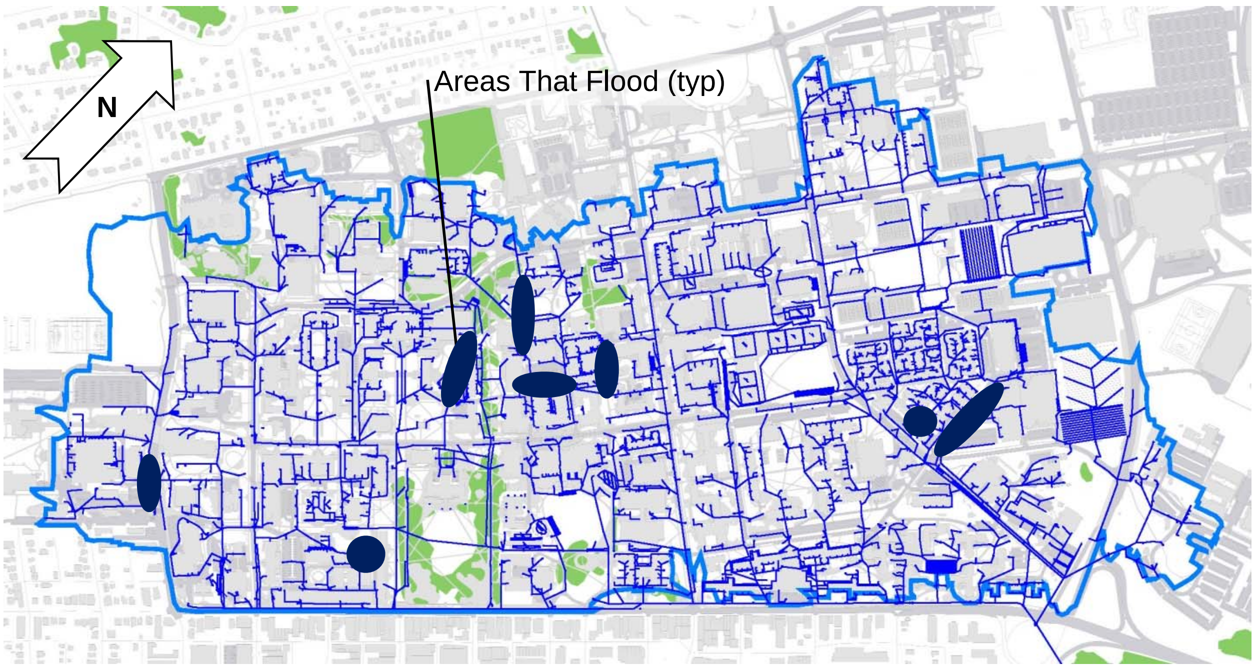

Figure 6.g. Areas that Flood Due to Storm Drain Capacity Limitations

The areas in Figure 6.g and what major storm drain trunk lines they're associated with are:

1) Atherton Street between the ARL Water Tunnel and the Walker Building (Trunk I)
2) The area between Sacket Building and Engineering Unit A (Trunk I)
3) The area around Pattee Library, Pond Lab, and Chandlee Lab (Trunk D)
4) The area around Armsby Building, Weaver Building, Mueller Lab, and Whitmore Lab (Trunk F)
5) The area around Davey Lab, Osmond Lab (Trunk F)
6) The area between Wartik Lab and Pine and Arts Cottages (Trunk F)
7) The area Around Nittany Apartments (Trunk H)
8) McKean Street east of Bigler Road (Trunk G)

These problems are also not the same level of severity nor do they all have the same life safety considerations. The worst flooding occurs at numbers 1 (Atherton St), 3 (Trunk D), and 7/8 (Mckean Street and the Nittany Apartments). Frequently problems are related to adverse pipes (run up hill), siphons, or major bellies. Where some of these pipe issues occur can generally be seen in Figure 6.h.

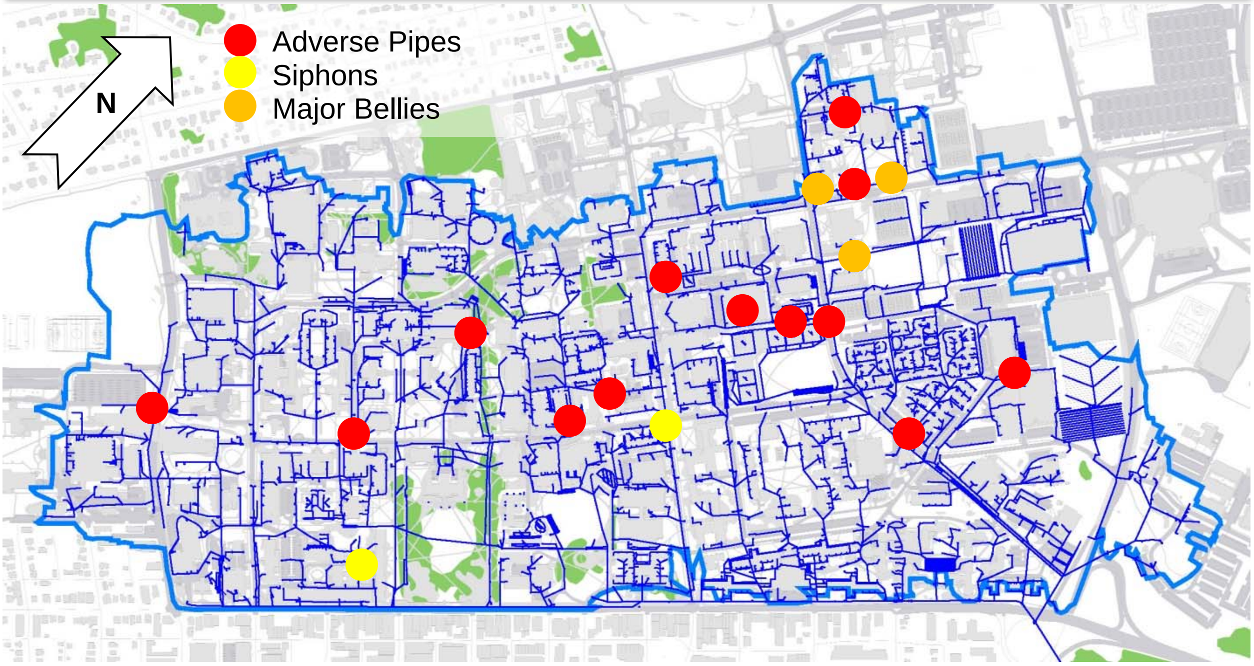

Figure 6.h. Known Adverse Pipe, Siphons, and Major Bellies in the Storm Drain System

Buildings that have had some type of flooding/wetness issue in the Main Campus Basin within the last five years are shown in Figure 6.i. Buildings that have had water entry at doors, windows, or due to roof leaks or mechanical failure are not included in Figure 6.i. From this figure it should be obvious that extensive stormwater problems occur, but several of them can be considered design related or due to a building issue that can be resolved without alterations to the larger conveyance system. Many of these issues have since been resolved. This is another reason why all projects should contact Engineering Services for additional information.

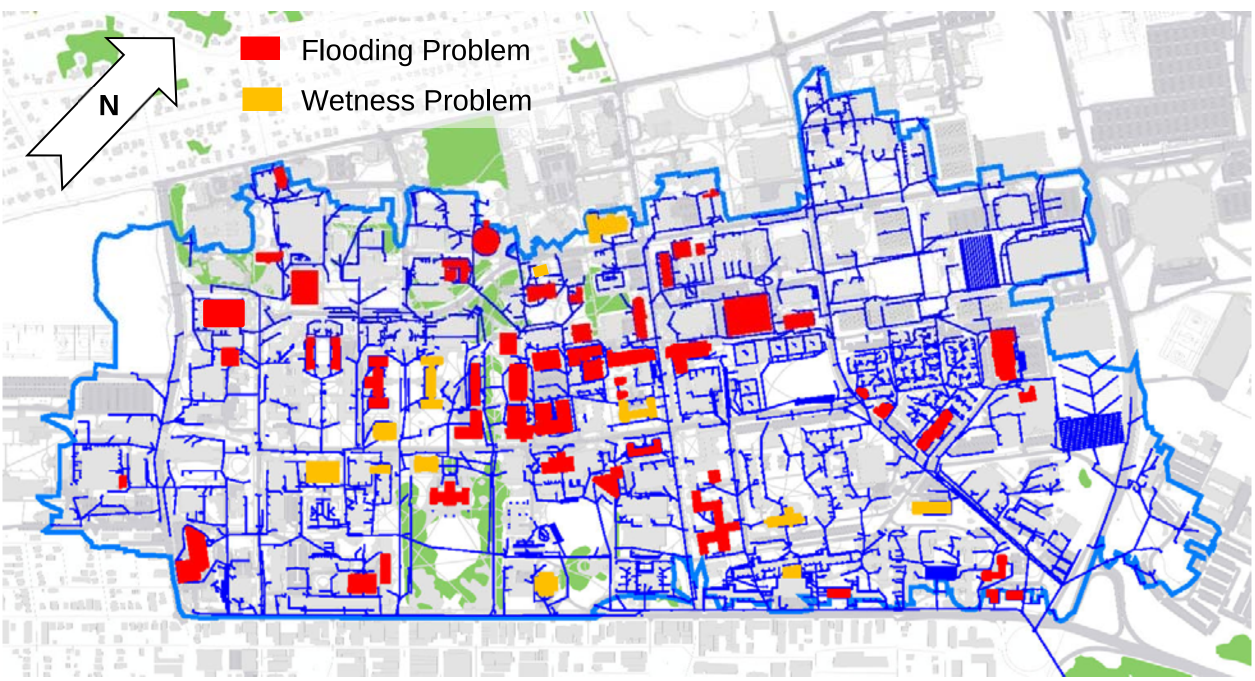

Figure 6.i. Buildings with Reported Flooding and Wetness Problems in the Last Five Years

Which buildings still flood routinely for which designs need to be conducted to remedy are shown in Figure 6.j. Additionally, the areas that flood due to storm drain capacity issues from

Figure 6.g have also been overlain. With a few exceptions, storm drain capacity issues cause the major flooding problems with buildings. The exceptions are:

1) Old Main, which is due to a suspected rain water conductor issue and clogging of drains to one of the drywells.
2) Rec Hall B, which is due to poor site/entrance design and no local inlets.
3) Eisenhower Chapel, which is due to the building being underground.
4) The Forum, which is due to the ramp and a cross connection.
5) Eisenhower Parking Deck, which is due to an adverse building storm line under the slab.
6) Pond Lab, which is due primarily to a historical drywell.

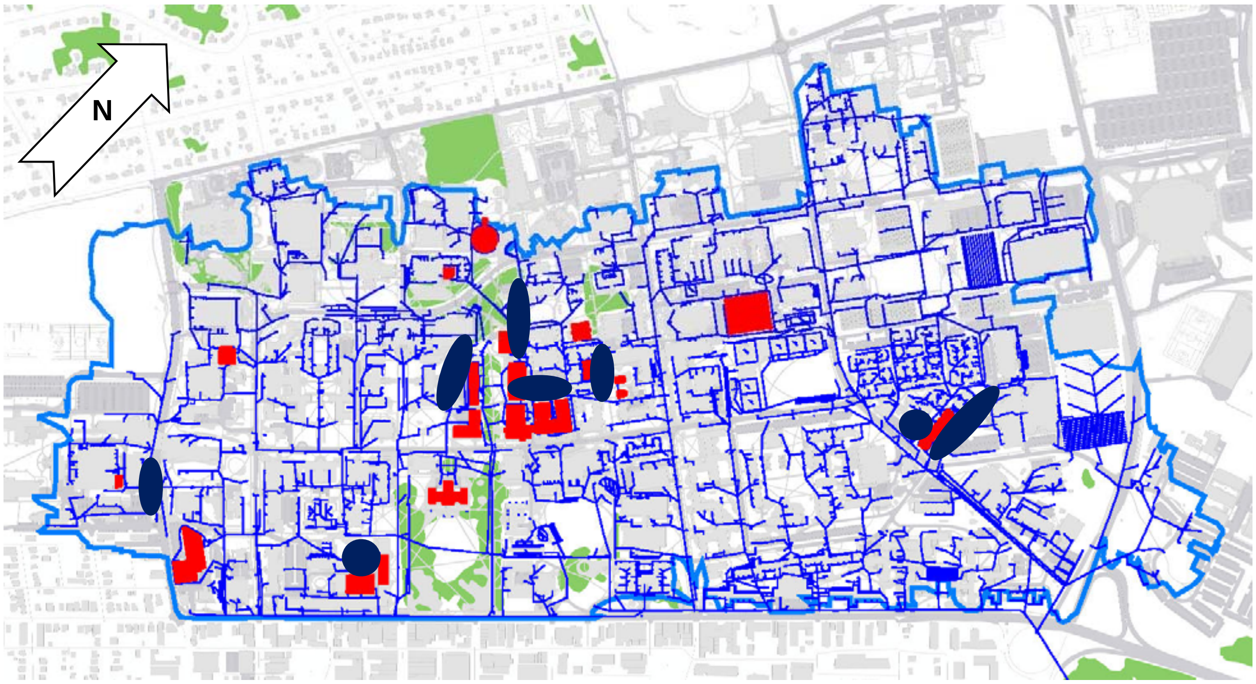

Figure 6.j. Common Major Flooding of Buildings and Storm Drain Capacity Issue Locations

The remaining problems in the Main Campus Basin; Atherton Street, the Sackett Area, Trunk D, Trunk F, and Mckean Road will be looked at more in depth.

Atherton Street Flooding

The flooding of Atherton Street between the University's Water Tunnel Building and the Walker Building occurs at the sag in the road (refer to Figure 6.k), which was originally a weakly defined drainageway prior to the 1930s with a single 24" RCP culvert under the road. In 1930, the University constructed the College Ave/Power Plant storm water conveyance system that connected to the existing 24" RCP. The drainage area and the 1930 storm drains can be seen in Figure 6.l. Development of the area and the widening of the road occurred over time without stormwater controls. This eventually resulted in the roadway flooding to some degree on average about every two months. Flooding occurs due to runoff from the impervious areas flashing quickly to the culvert, despite the drainage area being almost half pervious.

Prior to the construction of the IST building, parts of Campus on the east side of Atherton Street drained to the west side and then to the 24" under the road. This issue was fixed by the University during the IST Building construction, but today the roadway still floods approximately two or three times a year during high intensity rainfall events. Increasing the 24" pipe size is impossible and prohibited by the University because of existing downstream flooding.

Figure 6.k. Atherton Street Flooding viewed from Walker Building

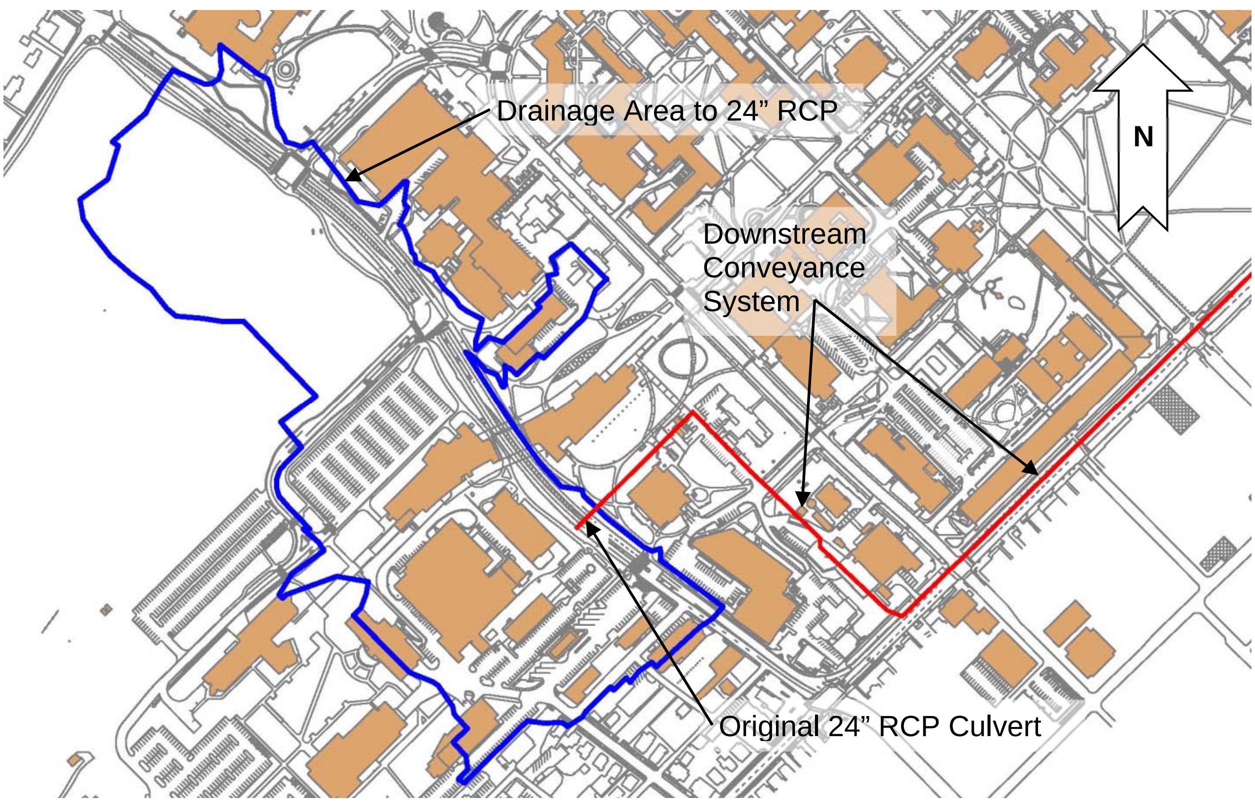

Figure 6.l. Atherton Street Drainage Area and Downstream Conveyance System

When Atherton Street floods, it creates a backwater condition to areas behind the Water Tunnel which results in flooding part of the Research West Building. Additionally, if the water gets high enough, it will overtop the curb and earthen berm, which acts like a levee along the ARL Buildings parking lot. If this occurs, the flows rapidly exceed the capacity of the storm system around the ARL Building and flood the basement. This last occurred in 1996 resulting in the loss of critical research. Unfortunately, until the flooding of Atherton Street is resolved, these other problems cannot be fully resolved.

Recommended Solution

While the downstream conveyance systems are already taxed; and therefore, pipes logically cannot be increased to push flooding safely downstream, PennDOT is currently conducting stormwater conveyance improvements along Atherton Street. Until such a time, no University efforts should be conducted. The possible solutions are to provide detention storage somewhere instead of on the roadway, remove large amounts of imperviousness, or divert runoff to the West Campus Watershed. Retrofitting the entire area with green practices or attempting stormwater reuse for extreme event control is unpractical in this area. Therefore, the only viable option is to provide subsurface detention storage, which would need to be located in multiple areas most likely under the parking areas. This can be done when the area is redeveloped or when the northern parking lot is repaved. Projects could be done in phases controls on the north or south sides are not dependent on each other.

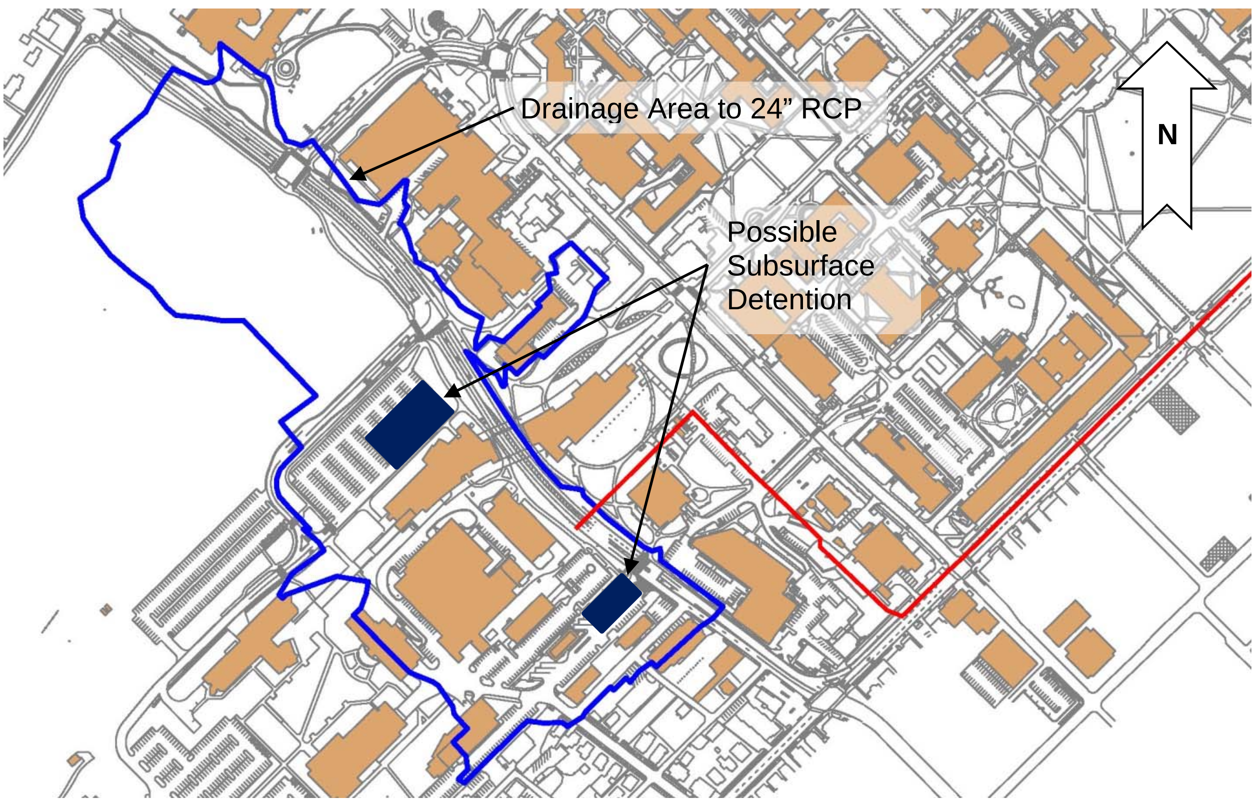

Figure 6.m. Atherton Street Possible Subsurface Detention Facility Locations

Sackett Building Area Flooding

The Area around Sackett Building has multiple minor issues that affect drainage as seen in Figure 6n. When the Engineering Units were increased in height and had the connector passageways installed, they installed a siphon under the northern side between Units A and B. Additionally, the Sackett roof leaders from the northern 1957 addition go under the Hintz Alumni Center Garden and are completely broken; however, landscape will not permit the repair in place due to the trees. Additionally, a Hydraulic Grade Line problem exists in the NW stairwell of Sackett causing the floor drain at the bottom of the steps to surcharge and flood the building. Uncontrolled runoff from the obelisk area floods the northwest corner of the building also.

In 2013, the University attempted to develop designs to route a new storm drain on the west side of the Sackett Building towards the 33" RCP in College Ave, thereby bypassing the siphon and the broken line. It was determined that too many utilities (electric and telecom, etc.) were in the way physically preventing such a route. In 2015 a sump pump was also installed inside the door at the bottom of the stairwell, which is flooding.

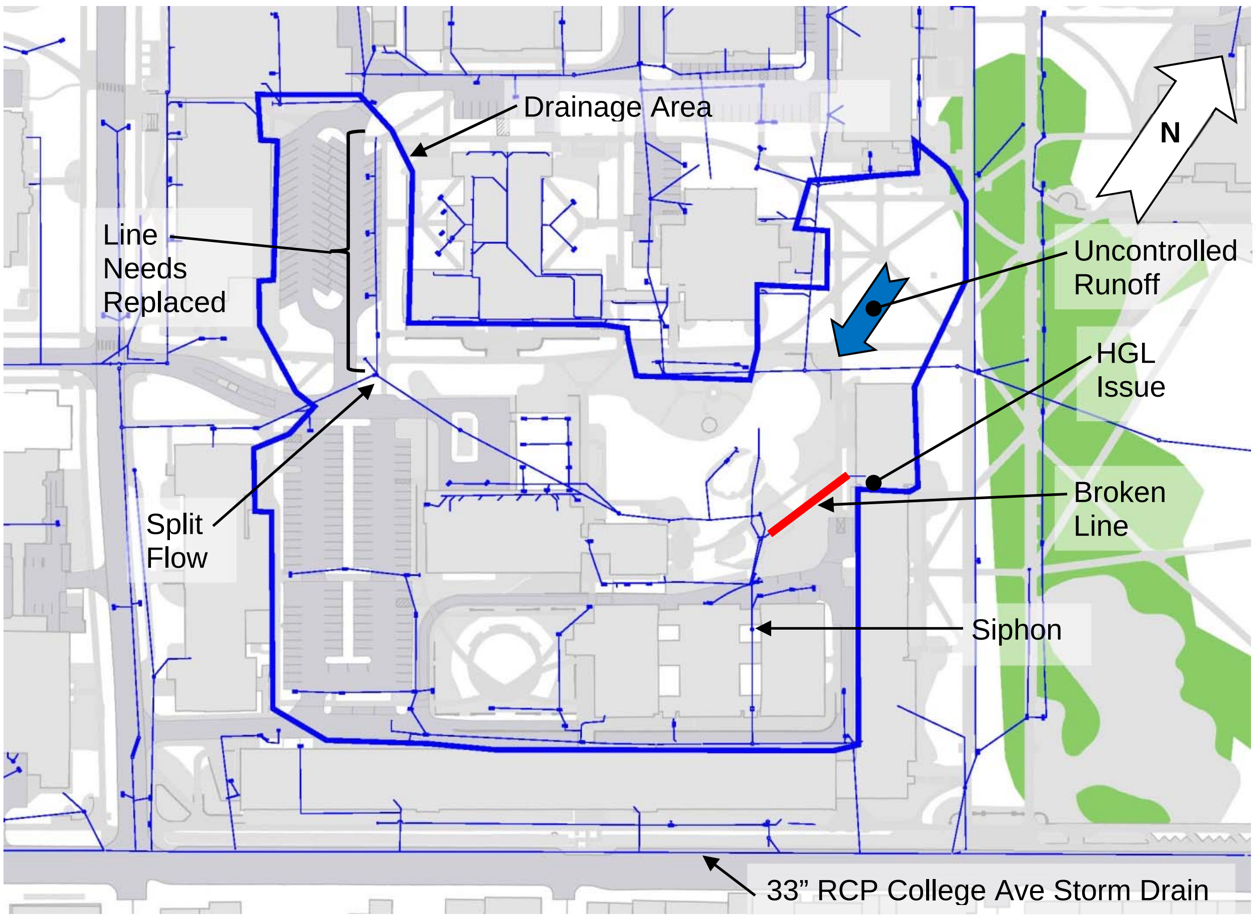

Figure 6.n. Stormwater Issues Around the Sackett Building

Recommended Solutions

In 2016 a project will be conducted to run the broken roof leader north while also providing inlets at the NW corner of the Sackett Builing to control upslope runoff. Otherwise all work is in a holding pattern until the Hammond building or the Engineering Units are razed allowing the proper design and repair of the conveyance system. A line in the parking lot on the east side of Deike Building is also in need of replacement as work is conducted in the area. Only conveyance improvements are recommended in this area

Conveyance System Trunk D

The Trunk D conveyance system is shown in Figure 6.o and primarily serves the core campus area immediately north of Old Main. The buildings in this area historically were served by drywells and sumps including the original portion of Pattee Library, Pond Lab, Schwab Auditorium, and Old Main. Minor storm drains were constructed in the 1940's; however, the majority of the trunk line storm drains were constructed starting in 1969 with a Department of General Services project. These later systems did not include any stormwater detention and later resulted in projects that abandoned or disconnected the historical drywells and expanded the drainage area imperviousness without consideration to the downstream capacity. Today the pipe system's capacity is significantly undersized resulting in the flooding of Pattee Library, Pond Lab, and Chandlee Labs. Whitmore Lab and Davey Lab also flood occasionally also due in part to Trunk F problems (discussed in the next section) in addition to Trunk D issue. The most significant and frequent flooding impacts Chandlee Lab.

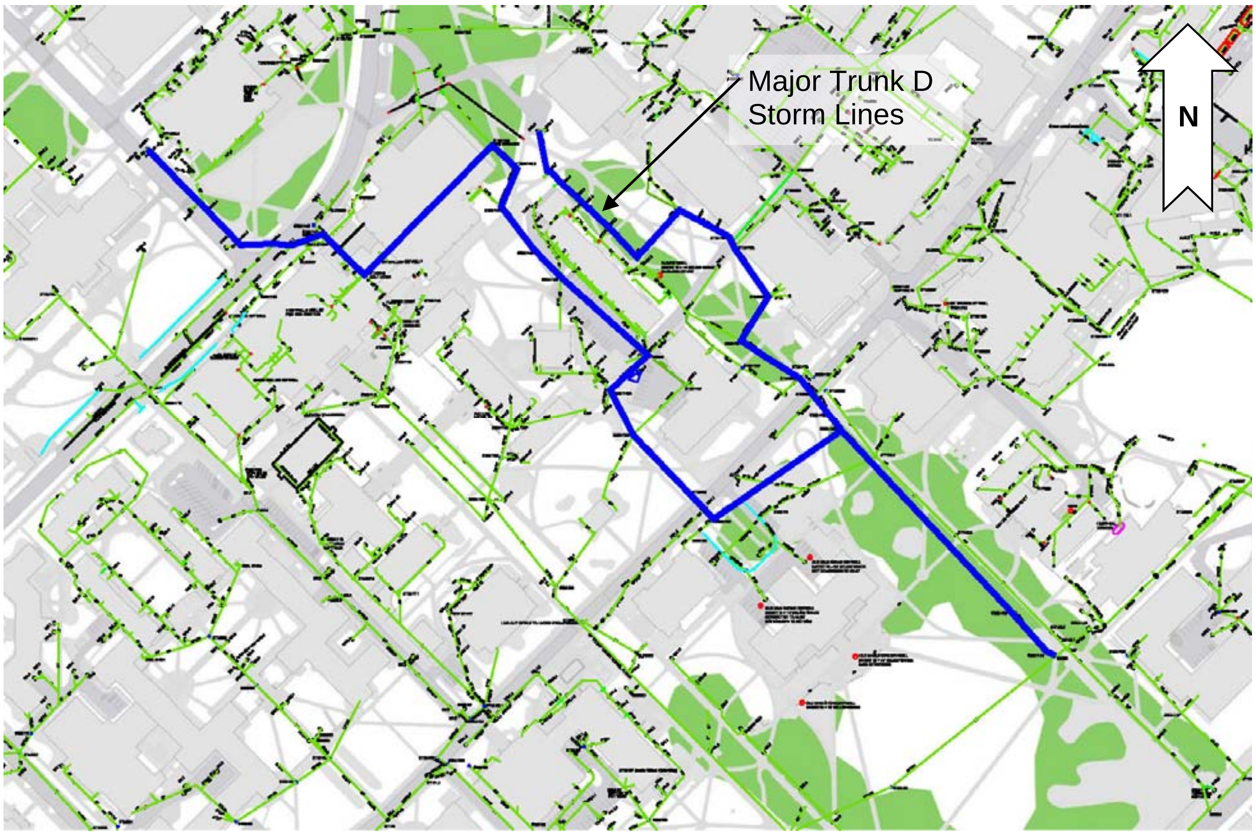

Figure 6.o. Overall Trunk D Storm Drain Conveyance System

Multiple issues exist around Chandlee because the building's north entrance was made the local low point without positive drainage away from the building. Many minor adjustments have been made to the area to reduce the incidence of nuisance flooding; however, major flooding will persist until the trunk line capacity is increased. The depth of flooding on 8/3/2014 in the Chandlee northern stairwell can be seen represented by the student in Figure 6.p. Additional major issues near Pattee Library include the storm (and sanitary) line being routed under the building and the fact that the contractor installed a major portion of storm pipe running upslope. The most significant flooding to occur at Pattee (resulting in filling up the entire underpass with stormwater) resulted from a construction error by Utility Services and is not normal flooding for the area (refer to Figure 6.q). Flooding of the underpass has historically occurred a couple inches in depth due to the adverse pipe located immediately downstream. Significant flooding of Pond Lab also occurs; however, this is primarily due to the drywell depth causing backwater flooding of the window areaways since the existing storm system is not deep enough.

Figure 6.p. Flooding at Chandlee Lab on 8/3/2014

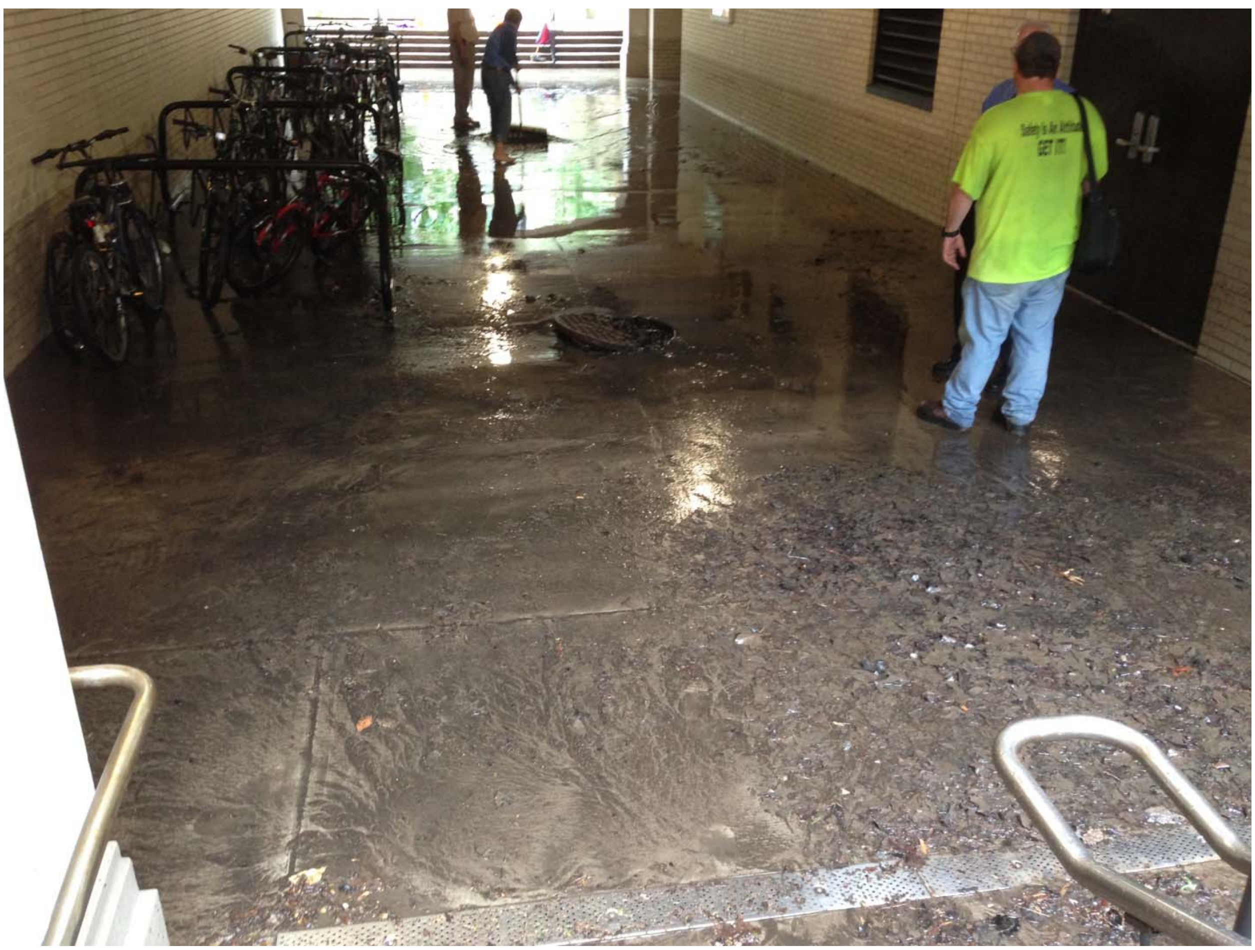

Figure 6.q.The Pattee Tunnel after Flooding 2 feet Deep on 6/25/2014

Recommended Solutions

In 2015 the upgrading of trunk Line D began in the upper reaches with the first phase (Phase A) anticipated to be complete in 2016. This new system (shown in red on Figure 6.r) will be deeper than the existing system in some areas, but unfortunately will still not be deep enough to abandon the use of the Pond Lab drywell. Either Phase A or B can be constructed first without resulting in adverse impacts. Phase A is being coordinated with the Upper Henderson Mall improvements and the Phase B area is waiting for the existing tree to die off, which currently sit over the line. The new system will allow the adverse pipe near Pattee to be abandoned and will significantly reduce the area in the existing line that surcharges on the northwest side of Chandlee. However, the new Trunk D line will not solve all of the problems in the area. Additionally, because of the number of existing utilities in the area, the Upper Phase A storm drain will be limited in size and slope. Once constructed, the entire area will need to e remodeled to determine if additional improvements need to be made.

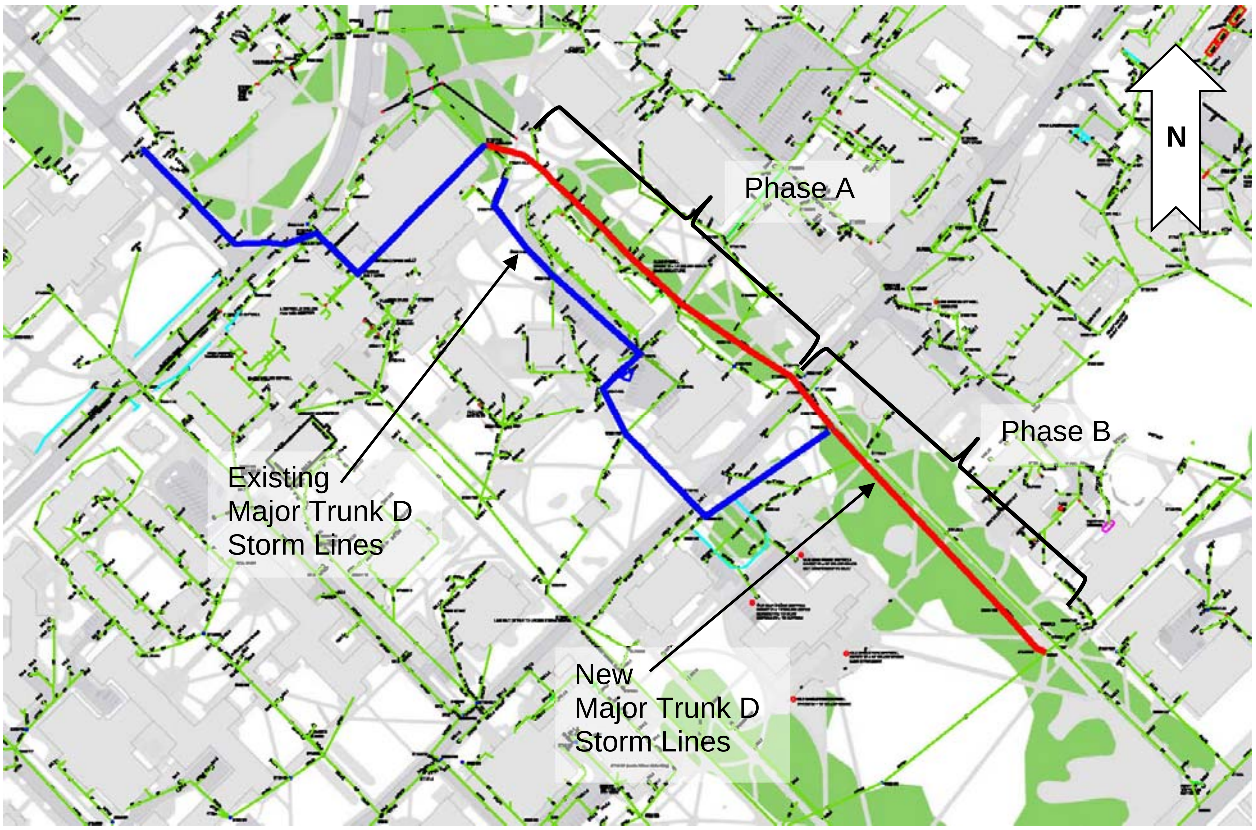

Figure 6.r. New Trunk D Main Line Route

Current design standards prohibit the routing of major storm lines under buildings; however, there does not appear to be any projects in the near future that will physically allow the line under Pattee to be rerouted. However, this should always be a consideration on the table when major projects occur in the area.

Additionally, current plans call for the demolition of the Oswald Tower. If and when this occurs the project will be required to improve and repair the existing storm line in that area. Unfortunately significant flooding occurs from the uncontrolled runoff south of Pattee between Burrows and Pond Labs; however, the area is a historical grove of trees that currently cannot be impacted. Alleviating this uncontrolled drainage will need to eventually be addressed in the grove or by the redesign of the parking areas north of Chandlee Lab. Again, these are site/landscape caused issues that are not considered herein.

Conveyance System Trunk F

The Trunk F conveyance system is shown in Figure 6.s and primarily serves the core campus area between the Forum to the Ritenour Building. The portion of the system between Shortlidge Road and the northwest corner of the Frear North Building was constructed between 1933 and 1940 and the remaining portion towards the Forum was constructed in 1955. Multiple problems exist with this system's layout and capacity resulting in the flooding of the Arts Building, Armsby, Althouse, Davey Lab, Mueller Lab, Osmond Lab, Wartik Lab, Whitmore Lab, the Spruce Cottage, and the Pine Cottage. Additionally, the Forum Building and the Frizzell Room of the Eisenhower Chapel also have water problems, but neither is related to the storm drain system.

As can be seen in Figure 6.s. a portion of the main trunk line also goes under the Boucke Building and Ritenour. Two short adverse sections of pipe also exist. The storm lines north of the Frear North Building are limited currently in depth and slope by the east-west steam tunnel and the existing storm lines from the north are shallow and flat until they cross the tunnel where the suddenly drop down in slope. Therefore, one cannot simply estimate the actual pipe slopes using structure inverts above and below the steam tunnel.

In addition to the main trunk line being overtaxed and surcharging, the minor systems that feed the main line are also a hodgepodge of undersized, shallow, and twisting lines with multiple blind connections. However, these minor systems issues cannot be corrected until the issues with the main trunk line are corrected. Most of the lines around the Osmond Building are also filled with debris from historical construction projects.

Figure 6.s. Overall Trunk F Storm Drain Conveyance System

Recommended Solutions

While the minor conveyance systems need to be rerouted in several places, the main trunk line needs to remain in its current alignment and position because of other existing infrastructure. Therefore, the recommended solution is to remove pressure and reduce peak discharges from the main line through the use of a regional subsurface detention facility as seen in Figure 6.t. The facility will need to be located in the northern portion of the Brown C parking lot, which can remain over the system. This subsurface system will be fed from a new storm drain system starting on the west side of Armsby that picks up flow between Frear North and Mueller Lab. Additionally a flow splitter would be installed near the east side of Frear South. Reduced discharges would be sent back into the main line. The size of the subsurface system would need to be evaluated with the hydraulic capacity of the main trunk line. A planning level estimate has been conducted and the amount of impervious area that would be controlled would be approximately 6 acres, which would require approximately 1.0 acre-foot of storage capacity with a goal of reducing all existing discharges to STMH213 by approximately 75%.

Additionally, the storm drains starting near the east side of Buckout Lab down to the trunk line need to be upgraded and straightened out, also removing blind connections as shown in Figure 6.t.

Figure 6.t. Recommended Improvements in the Trunk F Area

McKean Road Area Flooding

McKean Road between the Nittany Apartments and Greenberg floods for almost any light rain due to the existing deficient storm drain system that runs down the road, which is considered second order Trunk Line 305 (part of Trunk line G), refer to Figures 6.u and 6.v. However, the area around the Nittany Apartments also results in frequent flooding of the Apartments due to trunk line H (refer to Figure 6.w). The problems with the Mckean Road storm drain system were partially controlled by the larger downstream Bigler Road Trunk line, which was upgraded in 2015. Now that the Bigler Road storm drain system has been repaired, the McKean Road system can also be addressed.

The drainage area includes two subsurface facilities (Lasch and Sarni). Despite these facilities, significant flooding occurs at the Nittany 60 Apartments due to an adverse section of pipe and a conveyance system that was not originally designed for the additional runoff from the Bigler Fields Area.

The McKean Road system will be rebuilt in 2016; however, this will not alleviate all nuisance issues in the larger area. Nittany 11 also floods due to hydraulic grade line issues with the remaining Biger Road System due to flat pipe slopes near Pollock Road. In 2015 a large sinkhole occurred on the main Bigler Road trunk line immediately above this flat section of pipe (upslope of STMH 274). The pipe at the sinkhole was increased to a 42" RCP with the expectation that eventually the pipe downstream to the Bigler Road 2015 repair location would be deepened and upsized as future roadwork permits.

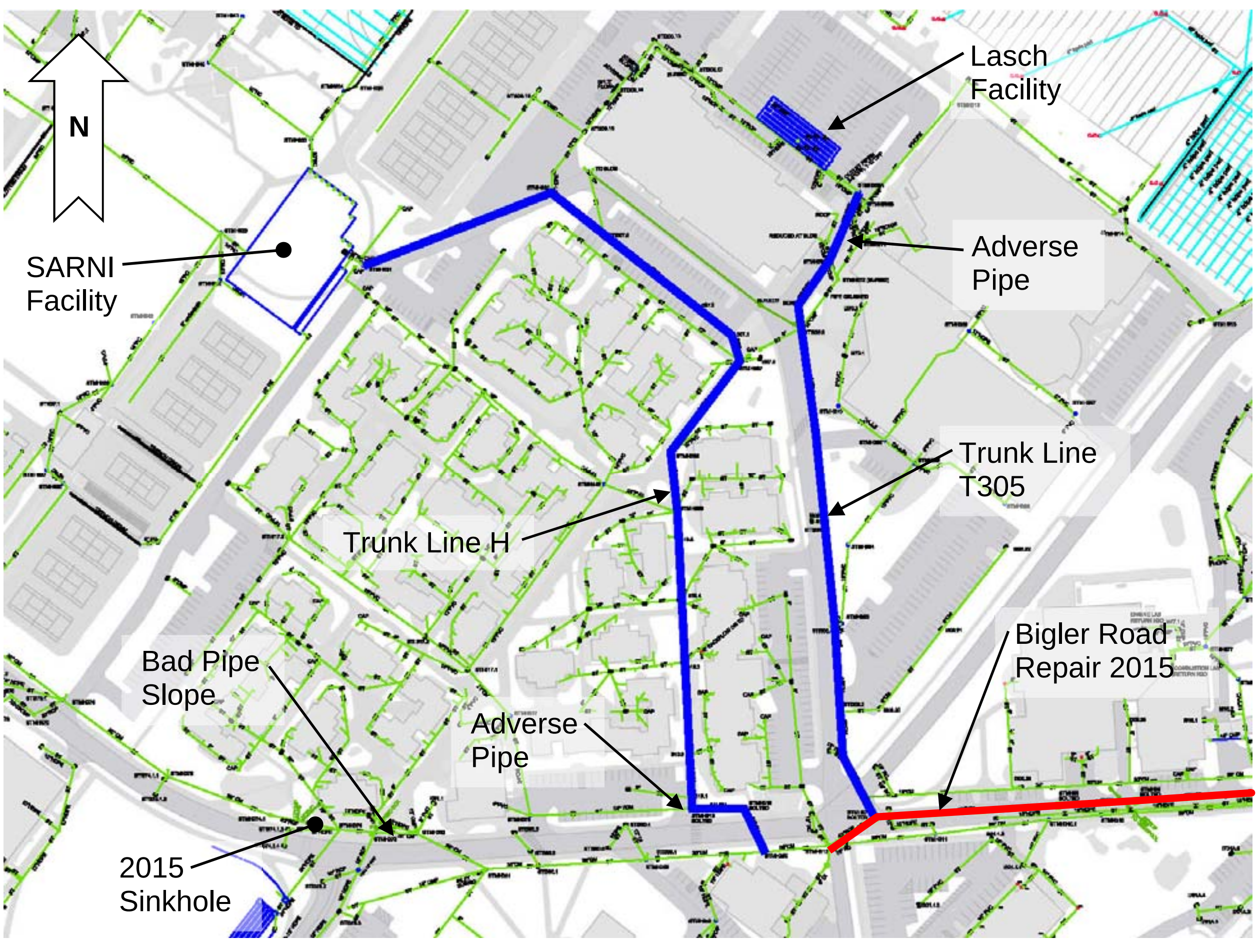

Figure 6.u. Trunk Lines and Stormwater Facilities Around McKean Road

Figure 6.v. Surcharging of Mckean Road Inlet for a Moderate Rainfall Event

Figure 6.w. Flooding Along the North Side of Nittany 60

Recommended Solutions

The Bigler Road 2015 storm drain project increased the pipe size and deepened the line allowing the McKean System to be improved and allowing the Bigler Field drainage from the SARNI facility to be diverted to the new line (refer to Figure 6.x). This work is anticipated to be completed in 2016. This will also result in significantly reducing the flows to the adverse pipe section below Nittany 60.

Engineering Services has also analyzed the Lasch Subsurface Detention Facility and determined that it is not being used effectively at all. Plans are being made to improve the function of this system in 2016.

The last manhole installed on the Bigler Road project was deepened with the expectation that the upslope pipes would also be increased in size and deepened all the way to Pollock Road as shown on Figure 6.x. This would also allow the adverse pipe section below Nittany 60 to be removed. However, these reaches of pipes are in adequate condition and the most significant flooding has been resolved with the lower Bigler Road work; and therefore, this section of pipe replacement is not a priority and should simply be done when major roadway work is conducted.

Because the Nittany Apartments are indicated to be demolished in the future, additional work in the area of the Apartments is not recommended.

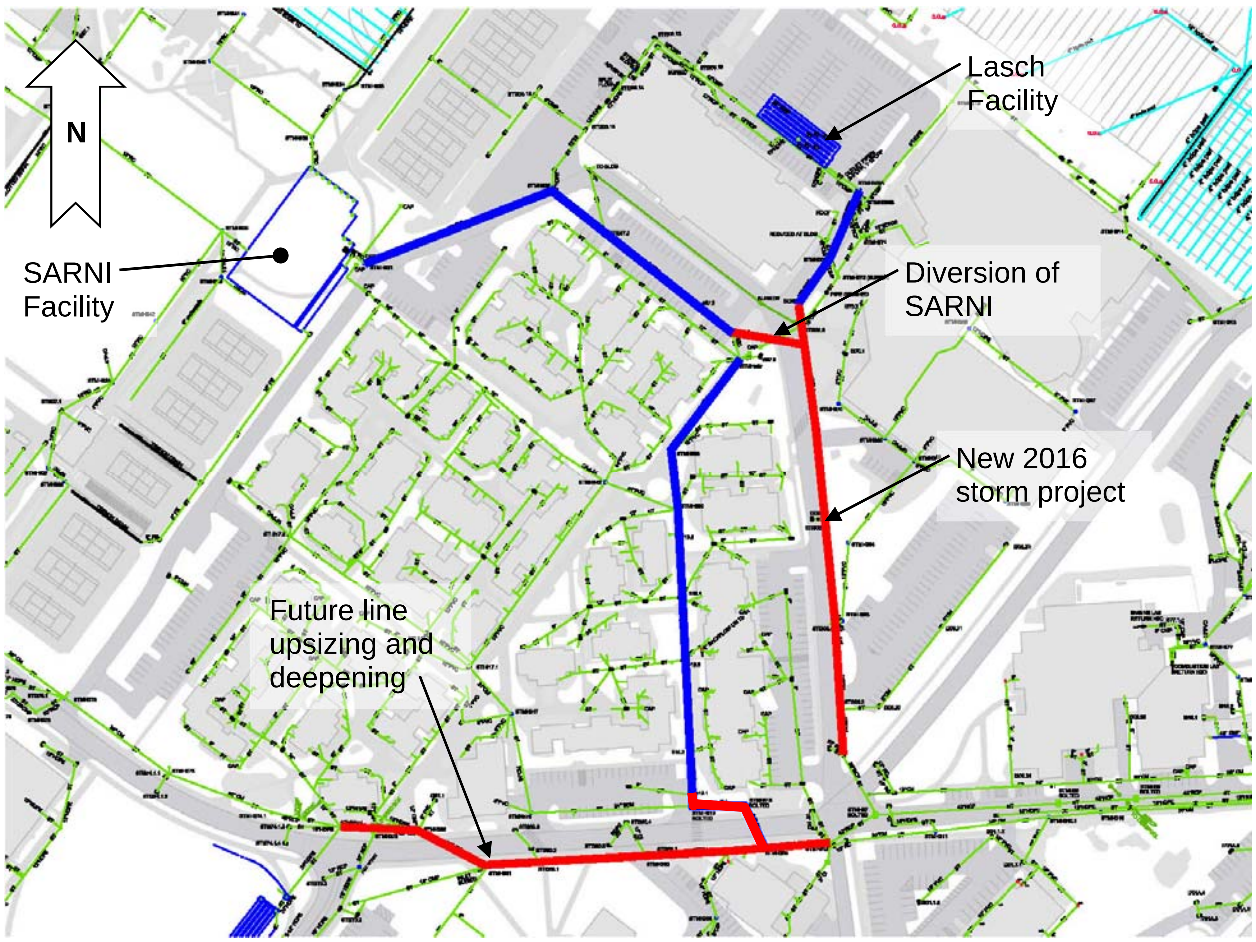

Figure 6.x. Recommended Improvements in the McKean Road Area

Section 7. Fox Hollow Drainage Basin

Background Information

The Fox Hollow Drainage Basin (FHDB) is located within the State College Borough and College Township. The basin has a mix of several different land uses ranging from urban to agriculture with the outlet defined approximately 1,000 feet southeast of the overpass of U.S. 322 at the concrete v-notch weir. The FHDB surface drainage area is approximately 453.6 acres in size, of which currently 118.9 acres are impervious (26.2% impervious) and the basin is underlain 100% by carbonate geology (refer to Figure 7.a). The FHDB does not have baseflow and surface runoff is primarily generated only by overland flow from impervious areas during rainfall events, with the exception of major snowmelt or rain on frozen ground conditions. The basin outlet was selected because it is the farthest downstream point where surface water can be controlled by the University prior to reaching the Big Hollow drainageway, which contains Penn State's primary potable well fields.

In the early 1960s, the FHDB was primarily in agricultural use and had a distinct main drainageway that only contained four small culvert crossings. By the 1970s over 6,500 feet of the drainageway was filled in and replaced with storm drainpipes. By the 1980s drainage problems existed in the areas of the former drainageway. The last remaining portions of the drainageway exist at the Mitchell Tract, site of the Penn State Arboretum, and at the pasture where the experimental low head weirs are located. Today there are over 110,000 feet of storm drains within the FHDB ranging in size up to 48" in diameter as seen in Figure 7.b.

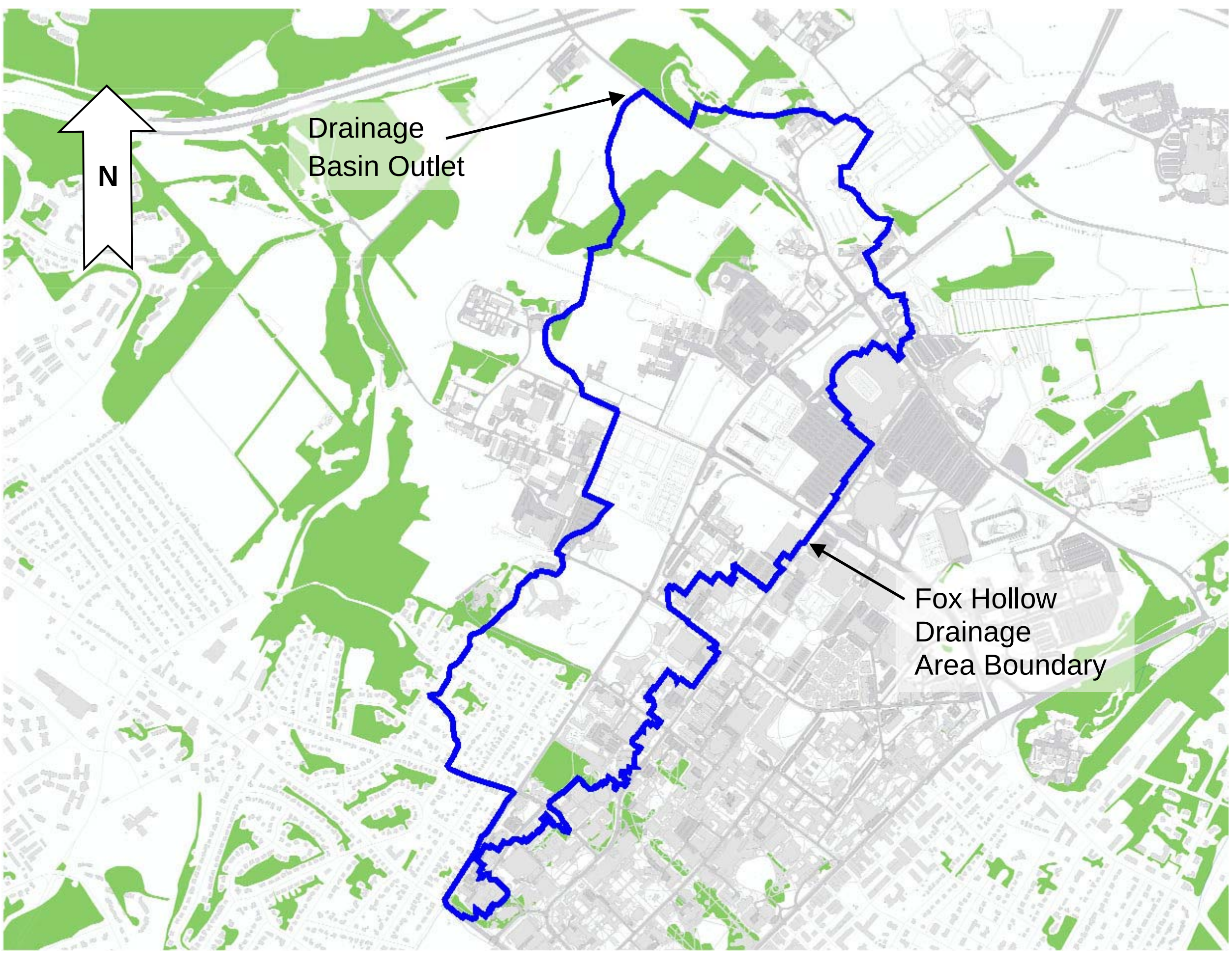

Figure 7.a. Fox Hollow Drainage Basin

The University has instituted the use of numerous stormwater BMPs such as green roofs, bio-infiltration systems, disconnection of impervious areas, and the protection of major natural recharge areas in the Basin. The use of natural and passive systems is preferred due to surficial sinkhole and water quality concerns and the failure of two porous pavement systems at the University in recent years. Figure 7.b shows the location of the major recharge areas, water quality facilities, and surface and subsurface detention areas within the basin. In addition, numerous additional smaller facilities (constructed for single land development projects) are located throughout the basin such as a porous pavement basketball court at North Halls.

The Fox Hollow Basin is also different from the other three main drainage basins at the Campus in that it has a large area of non-University owned lands that drain to a University Stormwater BMP. In fact, the majority of runoff to the Mitchell Tract recharge area in the Arboretum is from the College Heights area of the State College Borough as seen in Figure 7.b.

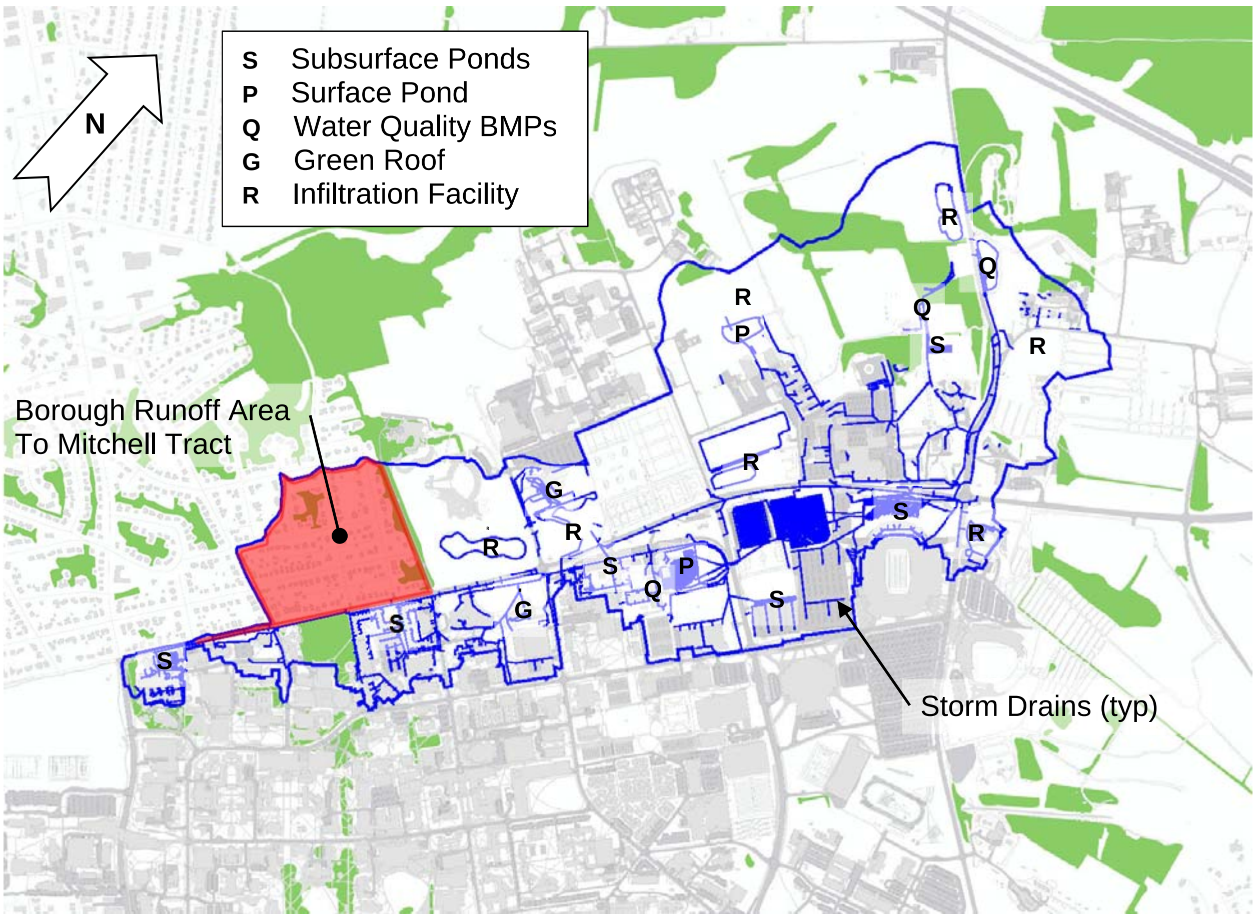

Figure 7.b. Major Stormwater Management Facilities in the Fox Hollow Drainage Basin

In the late 1990's the University investigated solutions to improving drainage, reduce flooding, and allow for future development with the watershed. A lined dam, similar to the Bathgate Dam, was proposed in two different areas near the current watershed outlet. However, in early 2000's after studying the soils in the vicinity, the University switched gears and focused on preserving and enhancing natural recharge areas. From 2002 to 2003, the University conducted a five phased plan which remedied flooding, protected water quality, and enhanced recharge culminating in the construction of the Fox Hollow water quality facilities and recharge areas. It was here in the basin that in 2003 the University pioneered the use of the low head weirs.

All discharges from the FHDB drain to the Big Hollow on the University's property where almost all runoff is recharged. Therefore, large scale infiltration is already occurring naturally.

History of Changes in the Drainage Basin

In order to fully understand flooding in the basin and how best to protect it in the future, one needs to understand changes that occurred in the basin over the last ¾ of a century. Figure 7.c shows the aerial photographs from 1938, 1957, 1971, 1995, 2005, and 2015. Each image shows approximately what the drainage basin boundaries were prior to man's changes (red hatched line) and what the drainage basin boundary currently is in 2016 (solid blue line). The images also include a phantom blue line that represents the original undisturbed drainageway prior to any development. While no photographs exist, it is almost certain that this drainageway had no bed and banks anywhere along its length similar to much of the Big Hollow.

Prior to any development in the basin, surface runoff would have been extremely rare likely only occurring with extreme rainfall events, snowmelts, or rain on frozen ground conditions. The first major drainage changes in the basin were made by the State College Borough when storm drains were installed along Park Avenue that terminated at the intersection of Shortlidge Road. A cross culvert discharged the surface runoff into the drainageway at the current location of the Mitchell Tract recharge facility. By 1938, the drainage basin was largely in agriculture with minimal dirt roads with the exception of small developed areas around Borland Lab and the Fox Hollow barns. Fox Hollow Road was constructed partly up the drainageway, very similar to the way Orchard Road is today upslope of Puddintown Road.

The dairy barns were constructed in the early 1950's and the area around the current Almquist Research area was also developed. Since there were still no storm drains along Fox Hollow Road, Almquist discharged roof runoff into a sinkhole/cesspool to the south of the building. Runoff in the area between Shortlidge Road and Fox Hollow Road was still likely very rare and the drainageway was largely intact. The late 1950's and early 1960's saw tremendous development stress in the drainage basin and significant impacts to the drainageway. The flower gardens were constructed in the early 1960's by placing fill directly in the drainageway, but no conveyance systems were installed likely because flow from the Mitchell Tract was still never observed.

The most significant drainage impact in the 1960s was from the installation of a culvert on the west side of the new University Drive that went under the new baseball field and was discharged just after the current location of the Stadium West parking area and OPP entrances. A surficial sinkhole quickly developed at the end of the culvert that remained until 2005 when it was removed. The construction of the Physical Plant Building complex resulted in pipes and open cannels being constructed along Fox Hollow Road. These were required to convey the runoff from the new culvert under the baseball field which now received runoff from Lot 80 and the northern portion of East Halls. All drainage west of Shortlidge Road still drained into the Mitchell Tract and the new Lot 83N lot likely never produced surface runoff that left the flower garden area. The construction of the southern portion of East Halls, and the movement of Beaver Stadium diverted large areas of the drainage basin to the Thompson Run watershed because storm drains existed in those directions at that time. Park Avenue beyond Bigler Road was still dirt with no drainage structures except for minimal culvert crossings.

The next two decades before 1995 saw limited development by the University with the exceptions of the IM building, expanding the OPP complex area, expanding Lot 83N and the construction of some other minor areas. Almost all football parking areas in the drainage basin still consisted of grass fields. The most significant drainage impacts occurred from PennDOT reconstructing and paving Park Avenue and Fox Hollow Roads in the early 1980s, at which time they made significant drainage modifications. The most significant was that they removed the cross culvert from the Mitchell tract, thereby diverting all runoff as far west as the Nittany Lion Inn now towards Fox Hollow Road. Unfortunately, since the area is very flat, construction resulted in an adverse section of pipe being installed along Park Avenue near the current Business Building that restricts all upslope flow. This same project upgraded all of the drainage along Fox Hollow Road. Unfortunately, the new PennDOT system largely disregarded the adjacent area drainage that simply was allowed to flow onto the road. The first stormwater detention facilities in the basin were constructed in 1990 for Nittany Lion and OPP parking lots; however, by this time significant flooding in the drainage basin was common.

In 1996, the University started the construction of the Stadium West parking areas, which eventually was expanded two more times by 2014. While each of these parking expansion projects included stormwater detention, flooding and stormwater problems already existed. In 2000 the University started seriously addressing flooding in the drainage basin. Additionally, in 2003 the University removed Lot 80 replacing it with the East Sub-Campus development. The Arboretum was developed starting in 2007 and in 2008 the Katz Building was constructed. Both the ESC and Katz projects saw a temporary reversal of imperviousness in the basin, but the overall net impervious essentially has been the same since the early 2000’s. Large parking areas (Lots 80 and 83N) have been removed from the basin; unfortunately, parking never really goes away on Campus and the lots were simply moved to other watershed areas.

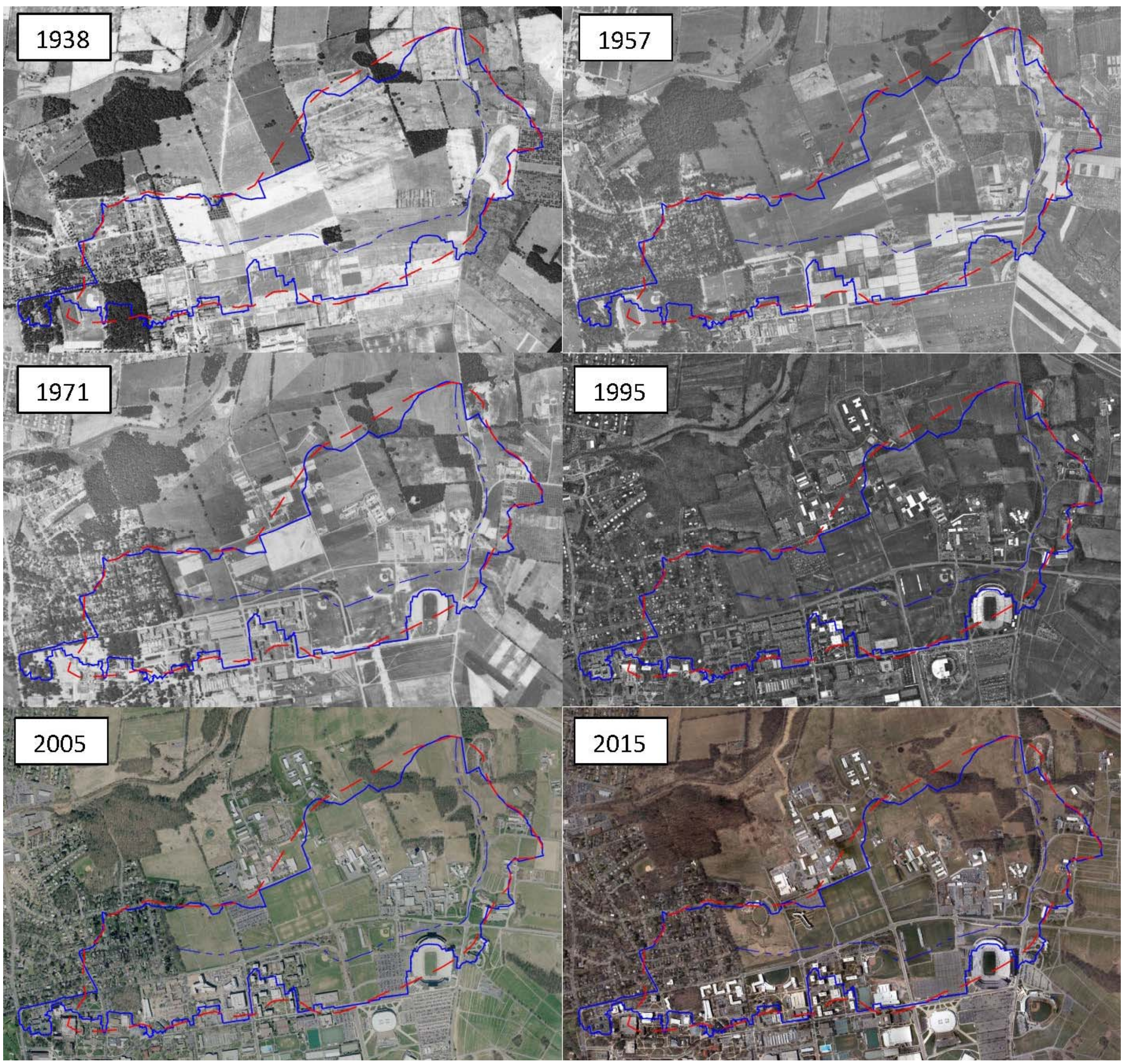

Figure 7.c. Changes in the Drainage Basin from 1938 to 2015

Current Problem Areas

Similar to other Campus areas, there are minor nuisance stormwater problems such as puddles at ramps or minor water issues at some building entrances. Significant flooding previously occurred in the drainage basin as discussed in Section 4 of this report. Large expanses of Park Avenue flooded historically, multiple buildings (such as the Nittany Lion Inn and the Katz Building), athletic fields (such as the Softball and Jeffery Fields), and even stormwater BMPs such as the Visitors Center infiltration bed have flooded routinely. Many of these areas have been fixed, but some problems still remain.

Because of the adverse section of PennDOT owned pipe in Park Avenue, pressure head is required to convey larger flows that end up flooding the intersection of Park Avenue and Shortlidge Road (refer to Figure 7.d). There is only a small 2'x2' inlet at the intersection low point (due to adjacent utility conflicts) that some believe may be responsible for the flooding; however, this is not the case since water actually comes out of the inlet during larger runoff events. This phenomenon can also be observed approximately 800 ft farther west at storm manhole 125 as seen in Figure 7.e. This manhole and others up gradient frequently had their covers thrown off until they were finally bolted down due to safety concerns.

The easiest way to fix this problem would be to disconnect the upslope drainage from the Park Avenue conveyance system and direct runoff back into the Mitchell Tract recharge area as it existing prior to the 1980s. The Office of Physical Plant attempted to do this in 2008; however, resistance by the Arboretum development team resulted in the project not coming to fruition. Unfortunately, development activities in the Arboretum make this no longer a recommended solution because of surficial sinkholes that are now occurring.

Figure 7.d. Typical Flooding at the Intersection of Park Avenue and Shortlidge Road

Because of this flooding problem, special design criteria have been instituted in the upslope area as previously indicated in Section 3-3 of this plan. Because of the lack of available land area, there are no other currently available options to reduce peak runoff rates below the capacity of the existing storm drains. The expectation is that PennDOT will eventually widen Park Avenue at which time they will upsize and repair the existing roadway conveyance system. The University does not want to be financially responsible for fixing the Park Avenue storm drain system.

Figure 7.e. Surcharging at STMH125 along Park Avenue

While the Intermural Fields on the north side of Park Avenue rarely generate surface runoff during moderate rains, they do generate runoff during extreme precipitation events and especially during snowmelt events. At those times, the runoff will move across the entire road because of the super-elevation design, which creates hazards during the winter months (refer to Figure 7.f). Snow management also creates issues with these fields especially with relation to snow drifts. While this area is not slated for redevelopment, future work on the intersection if done must address the control of the runoff from the adjacent fields.

During the construction of the West Stadium parking lot expansion in 2014, volume control was required because the project was adding approximately 4 acres of imperviousness. Because the site is due west of Beaver Stadium and the geological strike and preferential flow direction is in the direction of the Stadium, infiltration was prohibited on the project site. In order to meet the project schedule it was determined that the best course of action was to build a water quality/volume facility near Park Avenue in front of the Katz Building. This was an example of treating runoff from other areas in the same basin. Unfortunately, there was not enough impervious area that could be routed to the site for treatment so an attempt was made to divert runoff from the south side of Park Ave from the main stormwater conveyance system and divert it to the site for treatment. Because this type of design relies on complex timing issues and a conveyance system that pressurizes, it has already resulted in flooding Park Avenue while under construction as seen in Figure 7.g. The hopes are this system functions properly, but it is a clear example of the risks of attempting unusual BMPs in order to meet a project schedule.

Figure 7.f. Flooding by Uncontrolled Drainage at the Intersection of Park Ave and University Dr

Figure 7.g. Flooding of Park Avenue from a New Stormwater Volume BMP Failure

The softball field flooded fairly frequently prior to 2010 until the facility was moved approximately 200 feet west (as measured from the pitcher's mound) and rotated (the outfield was actually only moved approximately 70 ft west). The field was moved specifically because of the flooding. While flooding at this location is believed to be a problem by many people (especially the softball training staff), the area adjacent to the softball field is a stormwater detention pond, which is designed to hold water and pond. It was originally recommended to move the softball field and build it at a higher elevation as early as 2003 because it was known that more runoff would eventually be directed towards the softball field pond. During extreme runoff events, the pond discharge (and conversely the ponding elevation) is due to the 42" storm drain friction capacity under Jeffery Field. This pipe will not be made bigger and the pond will not be made smaller because it significantly controls flows sent down to the Fox Hollow Rd facilities. To reduce flooding in the pond would have significant adverse impacts along Fox Hollow Road and other downstream areas.

Unfortunately, during the design of the new softball field Intercollegiate Athletics (ICA) reduced the elevation of the new field as a design cost savings measure. Because of this, the left outfield elevation was lowered one to two feet, which has already resulted in runoff reaching the outfield running track since 2011. A typical image of the ponding in the field during a larger runoff event can be seen in Figure 7.h. The softball pond is a protected stormwater facility, but is currently unregulated (has no municipal or PaDEP permit or approval). However, OPP has constructed a special gate that promotes ponding because of recent construction projects to prevent downstream flooding. This special gate is raised during home football games when precipitation is anticipated to reduce the potential for flooding if cars are parked in the area. OPP and ICA staff work together on the control of the gate. However, because of the decisions ICA made regarding cost savings of the softball field, ponding may begin to creep onto the field during extreme runoff events. Because this is simply a recreational field and because it's not anticipated that the field will be used during such events, no further action is recommended.

Figure 7.h. Ponding adjacent to the Softball Field

Figure 7.i shows a photograph of a parking lot flooding adjacent to the softball field where an inlet is located at a low point in the lot. It is not clear at this time if the flooding was due to surface clogging of the inlet or backwater conditions and friction of the local system since the storm drains were just replaced as part of the softball filed reconstruction. This area will need to be observed in the future and the spaces immediately near the inlet may need to be taken out of service if the issue persists. The same area was known to previously flooding due to clogging of inlets by leaves.

Figure 7.i Flooding of Parking Lot Between the Softball Facility and Snyder Hall

During larger runoff events, the Fox Hollow Roadway floods on the south side of I-99 at two locations (It floods much more significantly from the north side of I-99 in recent years due to development in Patton Township). The first is at the Big Hollow Road intersection immediately below the FHDB defined outlet, which can occur from rare large flows in the Big Hollow, or from the PennDOT undersized cross pipe near the Fox Hollow Building. Runoff that causes flooding of the cross pipe near the Fox Hollow Building will usually occur, but not always, with the flooding of the road at the sag (refer to Figure 7.j) between the University's filtration area (on the east side of the road) and the recharge area (on the west side of the road).

Flooding of this sag is rare and should not be modified as it could have a significant impact on increasing downstream flooding. Ideally, to remedy flooding at the sag, the roadway elevation should be increased; however, this is a PennDOT owned Road. In 2012, PennDOT installed another culvert at this location that made matters worse rather than better. PennDOT did this work without advising or conferring with the University or understanding the complexity of drainage in the area. In late 2013, the University finally fixed the area by making minor modifications to PennDOT's work. Unfortunately, this is PennDOT right-of-way and the

University has little say in the State's activities. In the last several years PennDOT has done work on many of the roadway swales along Fox Hollow Road; however, they have not properly stabilized any of the channels as see in Figure 7.k, which is leading to new roadway erosion.

Figure 7.j. Flooding at the Sag in Fox Hollow Road During Overflow Conditions

Figure 7.k. PennDOT Controlled Swales along Fox Hollow Road

Future Development in the Drainage Basin

There are numerous protected recharge areas in the Fox Hollow Drainage basin that if removed can have a significant and immediate impact on flooding and other stormwater problems. All of these areas are included in currently available University mapping systems and under no circumstances should these areas be considered for future development activities or disturbance.

In reviewing the 2007 Master Plan proposed within the Fox Hollow Drainage Basin (refer to Figure 7.l), one can see that almost everything planned at that time has been developed. Therefore, new development pressure should be minimal unless another unplanned expansion occurs in the basin. The only two major projects still to be constructed are the building north of the Forestry Building and the redevelopment around Jeffery Field.

In the fall of 2012 a large sinkhole opened up in the very spot of the proposed building north of the Forestry Building. The sinkhole was significant and resulted in the complete disappearance of a 20 ft long piece of 15" storm pipe. By the time the sinkhole was repaired, an opening of over 3,000 sf was excavated for the repair. Therefore, this site is not recommended for a new building, but if planners insist on its construction in this spot, no infiltration, or raingarden/bioswale type facilities should be constructed. Blue roofs, green roofs, or stormwater harvesting and use should be the only allowable stormwater solutions.

If the re-development of Jeffery Field occurs, the only stormwater volume consideration should be stormwater harvesting and use. Additionally, any structure placed over the 42"CMP in the area will necessitate the rerouting of the storm line, which will potentially affect the ponding at softball; and therefore, comprehensive modeling of the entire drainage will be required.

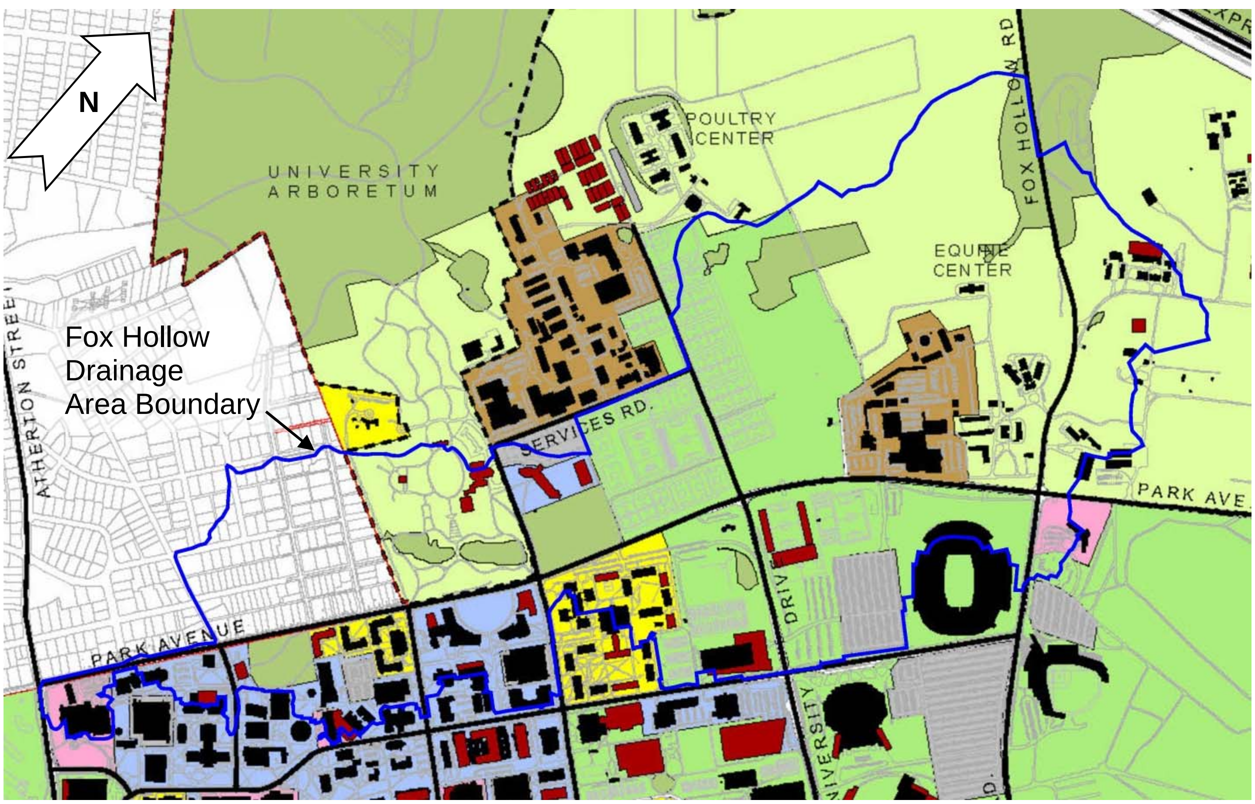

Figure 7.l. 2007 Master Plan Development in the Basin

Section 8. Bathgate Dam Drainage Basin

Background Information

The Bathgate Dam Drainage Basin is located in the State College Borough and College Township. The drainage boundary is defined by the Bathgate Dam, which is a regulated dam (D14-122) by the Pennsylvania Department of Environmental Protection (PaDEP) and has a drainage area of approximately 237 acres. The dam has a permanent pool with a normal pool area of approximately 1 acre in size. The maximum storage capacity is approximately 74 ac-ft. The dam discharges to Thompson Run approximately 100 ft before the confluence with Slab Cabin Run at Millbrook Marsh via a 66" reinforced concrete storm drain outfall pipe. The dam's primary function is to control stormwater runoff including peak runoff rates (the 1 through 100-year events) and improve water quality. The dam was also designed to safely pass ½ of the probable maximum flood (PMF). Bathgate Dam is classified as a High Hazard (category 1), size class C structure by PaDEP.

The drainage basin is a mix of developed campus areas (Beaver Stadium, the Bryce Jordan Center, Holuba Hall, the Multisport Indoor Complex, and parking areas), and open fields (refer to Figure 8.a). A large portion of the open fields are used six or seven times a year for football parking events. The Bathgate Dam (refer to Figure 8.b) is designed for a maximum impervious area of 95.9 acres. The Imperviousness in the watershed in 2016 is 85.8 acres. There are over 7.5 miles of storm drains in the Bathgate Drainage Basin varying in size from 4 to 54 inches in diameter. These storm drains terminate near Porter Road and stormwater is conveyed to the dam via a 1,600-foot long concrete swale with an average slope of 4.8% (refer to Figure 8.c).

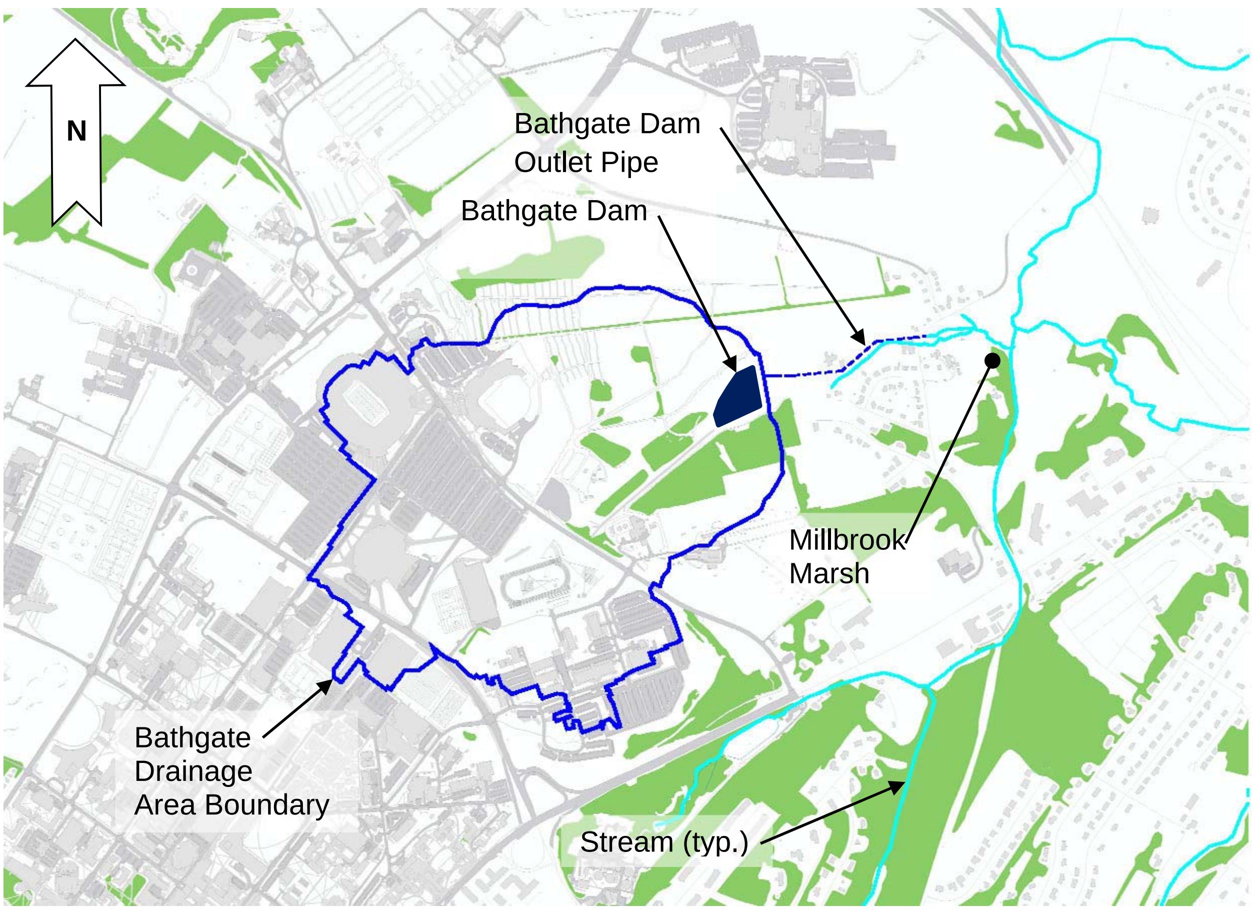

Figure 8.a. Bathgate Dam Drainage Basin

Figure 8.b. Bathgate Dam as seen from the Western Gate

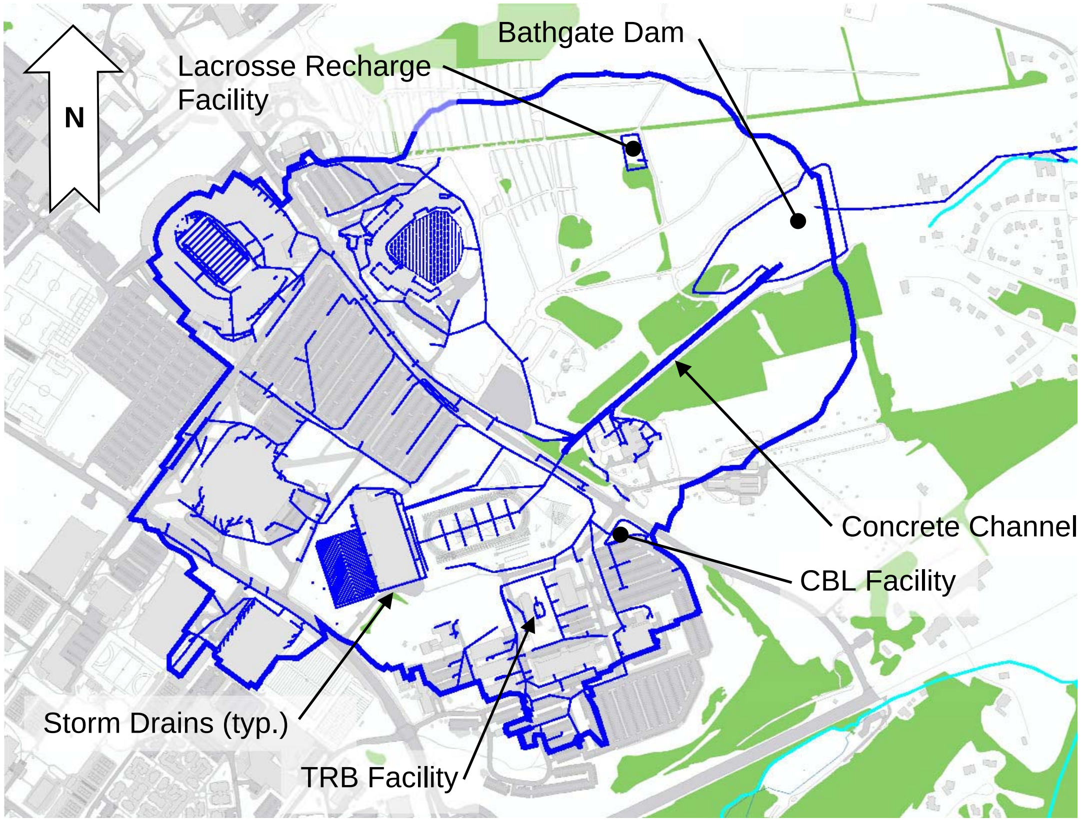

Figure 8.c. Storm Drain Facilities in the Bathgate Dam Drainage Basin

The Bathgate Dam was originally constructed with a clay liner in 1991 for the Bryce Jordan Center and other master planned areas. By 1996, the drainage basin reached its original impervious design limit. During the original design, the University attempted to get a drainage easement below the dam to convey runoff directly towards Millbrook Marsh. Downstream property owners resisted at the time, resulting in downstream flooding especially along Puddintown Road during the 1990's. In 1999, the dam was redesigned, greatly reducing the discharges, increasing the size of the dam, and increasing its allowable imperviousness. It was also at that time that the storm line was constructed below the dam discharging to Millbrook Marsh as shown on Figures 8.a. and 8.c.

The dam was also redesigned to improve water quality by the addition of a water quality forebay. Water quality tests were collected for College Township from 2005 through 2006 to confirm its effectiveness. Until November 19, 2010, the University and College Township allowed development within the watershed using a checkbook method for the remaining allowable imperviousness. Following that time, PaDEP under NPDES projects has mandated the management of runoff volume for new projects, which was interpreted by PaDEP staff as generally requiring infiltration. Unfortunately, the drainage basin has historically been prone to sinkholes. Therefore, during the redevelopment of the Lacrosse Field a low head weir type recharge facility was constructed away from critical infrastructure that allowed for some small additional development (refer again to Figure 8.c). Today a checkbook method is used for the dam and the recharge facility, but recharge credits are exclusively reserved for athletic projects.

In September 2011 a sinkhole occurred over an approximately 100 feet length of the Bathgate Dam's inflow channel length that was constructed from a Fabri-Form concrete lining. The repair took over two years to complete at a cost of over $800,000 (refer to Figure 8.d). The general area has a history of sinkholes and a portion of the running track was the University's incinerator that buried wastes under a portion of the site in old sinkholes between the 1930's and 1960s. Because of these issues, infiltration is never permitted in some areas of the drainage basin.

Figure 8.d Sinkhole under the Inflow Fabri-Form Concrete Channel

Current Problem Areas

Similar to other Campus areas, there are minor nuisance stormwater problems such as puddles at ramps, eroded gravel lanes, or minor water issues at some building entrances. However, in general the drainage basin is problem free from major flooding problems except for around the lower portion of Hastings Road near the intersection of Porter Road as seen in Figure 8.e, which floods during rare (greater than 10-year return period) runoff events. This flooding occurs because there are multiple surface point discharges (pipe end sections) in the upslope watershed. Flooding in this area will be remedied eventually as the area upslope redevelops by installing local detention storage. The flooding will not be fixed by upgrading the size of the conveyance systems simply because there is still available storage capacity in the Bathgate Dam. Refer to Figure 8.f for the area prone to flooding and the drainage area responsible.

Figure 8.e. Flooding of Hastings Road during June 27, 2013 Event

Another problem in the area is the old incinerator dump site. The approximate area is shown in red on Figure 8.f. Multiple problems such as sinkholes and collapsing storm pipes have occurred in this area. The University has rerouted the problem storm lines or lined them in recent years. However, all projects should avoid the area in general or expect to add significant potential cleanup costs to their budgets. The area currently acts as a landfill with a clay cap. Testing mandated by the PaDEP determined this area was not the source of PCE contaminants in the Bathgate Spring located downslope and the University believes the best long term way to deal with this area is leave it as is and undisturbed. However, because this area is in the original drainageway, any infiltrated water should be assumed to potentially travel towards this general direction. For that reason, infiltration up gradient is prohibited.

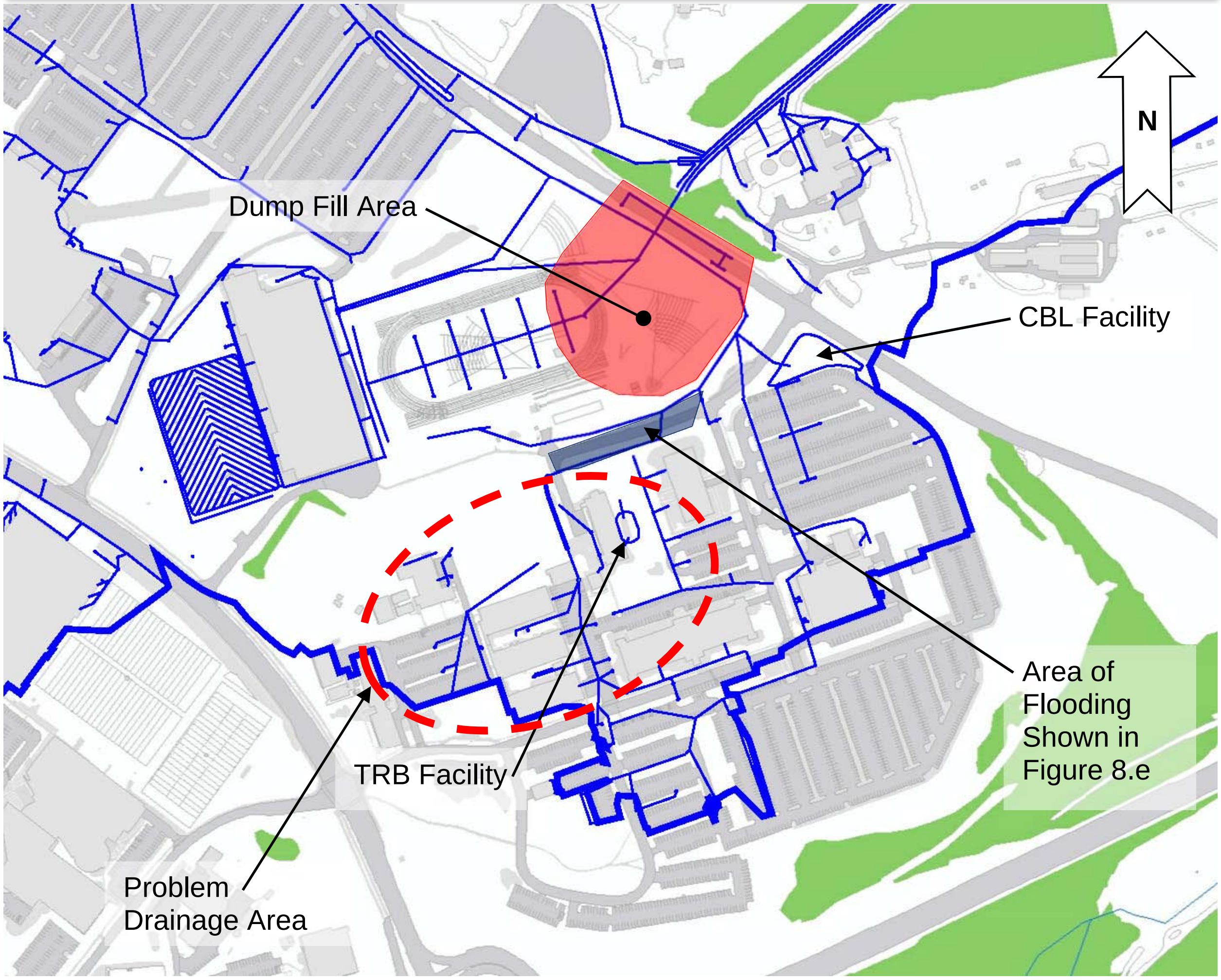

Figure 8.f. Problem Areas in the Bathgate Dam Drainage Basin

It is anticipated that eventually major redevelopment of the recreational fields and venues within the drainage basin may likely occur. Because it's assumed all projects will trigger NPDES permits and will also be time critical, regulated volume control will be extremely difficult to achieve. Stormwater harvesting and use for irrigation should be considered a priority for any such redevelopment. If engineered infiltration is the direction the owner and designers opt for, then it must be assumed that recharge facilities will be constructed within the northeast portion of the site as shown in Figure 8.g. This may necessitate the reevaluation of football and event parking areas, and 4th fest fireworks staging.

The Township and PaDEP in the past have allowed runoff from other existing impervious areas to be managed or treated anywhere within the drainage basin instead of the managing runoff from the new impervious areas. This may allow for a less significant impact that only requires the construction of some storm drain conveyance systems.

Under no circumstance should surface runoff be allowed to infiltrate into the ground anywhere near a major facility in the drainage basin, or immediately upslope of the dam.

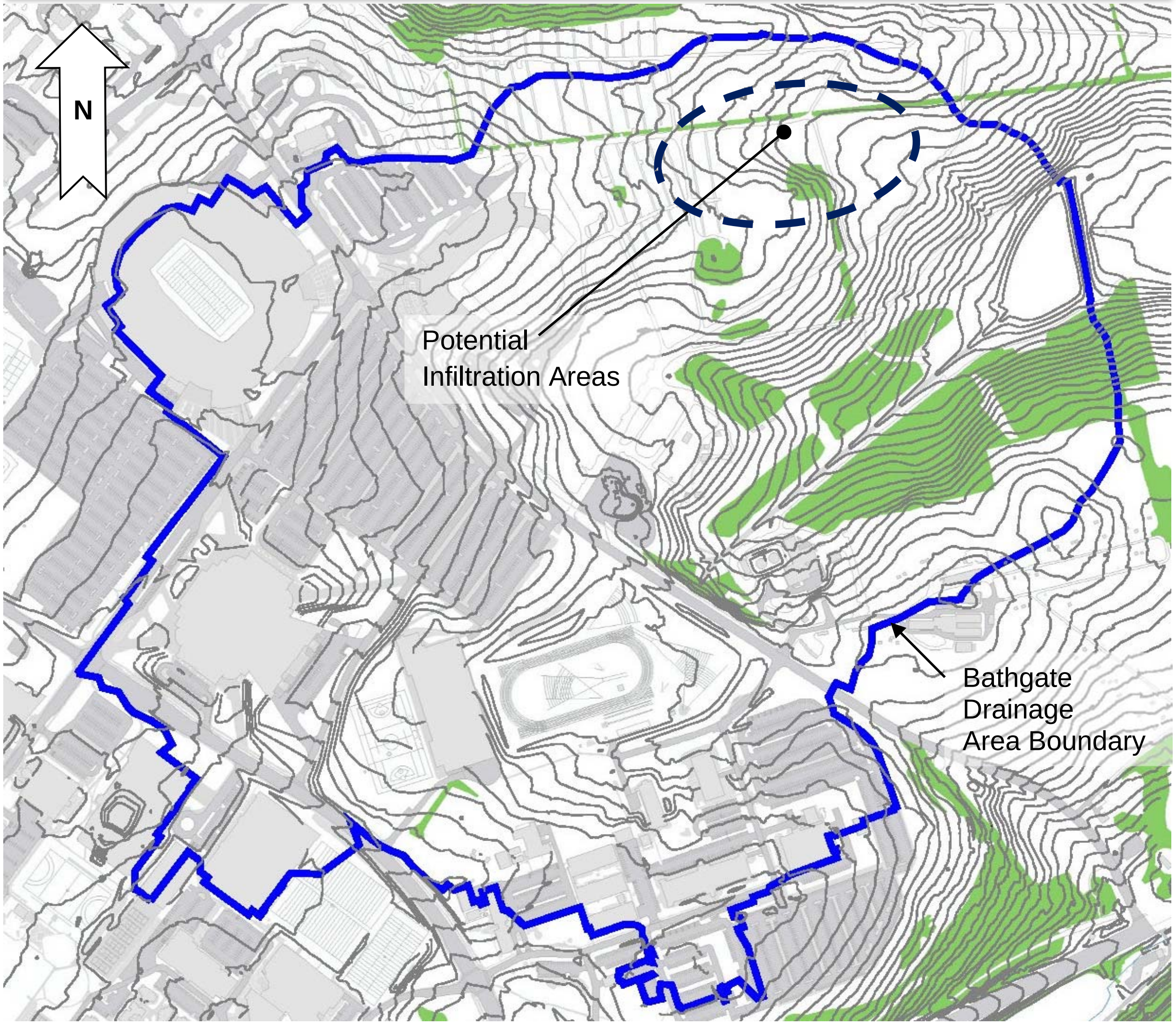

Figure 8.g. The Only Areas where Large-Scale Infiltration Facilities will be Permitted

Section 9. West Campus Drainage Basin

Background Information

The West Campus Drainage Basin (WCDB) is part of the Big Hollow Watershed and is defined as the effective surface drainage boundary to the University's property line at the Teaberry Development and bike path as seen in Figure 9.a. The WCDB is located in the State College Borough and Ferguson Township. The term effective drainage area is used because the Corl Drywell cuts off upslope drainage from an approximately 2 square mile drainage area known as the Pine Hall Basin, which is the upper extent of the Big Hollow watershed. The last known time the Corl drywell overtopped creating runoff into the WCDB is believed to have occurred in the 1990's during a rain on frozen ground event. The drainageway on the University's property is highly infiltrative and the last known incidence of water leaving the University's property was during Hurricane Ivan in 2004. Any runoff that leaves the University's property will likely be infiltrated at the downstream Radio Park Sinkhole located on the Radio Park Elementary School property and maintained by the State College Borough.

The West Campus Drainage Basin is approximately 190 acres in size and consists of the University's West Campus Development, a small area of residential housing along Park Road, and the University's White Golf Course. Prior to the University's development of West Campus, the entire area consisted primarily of the golf course as seen in Figure 9.b. The majority of developed lands in West Campus Drainage Basin drain to the West Campus pond as seen in Figure 9.c. Few stormwater problems exist in the basin and future development is currently proposed to consist of infill of existing areas that drain to the West Campus Pond.

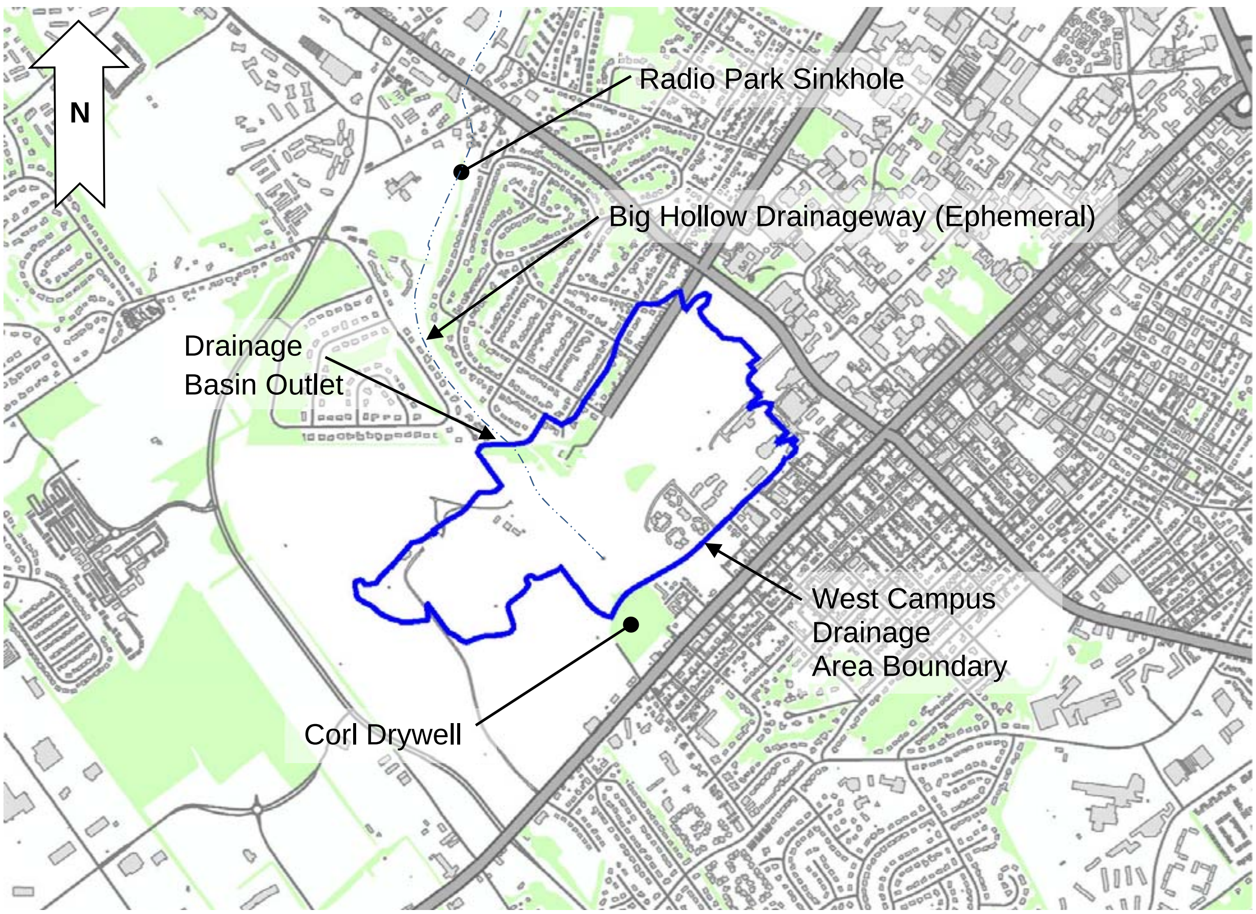

Figure 9.a. West Campus Drainage Basin

Figure 9.b. 1971 Orthophotograph of West Campus Prior to Development

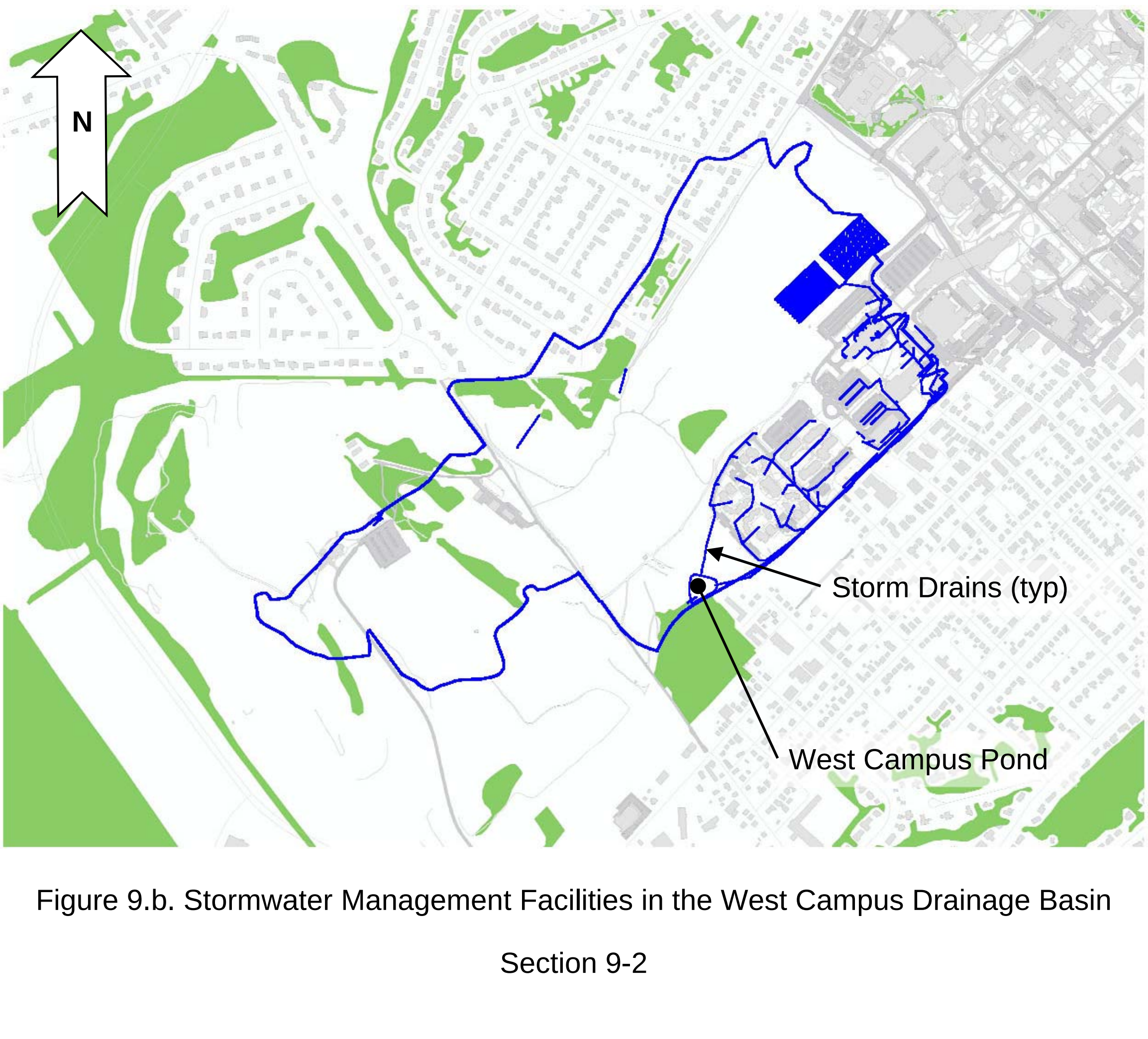

Figure 9.b. Stormwater Management Facilities in the West Campus Drainage Basin

West Campus Pond

The West Campus Pond was constructed in 1993 to account for Campus expansion west of Atherton Street. The pond is located south of White Course Apartments along the old railroad bed (refer to Figure 9.d). Most of the drainage area is located within the Borough and the pond itself is on the Municipal boundary with Ferguson Township. The pond has a contributing drainage area of approximately 50.8 acres with approximately 18.4 acres (36%) of impervious area. The imperviousness is almost fully connected by a new storm drain system. The basin consists of the west campus developed area, synthetic recreational fields, and part of the golf course.

The pond was constructed with a clay liner (Volclay soil mix) and a low flow concrete swale. The pond discharges directly into the Big Hollow drainageway that goes through the University's golf course. The pond serves two functions, to reduce peaks to the downstream infiltration area, and to remove antiskid material. All discharges from the pond are known to infiltrate in the drainageway prior to leaving the University's property, except for the most extreme runoff events. Continuous stage/storage data have been collected at the pond since July 2007. Data indicate that the pond has completely overtopped three (3) times in the last decade. The pond is known to be undersized; however, because it was expected to be moved due to the future road extension from White Course Drive to Blue Course Road it has not been improved. These roadway plans appear to have stalled from a planning perspective.

Because the pond has now overtopped three times, no future major development is permitted within the pond's drainage area without the pond being improved or reconstructed. Major development is defined as any new building, building addition, parking lot, or road. Only minor sidewalk work will be permitted without triggering this requirement. The project that triggers the required reconstruction is not responsible for the pond's funding since the pond has been on Capital Planning lists for some time; however, adequate planning time must be permitted to allow for funding, design, and construction.

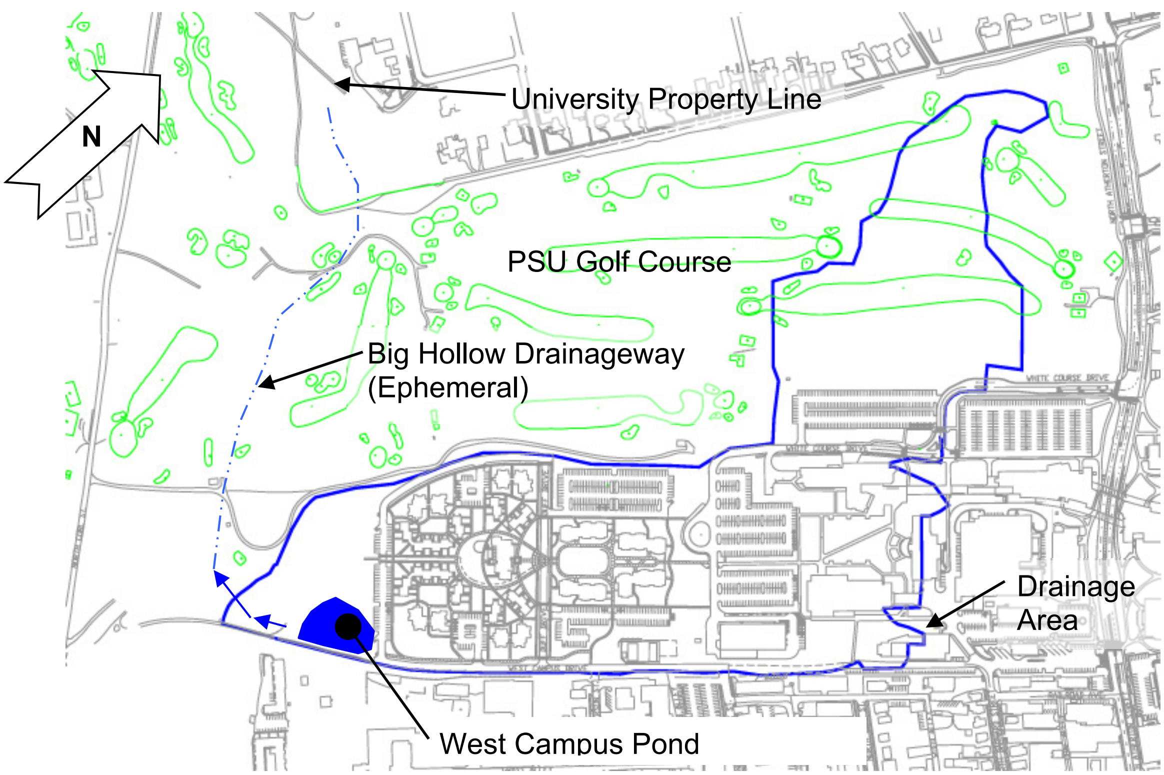

Figure 9.d. West Campus Pond Drainage Basin