Water Resource Publication

Thompson Run Watershed

OPP-WRP-SR-TR:2013

Executive Summary

Thompson Run from the Thompson Spring down to the current bridge under College Ave has been highly manipulated since the 1800s first for the Centre Furnace Village and later for the construction of College Ave. Flooding in the area of the current Blaise Alexander (formerly Clark Motors) and Your Building Centre (formerly Clasters) sites has occurred for decades. Photographs and mapping of the area before development indicates that the original mill race overtopped into this flood plain area. Remediating the flooding involves the potential removal of the existing roadside culvert; however, removing this culvert may result in instability in the downstream channel and at Millbrook Marsh. In order to remove the culvert's restriction, a comprehensive study must be done using hydraulic models and the available flow data in the watershed. Ultimately it may be found that one of more of these properties needs to be restored to flood plain.

Introduction to the Thompson Run Watershed

The Thompson Run Watershed is located in College and Ferguson Townships and the State College Borough, Centre County, Pennsylvania and currently consists of approximately 2,970 acres (4.64 sq. mi.) of land at the confluence of Slab Cabin Run. FEMA in its 2009 study defined the watershed as being 3.92 sq. mi., a discrepancy that will be discussed later in this report. Penn State is the single largest land owner in the watershed. A map of the current watershed is shown in Figure 1. The springs in the watershed play an important part in the history of the region and it's probably fair to say that without the existence of the springs, the town and University would surely not have been located here. The watershed has three main springs; Bathgate, Thompson, and Walnut springs (refer to Figure 2).

The majority of flow in Thompson Run is derived from Thompson Spring, which today flows around the University's duck pond, along the engineered conveyance channel of College Avenue and then through Millbrook Marsh. Walnut Run intersects Thompson Spring just upslope of the bridge under College Ave (Route 26), and Bathgate Springs and the Bathgate Dam flows enters Thompson Run approximately 50' above the mouth where Thompson Run intersects Slab Cabin Run. While Walnut Run is actually part of Thompson Run, if we compare the area of Walnut Run (1,415 ac) with the area that flows directly to Thompson Run (1,555 ac), we see that the areas are almost the same; however, the amount of development and the amount of stormwater control in the two basins is significantly different (refer to Figure 3). These differences have a significant effect on the hydrologic characteristics of the two basins as we will see later in this report.

Two other subwatersheds are frequently considered in the Thompson Run Watershed; they are the Bathgate Dam Subwatershed and the Duck Pond Subwatershed, both of which can be seen in Figure 4. Both of these subwatersheds will be discussed in detail later in this report. Figure 4 also shows the location of major manmade and natural stormwater control facilities within the watershed; the Bathgate Dam, the Westerly Parkway Reservoir, the Millbrook Marsh, the duck pond, the Orchard Park Pond, the South High School Soccer Pond, the Walnut Springs Park, and the Thompson Woods Preserve. Numerous other smaller stormwater facilities are located within the watershed, many of which are owned by the University.

Another important feature in the watershed and directly adjacent to it are sinkholes and injection type wells, which are shown on Figure 5. The Memorial Field Sinkhole located under the east bleachers is one of the largest sinkholes within the watershed and has a drainage area of approximately 45 acres, which is shown in blue on the figure. The majority of the other sinkholes are located in the headwaters of Walnut Run.

This document covers the history of development within the watershed, key stormwater features within the watershed, historical studies that have been conducted, and available data, with special emphasis on the area below the University's Duck Pond to Millbrook Marsh. This report specifically addresses flooding at the current Blaise Alexander and Your Building Center (YBC) sites, which in this report are referred to as the Clasters site (now YBC) and the Clark Motors Site (now Blaise Alexander) since they existed by these two names since the 1960's until recently. Refer again to Figures 1 or 2 for where these sites are located within the watershed.

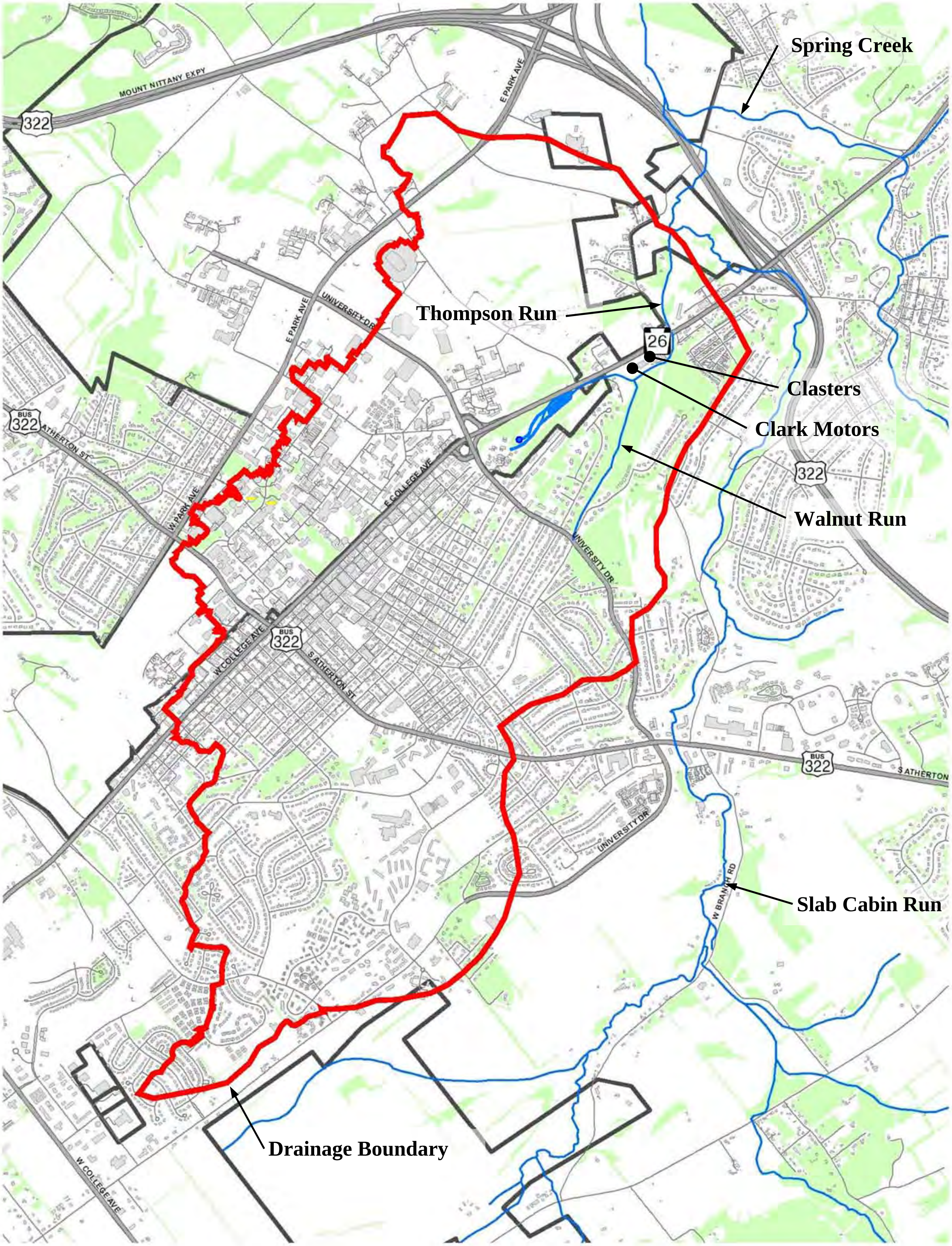

Figure 1. Approximate Current Drainage Area of the Thompson Run Watershed

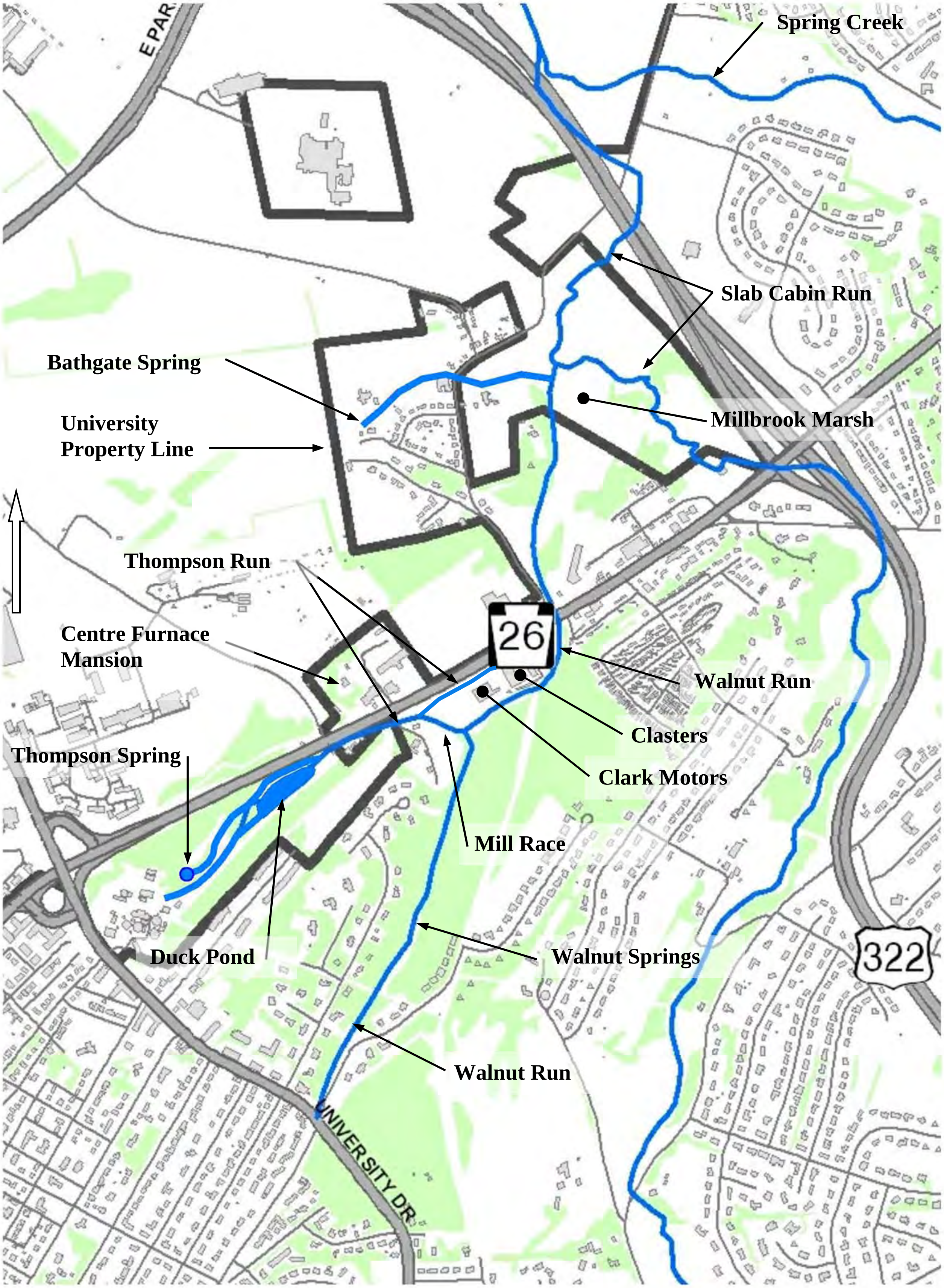

Figure 2. Location of Springs and Key Features in the Watershed

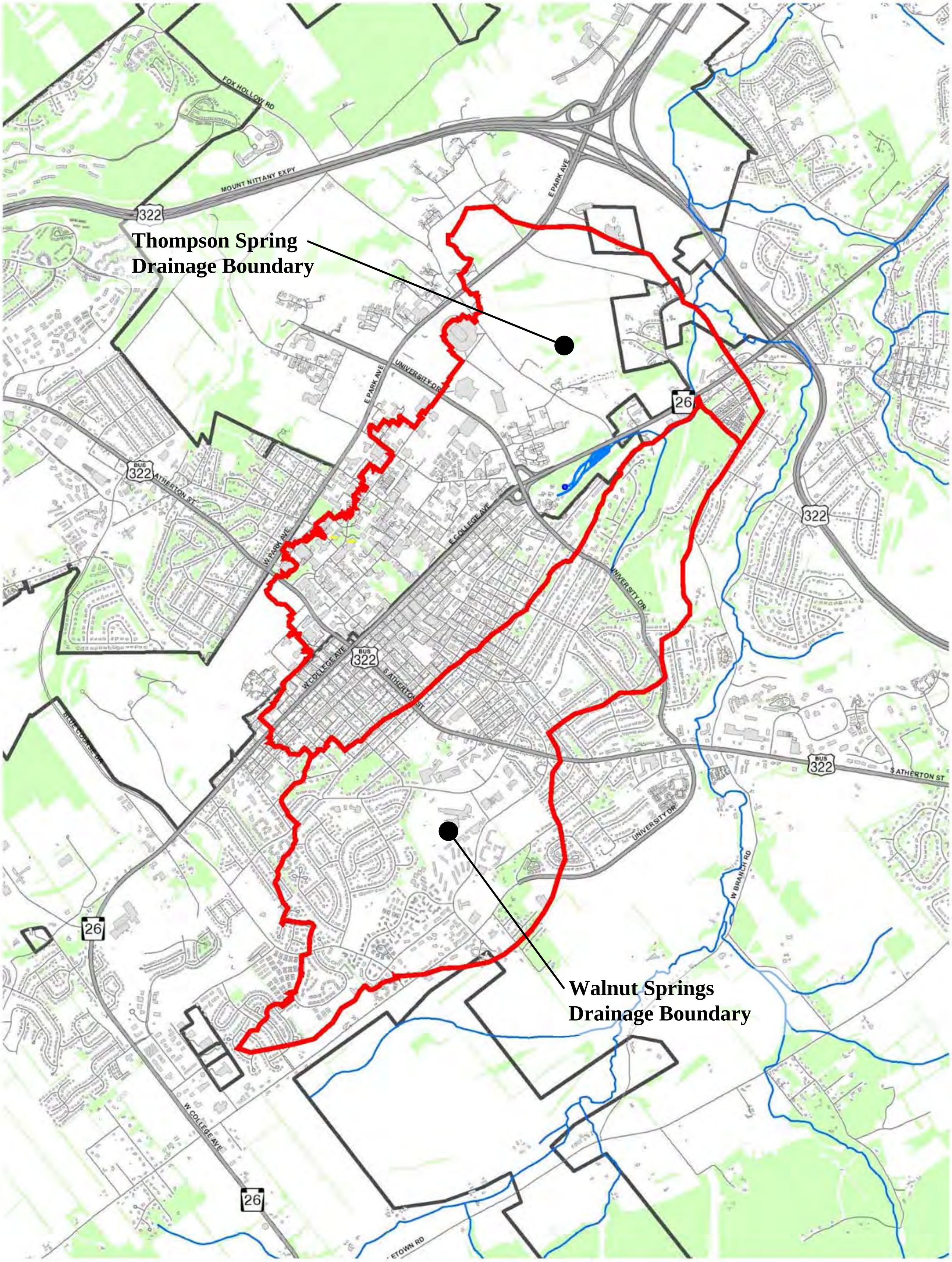

Figure 3. Walnut Run versus Thompson Run Drainage Areas

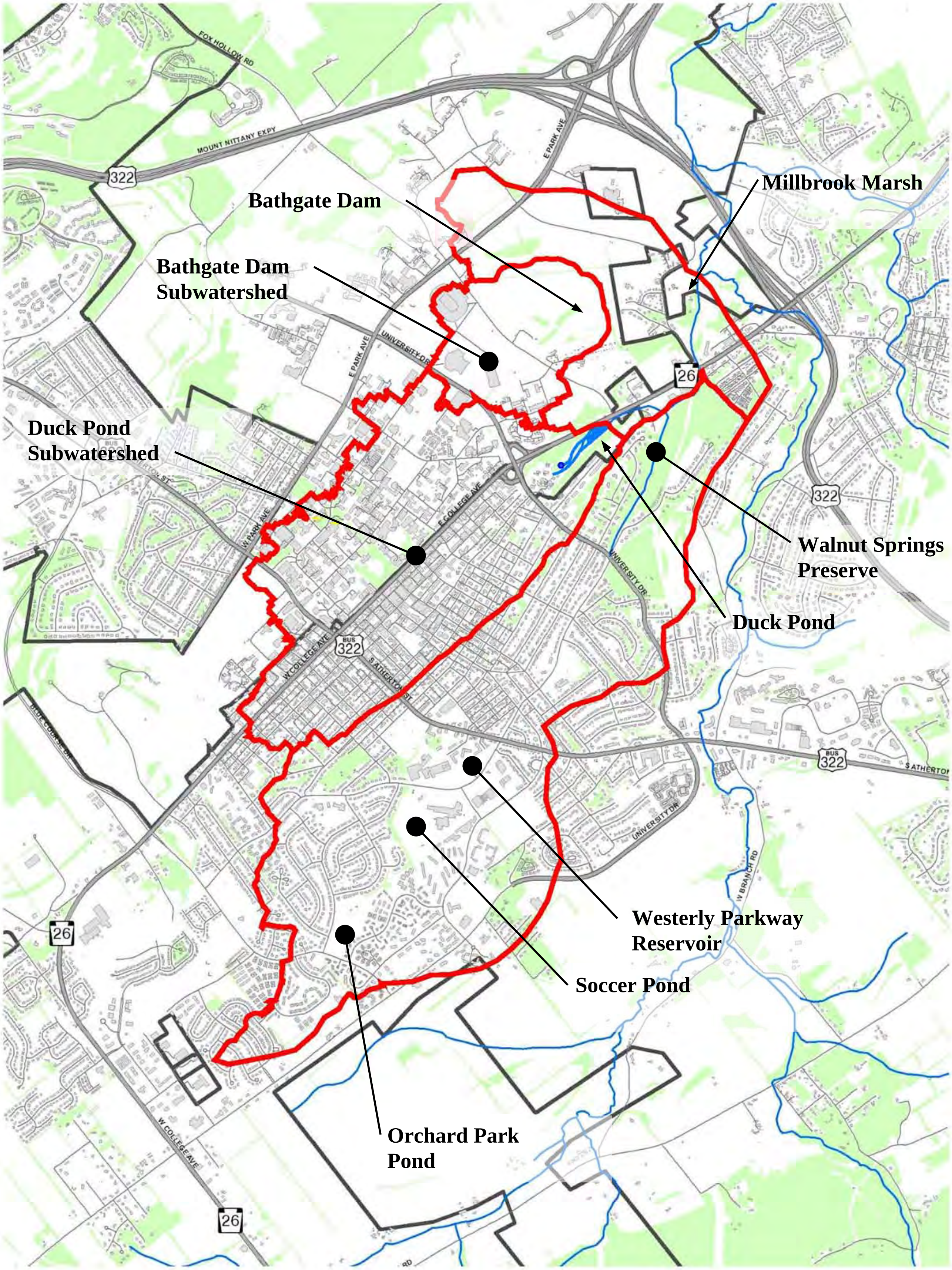

Figure 4. Bathgate and Duck Pond Subwatersheds and Major Stormwater Facilities

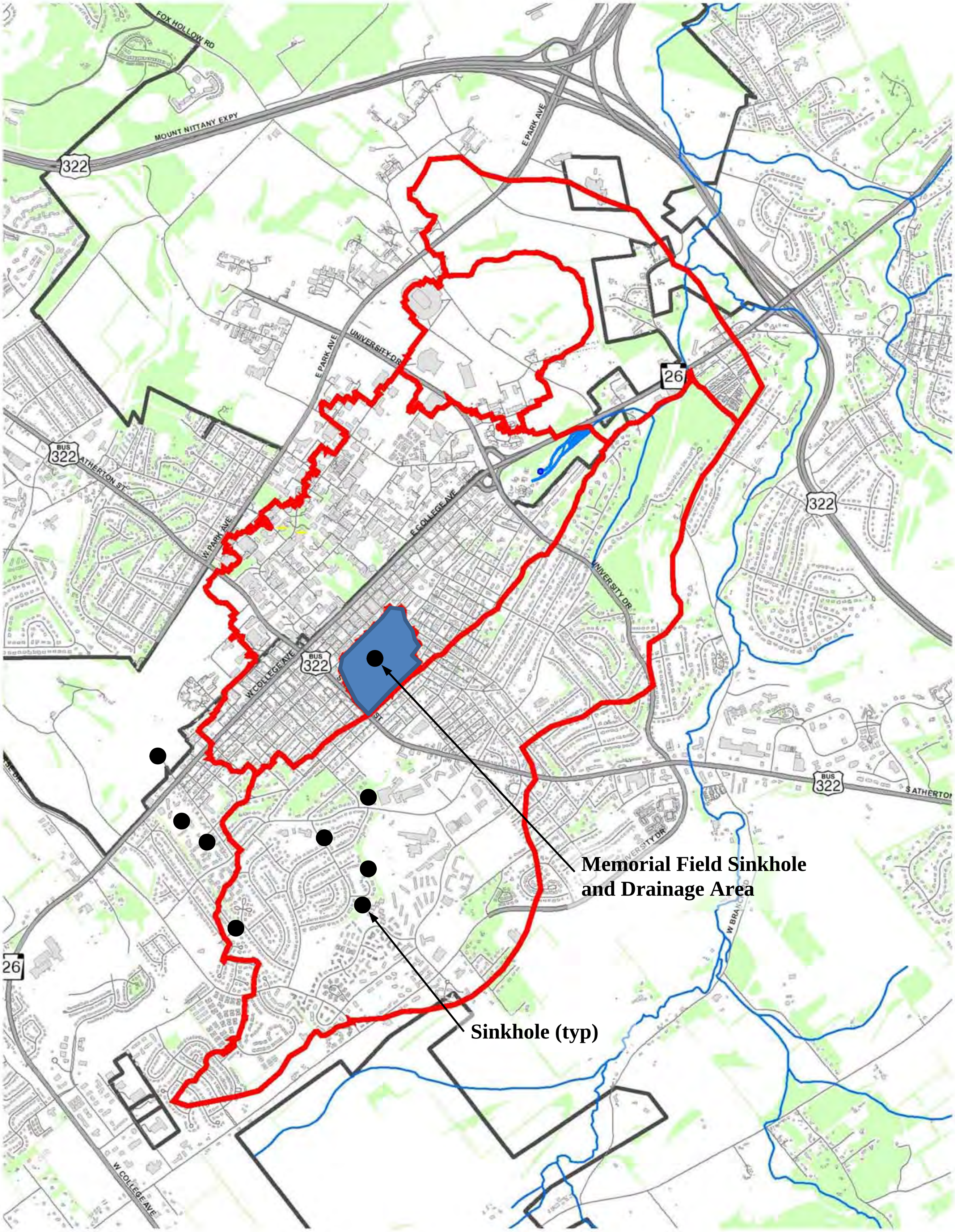

Figure 5. Active Sinkholes/Injection Wells in the Watershed

History of Development within the Watershed

The history of the regions early years can be found in several documents including *"The Center Furnace Story, A Return to our Roots"* by S.K. Stevens copy written in 1985 by the Centre County Historical Society, and the *"History of Centre and Clinton Counties Pennsylvania"*, by J.B. Linn in 1883. This report does not intend to supplant these documents or bring new light to them, but rather to review parts of them from a water resource perspective. Most of the following narrative is excerpted from the Centre County Historical Society document.

Development of the area started with the construction of a cold blast iron furnace in 1791 by Colonel Patton in a partnership with Colonel Samuel Miles, which was located near the present day furnace due to a constant available source of water. The source of water came from Thompson Spring, which in the early years was called Willy Brook. Not only was the creek needed for consumptive use of the village and workers, but it was required to power the waterwheel that powered two bellows for the furnace. The furnace operated from 1792 to 1809 and finally went out of operation due to a decreasing availability of high grade ore and the exhaustion of much of the forest land in the surrounding area.

The furnace went back into operation in 1826, and later was owned by General James Irvin. During the years between furnace's operations, the store, saw and grist mills from the former iron business kept operating to serve the flourishing little village around the furnace. Local historians indicate the village spanned from Thompson Spring to present day Millbrook Marsh and consisted of perhaps a dozen log cabins, a church, and boarding house, in addition to the mills and furnace buildings. Moses Thompson, who married General Irvin's sister, became part owner and manager of the furnace in 1842. At the time of Moses' death in 1891, he was regarded as the largest landowner in Centre County. It is also believed that Moses Thompson built the present day Centre Mansion shortly after 1842.

By 1847 the production of iron in Pennsylvania reached 400,000 tons, which was half the US production. At this same time, the original furnace started to function so badly that a new furnace was built in 1847. This 2nd furnace is the one that still stands today near the intersection of College Ave and Porter Road. The Centre furnace was a charcoal iron furnace, a type which eventually lost out in production to coke and anthracite fueled furnaces. The fuel switch came not from the quality of pig iron produced, but rather from the fact that even with the furnace owners vast land holdings in Centre County, the land had been stripped of its charcoal producing timber. In those days it's probably easy to have watched mud flowing into the creeks during storms since little vegetation covered the ground. The end of the iron producing days at the Centre Furnace came in 1858.

Unfortunately, no maps or sketches survive from the iron producing period of time. What is known is that Thompson Run from the spring down to the current bridge under College Ave had been highly manipulated for the furnace and the downstream mills. Maps or early photographs of the area below the duck pond to the old mill likely exist, but have yet been made public. It is reported that the Rare Books Room in the University's Pattee Library has the Centre Furnace record books preserved that include detailed information about day to day activities. These records surely include information regarding the spring and creek, but have yet to be reviewed from a water resources perspective. There are references to a mill-pond; however, it's not clear where this was located in those days.

Through a long political process, the Farmers' High School was selected to be located on 200 acres of land owned by General Irvin. The Farmers' High School opened its doors on February 19th, 1859 and for a good many years the Centre Furnace village provided the only church, school, or store in the vicinity of the new School. Following the death of Moses Thompson's son William in 1912, the Centre Furnace Mansion stood empty until 1920 when it was purchased by David Garver. David restored the mansion and later built a dance hall and swimming pool. In 1978 the mansion became the headquarters of the Centre County Historical Society.

Of special importance to this study is the fact that Thompson Run had been diverted behind the Clark Motors and Clasters (present day Blaise Alexander and Your Building Center) properties to supply the mills with power. A selection of historical maps and photographs are included on the following pages that provide a glimpse of the Centre Furnace village and surrounding area in the following Figures 6 through 14.

Figure 6. Thompson Run Area from 1861 Tilden Map of Centre County

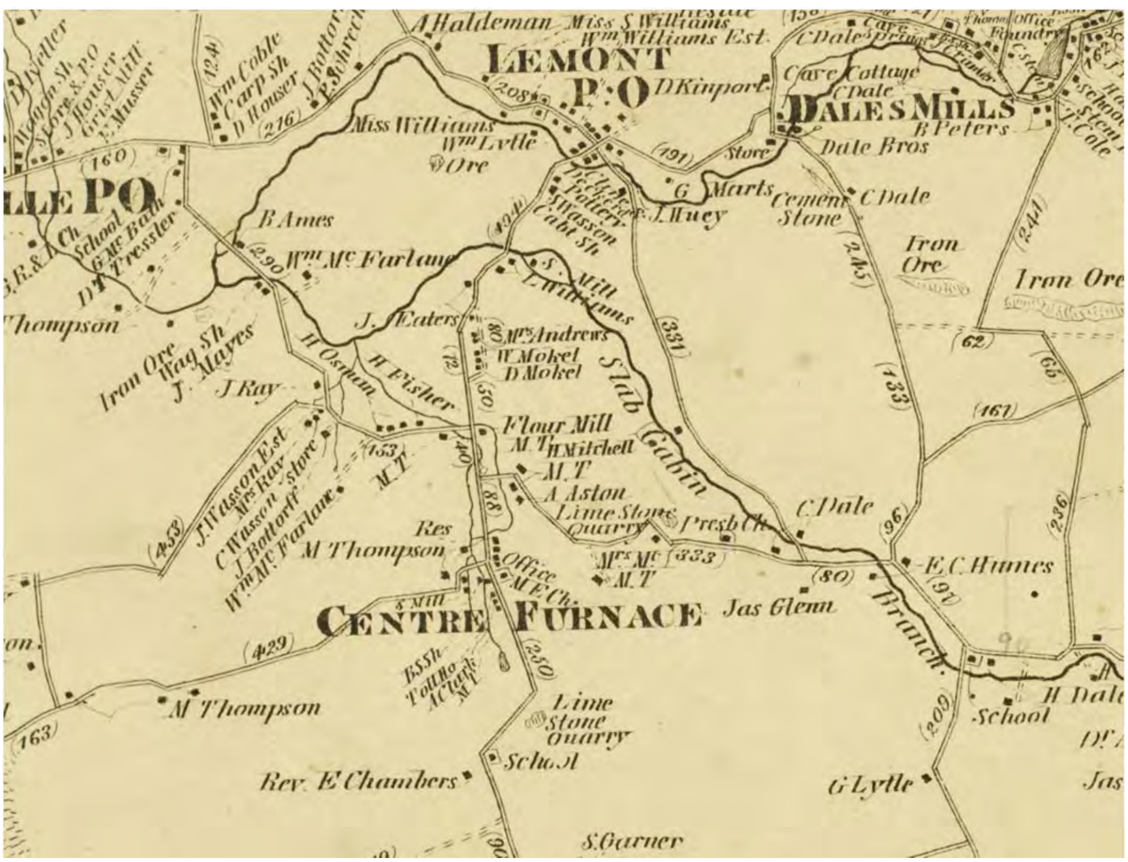

Figure 7. Thompson Run Area from 1874 Pomeroy Atlas of Centre County

Figure 8. 1800's Photograph of Thompson Spring

Figure 9. 1890's Photograph of Thompson Spring Area from Current Day Wastewater Treatment Plant

Figure 10. 1904 Photograph of the Furnace Area while Most Structures were Still Standing

Figure 11. Civil Engineering Students Taking Velocity Measurement on Thompson Run

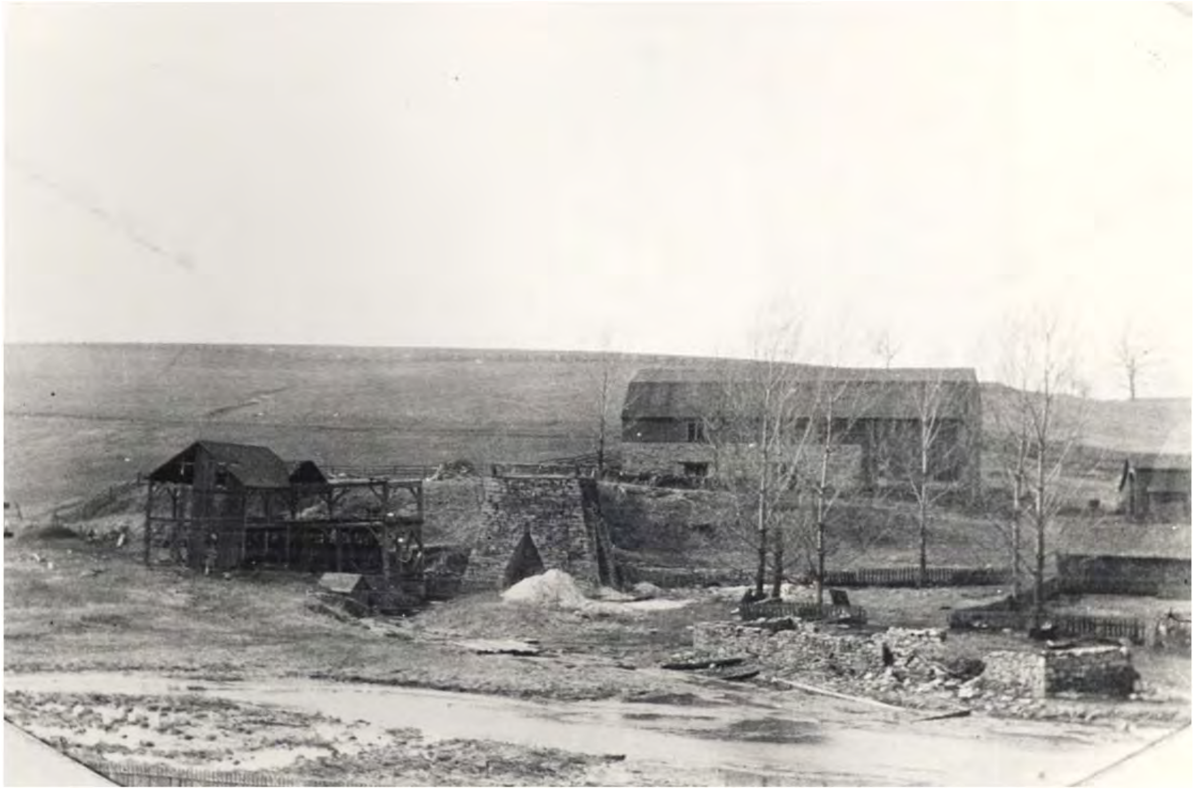

Figure 12. Panorama of Furnace Area in Early 1900's, Courtesy of Centre County Historical Society

Figure 13. View of Thompson Run in Front of Mansion, Courtesy of Centre County Historical Society

Figure 14. The “Mill Race”, Courtesy of Centre County Historical Society

The Farmers' High School struggled with available potable water from the start. In fact one of the major negative issues regarding the selection of the General Irvin 200 acre tract of land for the School was the fact that there was no available water supply in the area other than Thompson Spring, which was still owned at that time by the Thompson family. For the first 20 years of the School's existence, the only source of water was roof runoff that was collected in a cistern north of Old Main. In 1877 the University drilled its first well and later built reservoirs (including on one in Musser Gap) for its water needs.

In 1912 the University acquired the land that the Thompson Spring was located on. As part of the deed, a water rights agreement for the spring was recorded. This agreement granted 50% of the water from the spring to the University with the remainder being reserved for downstream heirs of the Thompson family. This document describes the downstream area as the "lower riparian lands" and had a minimum elevation (993.4 ft) that water could leave the purchased property. This elevation was clearly tied to the mill race and the mill, which was still in operation (refer to Figure 15). Between 1928 and 1957, the University conducted multiple flow and water quality studies on the spring, but it was never used for a water supply because tests showed the water was so grossly polluted that it could never be considered for human consumption (this is discussed further in later sections of this report). The reasons for this should be obvious since even in the 1930's the town had open sewer ditches and commonly used cesspools for sewage disposal even though the University built the wastewater plant in 1913.

In 1927 the University proposed a Memorial Arboretum to be located on the newly acquired property (refer to Figure 16). Dr. R.L. Sackett designed the duck pond, which was intended to be the central feature of a Winter Sports Area (refer to Figure 17). Surprisingly, Dr. Sackett's plans show an old dike approximately in the middle of the new pond, which was to be removed. We currently are not in possession of any information regarding this former pond and dike, which was removed. The Duck Pond was constructed and was the University's Class Gift for the years 1927 through 1930. Unfortunately, because of the Great Depression, all remaining plans for the area were scrapped.

The Duck Pond received a permit from the Commonwealth of Pennsylvania's Department of Forest and Waters, Water and Power Resources Board on October 20th 1927. The Pond's ogee spillway was designed with a 500 cfs capacity. Storm drainage from the University and town bypassed the pond via a storm ditch with a capacity of 810 cfs. Dr. Sackett's estimate for maximum runoff from the area was 700 cfs. Flooding occurred below the duck pond before and after its construction and Figure 18 shows two pictures (originals at PaDEP Dam Safety files) that show the significant debris following a flooding event in the 1930s.

The Duck pond is frequently thought by local residents to have been built for stormwater management; however, this is simply not the case. The Duck Pond was created as an ice skating rink, a picture of which can be seen in Figure 19. Water from the spring was not originally routed through the Duck Pond and flowed around to the north with a series of diversions to be able to provide the Duck Pond water as needed. The Duck Pond was originally 2.3 acres in size with a spillway in the current location with a design water surface elevation of 995.50. A 1-1/2" waterline to the Mansion's barnyard existed from the spring's diversion sluice.

Following the Duck Pond's construction, James I. Thompson wrote a letter on April 29th, 1929 to the State claiming that: *"the stream that has been our source of power for over a hundred years…the waters became lower in the summer such that we are not able to run our ice machinery."* This shows that even in 1929 the mill race was still in service and being used by the Thompson family. Today the millrace slopes backwards due to construction activities and now acts as an overflow during extreme runoff events for Walnut Run to Thompson Run. This issue will be discussed in detail later in this report. In an undated high resolution Photograph the University has, the millrace can be seen where it overtops into the current Blaise Alexander site, which was likely riparian floodplain (refer to Figures 20 and 21).

Prior to the 1940's College Ave was a gravel/dirt road. This road does not show up on the 1861, 1874 maps or on the 1922 University Plan (Figures 6, 7, and 15 respectively), but rather the road shown at that time is now the remnant of services road (Old Route 56) located south of the Furnace and Duck Pond. In the early 1940's, PennDOT constructed a two lane road of asphalt that was located just north of the Furnace (refer to Figures 22, 23, and 24). From these drawings it's clear that the mill race was the only major channel and that only a small drainage ditch existed on the north side to drain Garver's swimming pool, which appears to coincide with orthophotographs from 1938. Note on drawing 24 the area south of the road is indicated as swampy. How the entire watershed was developed in 1938 can be seen in Figure 25.

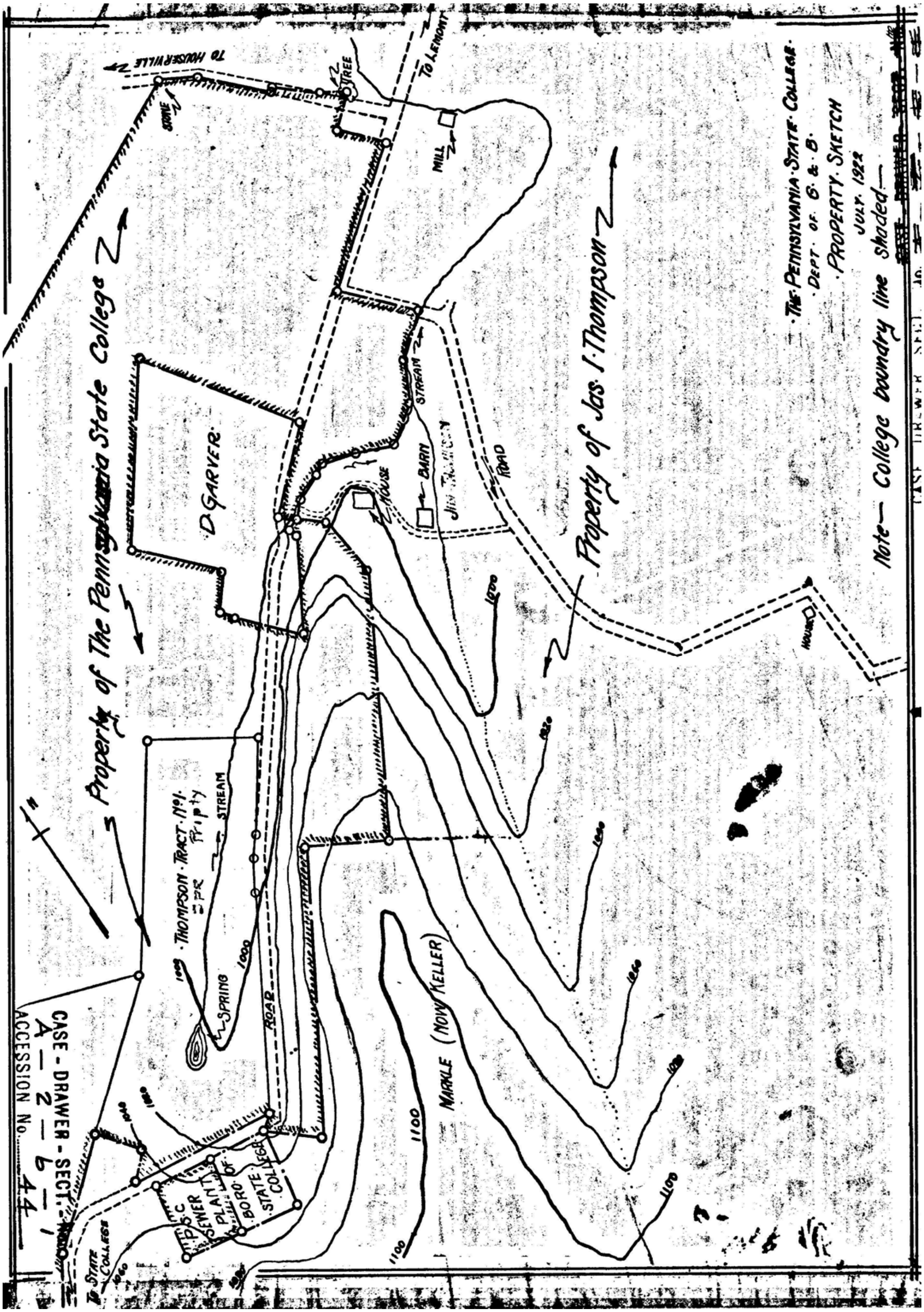

Figure 15. 1922 Map of the University Properties in the Area of the Centre Furnace Mansion

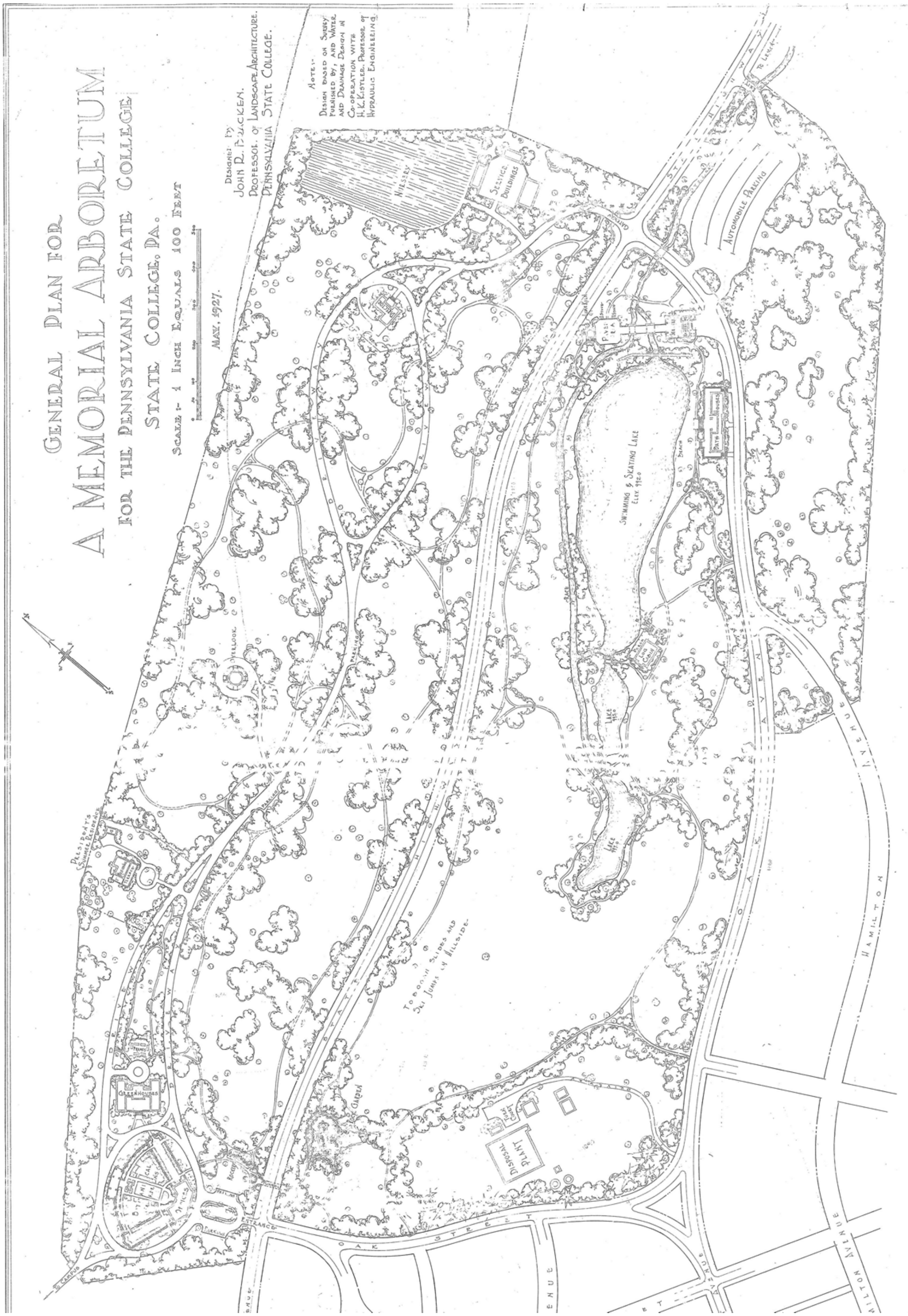

Figure 16. 1927 Proposed Location of the Arboretum and Winter Park

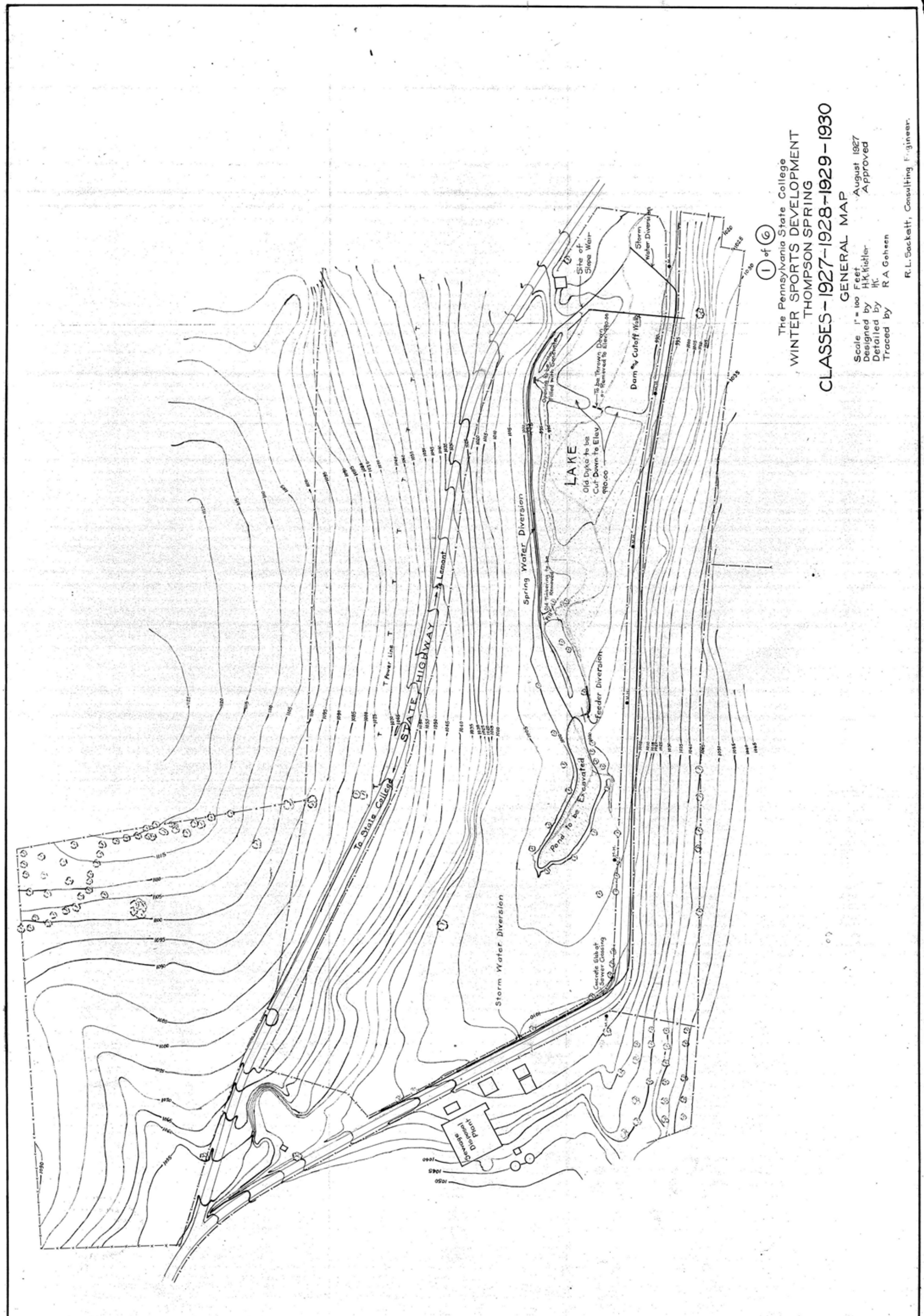

Figure 17. Winter Sports Park (duck Pond) Design Plans by Dr. Sackett

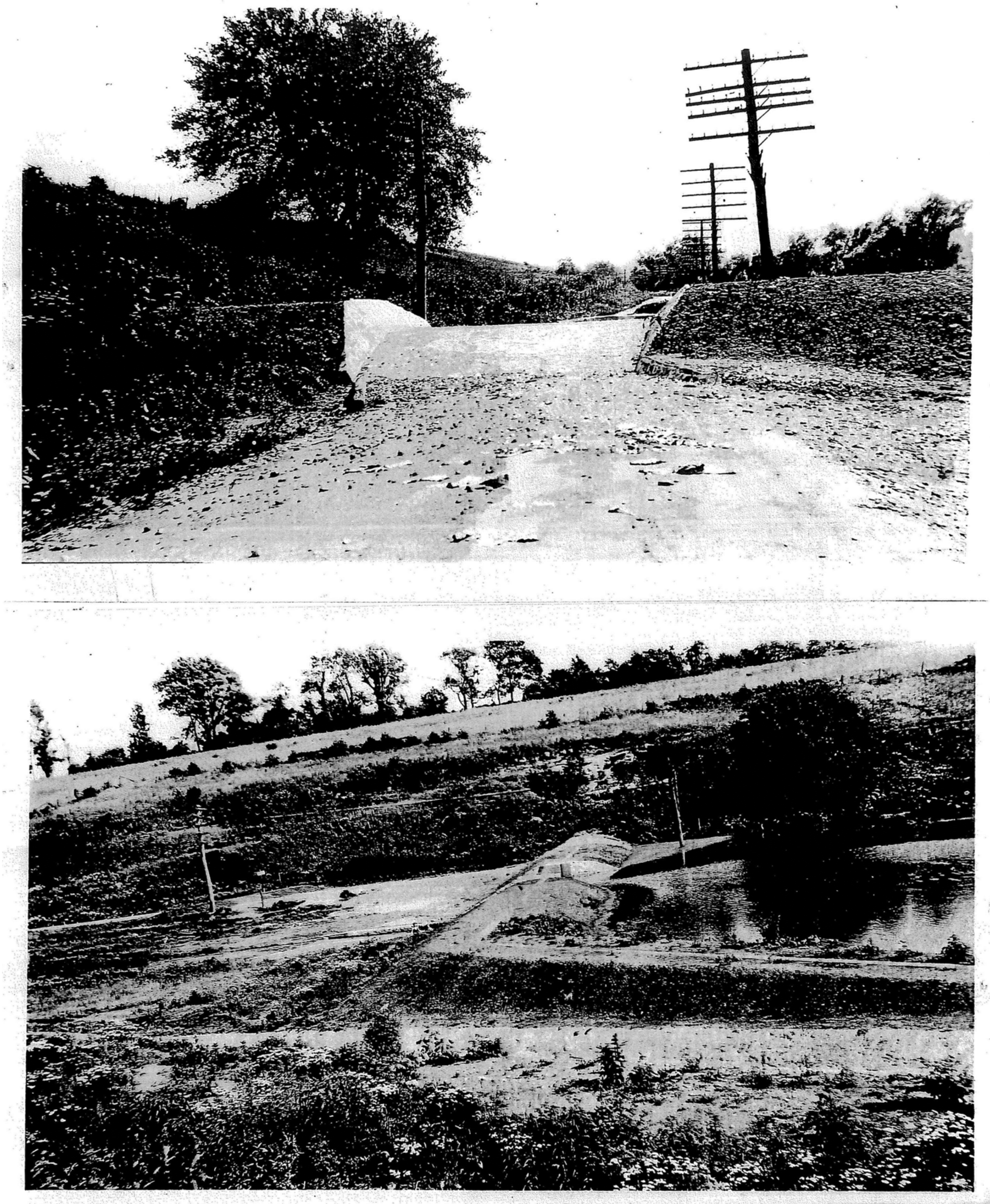

Figure 18. Two Photographs of the Duck Pond in the 1930 showing Flood Debris

Figure 19. The Duck Pond Skating Rink Prior to College Ave, Courtesy of Centre County Historical Society

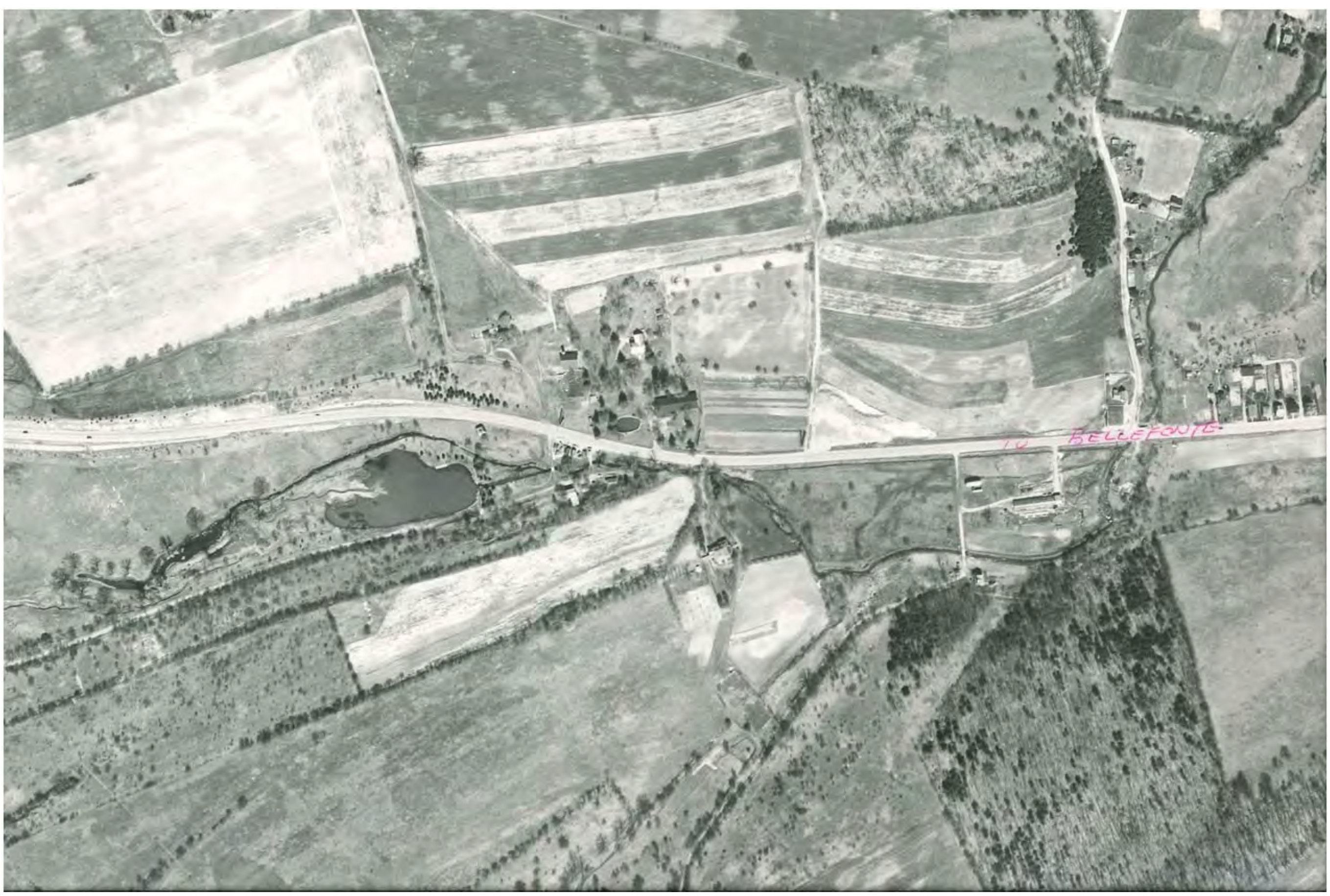

Figure 20. 1949 Photograph Showing Signs of the Mill Race Overtopping

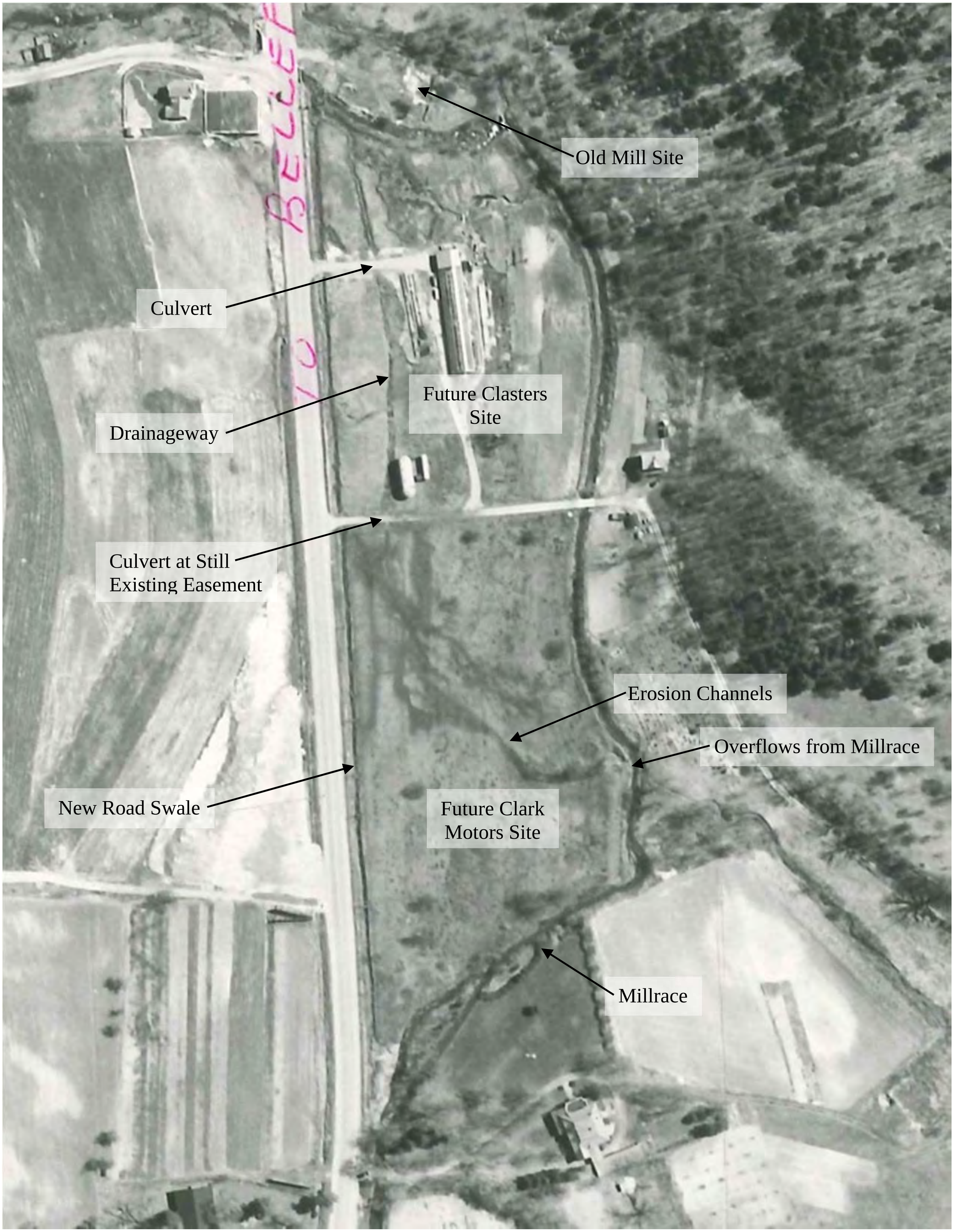

Figure 21. 1949 Photograph of Water Features on Clark Motors and Clasters Sites

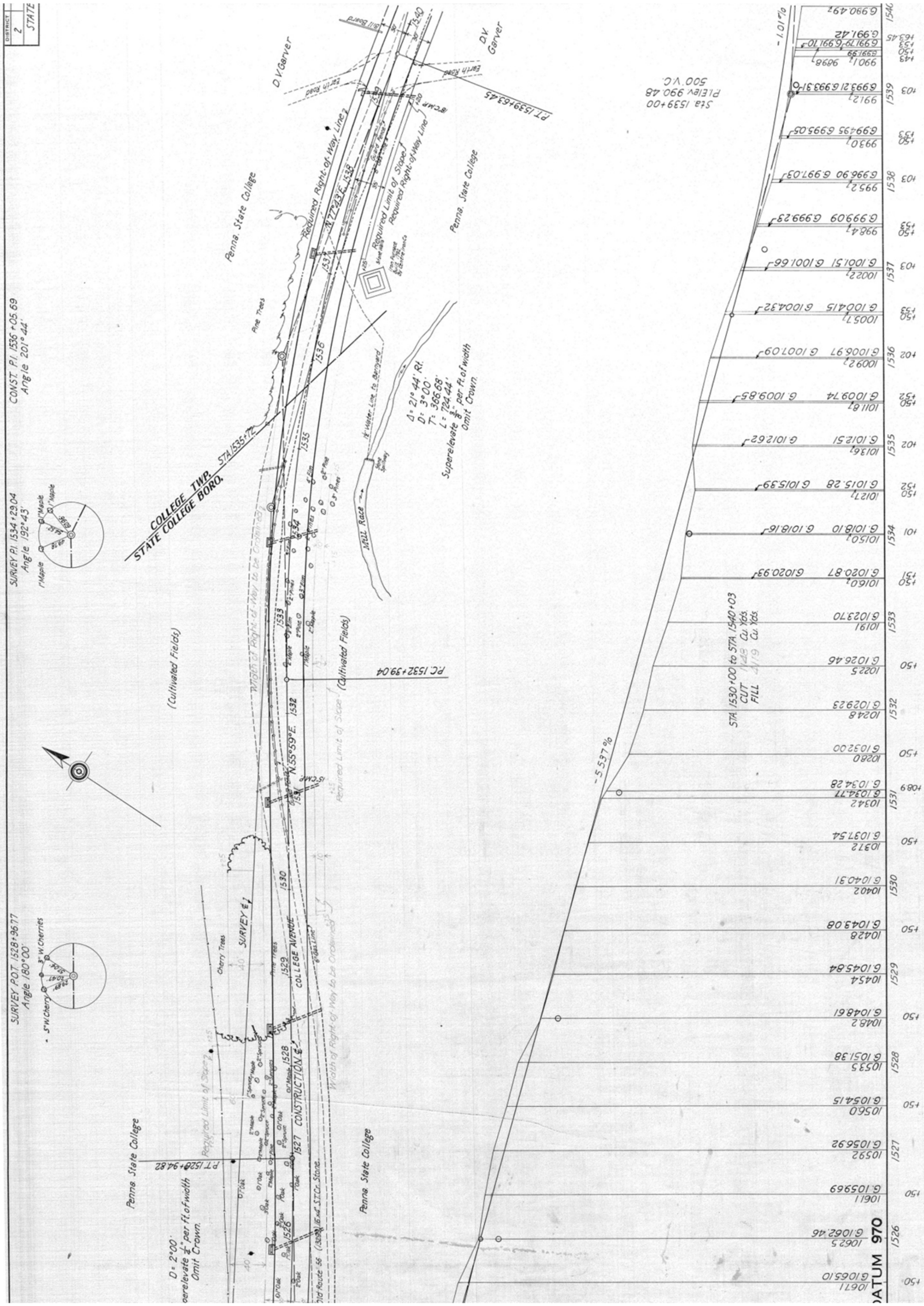

Figure 22. The 1940 Final Construction Plans for College Ave (sheet 5 of 21)

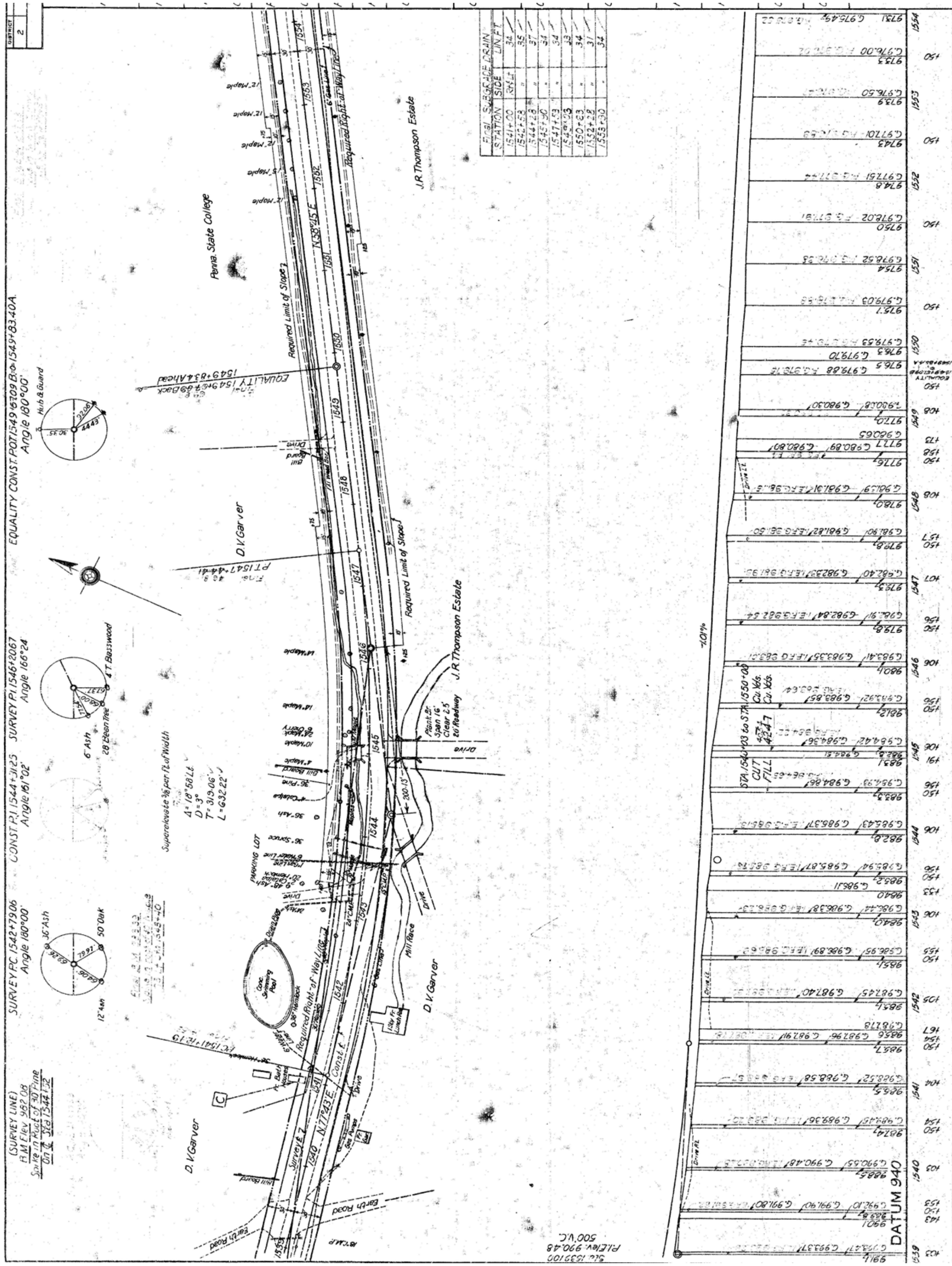

Figure 23. The 1940 Final Construction Plans for College Ave (sheet 6 of 21)

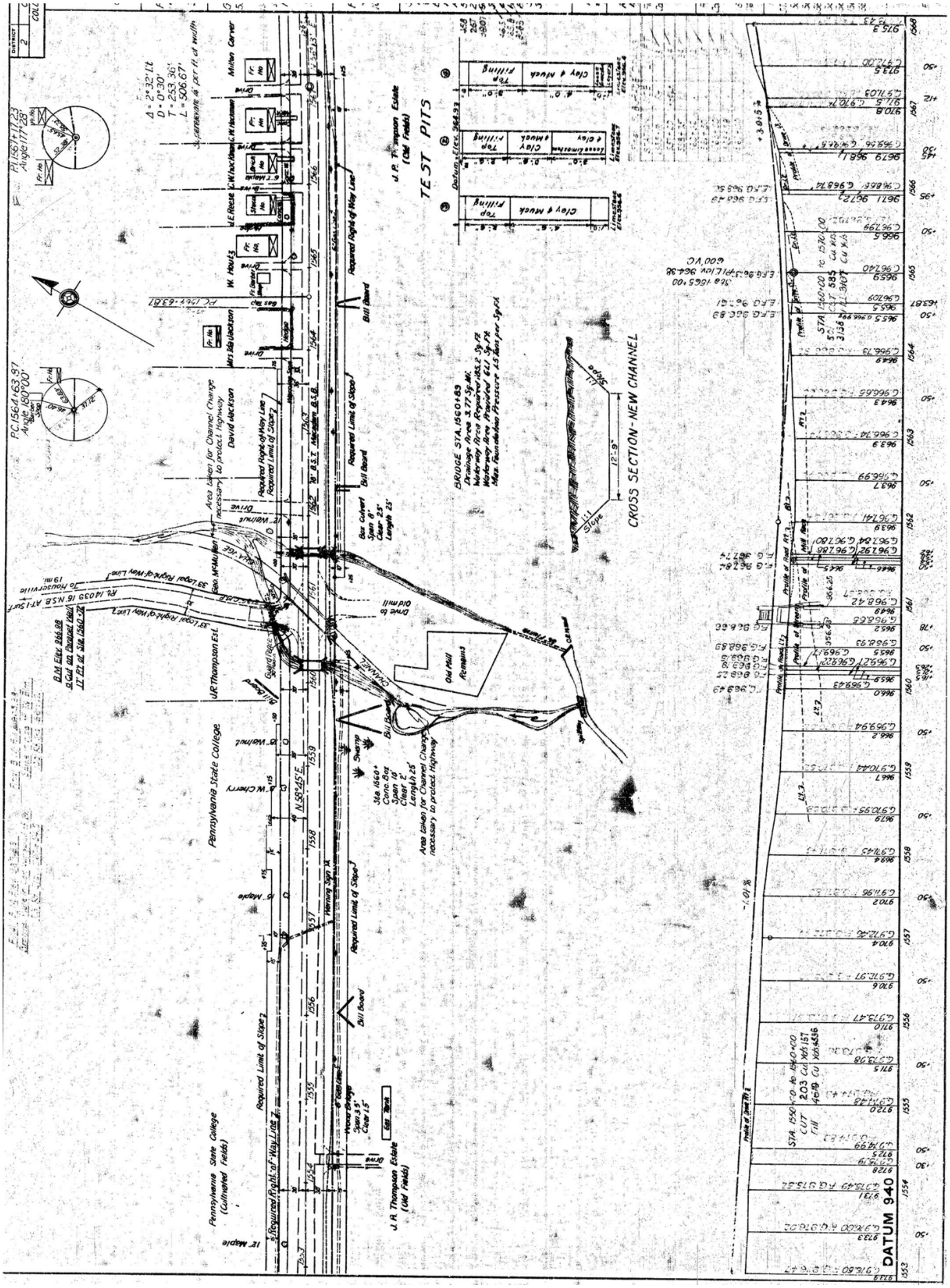

Figure 24. The 1940 Final Construction Plans for College Ave (sheet 7 of 21)

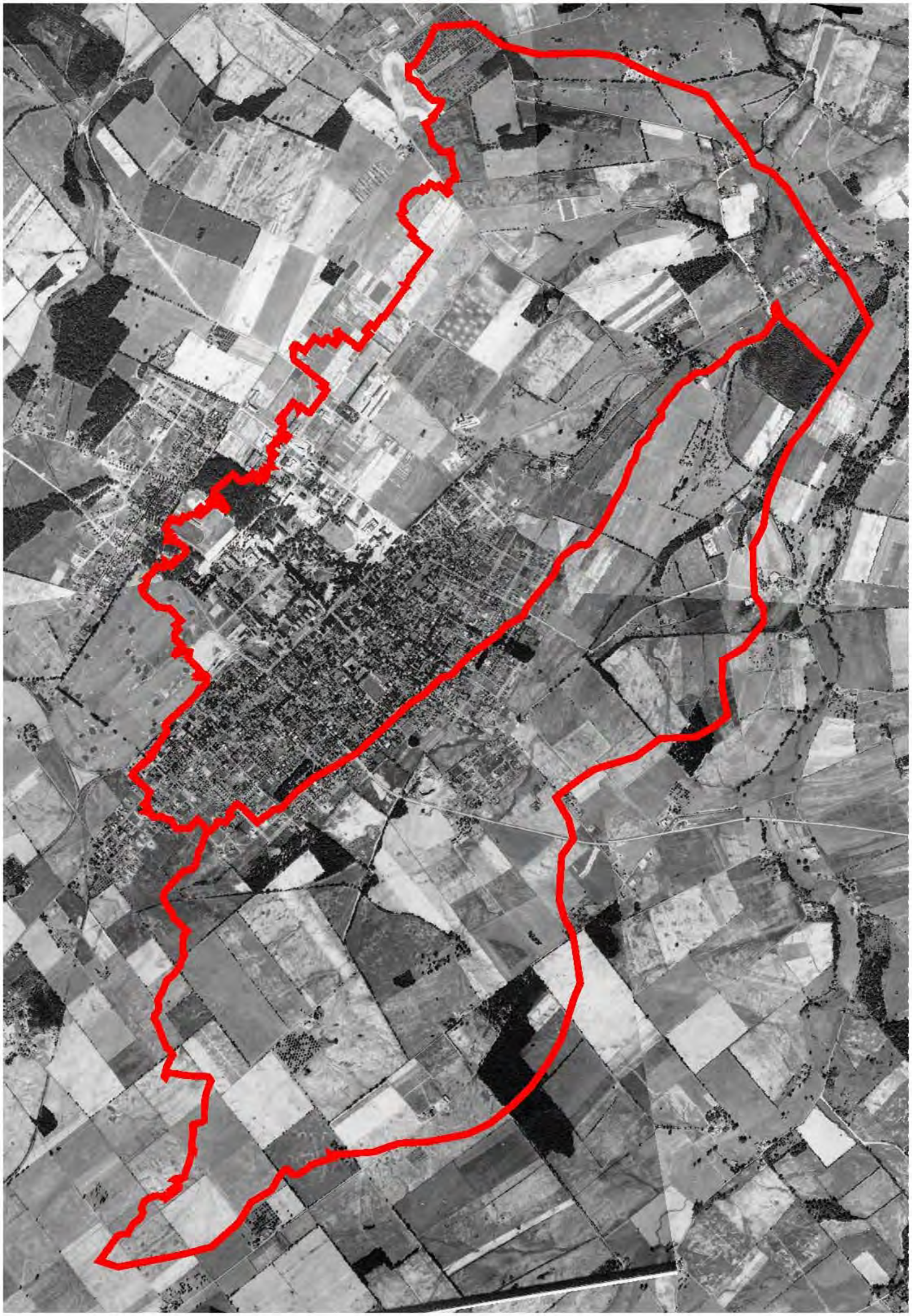

Figure 25. 1938 Land Cover Conditions of the Watershed with Current Drainage Areas Shown

Trout Unlimited indicates than prior to 1952, Thompson Run was an excellent Trout Stream. In the late 1950's the Pennsylvania Department of Transportation (PennDOT) widened and rerouted College Avenue to its present location. PennDOT removed the Thompson Spring diversion channel and allowed the spring flows to go directly through the pond (refer to Figure 26). The pond was also reduced slightly in size to approximately 2 acres. By PennDOT removing the diversion channel, it increased the discharges below the pond by approximately 10 degrees Fahrenheit and mixed the spring water with the stormwater. In the 1950's Thompson Run still went behind the existing Clark Motors and Clasters properties joining the current location of Walnut Run. No flows went along College Avenue where they exist today. The PennDOT plans show a new 8ft wide ditch was to be constructed on the south side of the new road (refer to Figures 27 and 28); however, there is no indication that the mill race was to be removed. How, or who, made the existing connection of Thompson Run to the new drainage ditch along College Avenue is unknown, but is one the reasons the flooding along College Ave occurs today in this floodplain.

The University constructed the wastewater treatment plant in 1913 that treated the wastewater from the University and portions of the Borough. While this plant was highly progressive for the time period, it still discharged the treated effluent directly into Thompson Run (30" CVP in Figure 27) and was considered in the 1950s one of the major negative water quality impacts to the creek. While this is still a common practice for wastewater treatment plants including other local facilities, wastewater effluent can significantly affect stream temperatures and nutrient loads especially in cold water fisheries such as Thompson Run. Therefore, in 1963 the University began conducting experiments on the spray application of wastewater on forest and agronomic soils. This research ultimately resulted in the University constructing its living filter system and since 1983 no treated wastewater effluent has been discharged into the creek.

Additionally, in 1947 and 1948 the University constructed numerous major stormwater works on Campus including a 66" storm drain along College Ave at the Campus to alleviate flooding. Today, there are three major storm drains that discharge into the Duck Pond; the University's 72" and the Borough's 66" and 48" pipes, which comprise the vast majority of stormflow into Thompson Run during runoff events. The University's 66" storm pipe drains only approximately 50 percent of the area tributary to the Duck Pond (refer to Figure 29). The Borough also installed the 106" x 73" storm drain system down Easterly Parkway in 1959 (refer to Figure 30).

The University had also purchased additional lands from the Thompsons in 1917, including what is known as Farm 7, which included the land Clark Motors was later built on (refer again to Figure 15). Figure 31 is the plat of transfer of this property in 1964 from the University to Clark Motors. As can be seen in the figure, the mill race still existed and the right of way that was given for the 1950's PennDOT road realignment can be seen. In the 1960's Clasters developed its site and is said to have installed the 72" wide x 48" high corrugated metal pipe culvert, with limited depth of cover. While it has been hypothesized that the Clasters' pipe may have been adequate when installed, this assumption appears to be incorrect. The University over a decade earlier had already installed a significantly larger sized pipe upslope that only drained a small portion of the watershed. Additionally, while the Clasters' culvert has an inlet capacity of approximately 130 cfs, Dr. Sackett had already designed the duck pond directly upslope for significantly higher discharges. This subject will be discussed further in later sections of this report. Unfortunately, no original plans or computations have been found from either the Clasters or Clark Motors site development, since both sites predate College Township's Zoning Ordinance, which was adopted in 1965. However, since the culvert was constructed within the State's right-of-way, there may be a file copy at PennDOT. Flooding of both sites has been documented into the early 1970's, and both sites have been further developed since that time. Refer to Figure 32 to see the location of the Clasters' culvert in question.

How much development existed immediately prior to the development of Clarks and Clasters can be seen in Figure 33, which is a mosaic orthophotograph on the area from 1957. A large portion of the headwaters of Walnut Run and the area that drained to Thompson Run Below the Duck Pond where still very much in agriculture and likely produced limited surface runoff except during extreme rainfall events or snowmelt type conditions. However, one can see that much of the University and the Borough tributary to the Duck Pond had been heavily developed; and therefore, generated large runoff quantities already. The late 1950's and early 1960s did see some growth in the watershed and by the University including diverting approximately 20 acres from the Fox Hollow Watershed towards Thompson Run due the existence of storm drains (refer to Figure 34). In the last 50 years there has been extensive infilling by both the University and the Borough within the watershed. Additionally, the previously agricultural headwater areas of Walnut Run have been developed with a mix of housing types and the last remaining large undeveloped area of the watershed lies in the vicinity of Porter and Orchard Roads (refer again to Figure 1).

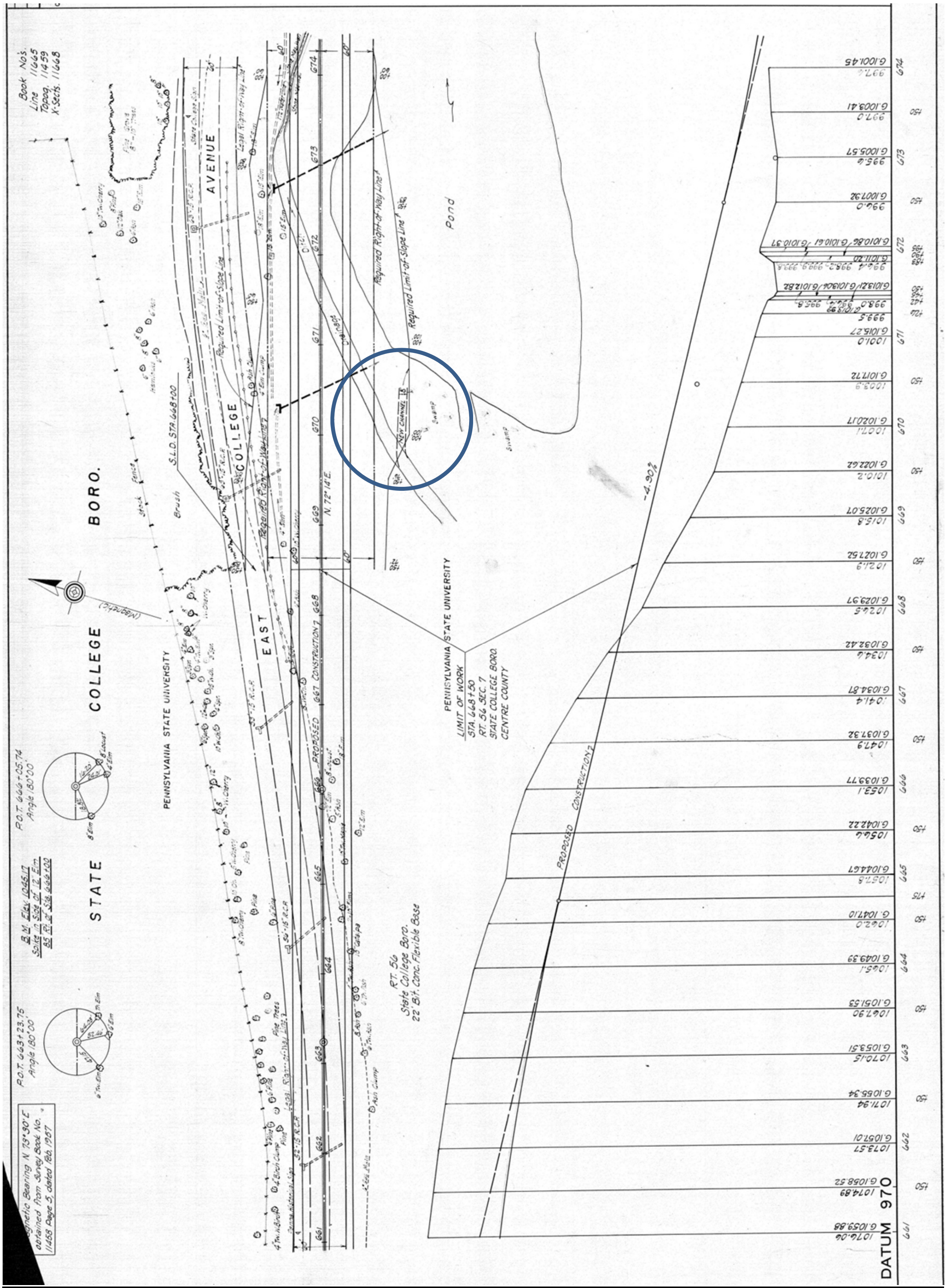

Figure 26. 1950s PennDOT Plans for the Realignment of College Ave (Sheet 6)

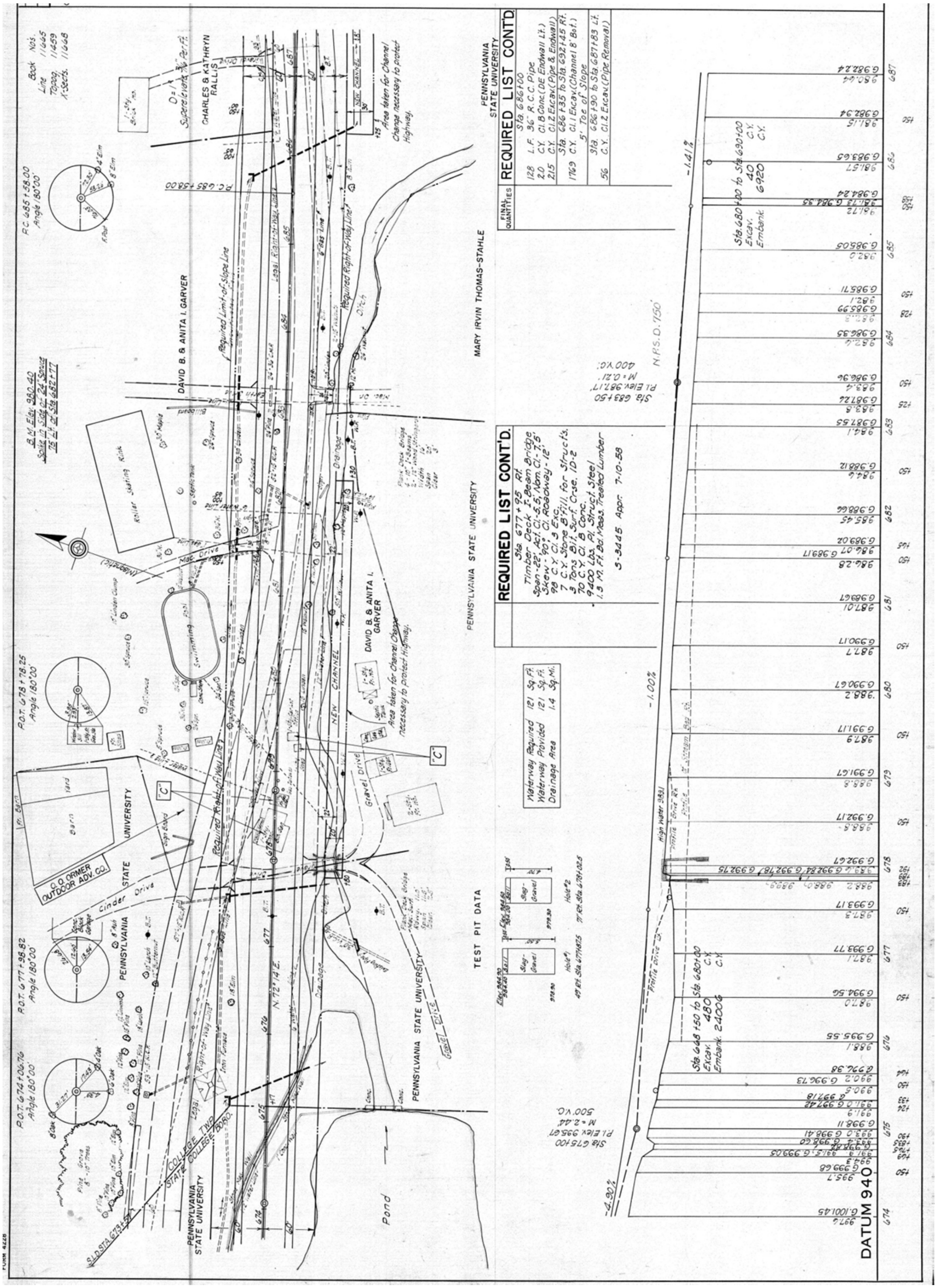

Figure 27. 1950s PennDOT Plans for the Realignment of College Ave (Sheet 7).

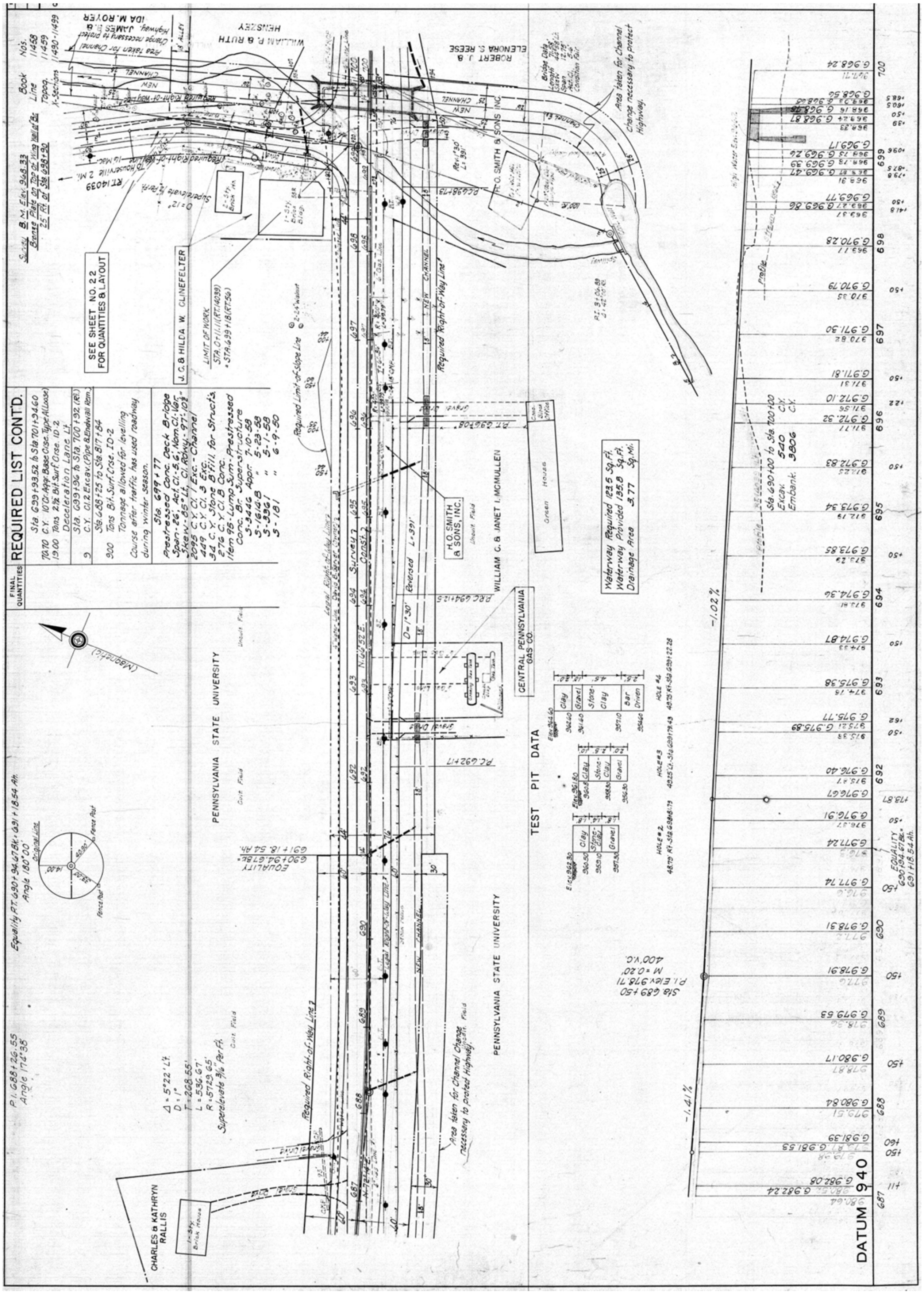

Figure 28. 1950s PennDOT Plans for the Realignment of College Ave (Sheet 8)

Figure 29. Installation of the 66" University Storm Drain along College Ave in 1948

Figure 30. May 1959 Completion of the Easterly Parkway Storm Drain System

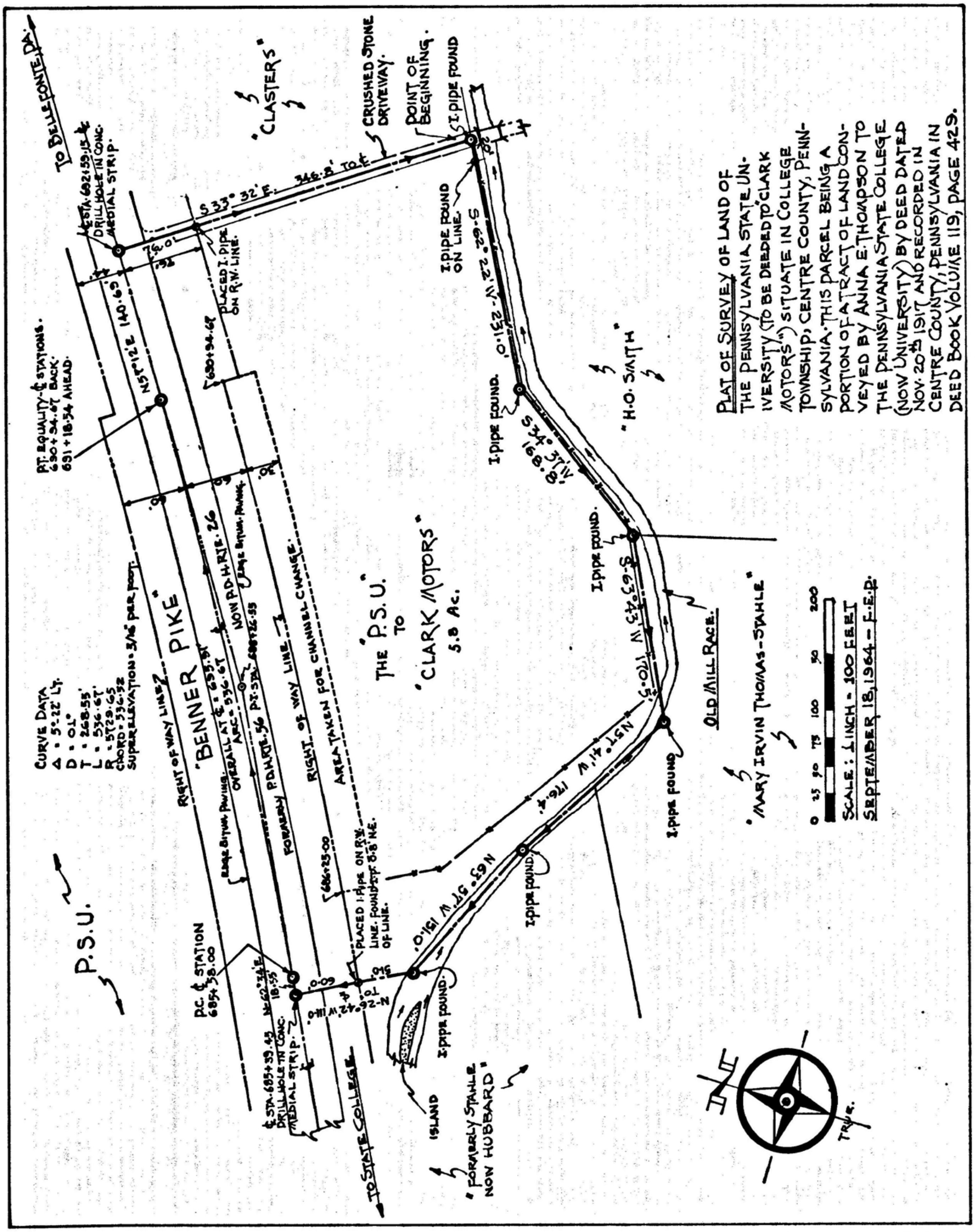

Figure 31. Transfer Plate for Land from the University to Clarks Motors

Figure 32. 2010 Orthophotgraph with the 1960's Clasters Culvert Shown that Causes Flooding

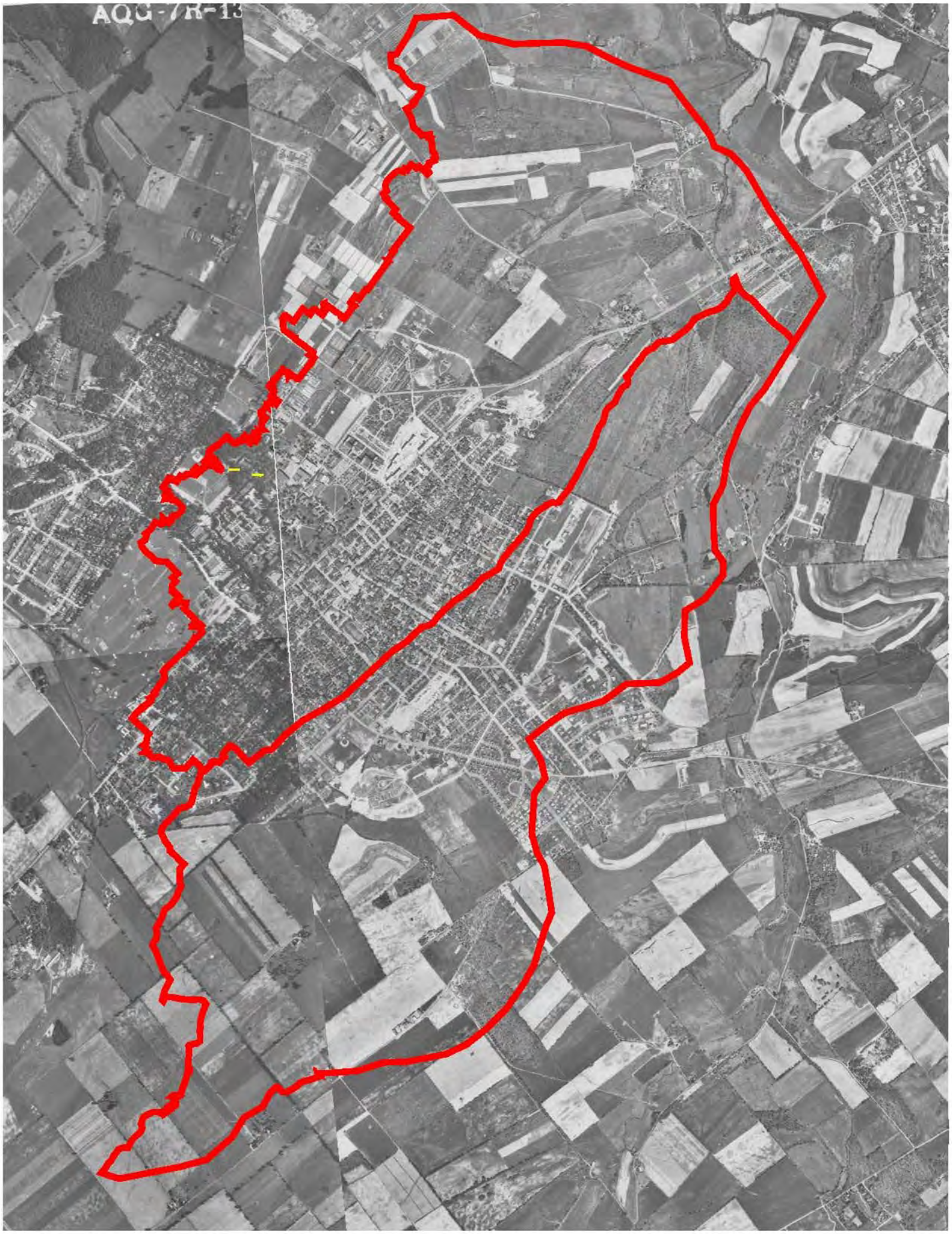

Figure 33. 1957 Land Cover in the Watershed

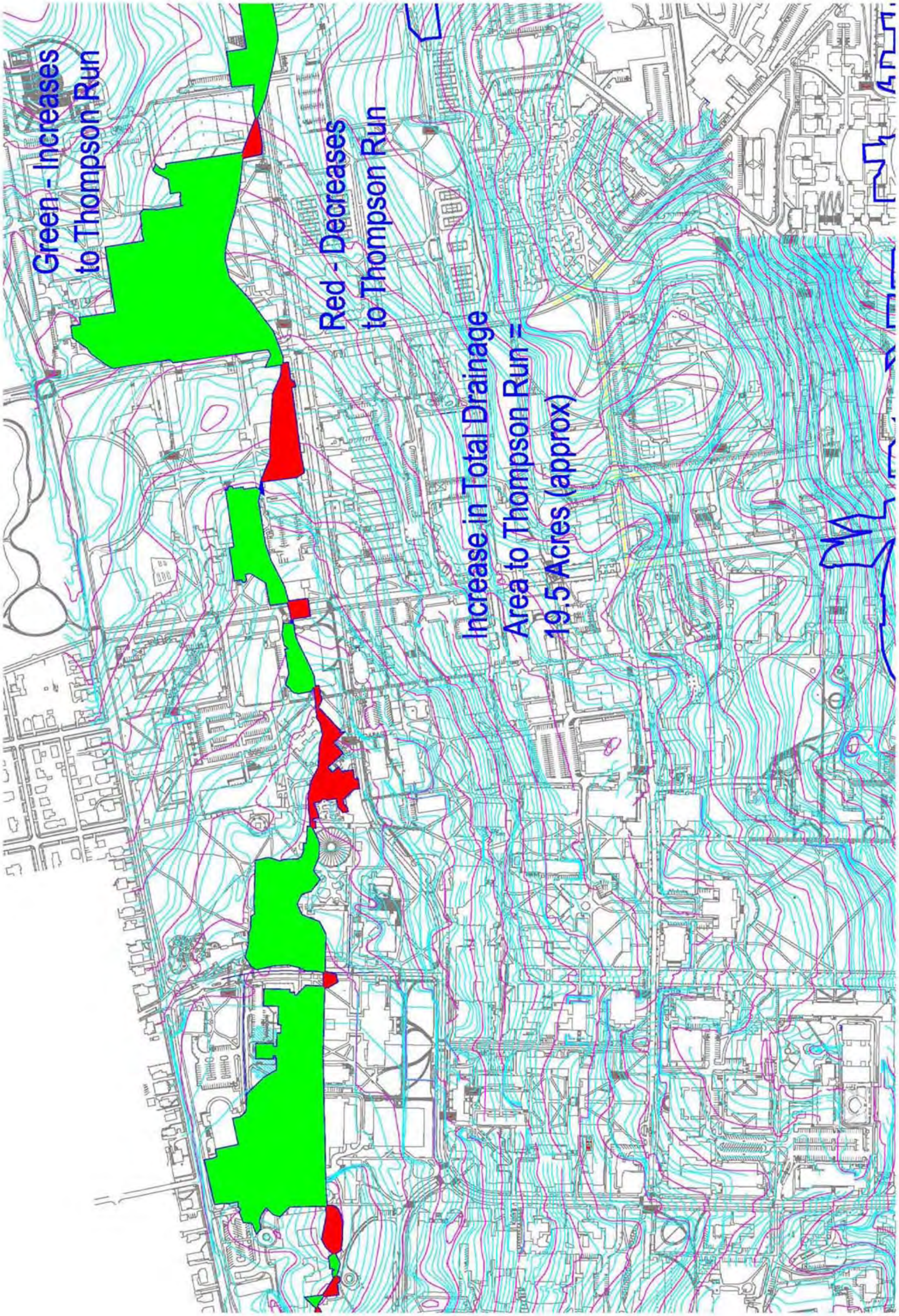

Figure 34. Map Showing Lands Diverted to and From Thompson Run near the Curtin Road Area

Trout Unlimited in the late 1970s requested permission from the University to reconstruct a diversion channel separating the spring flows from the Duck Pond. This was proposed because several developments had, or were, occurring that the Spring Creek Chapter of Trout Unlimited believed could greatly increase the quality of the flows in Thompson Run and Spring Creek. These were: 1) the construction of the College-Harris Joint Authority sewage system, 2) the flushing out of Spring Creek sediments by Hurricanes Agnes and Kloise, 3) the retrofitting of point discharges into the creeks, and 4) the construction of the University's living filter system for the wastewater. The University agreed to this work and using donations and volunteer help from Trout Unlimited, local contactor Glenn O. Hawbaker and local suppliers rebuilt the Spring's diversion channel in late 1977 over a two month period, which was coincidental with the pond's dredging by the University. The project included installing the CMP through the concrete cutoff wall and building the 540 ft long diversion channel 15 ft wide and 4 ft deep using stone fill. One of the few errors with the project was the planting of trees along the diversion (essentially a levee). These trees are now larger than the berm can sustain and when they fall breech the diversion (refer to Figures 35 and 36). Maintenance of this issue is difficult and costly for the University.

Despite the fact that significant flooding occurred at the Clark Motors and Clasters properties and on College Ave over the years, both properties continued to develop their sites further. Clasters was expanded in 1991 (refer to Figure 37) and Clark Motors went through another expansion in 1995 (refer to Figure 38). College Township records indicate that Clarks after development in 1995 did not complete the required FEMA permits even though the site was within a detailed study area flood plain and this issue appears to still be unresolved. Additionally, today the grade of the millrace section between Walnut Run and Thompson Runs flows in the direction from Walnut to Thompson. This reversal of grades likely occurred due to deposition, construction of the Boroughs sanitary sewer adjacent to the mill race and construction by adjacent land owners. The current FEMA floodplain analysis for the area includes an estimate of how much overflow goes from Walnut Run to Thompson Run via the mill race. How much if any flow actually does is unknown since there is no active stream gage monitoring.

Numerous meetings have taken place over the last 20 years in an attempt to resolve the flooding issues at Clark Motors and Clasters. Representatives from the University, local municipal officials, State officials, PennDOT, consultants, PaDEP, US Corps of Engineers, and the PA Fish and Boat Commission have attended varies meetings over the years. In 2002, cost sharing was determined between the Borough of State College, Ferguson Township, College Township and the University. In the end the project fell through and nothing was done other than a short section of the culvert end was later removed by PennDOT to promote water getting off of College Ave. Different funding sources have been pursued over the years; however, a common attitude appears to be that these two properties developed in flood plain and by the installation of an undersized culvert have created the problem themselves. In 2002, PaDEP notified College Township that PaDEP Flood Protection Project Funds could not be justified at Clark Motors. In 2003, an $85,000 Growing Greener request for developing a restoration plan was also not funded.

In 1999, the Pennsylvania Fish and Boat Commission defined Thompson Run from the Duck Pond to the mouth as a Class A Wild Trout Waters, which are defined as streams with wild trout populations that represent the best of Pennsylvania's naturally reproducing trout streams. Studies of Thompson Run in 1959 by the PA Fish Commission defined the creek reach as a "septic zone" and indicated dead ducks were along the banks and only carp and goldfish were observed. Water quality studies in 1971 showed similar conditions. A PaDEP study in 1979 found no fish at all in Thompson Run below the duck pond, but concluded that the creek had improved chemically. PaDEP proposed the classification of Thompson Run as a High Quality Cold Water Fishery in 2001 (PA Bulletin, Vol 31-49). In 2004 PaDEP declared that Thompson Run was impaired in regards to aquatic life for 1.87 miles (the entire length from the mouth to the spring is actually only 1.22 miles long) due to urban runoff from storm sewers. Thompson Run is now listed in Category 5 of PaDEP's Chapter 305b, which eventually will require a TMDL, even though 4,100 ft of its entire 6,450 ft length (64%) is nothing more than an artificial drainage ditch that has been moved and altered multiple times.

R.F.Carline et.al. (2011) stated that *"It is likely that water quality in Spring Creek is better now than it has been since 1900."* The Spring Creek Watershed and Thompson Run are clearly anomalies when it comes to sustaining fish populations. Carline reviewed studies from around the nation that seem to indicate that trout populations frequently decline or are lost when imperviousness reaches 6.6% or 11% respectively. Thompson Run is approximately 50% impervious above the duck pond. Environmental and stormwater regulations in the last decade have changed significantly and all new development and any future flood mitigation projects will be much more challenging and costly in the future regardless of the actual site health or conditions.

Figure 35. The Thompson Spring Diversion Berm in an Ideal Section

Figure 36. A large Trees Root Mass Breeching the Berm after Falling Over.

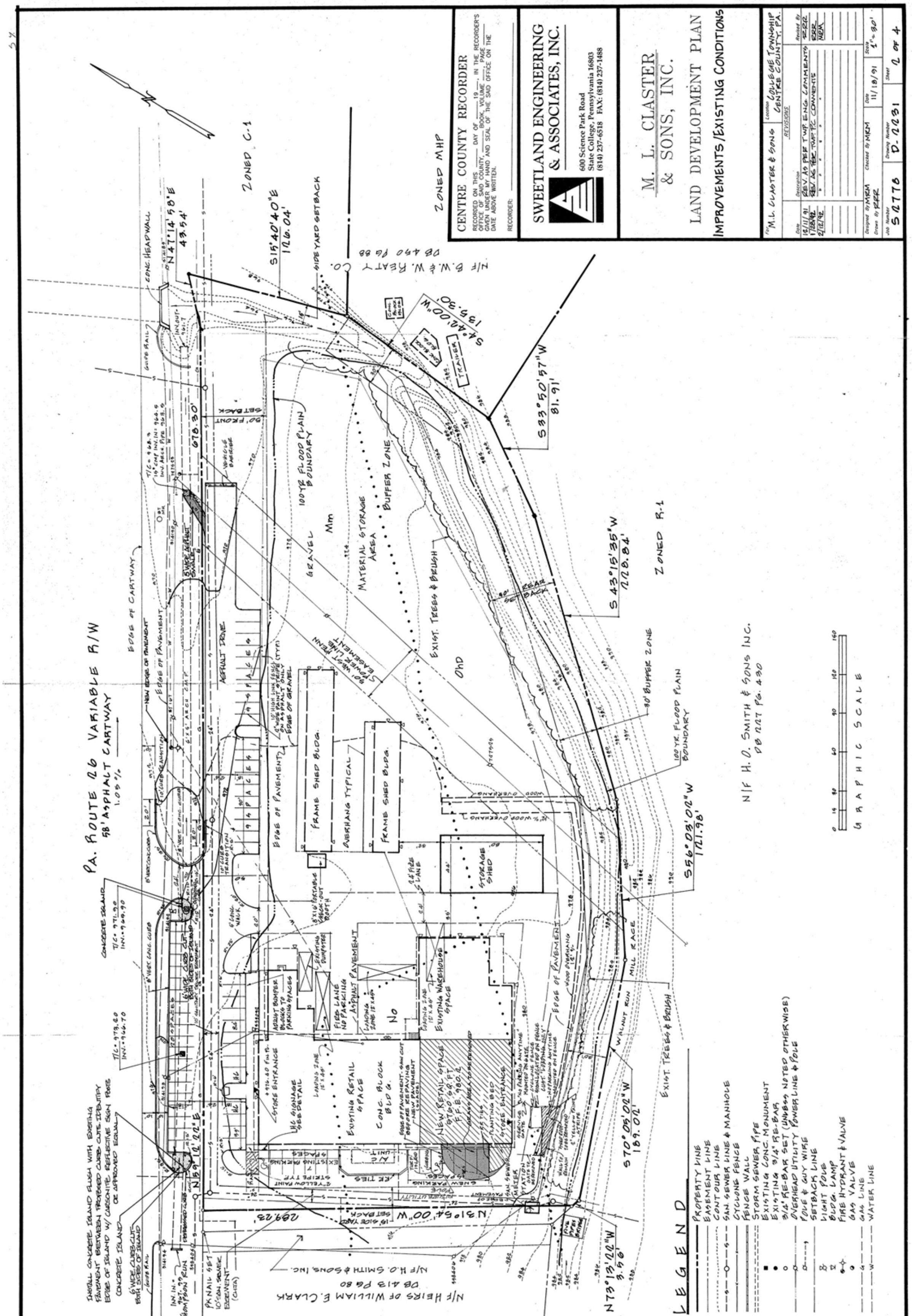

Figure 37. Site Plan for 1991 Clasters Additional Land Development

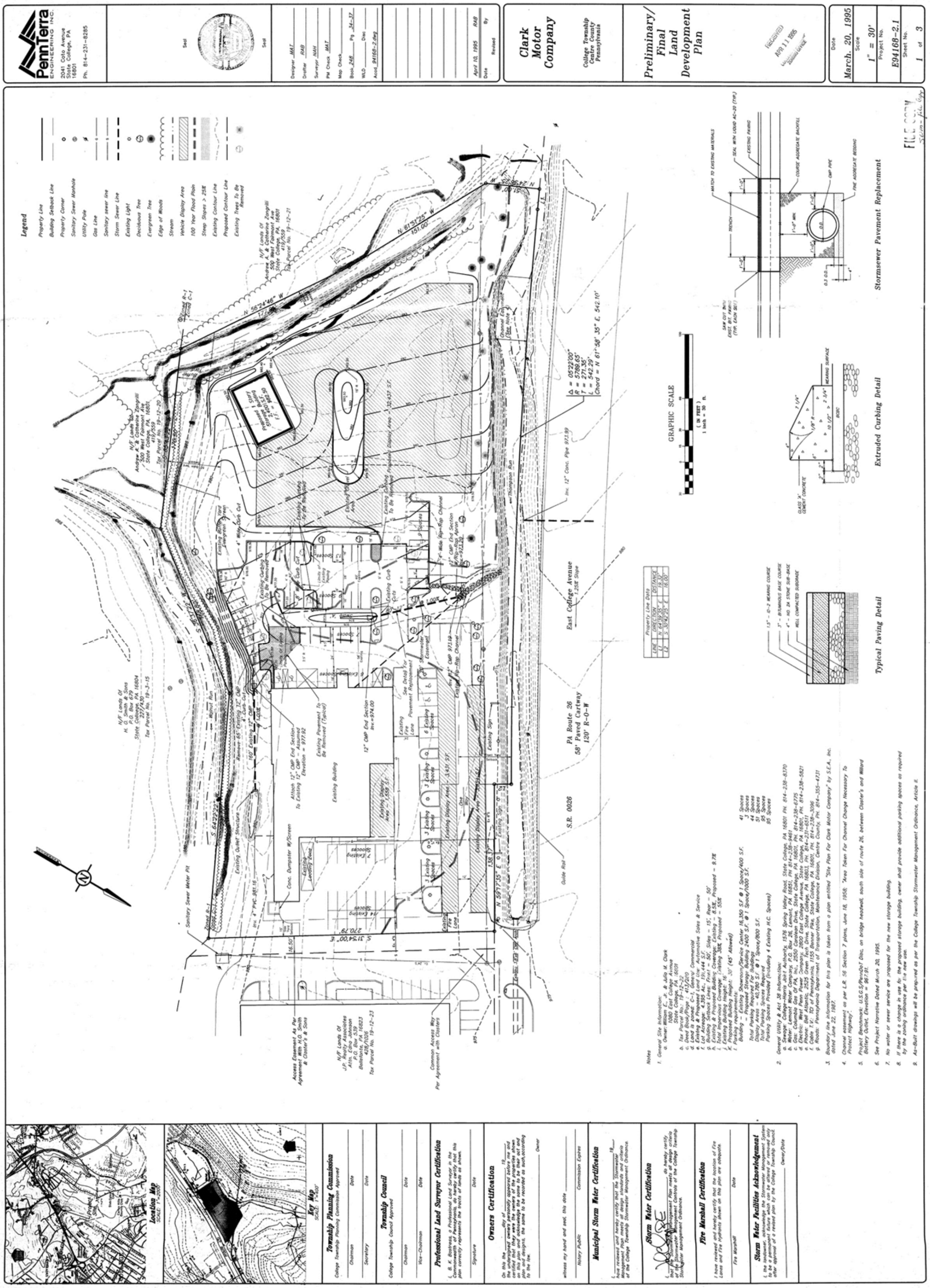

Figure 38. Site Plan for 1995 Clark Motors Additional Land Development

Key Stormwater Features within the Watershed

There are numerous stormwater facilities both natural and manmade within the watershed. The largest natural area is the Millbrook Marsh, of which a 62 acre tract is owned by the University. The University leases 12 acres to COG's Centre Region Parks and Recreation and the remaining 50 acres is held in a conservation easement by ClearWater Conservancy. The marsh has both artificial and natural wetlands and is believed to attenuate some level of peak runoff rates and provides flood control for both the Thompson Run and Slab Cabin watersheds. It is believed that if it were not for the marsh, runoff impacts from town would be much worse in Spring Creek. In the Walnut Run watershed is the Walnut Springs Park located downstream of University Drive and Easterly Parkway to just above the mill race. This area is believed to promote recharge and the Borough maintains several stormwater facilities within the park.

The University owns numerous stormwater facilities, some of which are located in subwatersheds tributary to Thompson Run (Bathgate Dam, Main Campus/Duck Pond, Lot 43). The earliest constructed facilities were in 1990s and consist to a large degree of ponds and subsurface detention facilities that control peak runoff rates. The largest manmade facility in the watershed owned by the University is the Bathgate Dam, which significantly regulates water quality and peak runoff rates. The facilities and types that the University owns can be seen in Figures 39 through 42. While the University does not generally promote recharge type facilities within the core part of campus due to sinkhole and building flooding problems, the University does have a number of buildings that do not drain to surface waters. One of the best examples is Old Main, which has its entire roof discharge into four drywells that were constructed in the 1929 rebuilding of Old Main. Many of the older areas of the Borough also have homes with drywells or cisterns. No known count of these residential recharge systems has ever been made.

There are several large stormwater facilities in the Borough, the largest of which is the Westerly Parkway Reservoir, which is believed to have approximately 15 acre-feet of storage. This facility was constructed in 1965 and originally was designed with an automatic control gate that closed off as the ponds discharge exceeded the capacity of the downstream storm drain system. In the last several years, the reservoir has been overtopped several times. Other large stormwater facilities owned by the Borough include the Orchard Park Pond, which was hydraulically improved around 2000 and the dual use Soccer Field stormwater detention facility constructed in 2005 by the Borough on the State College Area School District's property to attempt to mitigate flooding at the high school's north building. The Borough also has some stormwater BMPs such as subsurface detention facilities.

Additionally, as previously stated, a large portion of the Borough's headwater area of Walnut Run is discharged directly into sinkholes (refer again to Figure 5). Over the years these sinkholes have been surcharged resulting in significant flooding downstream. The Borough has been improving these sinkholes. One of the most notable sinkholes in the Borough is the Memorial Field sinkhole, which drains approximately a 45 acre area (31 acres of imperviousness) of the Borough at the boundary of the Thompson and Walnut watersheds. This sinkhole was a natural closed depression referred to locally as the "hollow" that was purchased by the school board in 1914 and was formerly used as a dumping ground by residents (refer to Figure 43). While the hollow was used as a school activity area playground with a baseball field and later running track, the field as exists today was constructed and improved by the Civil Work Administration in the mid-1930s. In 2003, an artificial grass surface was installed on the field and a number of injection wells were constructed in addition to the sinkhole. The sinkhole today is located under the home section bleachers and surcharges occasionally. It is likely, but yet unproven, that the Borough sinkholes and those in up gradient portions of Ferguson Township feed the Thompson Spring. When these sinkhole have their capacities exceeded, significant flooding results (refer to Figure 44).

The older developed portion of Ferguson Township located in the upper reaches of the Duck Pond watershed also likely include homes with drywells and/or cisterns because many of these homes like the Borough were constructed prior to there being a comprehensive storm drain system or municipal water systems. Again, like the Borough the quantity of these types of residences is unknown. Ferguson Township in the upper area of Walnut Run includes several stormwater management facilities for residential developments including mandatory drywells that are used for residential homes.

While both the Clasters site (now Your Building Center) and the former Clark Motors (now Blaise Alexander) are located in College Township, very little area within the Township drains to these two properties The majority of the lands in College Township are located in the downstream reaches of the watershed. However, while runoff to these two properties is generated upslope of College Township (primarily from the Borough and the University), the Township controls development and most decisions regarding these properties by their Ordinances and regulations.

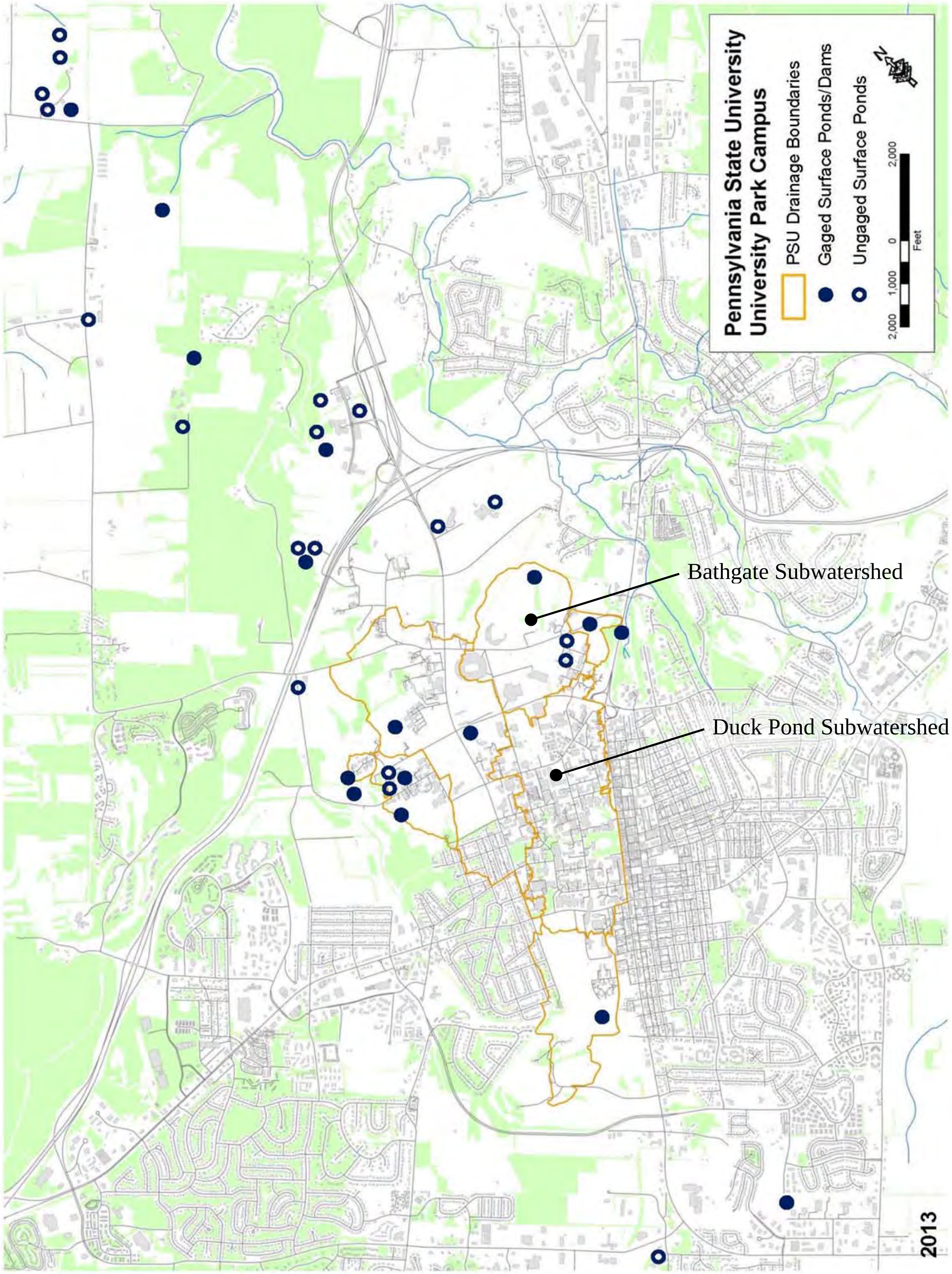

Figure 39. Surface Ponds Owned by the University

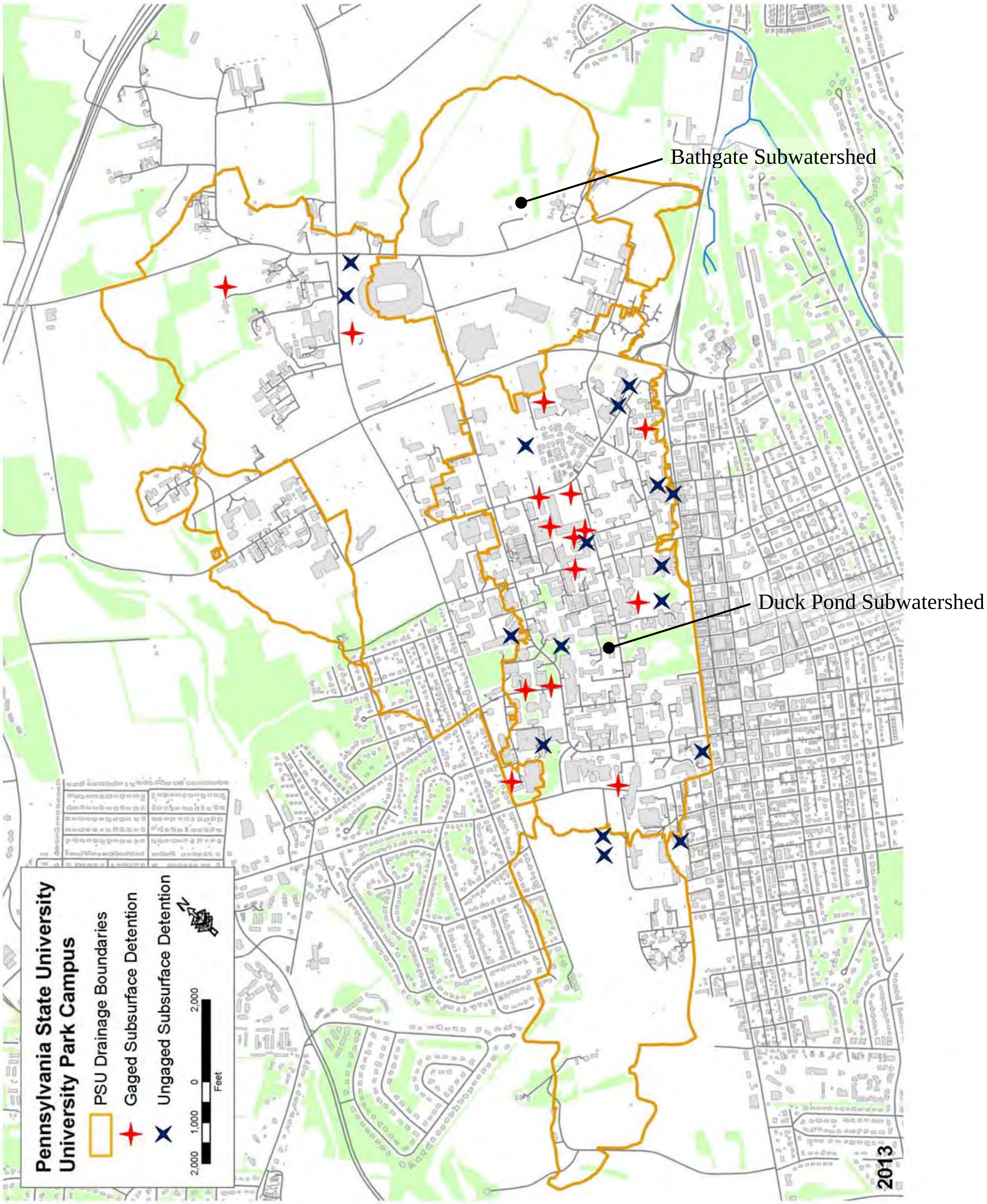

Figure 40. Subsurface Detention Owned by the University

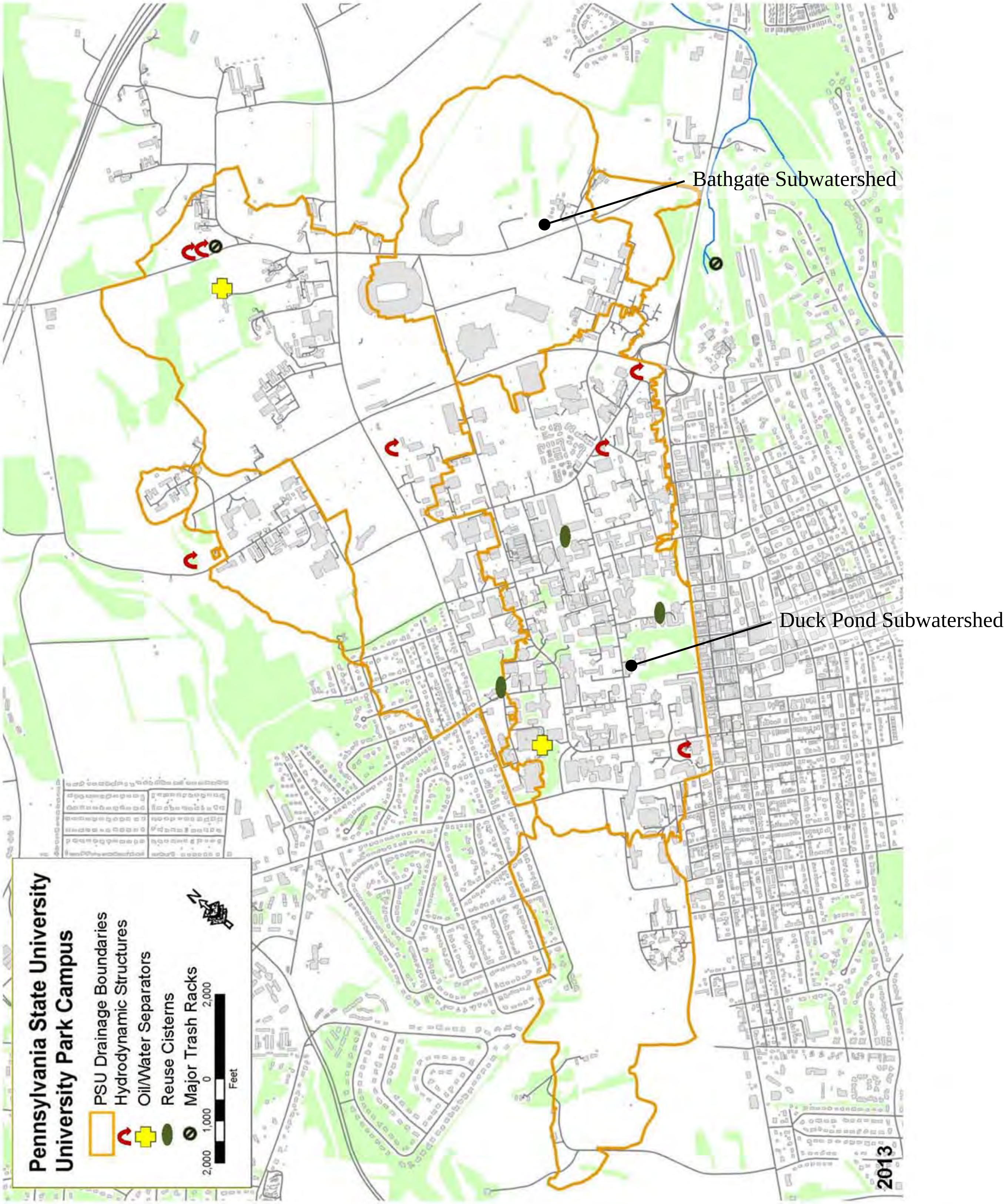

Figure 41. Stormwater BMPs Owned by the University

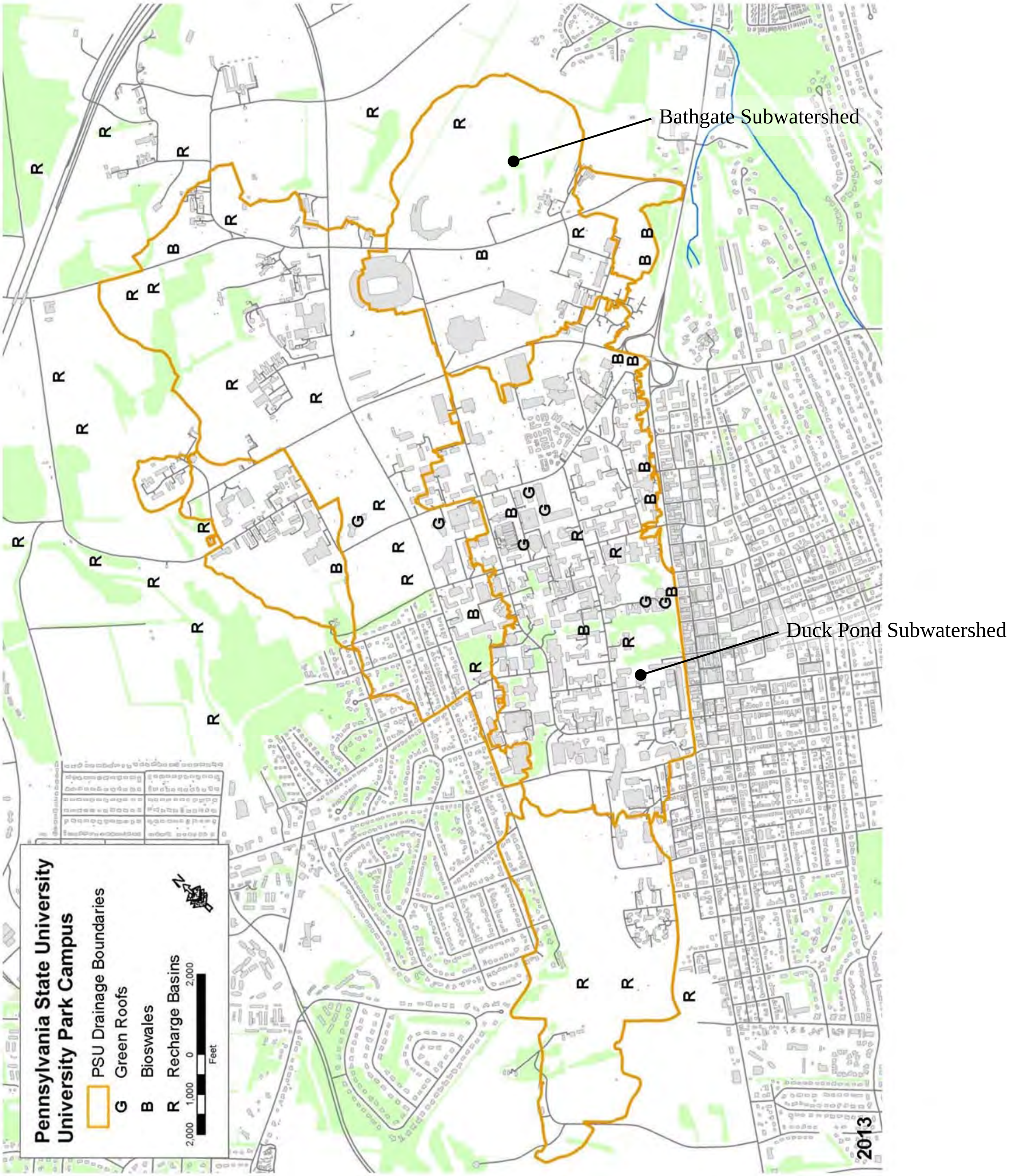

Figure 42. Additional Stormwater BMPs Owned by the University

Figure 43. 1896 Photograph of the “Hollow” and Memorial Field Sinkhole (seen to the right)

Figure 44. Flooding at the Intersection of Westerly Parkway and Sparks due to a Sinkhole Backing Up

Historical Studies within the Watershed

A large number of studies have been conducted on the watershed over the years starting with engineering students taking flow measurements of Thompson Run in the 1800's. Some of these studies have been specifically about Thompson run or the flooding and Clasters/Clark Motors and some have been larger watershed based studies. The following list is certainly not comprehensive. The list of larger studies follows:

Soil Survey of Centre County, USDA Soil Conservation Service. 1981. This document mapped both the Clasters and Clark Motor sites as being comprised almost exclusively of Nolin and Melvin Silt Loams, both of which are local alluvium that formed under water and are located on flood plains. Today the soils have been completely disturbed and can now be classified as urban. Refer to Figure 45.

The Fishery of Spring Creek, A Watershed Under Siege, Pa Fish and Boat Commission, Technical Report Number 1. 2011. R. F. Carline et al. This document provides a comprehensive look at the watershed, development, and practices that impacted aquatic health.

The Centre Furnace Story, A Return to Our Roots. The Centre County Historical Society. 1985. S.K. Stevens and P. S. Klein. This document provides an excellent history of the Centre Furnace.

Hydrogeologic Settings and Conceptual Hydrologic Model of the Spring Creek Basin, Centre County, PA. 2005. USGS Scientific Investigations Report 2005-5091. This report presents a somewhat comprehensive look at data that exists on the entire Spring Creek Watershed.

FEMA Flood Insurance Study. 2009. May 4. FIS Number 42027CV001A. This document presents the regulated flows including at Thompson Run and Walnut Run at the Clasters/Clark Motors site. FEMA uses a drainage area for Thompson Run of 3.92 square miles, which is significantly different than the 4.64 square miles defined by the University. While we do not have FEMA's drainage area maps, the discrepancy is believed to be related to FEMA not including the Bathgate Dam drainage area and parts below; however, this discrepancy would have no effect on the flows estimated upslope. A copy of the FEMA FIRM can be seen in Figure 46.

Spring Creek Water Resources Monitoring Project (WRMP) Annual Reports. 1998 to 2013. These reports funded by the local partners provide flow and water quality data for areas of Spring Creek including Thompson Run and Walnut Run and are available on the web at: www.springcreekmonitoring.com The WRMP also provides data for its gages to anyone on request.

Several studies have also been done specifically on elements within the watershed. A partial listing follows:

The Effects of Urban Runoff on the Benthic Macroinvertebrate Community of Thompson Run. Master's Thesis, Penn State. 1998. David A. Lieb

Flow, Water Quality, and SWMM Model Analysis for Five Urban Karst Watersheds. 2011. K.L. Blansett. Doctoral Dissertation. Study included flow and water quality analysis of PSU and Borough discharges to the Duck Pond. Available electronically at: https://etda.libraries.psu.edu/paper/12467/

Interim Evaluation of Selected Alternatives for the Penn State Duck Pond. 2007. T. A. Rightnour. A study commissioned by the University's Office of Physical Plant.

Duck Pond Channel Erosion Study. Herbert, Rowland & Grubic Inc. 1999. Engineering study conducted for the University regarding the channel between the storm pipe outfalls and the Duck Pond. Contains Hydraulic & Hydrologic Estimates.

Various Bathgate Dam, Thompson Spring, and Duck Pond Water Resource Publications. Penn State Office of Physical Plant. These documents provide data and background information specific to the facility starting in 2007 and are located on the web at: http://www.opp.psu.edu/services/stormwater/presentations-publications

Various Water Quality Reports on Thompson Spring. Penn State Commissioned. 1928, 1929, 1933, 1955, and 1957. Maintained in Office of Physical Plant Files.

Various Stream Aquatic Evaluations on Spring Creek Including Thompson Run Due in Part to the University Wastewater Treatment Plant. 1959, 1971, 1979, and 2002. Copies are Maintained at ClearWater Conservancy.

Technical Memorandum, State College Borough - Memorial Field Drainage Study. 2005. Herbert, Rowland & Grubic, Inc. This engineering study evaluates the Memorial Field sinkhole and 44.6 acre watershed.

HEC-RAS for Thompson's Run. AECOM. 2012. Summary of a model commissioned by the Office of Physical Plant on the Flooding of Clasters/Clark Motors using University Calibrated Duck Pond data for the runoff event of 8/12/2009 using unsteady flow option of the model. OPP has possession of this model; however, it has not been checked or verified.

A Hydrologic Analysis for the Culvert Beneath the Clasters' Lumberyard Parking Lot. C.E. 554. 1985. C.N. Dunn. Report done for a civil engineering class project (CE 554). Copy is located in College Township In this report, Dunn determines regarding the Clasters' culvert that "with friction control approximately 80 cfs can be conveyed through the pipe while with inlet control conditions roughly 132 cfs can be routed through." Refer to Figure 47 for the culvert inlet condition, which is considered very poor hydraulically.

Hydraulic – Hydrologic Analysis of Thompson and Walnut Runs for Clark Motor Co. 1988. G. Aron In this study of the mill race, Dr. Aron indicates the Clasters' culvert cannot carry more than 125 cfs and evaluates where flooding leaves the channels.

Recommended Hydrologic Procedures for Computing Urban Runoff from Small Watersheds in Pennsylvania. D.F. Kibler. 1982. DER#609-5/93. This report conducted for PaDEP evaluated the Borough's Calder Alley Storm System.

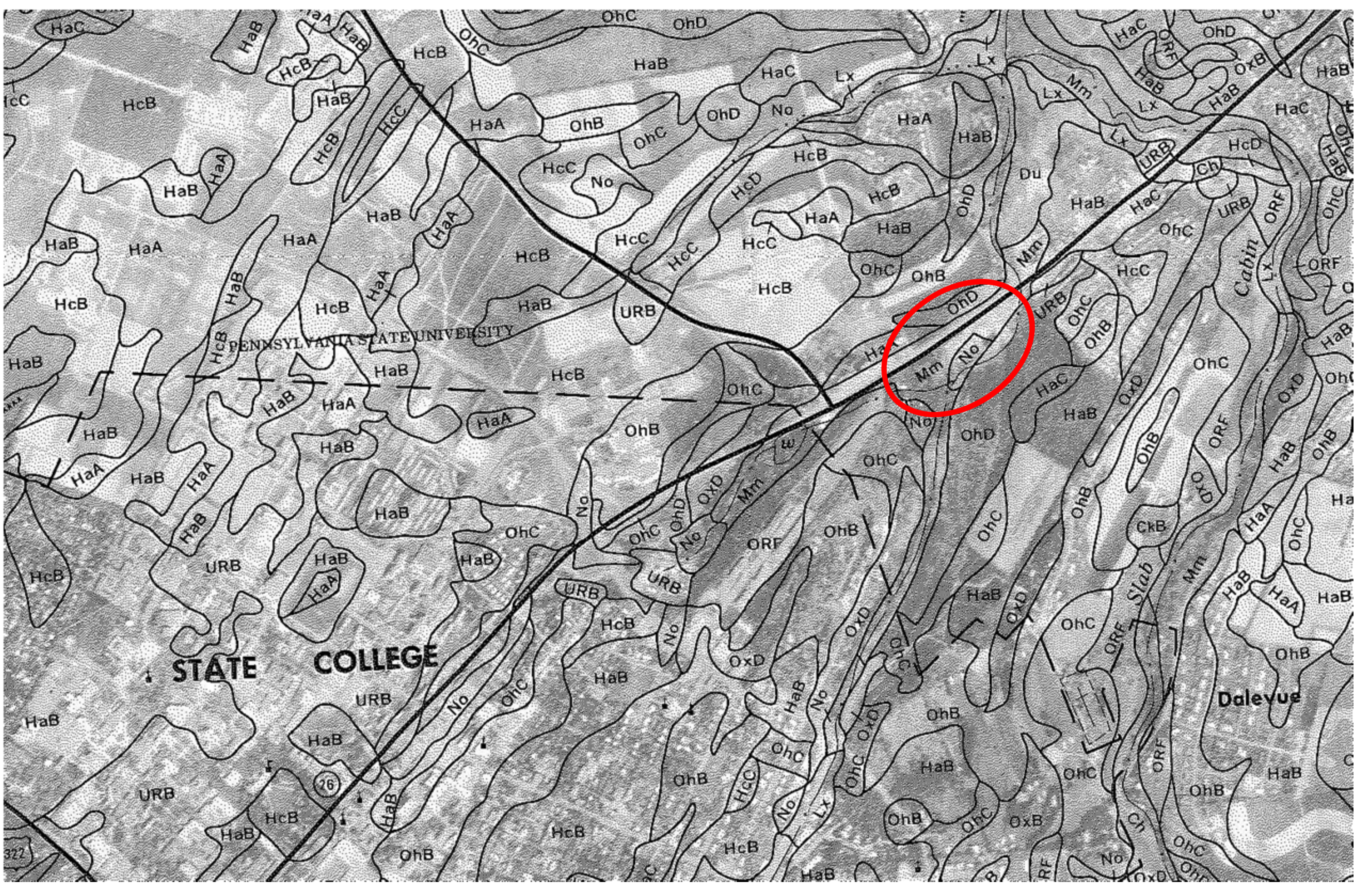

Figure 45. Soil Survey for Area Around Clasters'/Clark Motors Circled in Red

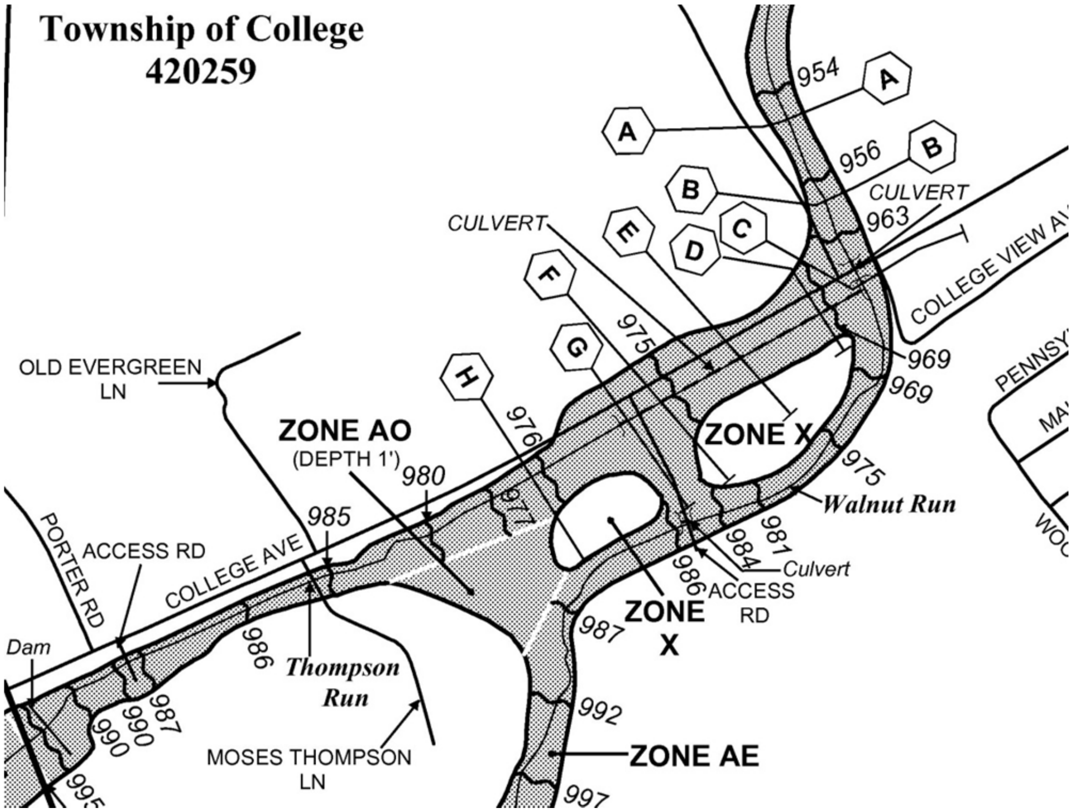

Figure 46. 2009 Effective FEMA Map for Area Below Duck Pond

Figure 47. Current Inlet Condition of Clasters' Culvert

Avaliable Data within the Watershed

There are a wide variety of data and flow estimates within and downstream of the watershed. The applicable data are the University's Engineering Services data of Thompson Spring, the Duck Pond outflows and the Bathgate Dam outflows; the Water Resource Monitoring Project's gages at Thompson Run, Millbrook Marsh, and Walnut Run; and USGS data at the Houserville Gage located downstream on Spring Creek.

Pertinent hydrologic estimates have also been conducted by FEMA, Herbert Rowland &Grubic Inc., Dr. Gert Aron, and Christopher Dunn.

While reviewing the following data, one should keep in mind that the generally accepted inlet control capacity of the culvert at Clasters is approximately 130 cfs.

The 2009 FEMA study presents the following 100-year flow estimates (refer to the FEMA study for methods used) at the indicated locations:

Walnut Run above mill race – 2.15 sq.mi. – 530 cfs
Walnut Run below mill race – 2.28 sq mi. – 250 cfs (difference due to spillover mill race)
Thompson Run below the Duck Pond – 1.52 sq.mi. – 500 cfs
Walnut Run and Thompson Run at College Ave Bridge – 3.82 sq. mi. – 980 cfs
Thompson Run at Mouth – 3.92 sq. mi. – 1,070 cfs

The 1999 Herbert Rowland & Grubic Inc. Engineering study conducted for the University Channel erosion study estimated the following discharges for an assumed 1.3 sq. mi. watershed area upslope of the Duck Pond using the Rational Method (these estimates would be conservative for larger return periods):

2 year Qp = 608 cfs
10 year Qp = 787 cfs
25 year Qp = 1,125 cfs
50 year Qp = 1,298 cfs
100 year Qp = 1,384 cfs

The 1988 Hydraulic – Hydrologic Analysis of Thompson and Walnut Runs by Dr. Gert Aron using the Penn State Runoff Model estimated the discharges of both Thompson and Walnut Runs at the Clasters/Clark Motors sites:

Walnut Run	Thompson Run
2 year Qp = 160 cfs	2 year Qp = 250 cfs
10 year Qp = 280 cfs	10 year Qp = 440 cfs
100 year Qp = 450 cfs	100 year Qp = 830 cfs

The 1985 Hydrologic Analysis for the Culvert Beneath the Clasters' Lumberyard Parking Lot by Christopher Dunn using the Penn State Runoff Model. This study notes that the Borough's Engineer at the time felt the Clasters'culvert was grossly undersized and surcharges for every 2-year storm. Dunn's estimates at the culvert were:

Walnut Run	Thompson Run
2 year Qp = 194 cfs	2 year Qp = 542 cfs
10 year Qp = 251 cfs	10 year Qp = 921 cfs
25 year Qp = 316 cfs	25 year Qp = 1,049 cfs

While there is normal variation in the model estimates due to time period conducted and methods used, it is clear that the culvert is significantly undersized for even the 2-year runoff estimates.

Duck Pond Subwatersed Data

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. 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 1200 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. The Duck Pond is actually a Class 3 regulatory dam and is permitted by the Department of Environmental Protection. The Pond's principal spillway is a two-stage concrete Ogee spillway. Prior to reaching the maximum design stage on the Ogee crest, water also can pass through the service road driveway, which has a trapezoidal section cut into the dam and flows can also overtop to the Thompson Spring channel. The resulting stage/discharge rating curve is complex and was developed using the US Army Corps of Engineer's HEC-RAS model. Continuous stage/storage data have been collected at the pond since January 2007 at 5-minute intervals, which are shown in Figure 48.

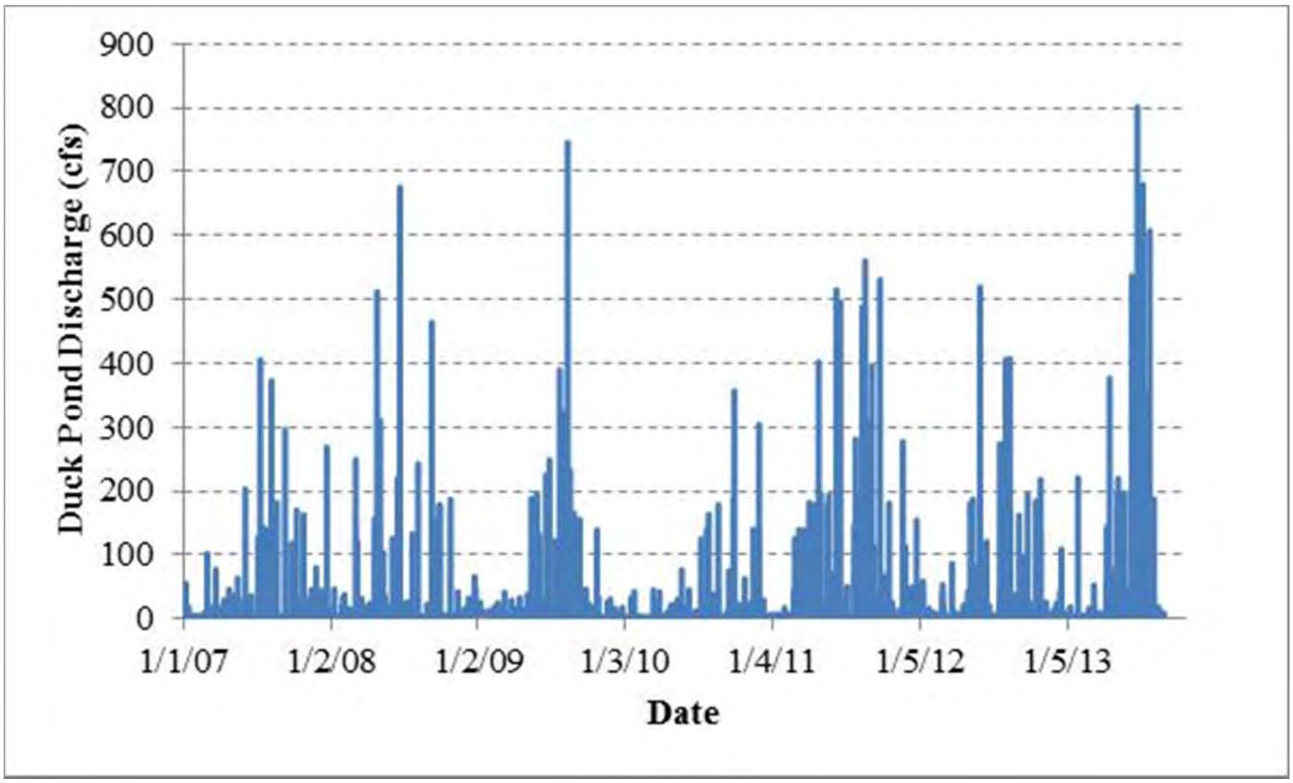

Figure 48. Duck Pond Discharges from 1/1/2007 to 9/13/2013

While Figure 48 only has approximately 7 years of continuous data, it is clear that a discharge of over 200 cfs is quite common and a discharge of 100 cfs (close to the capacity of the clasters' culvert) occurs on average monthly. Additionally, it appears to the casual observer that runoff events to the Duck Pond have become more severe in recent years. While the following Table 1 shows that of the seven highest runoff events in the last seven years, four of them occurred in 2013 (note the date refers to the official Walker Building precipitation and not the actual date the runoff event occurred). This increase is not related to development, but rather the cyclic nature of extreme precipitation events. While some scientists believe that more intense storm are occurring in recent years due to global warming, the lack of long term precipitation intensity data would make this assumption un-supported and pre-mature. Numerous high intensity events have occurred in the last several decades that have resulted in significant flooding below the duck pond. Unfortunately, no one documented flow data from earlier periods of time, and observational opinions of increases in the frequency or severity of flooding need to be dismissed without supporting data.

Table 1. Seven Highest Runoff Peak Rates Recorded Since 2007 at the Duck Pond

Date	Rainfall (in)	Rainfall (ac-ft)	Event Qp (cfs)	Event Q (ac-ft)	Event Percent Q/P (%)
6/28/2013	3.38	244.2	800.8	153.3	63%
8/13/2009	1.90	137.3	745.3	55.7	41%
7/10/2013	1.15	83.1	679.8	52.7	63%
6/22/2008	1.90	137.3	675.3	60.8	44%
7/7/2013	1.20	86.7	640.1	51.7	60%
8/22/2011	1.35	97.5	560.0	36.8	38%
6/13/2013	0.90	65.0	536.4	40.8	63%

The rainfall event of 6/27/2013 (identified as 6/28/2013 in Table 2 below), was an extreme "design" type of event to engineers.

Table 2. The Rainfall Event of 6/27/2013 Intensities and NOAA Atlas 14 Associated Return Periods

Date	Rainfall Max 5-min I (in/hr)	Rainfall Max 10-min I (in/hr)	Rainfall Max 15-min I (in/hr)	Rainfall Max 30-min I (in/hr)	Rainfall Max 60-min I (in/hr)	Rainfall Max 2-hr I (in/hr)	Rainfall Max 6-hr I (in/hr)	Rainfall Max 24-hr I (in/hr)
6/28/2013	0.33	0.62	0.87	1.52	2.05	3.04	3.63	3.73
Approx Return Period	1 yr	2 yr	2-5 yr	10-25 yr	10-25 yr	50-100 yr	50 yr	5-10 yr

There are many meteorological factors that result in how severe a storm event's peak runoff may become such as temperature, storm type and distribution, total precipitation depth, and intensity. However, for the Duck Pond watershed the single biggest factor related to peak runoff events is the 30 minute to 60 minute rainfall intensity, which is the approximate time of concentration for the watershed. Both of these rainfall intensity intervals can be seen in Figure 49 in addition to the linear best fit R squared equation.

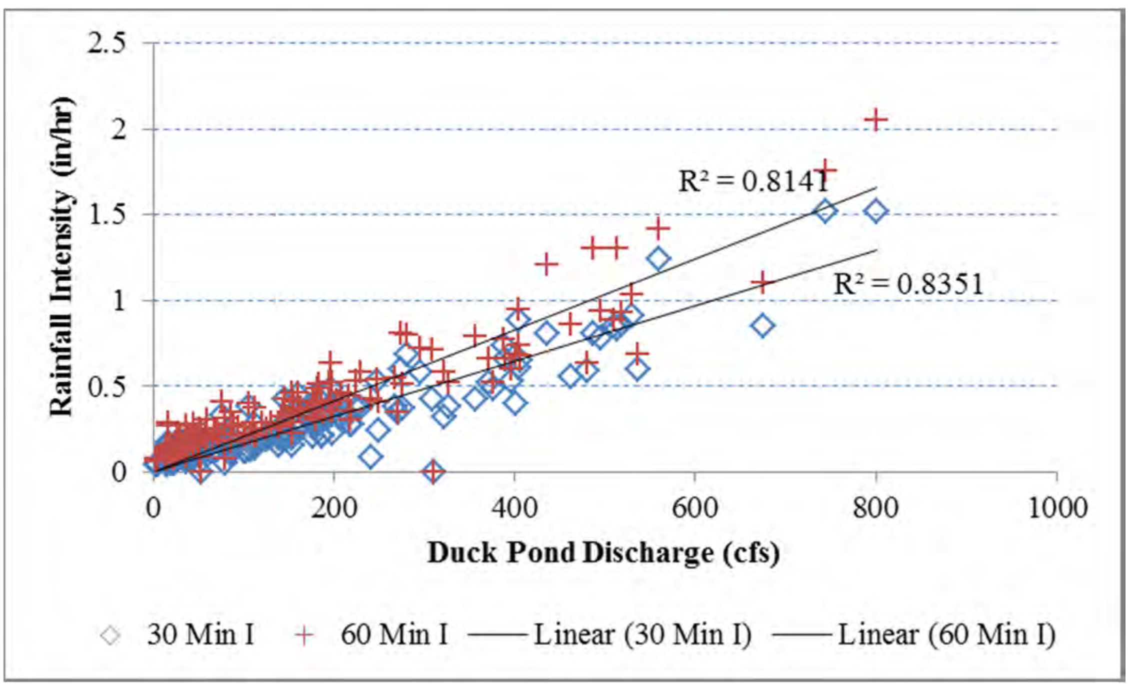

Figure 49. Graph of Peak Runoff Rates to Rainfall Intensity Interval

The total event runoff volume is highly correlated to the total rainfall event depth, which is intuitive and the relationship can be seen in Figure 50.

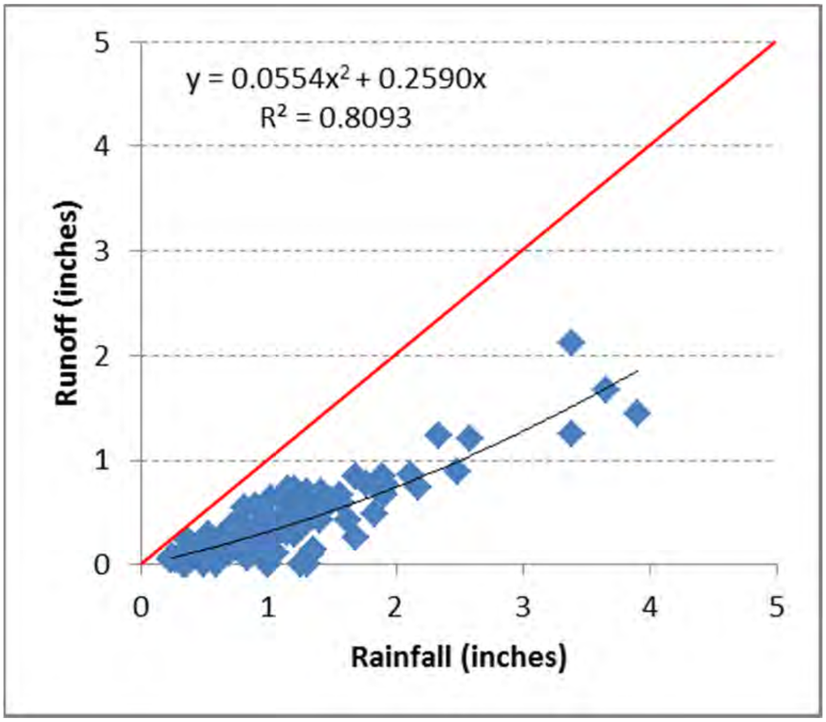

Figure 50. Rainfall to Runoff Relationship for the Duck Pond

This simple relationship can be used to develop an average estimate of how much runoff in gallons is discharged from the Duck Pond watershed for what size rainfall event (refer to Table 3). These data would be useful for anyone proposing the use of technologies such as residential rain barrels or rain gardens to be able to determine what percent of the volume could be affected. However, the use of infiltration systems must come with a word of caution in the watershed. This subject will be discussed further in the section of Thompson Spring.

Table 3. Simple Estimate of the Runoff in Gallons for a Precipitation Event

Rainfall P (in)	Runoff Q (in)	Q/P Percent	Runoff Q (gal)
0	0.00	0%	0.0
0.10	0.03	26%	622,829
0.50	0.14	29%	3,374,828
1.00	0.31	31%	7,401,358
2.00	0.74	37%	17,409,527
3.00	1.28	43%	30,024,507
4.00	1.92	48%	45,246,296
5.00	2.68	54%	63,074,896

The duck pond also has a thermal impact on Thompson Run and in the summer can rapidly increase stream temperatures or in the winter rapidly decrease stream temperatures. Impacts in the summer are of most concern because the duck pond warms from solar radiation and then during storm events, runoff pushes the warmed water out of the pond and into the stream. For this reason, many people concerned with fish health would like to see the duck pond removed; however, it serves as an excellent settleable solids remover and this function would need to be replaced since Spring Creek is defined as being impaired due to sediments. The University has evaluated lowering the duck pond water surface elevation thereby creating a wetland condition while still maintain the dam. This would provide a little detention storage during storms.

Bathgate Dam Data

The Bathgate Watershed is located at University Park, Centre County, Pennsylvania. The watershed 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 normal pool area of approximately 1 acre in size. The maximum storage capacity is approximately 74 ac-ft. The dam discharges to 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 watershed is a mix of developed campus areas (Beaver Stadium, the Jordan Center, Holuba Hall, the Multisport Indoor Complex, and parking areas), and open fields. A large portion of the open fields are used six or seven times a year for football parking events. The Bathgate Dam is designed for a maximum impervious area of 95.9 acres. The Imperviousness in the watershed at the end of 2010 is 83.4 acres. There are over 7.5 miles of storm drains in the Bathgate Watershed 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 fabric-form concrete swale with an average slope of 4.8%. Since late 2006, the University has instituted a continuous discharge-monitoring program at the Bathgate Dam.

Figure 51 below shows the discharges from the Bathgate Dam since 2007. These flows are directed to Millbrook Marsh and do not affect the Clasters’/Clark Motors sites. However, similar to the Duck Pond, one can see that the summer of 2013 produced some of the most significant runoff events from the dam. The event of 6/27/2013 resulted in a runoff event significantly higher than any other event recorded, and the 2nd highest event was the 7/10/2013 runoff event that was the 3rd highest discharge from the Duck Pond.

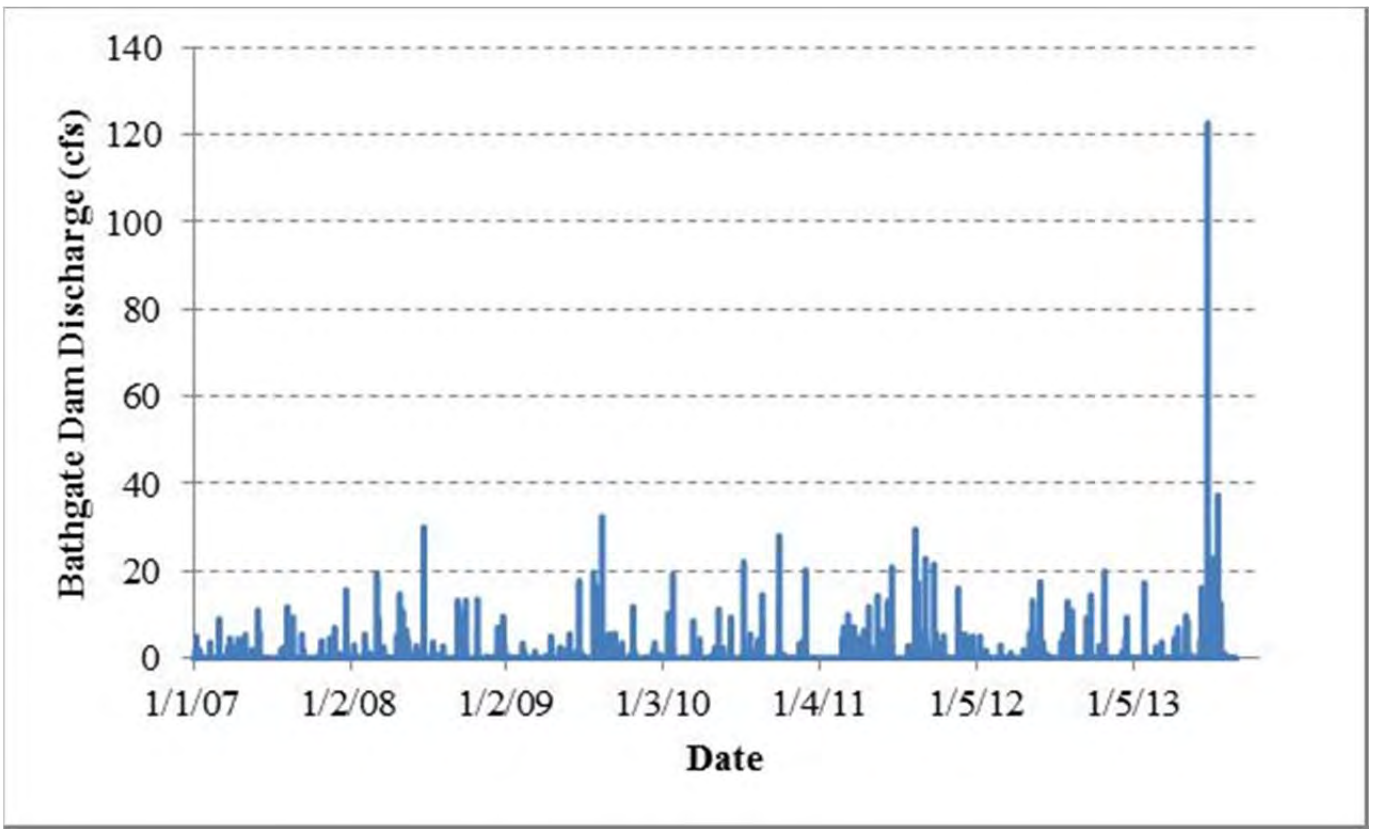

Figure 51. Bathgate Dam Discharge from 2007 through 2013

Thompson Spring Data

The discharge from the spring has been recorded at 5-minute intervals since June 29th, 2007, with the exception of Jan 1, 2010 to Sep 2010 due to the old flume failure. The discharges over this period of time can be seen in Figure 52. The University has a permit to draw water continuously (approximately 330 gpm) from the spring for non-contact research activities. This water is returned back to the stream via the Duck Pond bypassing the Parshall Flume. The small spikes seen in Figure 52 represent the University turning off the water circulation system for maintenance. Large spikes in Figure 52 represent quick flow increases, which are discussed in a following section. From the graph it appears that the spring flow increases also respond to large precipitation events. The large doubling flow event when the old flume was still in use occurred in response to the March 5th 2008, rainfall event of 2.34" with approximately 5" of snow on the ground. The Old Flume average annual spring discharge appeared to be approximately 2,000 gpm (2.9 MGD). The reason for the increase between the old and new flumes was that the old flume was supported on number 4 rock and a significant amount of underflow was occurring that could not be seen due to the plunging flow of the flume. The new flume was the exact type and size of the old flume and was reset over a more impervious embankment core. The average discharge of the spring since the new flume was installed is 4,700 gpm (6.8 MGD). The large increase seen after the new flume was installed was for the runoff event of June 27th, 2013. In personal communications with Dr. Richard Parizek, he indicated that the new flume flow magnitude is in the range of his previous historical research findings.

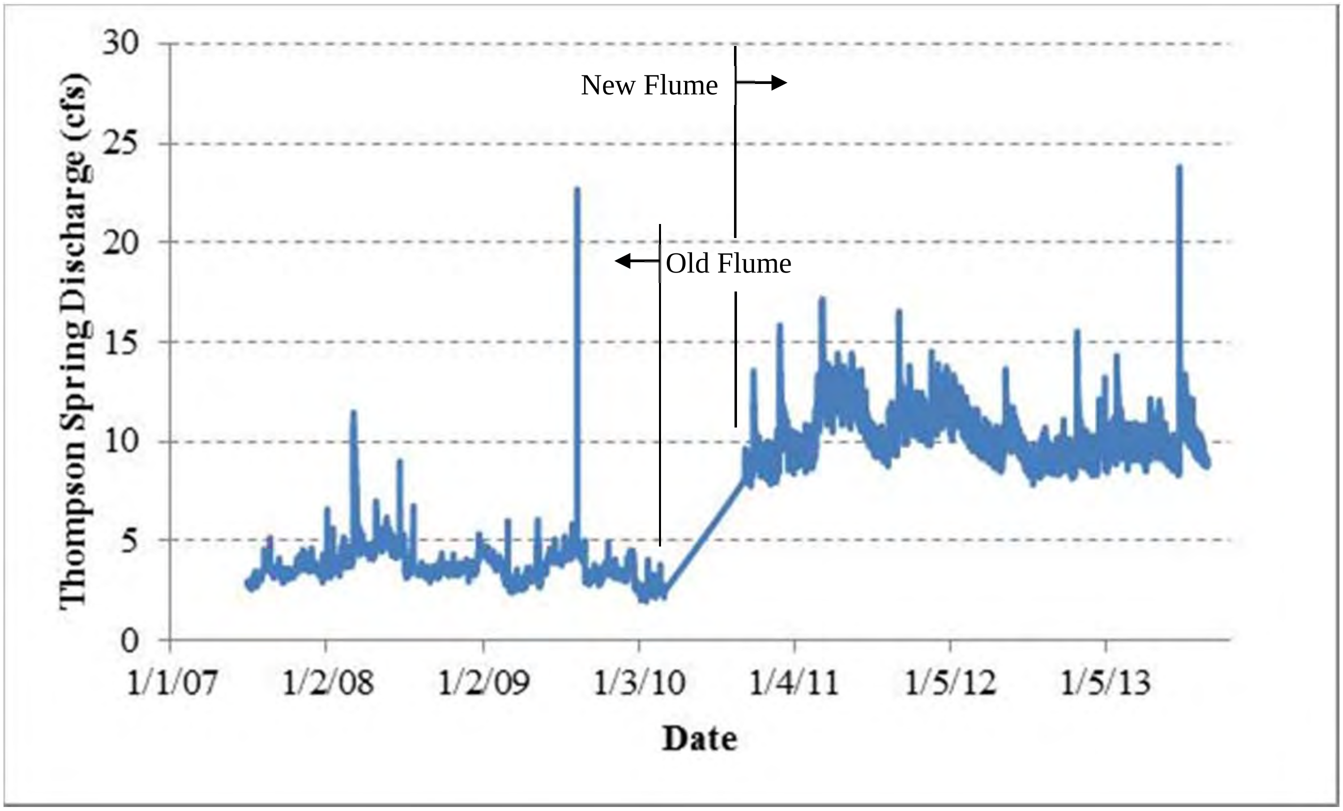

Figure 52. Spring Discharges

The University has extensive historical records regarding the Thompson Spring's flow and water quality. The first documented flow studies in the University's possession were for the construction of the Duck Pond in 1928, Table 4 reports documented studies of the spring's flow and water quality. Extensive additional data were collected over the years by faculty and students as part of research projects. These data will be added as they are located. The new flume data show much higher maximum spring flow events. The reason for this is historical data estimates are likely from incremental periods of time. Current data are collected continuously even during the significant rainfall events. Of special note is that the event of 6/27/2013 reached the maximum elevation of the weir and may have been slightly higher during the data interval.

Table 4. Water Quality and Flow Data for the Thompson Spring

Year	Min (cfs)	Max (cfs)	Min (GPM)	Max (GPM)	Min (MGD)	Max (MGD)	Data Source
1927	**5.0**	**8.5**	2244	3815	3.2	5.5	Report for original permit for Duck Pond Dam, dated 11/9/1927, not known as to the source, but Dr. Sackett designed the dam and may have made estimate
1929							J.G. White Report 7/8/1929, no flows but did WQ sampling; "tests show the water to be so grossly polluted that it should not be considered as a source of public water supply…"
1932	3.6	7.9	1597	3542	**2.3**	**5.1**	Data collected by R.R. Cleland from 1931 to 1933, showed spring flow affected by precipitation, also did dye trace tests of the Spring
1933	5.4	9.3	2431	4167	**3.5**	**6.0**	Morris Knowles Report 1933, "The flow has been estimated by some authorities to vary from 3,500,000 to 6,000,000 gallons per day"
1955	3.1	8.3	1389	3715	**2.0**	**5.35**	Gilbert Associates Inc. report dated 12/29/1955 collected continuous data from 1/4/1955 to 9/1/1955. Graph on last day of data collection ends in a downward trend at 2.0 MGD
1955	3.1	11.3	1389	5056	**2.0**	**7.28**	Gilbert Associates Inc. report dated 12/29/1955 stated as min and max values from all his sources
1957	3.1		1389		**2.0**		OPP 1957 water study, which was a summary of all past reports calls 2.0 MGD as never less than value
1968	**5.66**	**7.03**	2540	3155	3.7	4.5	Actual recorded values from the 24" Parshall Flume, represents 27 values from 7/28/1968 to 2/17/1969
2008	3.2	12.2	1436	5475	2.1	7.9	Old Flume OPP data from 6/29/2007 to 12/03/2009 using continuous 5-minute records that count Parshall Flume flows, reactor use and estimate leaks at spring pool
2013	**7.7**	23.8	3480	10661	5.0	15.4	New Flume OPP data from 9/9/2010 to 9/02/2013 using continuous 5-minute records

Bold values are those actually reported in the study, others are conversions.

OPP conducted an analysis of four moderate rainfall event quick flow responses (rises in the flow from precipitation) in 2007 that indicated that an impervious area of approximately 36 acres in size is responsible for the moderate flow event changes seen at the spring. This area is very close in size to the documented impervious area for the Memorial Field sinkhole (HRG estimate 30.7 acres), which OPP believes may be the source of part of the quick flow. (Note the bottom elevation of the Memorial Field sinkhole is 1100 ft, the Thompson Spring pool elevation is 996 ft and the distance between the two features is 5,120 ft, which works out to approximately a 2% slope between them). One of the four quick flow events analyzed can be seen in Figure 53 (refer to the following WRP for the entire analysis: http://www.opp.psu.edu/services/eng-resources/OPP-WRP-SW-TS-1-2008.pdf). The lag time between the precipitation events and the indicated quick flow is approximately 10 to 15 minutes. OPP is continuing to study these phenomena to determine the source using die trace studies.

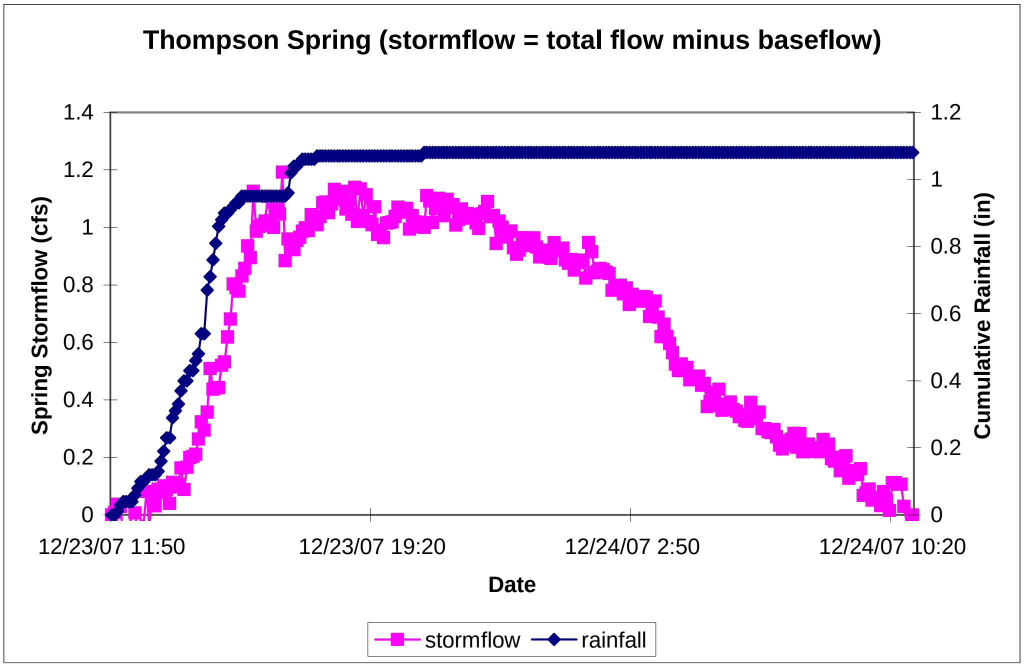

Figure 53. Rainfall Event of 12/23/2007 - 1.08”/6 hrs, 0.22”/15 min
Q = 1.2 ac-ft, rain, air temp around 40’s

It’s not known if quickflow may have increased historically due to development and sinkhole discharges, because the issue is extremely complex as illustrated in the following three figures that show the three largest event driven flow changes at the spring. The March 5th 2008 runoff event increased the spring flow from 1,874 gpm to over 5,100 gpm in 16 hours, with an event Lag time of approximately 10 hours. This increase in flow would have been from a very large contributing area significantly larger than the 36 acre area related to the previously discussed quickflow events (refer to Figure 54). This event appears to have been generated slowly from the entire springshed.

Figure 55 shows the event of 8/12/2009, which resulted in the 2nd most significant quickflow response at the spring. This event was a warm quick high intensity rainfall event of only 1.9 inches, which did not result in generating runoff from most pervious areas. As can be seen, the spring flows quickly return to pre-event conditions.

Figure 56 shows the event of 6/27/2013, which resulted in the most significant quickflow response at the spring. This event was also a warm high intensity rainfall event; however, it was 3.38 inches of rainfall over a very short period of time that resulted in generating rare surface runoff from almost all pervious areas. Like the March 2008 event, the spring flows took a long time to decay and did not soon return to pre-existing discharges.

There is no known estimate of the maximum capacity of the Thompson Spring and while it is considered by local hydrogeologists to be diffuse bedrock driven system, it clearly has highly formed conduit flow near the spring as observed in the quickflow data.

Future stormwater infiltration requirements may have the effect of increasing spring flows in the area. Likewise, the increased use of engineered infiltration systems (such as PADEP regulations require), may result in little benefit with large sinkhole potential risks.

Finally, one should note that the spring high flows represent approximately 1/5 of the culvert inlet capacity at the Clasters’ culvert, and almost 1/3 of the friction control capacity of the culvert.

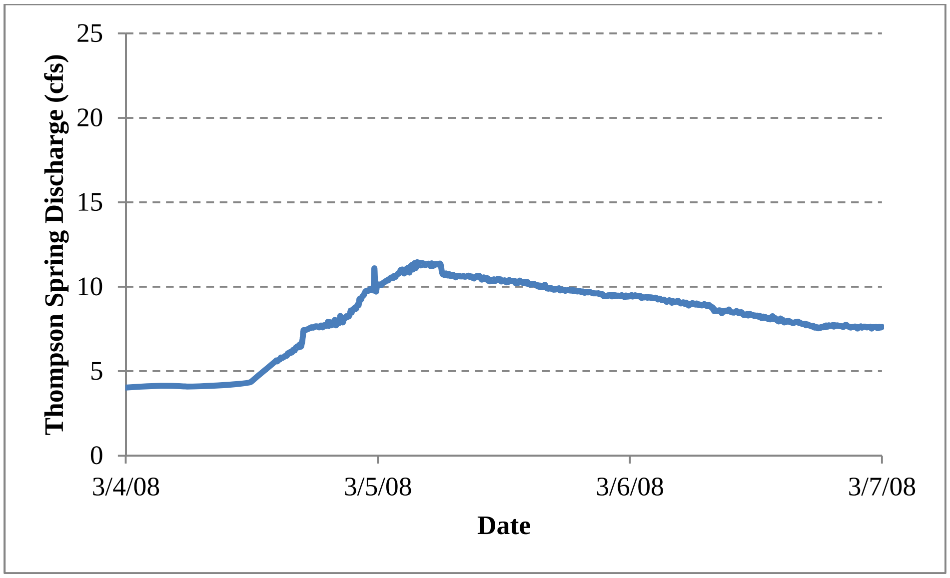

Figure 54. Spring Flow Response Due to a Major Snow Melt Event

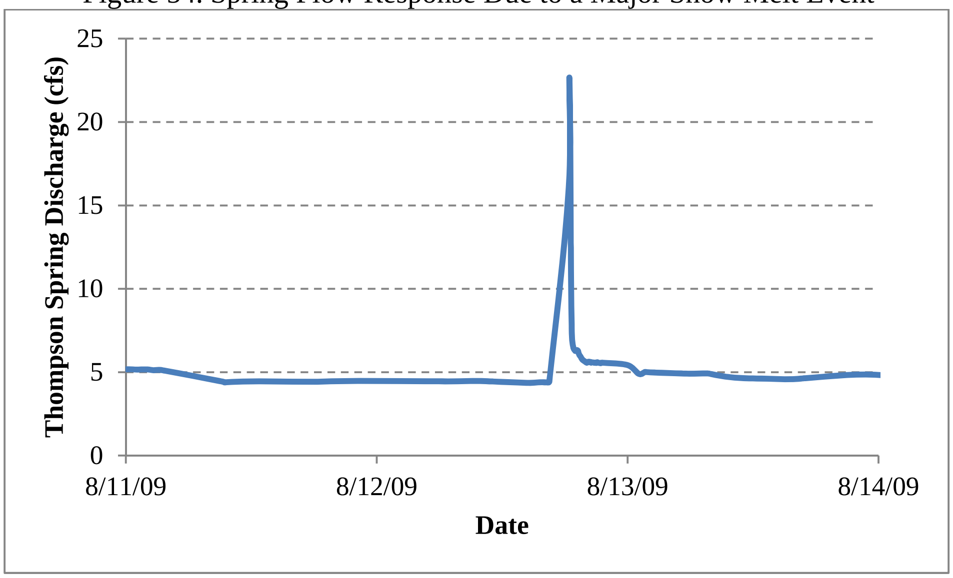

Figure 55. Spring Flow Response Due to a Small High Intensity Rainfall Event

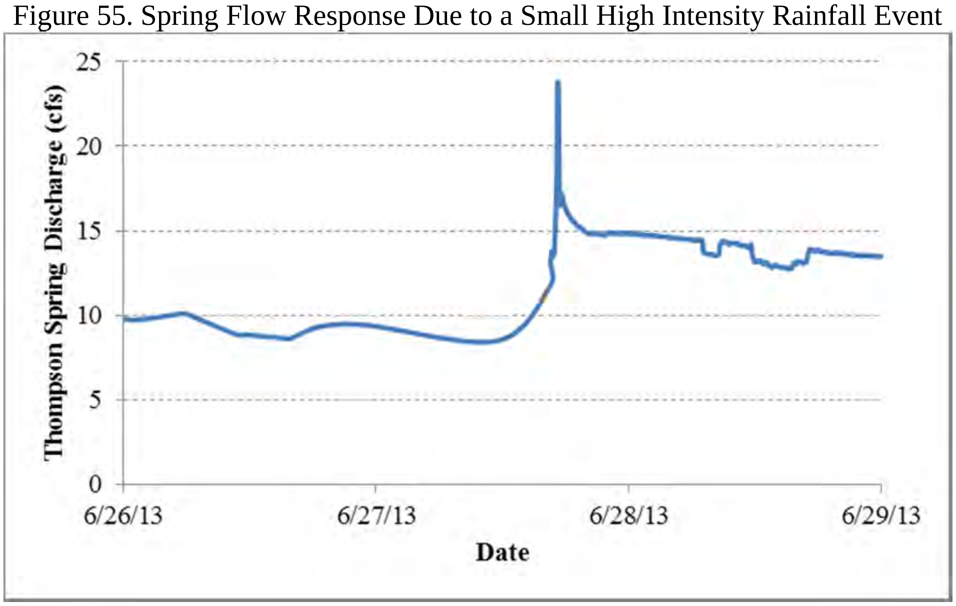

Figure 56. Spring Flow Response Due to a Large High Intensity Rainfall Event

WRMP Walnut Run Upper Data

The Water Resources Monitoring Project (WRMP) is a locally funded partnership first organized by the Spring Creek Watershed Association. Currently 18 surface water gages are monitored in the Spring Creek Watershed and several gages have been in service since 1998. At the current time many of the WRMP gages are extremely accurate for baseflow conditions and at some locations stormwater event peak estimates are reasonable. However, since the rating curves are developed under only baseflow conditions, sometimes a small change in the rating curve for baseflow may result in significantly different estimates for storm event peaks. The Thompson run gage located immediately below the bridge on College Ave is one such example. It would be an excellent gage for determining the effect of the flooding at the old Clasters'/Clark Motors sites; however, current peak runoff estimates are not suited to that purpose yet.

In 2008 the University, the Borough, College and Ferguson Townships funded the WRMP to install three additional gages on Walnut Run with data to be collected at 5 minute intervals. Two of the locations present the same high flow problem estimation as previously discussed; however, the Upper Walnut Springs gage can be used for estimates. While this location is not ideally suited to gaging, because it is a weir structure installed by the Borough, a reasonable estimate (+-30%) can be made (refer to Figure 57). From 2008 to 2011 the data collection interval was 30 minutes, which was not adequate for peak runoff rate estimation. Figure 58 shows only events collected at 5 minute intervals through July 2nd 2013; and therefore, do not include the events of 7/7/2013 and 7/10/2013. However, again in the two year record shown, the 6/27/2013 event resulted in the highest peak discharge of approximately 200 cfs, which is significantly less than the duck pond peak discharge.

If the Duck Pond Discharges and the Walnut Run Upper gage discharges are simply combined for the 6/27/2013 event without routing, the resulting discharge to the Clarks'/Clark Motors site is approximately 1,000 cfs as seen in Figure 59. This combination would also neglect an area of approximately 245 acres that drains below the gages and above the College Ave bridge.

Figure 57. The WRMP Upper Walnut Run Gage Site (note gage on left)

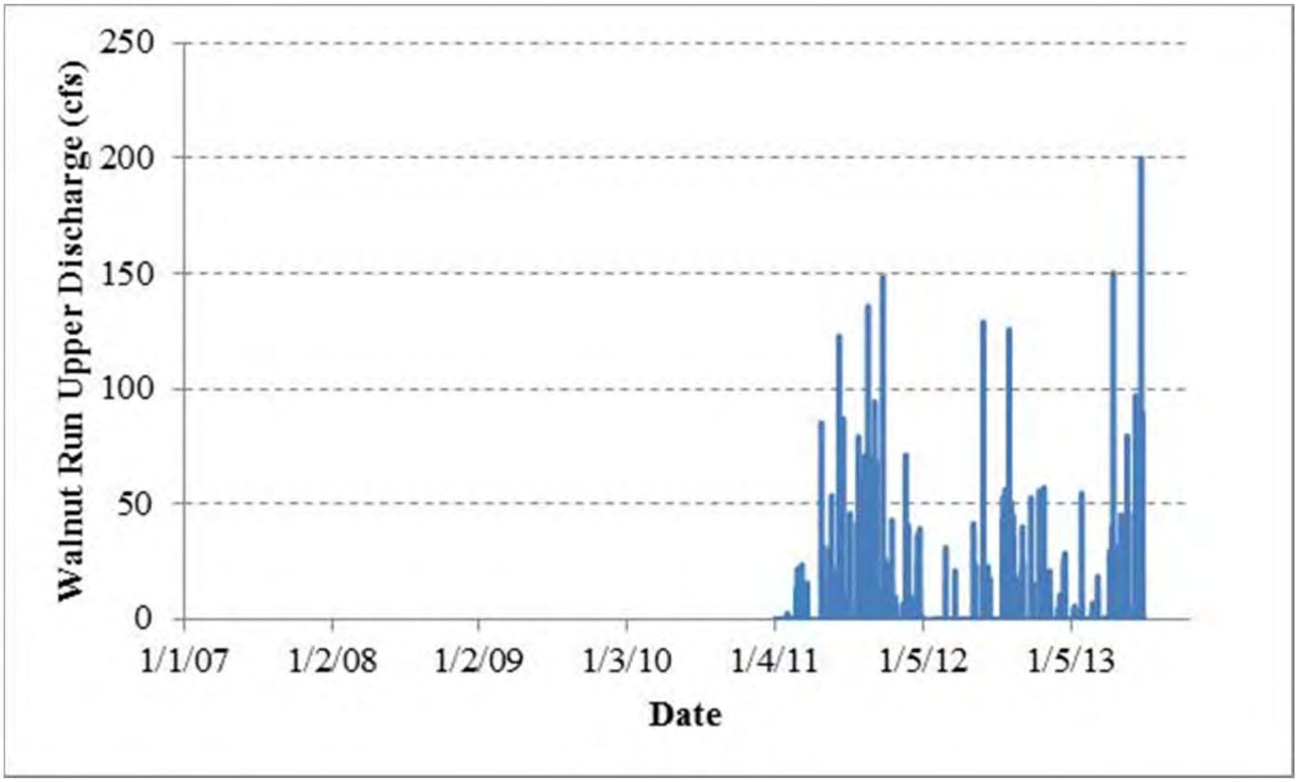

Figure 58. Upper Walnut Run Peak Discharge Estimates

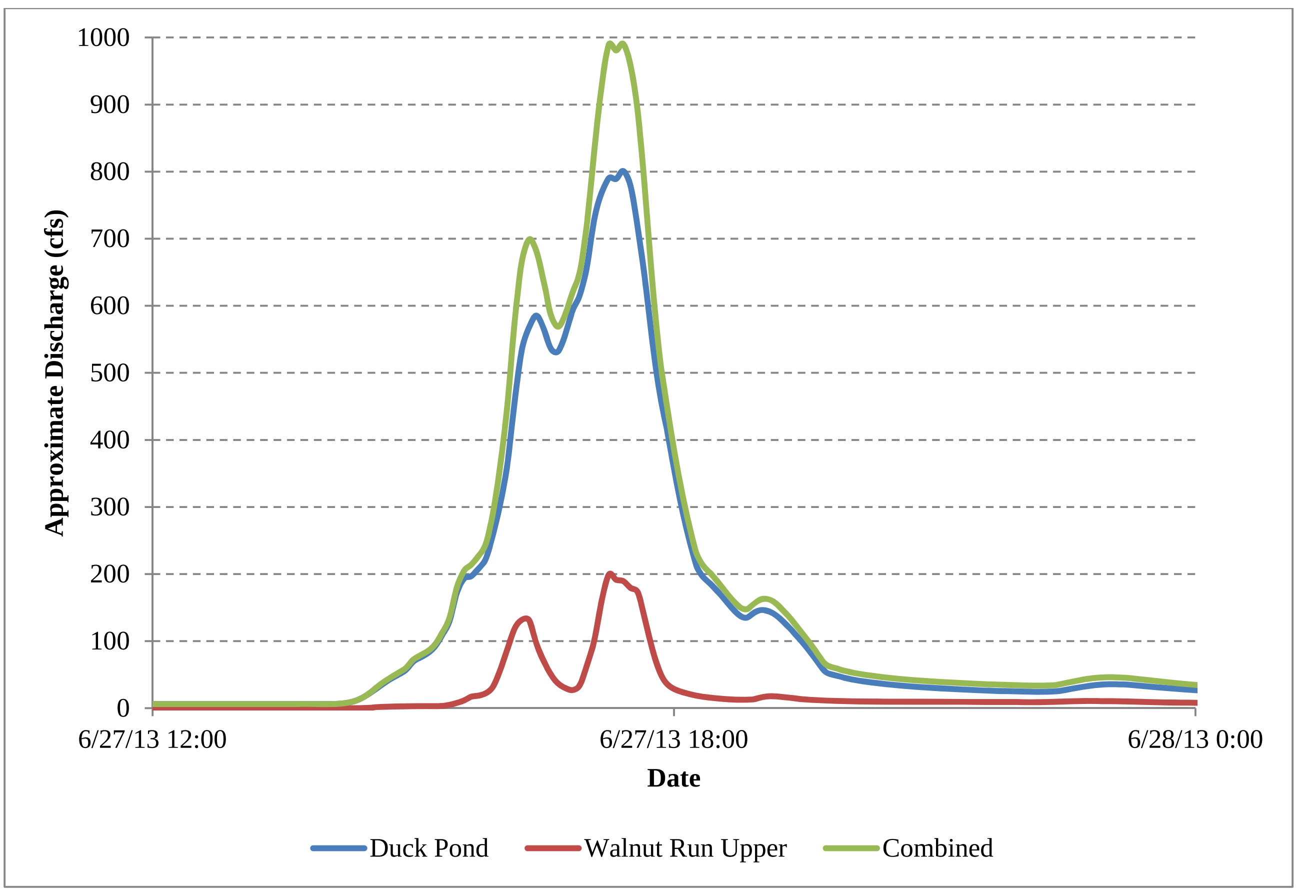

Figure 59. Duck Pond and Walnut Run Upper Outflows Combined

USGS Houserville Gage Date

The USGS gage at Houserville was installed in 1984 and has a drainage area of 58.5 square miles and drains Spring Creek, Slab Cabin Run and Thompson Run. The measured flood of record is 2,370 cfs during the January 1, 1996 snowmelt runoff event.

The USGS annual maximum water year data are:

2007 – 657 cfs
2008 – 964 cfs
2009 – 274 cfs
2010 – 648 cfs
2011 – 692 cfs
2012 – 404 cfs
2013 – 830 cfs (June 27th 2013 provisional estimate)

Figure 60 shows the instantaneous peak runoff rates at the USGS's Houserville gage. If we assume that the Thompson Run Watershed is 4.64 sq.mi. in size than it would represent approximately 7.9% of the watershed area; however, the peak runoff rates shown in a portion of the watershed alone (Duck Pond and Walnut Run Upper) are as high as the complete peak. Since the WRMP has data available, one could use the data to determine what portion of flow comes from where and what possible peak attenuation is gotten in some flood plains. The Houserville gage could be used for estimate calibration.

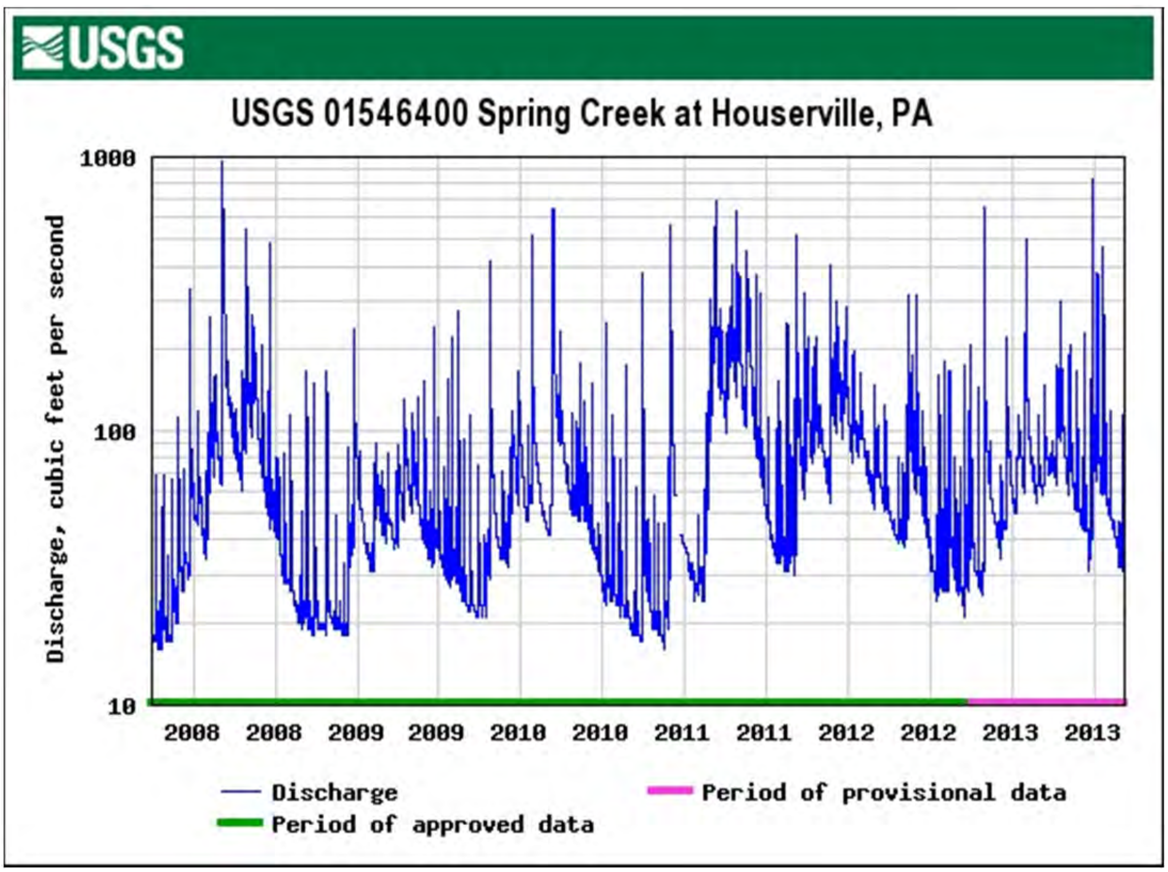

Figure 60. USGS Houserville Gage Peak Runoff Rates (cfs)

Likely Outcome of Removing Clasters' Culvert

For 30 years or more, the community has actively discussed and looked for solutions to the flooding at College Ave and the Clasters/Clark Motor sites. Typical photographs of the flooding can be seen in Figures 61 through 63 below. The simple answer is that the problem culvert is much too small and needed to be replaced; however, this would impact the ability of the Clasters' site to provide adequate parking without major alterations to the site, or incurring a large cost for installing a larger culvert. This is the same design issue that resulted in Clasters installing the pipe where it is in the early 1960s. Since no resolution has ever been come up with even though the flooding creates manpower requirements and poses a significant life safety issue, the correct answer to the problem is likely what no one wants to hear.

The University has a vested interest in how the flooding is remediated. In 2002, the University was a potential funding source for conducting a watershed study. Recent litigation has resulted in determining that Small Municipal Separate Storm Sewer Syetem (MS4) permits (which the University holds) may be responsible for problems caused upstream. Therefore, if a future problem occurs downstream in the Millbrook Marsh (the University's property), the University may be liable for repairs, especially since a portion of the flows comes from the University's property. The reason this issue has been brought up is because the current flooding along College Ave is similar from a peak runoff rate perspective to a detention pond. Until the roadway is fully overtopped, which does not occur that frequently, all discharges that exceed the capacity of the culvert, back up in the channel and are kept below the inlet or friction capacity of the culvert. In other words, a discharge of approximately 100 cfs, which is exceeded on average monthly, becomes the maximum discharge downstream. Simply removing the culvert could potentially create stream instabilities downstream. In other words, the flooding along College Avenue is likely protecting the downstream channels and marsh from being degraded. One needs to weight the repercussions of potentially transferring the problem to different land owners downstream.

Flow velocities through the Clasters' culvert range from approximately 4 to 7 fps (feet per second). When flooding occurs, overland flow velocities are reduced generally to less than 2 fps. More importantly, large areas of ineffective flow occur where the flow velocity is near zero, similar to what occurs in floodplains. These ineffective flow areas can be observed to some degree in the following photographs and would occur primarily in and around the Clasters' site. Accounting for the loss of these ineffective flow areas needs to be done if the culvert is removed or upsized.

Figure 61. Flooding at Your Building Center due to the Culvert

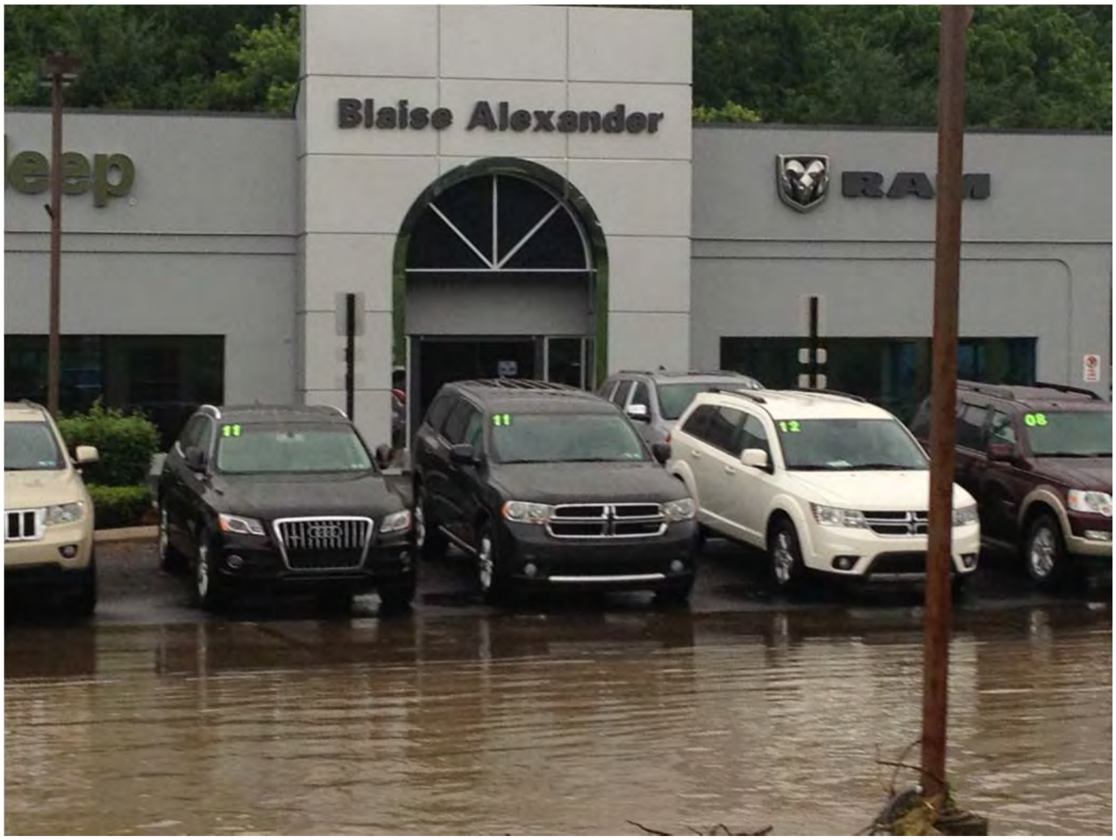

Figure 62. Flooding in Front of Blaise Alexander Auto Showing Ineffective Flow Areas

Figure 63. Flooding in Front of YBC, at the peak of the 6/27/2013 water is said to have been over the cars wheels

Stable channels are formed in response to the dominant stream discharge the stream experiences, which is generally thought to be around the 2-year event discharge. If the current flooding is stopped along College Avenue, the peak runoff rate will be increased downstream essentially increasing the 2-year event discharge. Degradation by stream bank erosion will be the likely response. A photograph of the downstream channel, which is mostly on private property, is shown in Figure 64. Figure 64 also shows recent scour along the right bank from the events of June and July 2013.

The culvert has created a hard point that does not allow unstable processes occurring upstream to pass to the downstream area. Therefore, in order to remove the culvert, a comprehensive analysis needs to be conducted that evaluates the peak runoff rate effect of the flooding. Such an analysis could actually help to show not only what the resulting destabilizing processes might be, but it could also help to provide a sense of what would need to be done prior to removing the culvert to prevent destabilizing. Once the culvert is removed, it will be very difficult to stop the unraveling of the streambed.

Intuitively, one would guess that either one or both of the Clasters/Clark Motors sites would need to be removed and returned to flood plain. Removing the culvert to remedy flooding at these two sites without such an analysis should be prohibited. Such an analysis would require the use of more sophisticated models. The University Office of Physical Plant previously used the HEC-RAS model to determine if an unsteady flow simulation could be conducted of the area using the duck pond outflow data. The HEC-RAS simulation shown in Figure 65 was calibrated from high water marks (refer to Figure 66) during the 8/12/2009 runoff event. This modeling effort also showed that adequate survey data did not exist to accurately model the reach because of an elevation bust between the Clark Motors and Clasters' site plans; and therefore, a comprehensive survey should be one of the first steps when undertaking a remediation plan.

An additional consideration to accelerating the velocities through this area is the possible impact east of the bridge under College Avenue. Prior to PennDOT removing part of the culvert's end, flooding frequently went past the bridge and caused flooding of the adjacent properties including the Battery Shop. With the removal of part of the culvert, this flooding no longer occurs. Since the majority of flow is from Thompson Run intersects the bridge at 90 degrees, a possible negative consequence is that flooding could again occur to these properties if larger peaks jump the bank.

As a community member, and a contributor of runoff to the flooding, the University should be an active participant for all major improvements downstream of its properties.

Figure 64. Channel Downstream of College Avenue Bridge

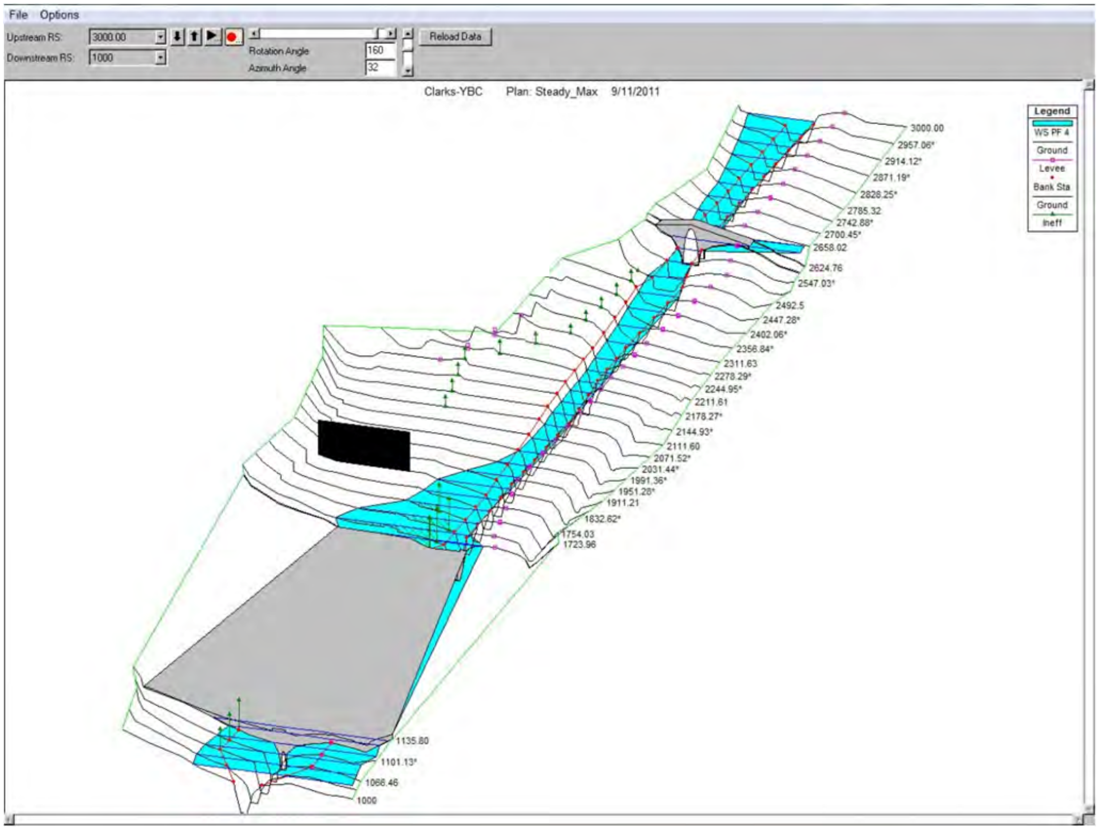

Figure 65. 3D view of a HEC-RAS Model Simulation at the Clasters/Clark Motors Site

Figure 66. High Water Mark (11”) from 8/12/2009 Event on the West Side of the Your Building Center Building

Publisher: Penn State University, Office of Physical Plant, Energy and Engineering Division, Engineering Services
Editor: Larry Fennessey, OPP Stormwater Engineer, Ph: (814) 863-8743, email: laf8@psu.edu