SECTION IV: CONCEPTUAL STORMWATER BEST MANAGEMENT PRACTICE ANALYSIS

A. Potential Stormwater Best Management Practice Sites

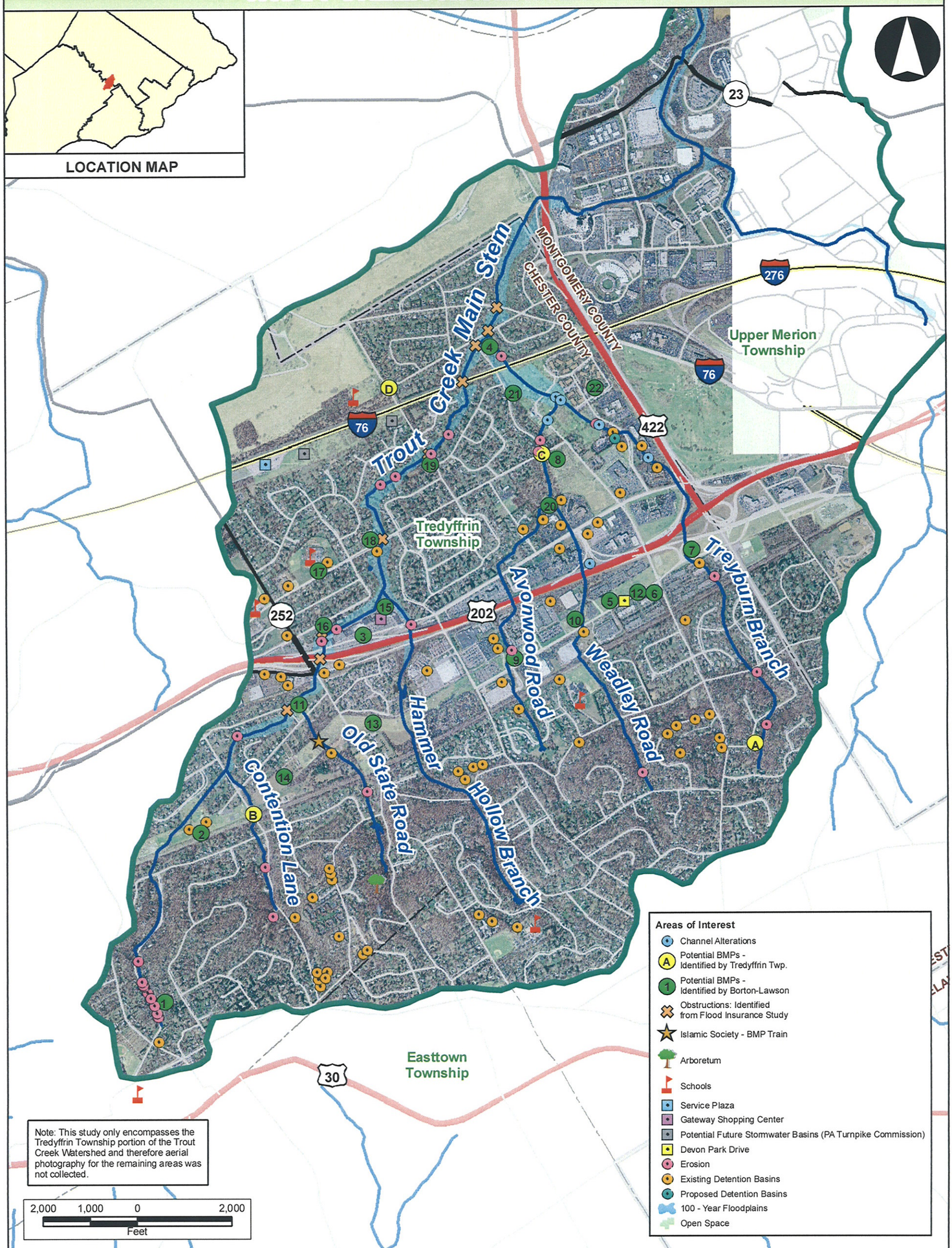
After completing Task I of the project, twenty-two individual sites were identified as potentially good candidate locations for consideration as prospective sites for installation of stormwater best management practices (BMP) to better manage stormwater runoff in the Tredyffrin Township portion of the Trout Creek watershed. These sites were identified based upon the data presented in the Trout Creek Watershed Restoration Plan, observation of the watershed during field views for the study, discussions of stormwater management issues related to the Trout Creek Watershed with Township personnel, consideration of existing problem areas within the watershed and a list of potential stormwater management projects identified previously by the Township. Map IV-1 is a watershed map showing the location of the conceptual BMP sites with respect to existing key features such as floodplains, stormwater management controls, erosion problem areas, and channel modifications. Table IV-1 contains the list and brief description of the twenty-two sites selected for initial consideration along with the initial selection rational. Each of these initial twenty-two stormwater BMP locations were identified based upon, their capability to restore the creek and its tributaries, their ability to protect the watershed or mitigate some of the existing problems (flooding, streambank erosion and water quality) within the watershed, or their potential to act as a demonstration project to promote the installation of other BMPs within the watershed.

B. Ten Conceptual Stormwater Best Management Controls

The initial list of 22 sites was narrowed to 10 locations for conceptual evaluation and further assessment. The top ten sites were selected by Township personnel with input from the project team based upon a general qualitative assessment of the following issues:

- Opens Space – identify locations where existing open space is available that could be converted into a stormwater BMPs, locations where a BMP could be constructed to augment existing open space or locations where BMPs could be placed that would work in conjunction with existing uses and not significantly alter the existing use of the site or adjoining properties.
- Location – provide one site in each of the major tributaries to the main stem of the Trout Creek (un-named tributaries are identified by the name of a nearby street that crosses the tributary).
- Benefits – identify the type of benefits each site is capable of achieving (i.e. local or regional) and select those projects the greatest benefit to cost ratio.
- Property Ownership – categorize each of the sites by ownership and provide preferential treatment to those sites that are either owned by the Township or another government entity, or a land owner that is willing to cooperate with the Township.
- Stream Conditions – identify sites that are hydrologically connected to points within the watershed that are suffering from the most severe stormwater related problems for locations that could be used to improve existing conditions.

TREDYFFRIN TOWNSHIP
TROUT CREEK WATERSHED STUDY



Map IV-1
CONCEPTUAL BMP MAP

Prepared For:
Tredyffrin Township
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Legend
- Watershed Boundary
- Water Bodies
- Streams
- Interstates
- U.S. Highways
- PA State Routes
- Other Roads
- Municipal Boundaries
- County Boundaries

NOTE:
Portions of this map were generated from existing data sources as listed below. These data are shown on the map for spatial reference only. These data did not enter into any computations or affect the reliability of the hydrologic analysis. Borton-Lawson Engineering has found some inaccuracies in some of these data and has corrected the data in locations where discrepancies were obvious, however, it was not a part of this plan to correct all of the mapping data.

DATA SOURCES:
Watershed Boundary - PADEP (Modified by BLE)
Aerial Photos - Tredyffrin Township
Streams - PADEP
Water Bodies - USFWS (Derived from NWI Wetlands)
Roads - PennDOT
County and Municipal Boundaries - PennDOT
Problem Areas - Tredyffrin Township; The Ratsep Group
Stormwater Facilities - Tredyffrin Township; The Ratsep Group

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PREPARED BY: SJD CHECKED BY: SAV
DATE: 9/18/2007 PROJECT #: 2007-2196-00

FILE:\\WB\Data\Projects\2007\2196\00\DATA\GIS\ARCMAP\TroutCreekFinal.mxd

Table IV-1

Trout Creek Watershed Best Management Practice / Stormwater Retrofit Projects

ID NO.	Branch	Location	Problems to Resolve	Selection Rational	Notes / Considerations from Township Meetings	Primary Project Type	Secondary Project Type	Regional Benefit (Y/N)	Ownership
1	M	Old State Road Road [Cassatt Rd (PADOT) to Hickory & Orchard Way]	Channel Erosion	Initial screening suggested presence of an existing upstream detention basin that could potentially be retrofitted to improve several downstream streambank erosion areas.	Upper Watershed is Main Branch - Twp has already identified areas in need of storm sewer and infrastructure rehab/replacement/upgrade, possible BMPs, and stabilization near numerous eroded areas. Residential house flooding from runoff and groundwater, bank erosion near roadway in several locations. Opportunity for residential retrofit program / educational initiative (homes drain to steep slopes).	S	R	Y	T, Pr
2	M	Teegarden Park (Westwind Drive)	Downstream Flooding	Two existing basins and large open space area, located in a park for potential educational opportunities	Township Park along Main Branch of Trout Creek. PECO has aerial ROW in Park. Drains to residential areas with bank erosion and localized flooding issues. Site of GG Grant Stream Stabilization Design by FX Browne	R	ED, P, B,	Y	T, U
3	M, H	Gateway Shopping Center (Parking retrofit)	Unused Parking Area Encroaching Stream	Site directly adjacent to a Trout Creek Tributary with a large impervious area and potentially unused parking at the side and rear of the building	Large amount of impervious coverage with parking and buildings with little to no SWM. Trout Creek on 3 sides of developed area. High public exposure site potnetially work with store owners trader joes?	R	P, B, S, G	N	Pr
4	M	Richards Road and Glenhardie Road Culvert	Flooding	Known obstructions with regular flooding and maintenance issues.	Serious Area of Flooding, sediment deposition, and routine and emergency maintenance and road closures. Could new bridge design provide measureable benefit vs. cost, reduce Twp maintenance expenditures, and reduce flooding ? ? Public works has to clear sediment several times / year at significant cost. Evaluate impacts of projects 1, 2 in terms of reducing peak flows vs. culvert capacity	C	S	Y	T
5	We	Devon Park Drive Open Area	Nonpoint Source Pollutants from Devon Park Drive	Large grassy area adjacent to Devon Park Drive with a considerable portion of unused open space that could be incorpated into a BMP	drains to key problem areas	R	P, B, Ed	Y	T, Pu, U
6	We, A	Devon Park Drive Streetscape	Nonpoint Source Pollutants from Devon Park Drive	Extra-wide roadway, with additional width that could be converted into boulevard style roadway with adjoining BMPs for stormwater control.	Reduction of roadway width (impervious) combined with BMP Retrofit (Bioretention area) in center of street. Short term vs long term workin with redevelopment through new comprehensive plan to encourage developments to include recommendations for Devon PArk Drive to either reduce width and impervious coverage, add Green space , and incoporate SWM BMPs. need to define base cross section for model	B	R, Ed	N	T
7	T	S.R. 202 Interchange	Armored Downstream Channel, Impervious Channel, Highway Runoff	Large unused area adjacent to the highway available for use as a stormwater BMP	drains to key problem areas	R	Ed, W	Y	T,U
8	Wa	Richter Property	Downstream Flooding and Erosion in the Vicinity of Walker and Glenhardie Road	Large undeveloped parcel downstream of a commercial area that could be used as a regional basin to reduce flows around Walker and Glenhardie Roads	Twp needs to consider all alternatives and Benefits vs. Costs for Land Acquisition as well as culvert and BMP design and construction. southern parcel for sale (10.47ac). Northern parcel is focus. Look at range of storms to improve stormwater conveyance in the vicintiy of Walker Road.	R	W, Ed, C	Y	Pr
9	A	Devon Park Drive Natural Area (north of adjacent to Avonwood Branch)	Nonpoint Source Pollutants from Devon Park Drive, Sediment from Upstream Area	Available open space adjacent to tributary that could be converted into a SWM BMP	drains to key problem areas - Green areas adjacent to Creek possible BMP areas	R	S	Y	U
10	We	Devon Park Drive Natural Area (north of adjacent to Weadley Branch)	Nonpoint Source Pollutants from Devon Park Drive, Sediment from Upstream Area	Available open space adjacent to tributary that could be converted into a SWM BMP	drains to key problem areas - Green areas adjacent to Creek possible BMP areas	R	S	Y	U
11	M	Coldstream Drive	Flooding	Location of known obstruction	Private Ballfield and Residential properties outside Twp roadway ROW. Area located withing FEMA floddplain and experiences localized flooding and bank erosion.	C	R	Y	T, Pr
12	We, A	PECO Right of Way (East of Valley Forge Road)	Downstream Obstructions and Flooding	Considerable unused open space within Utility ROW which could be incorporated into a stormwater management BMP	Existing Basin in Area, Old Forge Crossing experiences existing issues	R	S, B, M	Y	Pr, U
13	S	PECO Right of Way (West of Valley Forge Road)		Considerable unused open space within Utility ROW which could be incorporated into a stormwater management BMP	Duncan Farms has lots of debris in area around stream.	R	B, Ed	Y	Pr,U
14	C, S	PECO Contention Lane Right of Way		Considerable unused open space within Utility ROW which could be incorporated into a stormwater management BMP	Site of GG Grant Stream Stabilization Design by FX Browne	R	B, W	Y	Pr, U
15	M, H	Gateway Shopping Center (Rear Area and Offline Storage adjacent to Channel)	Large Impervious Surface with Direct Discharge to Trout Creek Tributary	site is directly adjacent to Trout Creek Tributary with a large impervious area and potentially unused impervious area at the side and rear of the building	Rear Area and Offline Storage adjacent to Channel Groundwater Pollution (from Gateway Cleaners) ?	R	G, P, S	N	Pr
16	M	Tributary Between East Swedesford Road and Anthony Wayne Drive	Flooding and Erosion	site of documented erosion problem and obstruction	Gateway Greenspace - along stream corridor to Walker Rd. Floodplain.	C	S	Y	Pr
17	M	Valley Forge Middle School	None	educational opportunities, ease of buy-in from quasi governmental owner	School Approval - Provide recommendations to T/E School District for their consideration for potential future retrofit projects for Basin retrofit, Green Roof, Bioretention, Porous Pavement , etc.	M	Ed, G, P, R, B	N	Pu
18	M	Walker Road (Between Prussian Lane and Anthony Wayne Drive)	Flooding	location of known obstruction	Chester County is to replace in '08 or '09	C	S	Y	T, Pu
19	M	Thomas Road (Between Park Ridge and Colonel Dewees)	Flooding and Erosion	location of known obstruction and erosion	Chester County Bridge - Bank Erosion on both sides of structure.	C	S	Y	T, Pu
20	We, Wa	Wembley Drive (Near East Swedesford Road)	Downstream Flooding and Erosion	several existing upstream detention basins in close proximity to downstream flooding problem area identified by township	drains to key problem areas. Encourage property owners to do BMP retrofits maybe work to identify Grants to foster this work to better address SWM and reduce peak flows, especially small storms, and add WQ benefit	R	Ed, M	N	Pr
21	T	Glenhardie Country Club	Channel Alterations	location of significant channel alterations identified by Trout Creek Watershed Restoration Plan, surrounding open space	drains to key problem areas Need to discuss with propety owenr and identify areas for BMP retrofit	S	B, R, Ed	N	Pr
22	T	Drummers Lane Apartments/ Offices	Channel Alterations, Erosion, Obstructions	drainage area comprised of large impervious surfaces, limited stormwater runoff treatment	drains to key problem areas	R	B, P, R, Ed	N	Pr
23	All	Institute Model SW Ordinance with Redevelopment Controls	Long Term Sustainable SW Management	Available Land for Retrofit controls may not be sufficient to improve flooding and water quality to required levels		R,B, G, P, M		Y	

Stream Branches

A	Avonwood Drive
C	Contention Lane
T	Treyburn Branch
H	Hammer Hollow
M	Main Stem
S	Old State Road
Wa	Walkers Road
We	Weadley Road

Project Types

R	Structural BMP Retrofit (extended detention / retention / swale)
S	Stream Restoration
B	Bioretention / Streetscaping
G	Green Roof
P	Porous Pavements
C	Conveyance Improvement (e.g. increase culvert capacity)
M	Modify Existing Basin (e.g. outlet structure / vegetate for water quality)
Ed	Educational

Ownership

T	Township Owned
Pr	Privately Owned
Pu	Publicly Owned
U	Utility Right-of-Way

Wa Walker Road

Sites 1 through 10, as shown on Table IV-1 and on Map IV-1, are those sites selected by the Township for conceptual stormwater management analysis. These sites are described in greater detail in the following section of the report with specific conceptual stormwater BMPs proposed for each of the locations.

Six of the BMPs considered involve the creation of a storage facility to better manage stormwater runoff in the watershed and improve the hydrologic and hydraulic conditions within the Trout Creek and its tributaries. To test the effectiveness of the potential facilities the hydrologic model of the watershed was modified to incorporate elements into the model which reasonably portrayed the amount of storage at each of the six sites. Each of the storage areas were sized by preparing a conceptual grading plan based on five-foot contours and parcel lines showing the size of the parcels. This exercise helped to make certain that those storage facilities inserted into the model could be physically constructed at the individual sites and could be built such that water could both enter and exit the proposed storage area. Many of the proposed facilities focus on surface features, or stormwater Best Management Practices placed on the surface of the land. The reason for this is that typically these types of facilities are able to manage more stormwater than there subsurface counterparts. However, in instances where space is limited, certain of the BMPs may be placed underground in lieu of on the surface.

Four of the ten sites evaluated proposed conceptual improvements that did not offer sizeable stormwater storage. Therefore, these four sites were not evaluated using the hydrologic model of the watershed but were assessed more on a qualitative level than on a quantitative level with the hydrologic model. The hydrologic model developed for this project includes the entire Trout Creek Watershed. However, the primary area of interest for this study was the portion of the Trout Creek watershed within Tredyffrin Township and the small portion of the watershed within Easttown Township. As the main focus of this study is in the Tredyffrin Township portion of the watershed, special attention and most of the effort to develop the model focused on that portion of the hydrologic model.

C. Stormwater Best Management Practice Concept Designs

1. Site 1: Old State Road (Cassatt Road to Hickory Lane)

Tributary: Trout Creek, Main Stem

Site Description: Old State Road, situated in the southwest corner of the watershed, intersects Cassatt Road, near the drainage divide. The roadway is aligned roughly parallel to the main branch of the Trout Creek, with the waterway situated to the east side of Old State Road near the drainage divide. Approximately midway between the two intersections the stream crosses to the west side the roadway. This section of the township appears somewhat rural in appearance with many single family homes situated along the roadway on wooded lots. A photograph of the area is shown in Figure IV-1. As Old State Road somewhat parallels the main branch of the stream, the roadway is situated in a valley between two ridge lines. With the creek in close proximity to Old State Road many of the residences along the upper portion of the roadway have individual stream crossings, constructed mostly from culverts, which provide access to homes that are situated on the ridge to the east of the stream. Given the setting and the topography there are essentially no locations in this section of the watershed where a large regional stormwater management facility could be placed.

However, the somewhat deleterious effects of uncontrolled stormwater runoff in the area are evident from the streambank erosion occurring in the Main Branch of the Trout Creek.

Figure IV-1 – Old State Road (looking north)

Proposed Stormwater Management Function: With the absence of a large open area to create a regional facility in this portion of the watershed the most feasible conceptual stormwater management controls proposed for this portion of the watershed are those that can be implemented on small sites in multiple locations. The first type of conceptual stormwater management controls are individual on-lot controls intended to control the stormwater runoff from impervious areas associated with the single family residences. The average amount of impervious area created by each of the residences and their corresponding driveways appears to be approximately 6,000 square feet per parcel. Assuming a majority of the watershed was woods before being converted to residential area, the stormwater runoff for the 2-year, 24-hour event would increase by approximately, 1,280 cubic feet (9,600 gallons) per residence. To provide "Full Volume Control" one alternative to control this difference in the stormwater runoff is a seepage pit consisting of stone with a 40% void volume. However, using a 4-foot deep storage chamber, each residence would require a 800 square foot footprint to control this volume. Assuming a 2:1 length to width ratio, this would equate to a 20-foot wide by 40-foot long facility. To reduce the size of the footprint a pipe manifold consisting of 24-inch high density polyethylene pipe could be placed within the stone seepage pit. This alternative design would provide the same volume of storage and reduce the size of the pit by about 200 square feet, or reduce the length of the facility by about 10 feet.

As this size facility seems somewhat large for existing residences, a more practical alternative may be to provide incentives for the residences to install on-lot controls to remove 125-150 cubic feet of stormwater per residence. This "Reduced-Volume-Control" equates to about 1,000 gallons of storage volume per residence and was selected because prefabricated underground concrete seepage tanks of this size are common and readily attainable. Although an underground concrete structure could be used, this storage could be accomplished by any combination of means, including rain barrels, rain gardens, underground concrete seepage tanks, infiltration berms or capture and reuse techniques.

If roughly one third of the estimated 100-130 residences in the area were to incorporate volume controls, this would result in a reduction of approximately 45,000 cubic feet of volume for the "Full Volume Control" alternative. However, to obtain this amount of voluntary participation in "Full Volume Control" appears optimistic and a much more realistic amount of participation would be on the order of about 10% which would provide about 13,000 cubic feet of storage. With one third of the homeowners in the area participating in the "Reduced Volume Control" alternative a total of about 4,700 cubic feet of volume would be removed under this scenario. Table IV-2 provides the amount of volume reduction expected in the 1- and 2-year storm events for the various scenarios discussed above.

TABLE IV-2
Old State Road - Reduction in Stormwater Runoff Volume with On-Lot Volume Controls

Event	Volume of Runoff To Old State Road (cf)	Full Volume Control		Reduced Volume Control
		30% Homeowner Participation	10% Homeowner Participation	30% Homeowner Participation
		Percent Reduction in Volume	Percent Reduction in Volume	Percent Reduction in Volume
1-Year	92,000	49	13	5
2-Year	118,000	38	11	4

Since, the volume of stormwater runoff from the 1-year runoff event results in approximately ninety-two-thousand cubic feet from this portion of the watershed along Old State Road, without significant participation by a large number of individual property owners, on-lot stormwater management controls for existing residential properties is expected to result in very little notable impact upon the rate or volume of runoff to the tributary and the watershed as a whole.

As Old State Road through this section of the Township is somewhat confined by the stream channel and existing topography, applying a typical section along the entire roadway length with innovative stormwater best management practices immediately adjacent to the roadway appears somewhat impractical. This assessment is underscored by recent site observation made during 2008 storm sewer repairs conducted by the Township in which high groundwater elevations were observed beneath Old State Road. A more feasible approach may be to construct bioretention facilities at select locations along Old State Road and Orchard Road to reduce the runoff flowing to the Trout Creek. Each facility, consisting of a depressed area where stormwater may be collected and retained, would be constructed by replacing the existing soils with amended soils produced from a combination of sand, compost, and topsoil. The facility would be planted with native vegetation, which is known to thrive in such locations and would aid in the removal of excess stormwater by the processes of storage, infiltration, evaporation and transpiration.

A typical size of these bioretention facilities is estimated to be approximately 300 to 1,500 square feet in size and would be located adjoining Old State Road and Orchard Road. The bioretention areas would be designed to receive stormwater runoff mainly from the roadway with large offsite drainage areas diverted away from the facilities using roadside swales and storm sewer. Cursory observation of Figure IV-2, the aerial photograph in the vicinity of Old State Road, indicates that there are approximately 7 areas where bioretention facilities could potentially be constructed. Conceptual sites were selected based upon their location, sites adjacent to the roadway right of way; hydrology, areas outside of the direct flow path to the Trout Creek so as to not require large bypass structures; and topography, locations that are relatively flat where additional storage could be created. As the conceptual facilities are dispersed at several locations throughout the area, the concept is to provide additional stormwater management adjacent to the roadway to affect a reduction in the stormwater flow without adversely impacting any single property owner. Although there may not be enough right-of-way to construct these improvements it is conceivable that the facilities could be constructed by the Township without acquiring additional right-of-way by obtaining an easement or similar agreement with private property owners along the right-of-way.

With a drainage area to BMP size of 5:1, each 1,000 square feet of bioretention would be capable of collecting stormwater runoff from about 200 feet of road length. Assuming a total of approximately 8,000 square feet of bioretention area could conceivably be created at various locations along Orchard Road and Old State Road, with about one-half foot of ponding in each area, the total reduction in stormwater volume would be similar to the Reduced Volume Control option shown in Table IV-2. It is important to note that although each of the facilities would collect runoff from all storm events, each facility would provide the most control for the small runoff events, such as the 1- or 2-year events.

For further description of bioretention and its relationship to this project see the project descriptions for Gateway Shopping Center conceptual BMP and the Devon Park Drive streetscape. Additional information on rain gardens and bioretention BMPs is provided on the Township website and was mailed to homeowners as part of a Growing Greener Grant project for Trout Creek.

2. Site 2: Teegarden Park

Tributary: Contention Lane Branch

Site Description: Teegarden Park is a Township park located in the southwestern portion of the watershed. The park borders the Main Stem of the Trout Creek on its western border and the Contention Lane tributary on its eastern border. It appears to be well maintained and consists of several ball fields, tennis courts, basketball courts, grassy areas and a parking lot. There are no sizeable stormwater management storage facilities located at the park. A photograph of a portion of the park in the vicinity of Contention Lane is provided in Figure IV-3.

Proposed Stormwater Management Function: Since most of the park is used for recreational purposes it is difficult to provide a regional stormwater management benefit without disrupting the recreational uses of the park. Therefore, a somewhat less used smaller area at the east side of the park along Contention Lane was identified as the best location for a stormwater management feature. This location was selected because of its limited

FIGURE IV-2 Site 1 – Old State Road

FIGURE IV-3 – Teegarden Park
(looking southeast toward Contention Lane)

recreational value and its close proximity to the Contention Lane Branch of the Creek, where water from the tributary could be diverted into the stormwater management facility and then returned to the same tributary below the site. Three different management scenarios where evaluated at the park. Scenario A considered the effects of diverting the entire flow from the Contention Lane tributary into the proposed storage area creating an on-line facility. Scenario B considered reducing the drainage area to a fraction of the total drainage area to yield a more manageable amount of stormwater runoff, thus creating an off-line facility. Scenario C considered a variation of the on-line option, diverting only a portion of the flow from Contention Lane Tributary into the proposed facility. This could be accomplished by placing weir-like diversion structure within Contention Lane Tributary, thereby keeping a majority of the flow in the existing channel. As the site appears to be in the right-of-way for the electric utility, special grading accommodation would be required for the storage facility in order to not interfere with its existing function. For the performance evaluation the storage for each of the scenarios was identical and only the orifice size was varied to maximize the amount of storage in the basin. See the aerial photograph provided in Figure IV-4 for the conceptual site layout and Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process. As the soils within the area are classified as Hydrologic Soil Group B, the area may be a suitable location for infiltration facilities which would reduce the volume of runoff for more frequent runoff events.

Although this evaluation focuses on surface storage of stormwater there are several locations where a subsurface or underground facility could be placed, such as to the east of the basketball courts, beneath the basketball courts or beneath the parking lot, located to the north of the basketball courts. Porous paving of the parking lot or basketball courts could be incorporated into the design of the facility to facilitate the conveyance of stormwater into the system. Porous paving can come in various forms including asphalt, concrete, or paving bricks. Given the location of the project the most appropriate form of porous paving for Teegarden Park would likely be the asphalt based system. The most notable difference between porous paving and standard asphalt is that porous paving leaves out the finer fraction of particles that make up the aggregate mix used in standard asphalt mix. This

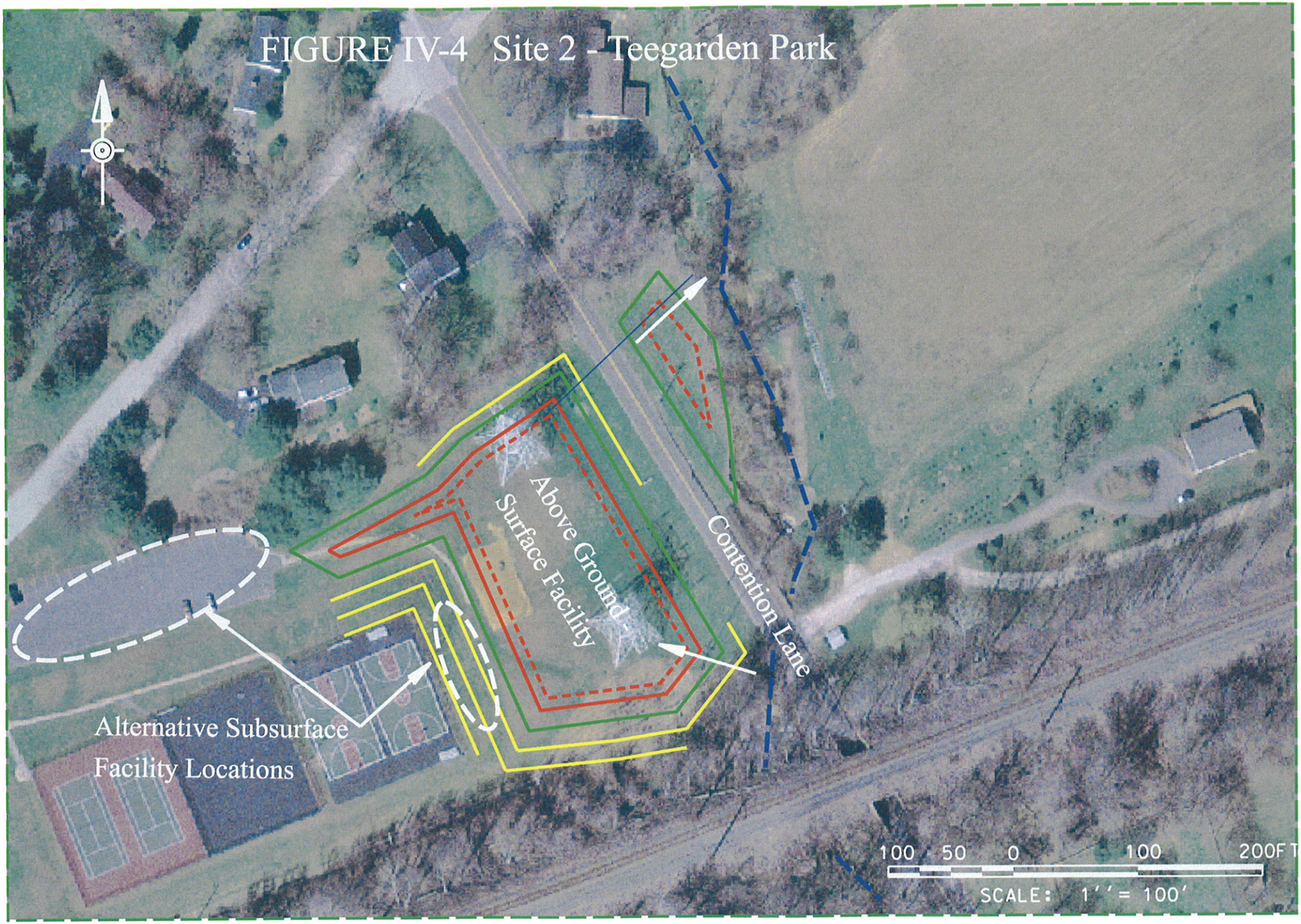


FIGURE IV-4 Site 2 - Teegarden Park

omission of the small particles from the mix allows water to pass through the paving to a storage chamber, beneath the porous paving, which is typically constructed of stone or any one of a number of proprietary subsurface storage materials.

3. Site 3: Gateway Shopping Center (Parking Lot Retrofit)

Tributary: Hammer Hollow

Site Description: The Gateway shopping center, located off of East Swedesford Road, is a retail shopping area on a 34-acre parcel of land situated between two tributaries of the Trout Creek. To the west and north of the parcel is the main stem of the Trout Creek while the Hammer Hollow tributary lies to the east of the site. Nearly 65% percent of the 34 acres of land is covered by impervious surface which is comprised either of buildings or parking lot. Within the parking lot there are numerous vegetated islands which break up the parking aisles. Other than several inlets within the parking lot there is no evidence of any stormwater management controls for the property. As the property appears to be fully occupied and the number of parking space cannot be reduced to provide additional stormwater controls, based on observations of parking shortages in the front of the facility, the only potential stormwater management controls available for installation in the front of the building are facilities which would not have a large footprint. A photograph showing the front of the Gateway shopping center is shown in Figure IV-5.

FIGURE IV-5 Gateway Shopping Center

Proposed Stormwater Management Function: Given the high visibility of the site, and the numerous planting islands within the parking lot, the front of the shopping center is considered a good location to convert one or more of the existing islands into a demonstration bioretention facility. The conversion of one or more of the islands would not significantly alter the rate or volume of stormwater runoff from larger storm events such as storms with a return frequency greater than the 2-years but would be a good exhibition project to draw attention to stormwater Best Management Practices, how they function and

their benefits. Such a device could be designed to manage small frequent events such as the 1-year storm. This is important because approximately 85% of the total annual rainfall in southeastern Pennsylvania is estimated to occur in rainfall amounts of 2 inches or less. The conversion of one existing island would involve approximately 400 square feet of parking lot that is not presently used for parking, resulting in no net reduction in the amount of parking. See Figure IV-6.A and IV-6.B for a plan view and cross section of one concievable bioretetnion configuration for the Gateway Shopping Center. With a 1-foot deep stone storage chamber placed below the island, the bioretention facility would be capable of storing up to 160 cubic feet of stormwater runoff or managing up to 2 inches of precipitation falling on about 1,000 square feet of parking lot and thus managing nearly 85% of the annual precipitation volume for the same area. Each facility could be designed such that in large storm events excess stormwater runoff would be collected by an overflow drain, connected to the existing parking lot drainage system.

Some infiltration from the system is expected to occur but without infiltration testing below the islands it is impossible to conclusively determine the amount of volume that can be potentially infiltrated. Also, vegetation planted in the island will reduce a portion of the precipitation volume managed by the facility via the process of evapotranspiration. Annual evapotranspiraton losses can be as high as 26 inches a year or result in the removal of approximately 850 cubic feet per year of stormwater runoff.

With the size of these facilities being relatively small compared to the total amount of impervious surface for the shopping center, the benefit of a single island would be mostly in the area of water quality. Based on 43-inches of annual precipitation, the impact of a single 400 square foot bioretention island upon water quality and nonpoint source pollutant reduction would be on the order of magnitude of that shown in Table IV-3.

TABLE IV-3
Gateway Bioretention
Potential Nonpoint Source Pollutant Removal

Nonpoint Source Pollutant	Annual Loading Rate (mg/l)	Annual Nonpoint Pollution (lbs.)	Bioretention Nonpoint Pollution Removal Efficiency (%)	Annual Nonpoint Pollution Removal (lbs.)
TSS	120	9.1	85	7.73
Total Phosphorous	0.39	0.03	60	0.018
Total Nitrogen	0.60	0.04	30	0.012

In addition to the nonpoint source items summarized in the table above, such a facility would help decrease the thermal impact of the parking lot, which stores energy from the sun in the form of heat and transfers this energy to stormwater runoff by heating the stormwater, thus increasing the heat of the receiving waters and causing a number of deleterious effects upon the aquatic habitat. Bioretention facilities are able to reduce the thermal impact of the parking lot on stormwater runoff by retaining the runoff and returning a portion to the atmosphere through the process of evapotranspiration. Further cooling of the stormwater is achieved in the storage of the stormwater runoff below the surface in the planting media.

Figure IV-6.A Conceptual Bioretention Island Cross Section

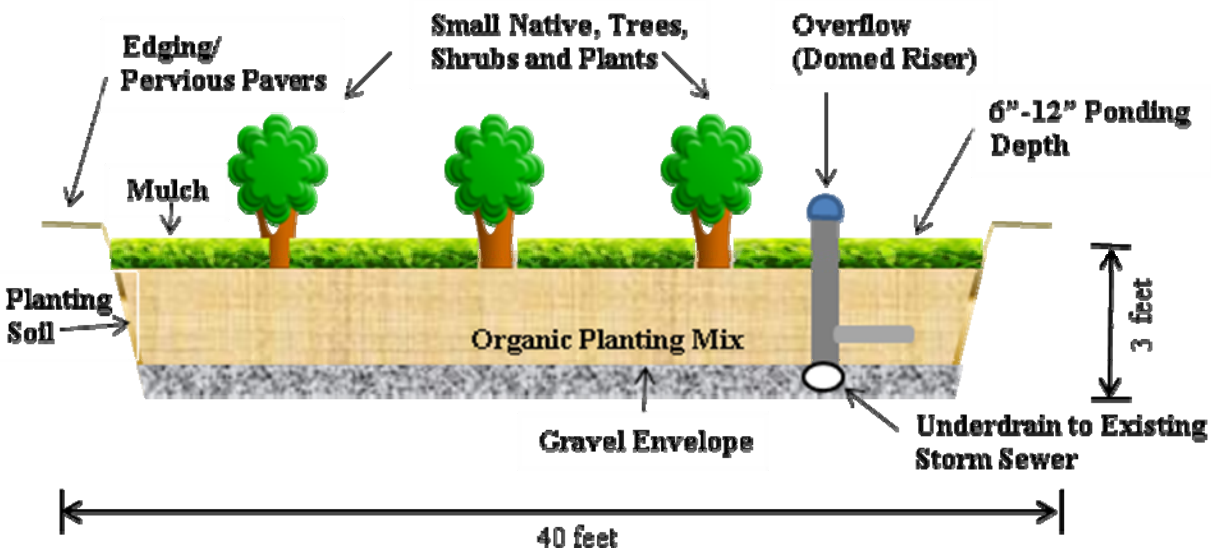
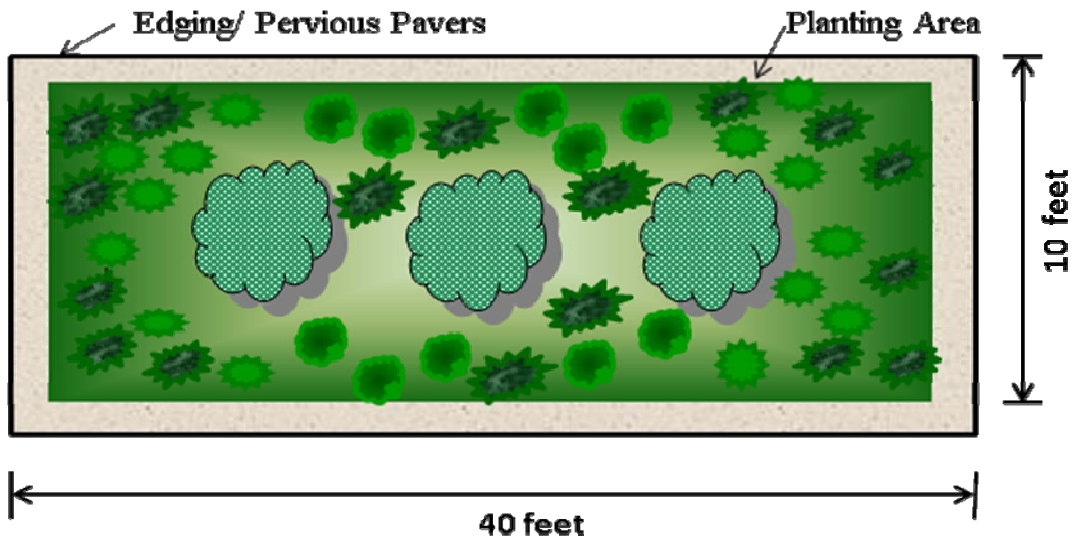


Figure IV-6.B Conceptual Bioretention Plan View Layout



Although the performance of one bioretention area for a parking lot the size of the Gateway Shopping center's is somewhat inconsequential, if multiple islands where eventually converted to bioretention islands, the overall effect would likely be significant to the receiving waterways and the Trout Creek. As there are over 50 of these islands located within the Gatyeway Shopping center's parking lot this retrofit option could have significant potential.

4. Site 4: Richards Road Box Culvert

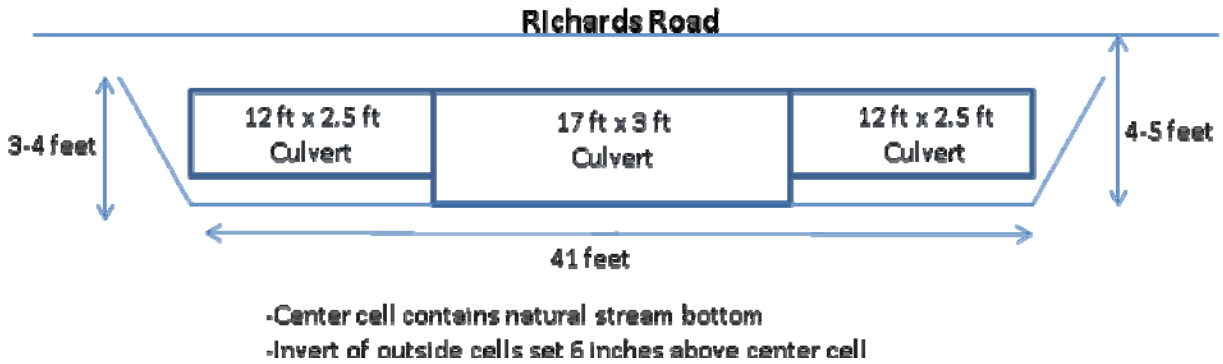
Tributary: Trout Creek Main Stem

Site Description: The Richards Road Box Culvert is a relatively new three-celled box culvert that conveys flow from the main stem of the Trout Creek under Richards Road. The center cell of the culvert is approximately seventeen feet wide by approximately three feet high and contains an open bottom to provide for a natural streambed through the main cell of the culvert. A photograph of the Richards Road crossing of the Trout Creek is shown in Figure IV-7 and a graphic depicting the layout of the culvert crossing is shown in Figure IV-8. Each of the two outside cells are approximately twelve feet wide by two and a half feet high and are set approximately 6 inches above the streambed and the invert of the center cell of culvert system. It appears to be the design intent of this culvert configuration to direct the normal low flows in the Trout Creek through the center cell of the culvert thus reserving the outside two cells for higher flow events. This type of culvert configuration is somewhat common in areas where there are large variations between normal low flows and flows from precipitation events where there is insufficient channel depth to provide conveyance through the culvert without overtopping the roadway. The stream banks in the vicinity or Richards Road are approximately three to four feet high with Richards Road approximately 6 inches to one foot above the top of the stream banks.

FIGURE IV-7 Richards Road Box Culvert
(looking downstream)

Although the culvert system appears relatively new flooding at the site is a concern. This flooding is not directly caused by the size of the Richards Road Culvert but is influenced by a backwater condition created by the S.R. 422 Culvert, located approximately six-tenths of a mile downstream of Richards Road. In addition to the flooding problem, the stream channel above the culvert is experiencing significant sediment deposition and debris accumulation which requires regular maintenance to provide unobstructed flow through the culvert.

FIGURE IV-8 Richards Road Culvert Configuration



Potential Conceptual Conveyance Improvements: To assess the flooding problem at the Richards Road Crossing the Federal Emergency Management Agency's Flood Insurance profile for the Trout Creek was examined. This profile shows that the S.R. 422 culvert is creating a backwater above the crossing that backs up to the Richards Road Culvert, and affects the performance of Richards Road Culvert. As the water surface profile on the downstream side of the Richards Road Culvert is not substantially different than the upstream side of the culvert, the backwater from S.R. 422 appears largely responsible for creating the flooding around Richards Road. Without modifying the S.R. 422 crossing there is essentially nothing that can be done at Richards Road to rectify the flooding condition. Without the S.R. 422 culvert modification to reduce the flooding at Richards Road the only other option available is to reduce the peak rate of water flowing to that point in the watershed. As the amount of water flowing to this point is sizeable, 3,077 cfs for the 100-year event, to produce any significant reduction in flow at the culvert requires either a single storage area or muliple storage areas located in the upstream watershed. To create any noticeable change in the water surface elevation at this location it is estimated that a stormwater storage volume on the order of magnitude of 50 acre-feet would be required. The Flood Insurance profiles for the Trout Creek from both the Montgomery County and Chester County studies are shown in Figure IV-9.A and IV-9.B, respectively.

Although flooding is one issue at this location another primary complaint with respect to the culvert's performance is the regular deposition of sediment and debris at the entrance to the culvert requireing frequent maintenance by the Township Public Works Department. Therefore, the remainder of this analysis focused on developing an improved culvert configuration to better convey the stream in the low-flow events, and when the channel is flowing full. In its present condition, the existing channel upstream of the culvert is widened to approximately double the width of the existing channel to accommodate the movement of water from the upstream channel into the three-cell box culvert at Richards Road. With the widening of the channel, the flow in the channel is spread out across the entire channel bottom, thus increasing the flow area and decreasing the velocity within the channel. It is this drop in velocity upstream of the culvert that is partially responsible for the deposition of sediment and debris in the creek around the culvert and creating routine maintenance problems.

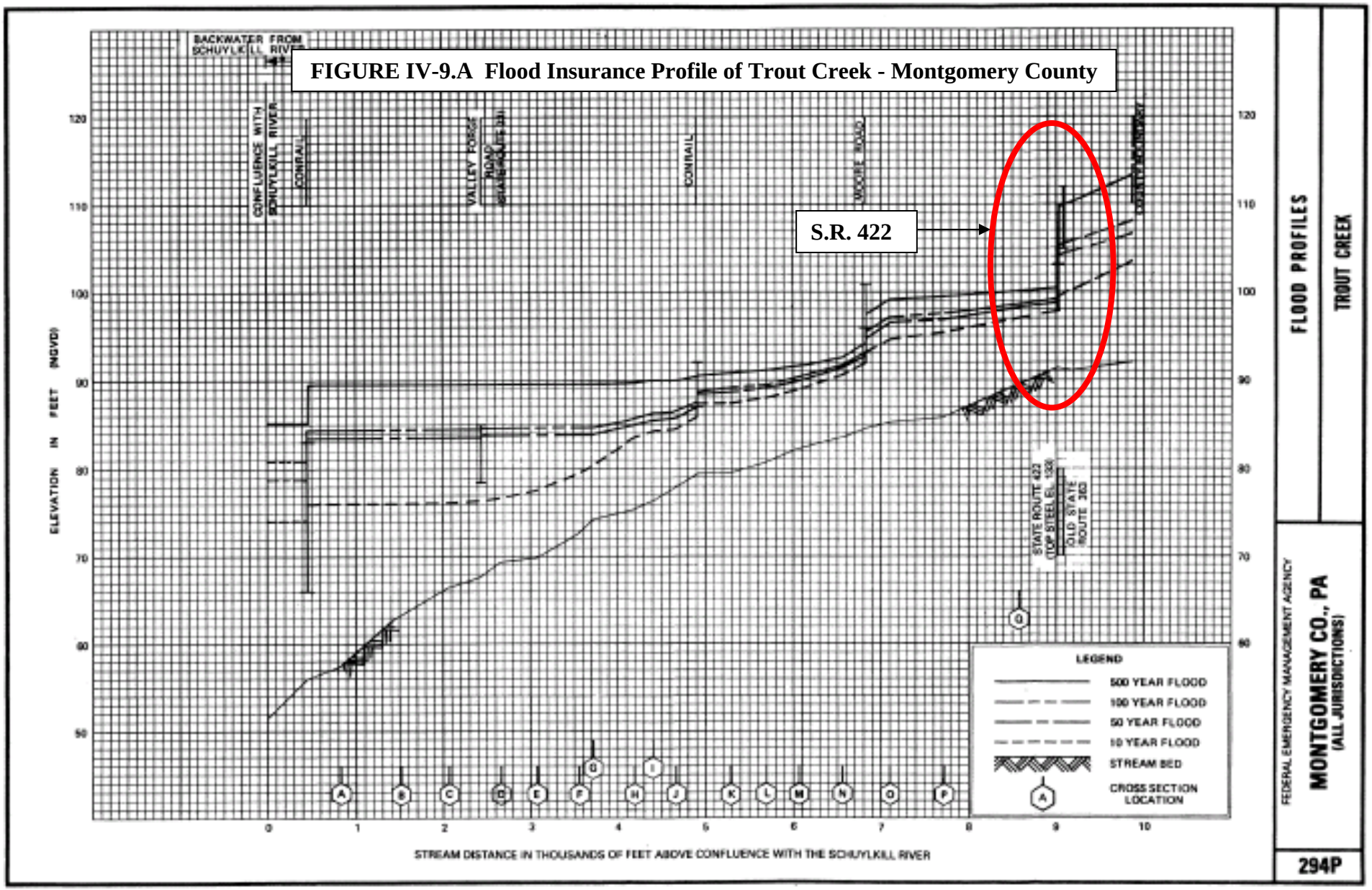


FIGURE IV-9.A Flood Insurance Profile of Trout Creek - Montgomery County

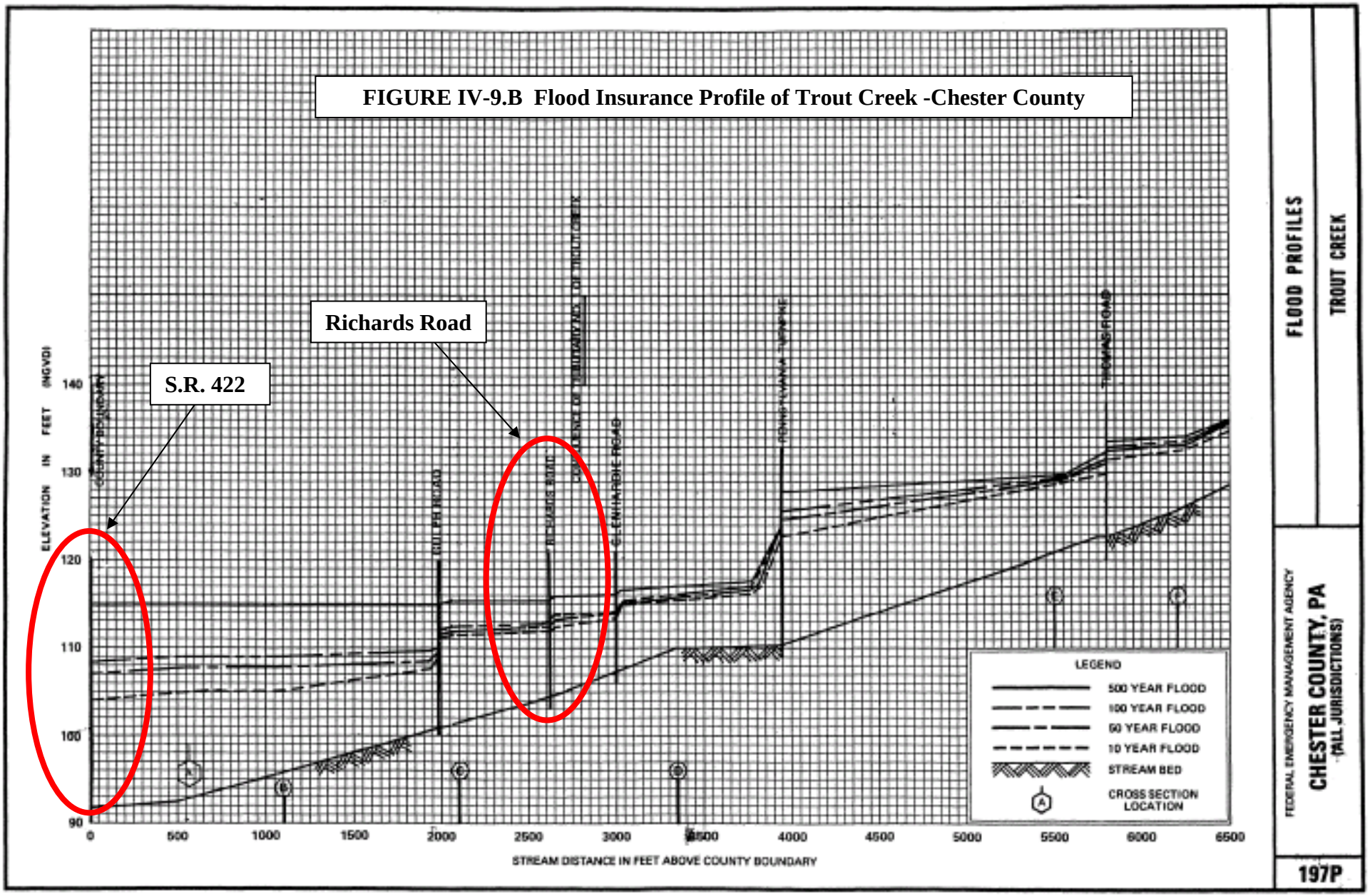


FIGURE IV-9.B Flood Insurance Profile of Trout Creek -Chester County
Richards Road
S.R. 422
ELEVATION IN FEET (NGVD)
140
130
120
110
100
90
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
STREAM DISTANCE IN FEET ABOVE COUNTY BOUNDARY
LEGEND
500 YEAR FLOOD
100 YEAR FLOOD
50 YEAR FLOOD
10 YEAR FLOOD
STREAM BED
CROSS SECTION LOCATION
FLOOD PROFILES
TROUT CREEK
FEDERAL EMERGENCY MANAGEMENT AGENCY
CHESTER COUNTY, PA
(ALL JURISDICTIONS)
197P

A conceptual hydrualic model of the culvert and the Richard's Road crossing of the Trout Creek was created using the FHWA's HY-8 Culvert Analysis Software and some rough field measurments of the channel and the culvert in order to develop a conceptual alternative culvert configuration. As the bankfull event is typically considered somewhere between the 1-year and 2-year event, for this analysis the 2-year event was used as a the design storm to guide the the conceptual design modifications of the culvert. The flow for the 2-year event is approximately 515 cfs and in its present condition approximately 4.3 feet of head is required to convey the flow through the culvert.

To reduce sedimentation upstream of the culvert, the upstream channel could be conceptually modified to reduce the overall width of the channel, and increase the velocity for the low flow events. The difficulty in accomplishing this is that the channel modification must be constructed in such a way that it does not reduce the overall conveyance capacity of the culvert and cause more frequent flooding of Richards Road. To improve the flow conditions around the culvert, one conceivable scenario is to create a low flow channel upstream of the culvert to reduce the flow area and increase the stream velocity upstream of the culvert. This could be accomplished by blocking the outside cells of the culvert, in a low flow condition, with a weir like device and narrowing the sides of the channel below the top of the weir, such that the normal low flow would only flow through the center cell of the culvert. A graphic depicting conceptual culvert modification is shown in Figure IV-10.A and IV-10.B. In larger storm events, flow would flow over the top of the weir and enter the outside cells of the culvert, and function in a similar manner to its current performance but with less sediment deposition during the smaller storm events. The benefit of the weir structure is that is that the flow would be directed to the center cell of the box culvert for the low-flow events but the full existing culvert capacity would be available for large flow events. This configuration would increase the velocity of the channel by about one foot per second and reduce the width to depth ratio from about 28:1 to 7:1. Changes in both of these parameters will help to limit the amount of sediment and debris deposited upstream of the culverts. As the Main stem of the Trout Creek Tributary joins the Treyburn Tributary approximately 75 feet upstream of the Richards Road Culvert, to complete this modification to the culvert entrance condition would require careful hydraulic engineering and most likely bioengineering or hard armoring to permanently stabilize the stream approach to the culvert.

This conceptual recommendation implemented in conjunction with streambank stabilization measures put in place at the Glenhardie golf course and areas above the Pennsylvania Turnpike along with a sizeable stormwater storage facility constructed at the S.R. 202 interchange with Devon Park Drive would help to control stormwater runoff from smaller events responsible for most erosion and sedimentation problems and would reduce the amount of maintenance required at the culvert.

5. Site 5: Devon Park Drive Open Area

Tributary: Weadley Branch

Site Description: As shown in Figure IV-11, the Devon Park Drive Open Area is situated inside the Philadelphia Electric Company right-of-way approximately 500 feet west of the intersection of Old Eagle School Road and Devon Park Drive, on the north side of Devon Park Drive. In its present state the site appears to be maintained as a grassy area with several

FIGURE IV-10.A Cross Section of Richards Road Conceptual Culvert Modifications

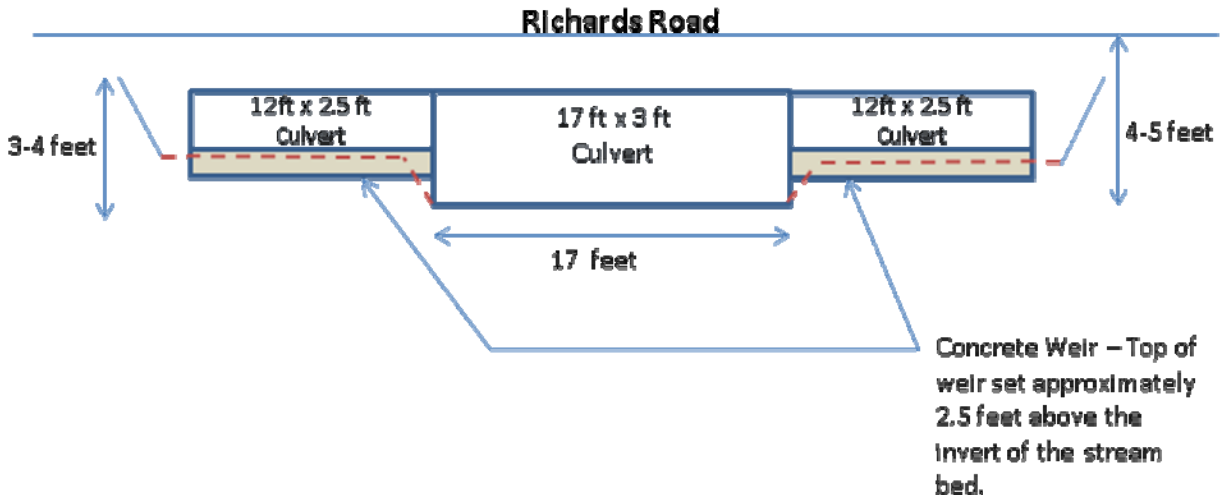
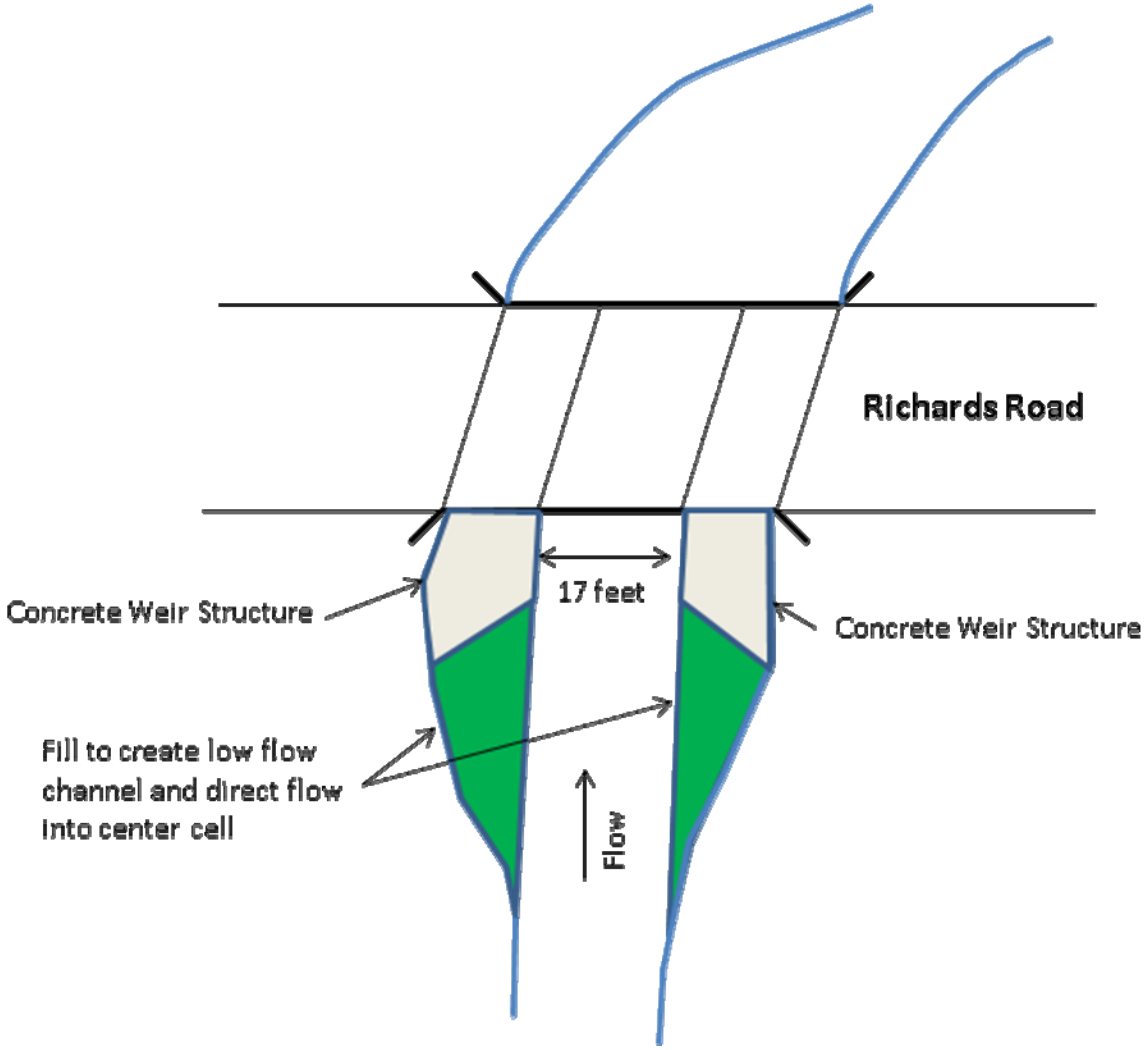


FIGURE IV-10.B Plan View of Richards Road Conceptual Culvert Modifications



electric utility towers situated inside the area. The site is somewhat large and contains an existing channel that bisects the open area. This existing channel appears to convey flow from the office complex to the south of Devon Park Drive toward the Weadley tributary of the Trout Creek. Other than the existing channel bisecting the site, the site presently serves no stormwater management function and provides virtually no storage.

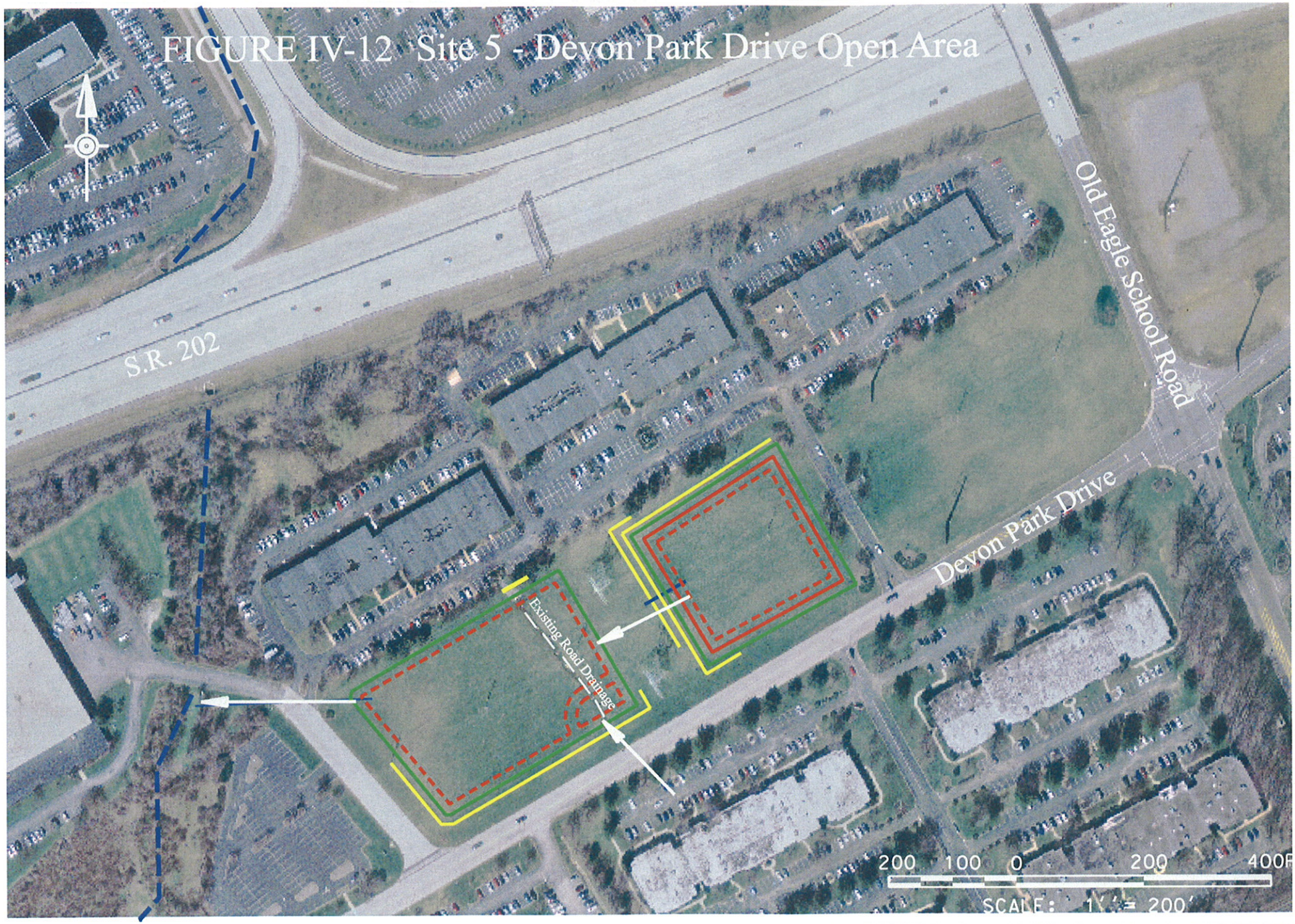
FIGURE IV-11 Devon Park Drive Open Area (looking west)

Proposed Stormwater Management Function: As the site is located some distance away from the Weadley Branch of the Trout Creek it is not a suitable location for an on-line stormwater management facility. However, the size of the site, its limited development potential and the somewhat large, developed drainage area make it an excellent location for an off-line stormwater management facility.

Several different conceivable configurations could be achieved at the site. To accommodate the existing electrical towers situated at the site a two-chambered storage area was considered the most practical. The eastern storage chamber could be designed such that it would receive stormwater runoff from the site itself as well as Devon Park Drive between the site and the Old Eagle School Road. From the eastern cell stormwater could be discharge into the western cell for further stormwater management. In addition to the flow from the eastern cell, the western cell could be designed to manage stormwater conveyed to the site via the existing channel, which appears to convey flow from the office park situated to the south of Devon Park Drive. After managing the flows in the western cell, stormwater could be discharged from this basin to the Weadley Tributary situated to the west of the site.

As the soils within the area consist of nearly all D soils, infiltration would not likely be suitable for this location. However, given the nature of the soils, this location may be suitable for either a stormwater wetland or a wet pond. If converted to a stormwater wetland the site could then be designed such that it would rely on evapotranspiration to remove a portion of the stormwater management volume. See the aerial photograph provided in Figure IV-12 for the conceptual site layout and Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process.

FIGURE IV-12 Site 5 - Devon Park Drive Open Area



6. Site 6: Devon Park Drive Streetscape (Between Old Eagle School Road and West Valley Road)

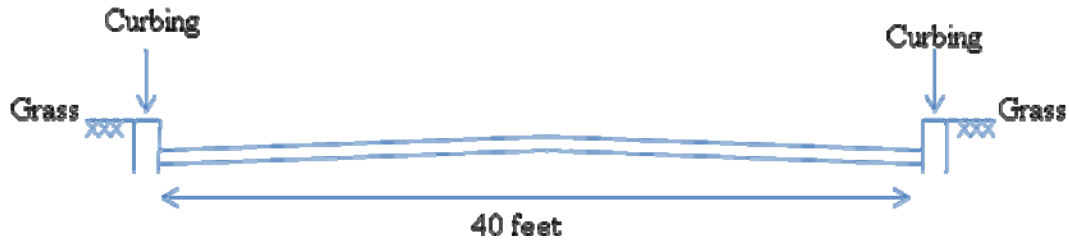
Tributary: Avonwood Branch, Weadley Branch

Site Description: Devon Park Drive, between Old Eagle School Road and West Valley Road is located in the central portion of the watershed and is aligned roughly parallel to S.R 202, about 1,000 feet to the south of the highway. This portion of the Township where the roadway is located consists mostly of light industrial facilities or offices buildings. The distance between the two intersections is approximately 4,500 feet with the roadway crossing two tributaries of the Trout Creek, the Avonwood Branch, furthest to the west and the Weadley Branch, furthest to the east. The typical section of the roadway is about 40 feet wide with curbs and adjoining lawn area surrounding the parking areas for the light industrial and office buildings located along the road. A photograph of the roadway and a typical section are shown in Figures IV-13 and IV-14, respectively. Although the roadway is approximately 40-feet wide there, appears to be no on-street parking, and no designated turning lanes throughout the section of the roadway.

FIGURE IV-13 Devon Park Drive
(looking east toward Old Eagle School Road)

Proposed Stormwater Management Function: Since Devon Park Drive appears to be excessively wide, for its present configuration and there appears to be no large tracts of land adjacent to this section of the roadway that are available for development and which would significantly alter the traffic volume and transportation needs with this section of the township, it is recommended that the Township consider modifying the typical section of the roadway to improve stormwater management within the project area. The typical section of the roadway could be modified to incorporate bioretention and/or underground infiltration to improve stormwater management in the area.

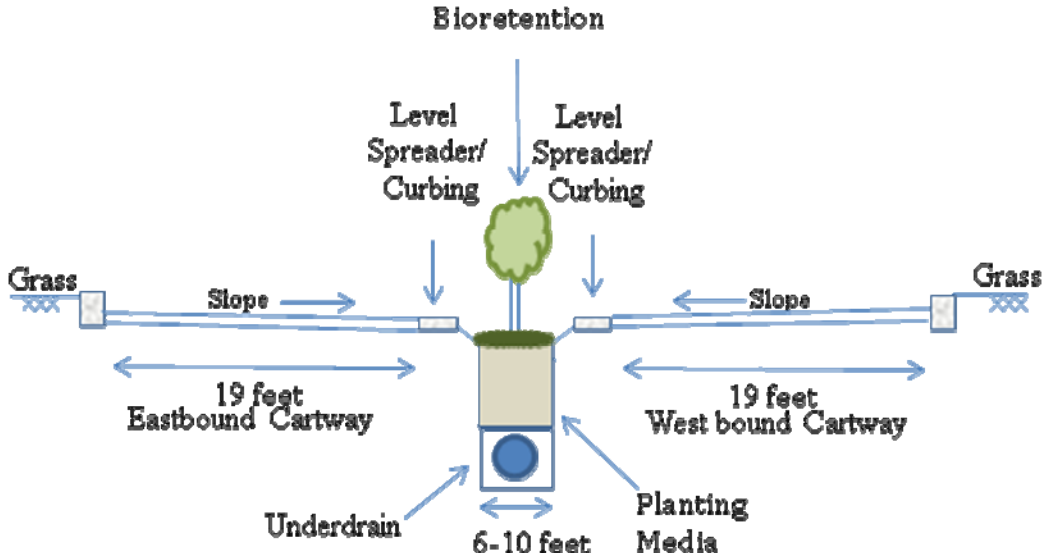
FIGURE IV-14 Devon Park Drive Existing Cross Section



One conceivable conceptual modification of the roadway is shown in Figure IV-15. This conceptual cross section contains a vegetated center island acting as a bioreteniton area in the middle of the section with an under drain connected to an overflow riser (not shown in schematic) to provide conveyance in large storm events. Although the ultimate configuration of the roadway could take on many different forms the key components of the typical section should include these components:

- impervious surface reduction- accomplished with the removal of regular pavement, reduction in overall cartway width and / or replacement of impervious pavement with porous paving material, either to one side or along both sides of the roadway
- impervious surface disconnection – accomplished with the removal of curbing from both sides of the street
- collection of stormwater runoff – installation of a longitudinal BMP such as a bioretention swale along the total length of the roadway or bioretention islands placed at select locations to manage stormwater runoff from the right-of-way
- interception of offsite drainage- a vegetated channel placed on the south side of Devon Park Drive to collect offsite runoff and convey it around the proposed BMPs

FIGURE IV-15 Devon Park Drive Conceptual Cross Section Modification



Application of the modified typical section along the approximate 4,500-foot segment of Devon Park Drive is anticipated to result in varying degrees of peak rate and volume reduction, depending upon the event. The conceptual quantities listed in the Table IV-4 are based upon a right-of-way drainage area of 6.2 acres, the conversion of 12 feet of impervious surface to semi-pervious surface, and a 4-foot wide bioretention swale along the entire length of the road segment.

TABLE IV-4 Devon Park Drive Streetscape
Conceptual Volume and Rate Reduction

		2-Year	10-Year	100-Year
Impervious Surface Reduction	Rate Reduction(cfs)	5.83	7.51	8.77
	Volume Reduction (cf)	3,600	3,960	4,230
Bioretention	Rate Reduction(cfs)	2.07	10.77	3.59
	Volume Reduction (cf)	15,750	15,750	15,750
Cumulative Reduction	Rate Reduction(cfs)	7.90	10.77	12.36
	Volume Reduction (cf)	19,350	19,710	19,980

7. Site 7: S.R.202 / Devon Park Drive Interchange

Tributary: Treyburn Branch

Site Description: The large open area in the infield of the Devon Park Drive interchange for S.R. 202, as shown in Figure IV-16, receives runoff from a significant portion of upstream drainage area. In its present condition this area of land is undeveloped and because of its size and location represents a good location for a regional stormwater management basin to control the flow to the downstream tributaries.

FIGURE IV-16 S.R. 202 / Devon Park Drive Interchange
(looking northwest toward S.R. 202)

In its present condition, inflow enters the area via two 6-foot RCP culverts from the east of the interchange and via one 15' x 6' box culvert from the south of the interchange. Both culverts are connected to a 6'x 6' discharge culvert under S.R. 202 via an existing drainage channel. Other than some limited channel storage, which creates head on the existing culvert, the area provides no stormwater attenuation.

Proposed Stormwater Management Function: Since available land area is somewhat large and the Trout Creek tributary flows directly through the interchange, this site would be an excellent location for an on-line regional stormwater storage facility. To obtain substantial stormwater storage capacity at the site excavation is required to the east of the existing channel located between the inflow and outflow culverts. As the amount of runoff flowing through the proposed basin is somewhat large, the rate of outflow from the basin will be regulated by the reducing the size of the existing box culvert from a 6'x 6' opening to a 6' x 4'opening. This can be accomplished without altering the size of the culvert by modifying the inlet end of the culvert only. In essence this configuration evaluates an "online" facility, managing all of the water flowing in the tributary to the basin. See the aerial photograph provided in Figure IV-I7 for the conceptual site layout and Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process.

As most of the underlying soils are classified as Type C or D soils, the site's infiltration capacity is anticipated to be limited and the site is not expected to be a good location for infiltration practices. A stormwater management wetland could be constructed on the site given the type of soils present in the interchange, with evapotranspiration being the major mechanism for removing stormwater volume during frequent small precipitation events.

8. Site 8: Richter Property (intersection of Walker and Glenhardie Roads)

Tributary: Weadley Branch

Site Description: As identified in the Trout Creek Watershed Restoration Plan there is a severe stream bank erosion problem located on the Weadley Tributary to the Trout Creek, just below the Glenhardie and Walker Roads intersection. To the north of this intersection, there is a 26-acre parcel of undeveloped land available which the Weadley Branch of the Trout Creek traverses. Although the site is undeveloped presently there is limited stormwater storage capacity provided upstream of the Walker Road crossing as the roadway embankment is relatively low and the culvert is somewhat small in comparison to the size of the contributing drainage area. A photograph of the site is provided in Figure IV-18.

Proposed Stormwater Management Function: The size and proximity of this site to the stream bank erosion problem at the intersection of Glenhardie and Walker Roads makes the site an ideal location for a regional stormwater management facility. Since the site is somewhat sizeable and the tributary traverses through the middle of the site the Richter property would be a good location for an on-line facility. To provide the necessary storage to attenuate the flows through this section of the creek two different scenarios were considered. Both scenarios propose constructing an earthen embankment on the south side of Walker Road between ten and fifteen feet high, placing a new culvert under Walker Road to convey flow from the basin to the north side of Walker Road and grading the area to the south of the proposed embankment to provide the needed storage. The two options differ in that Scenario A considers regrading the entire area, including the existing channel, to create the necessary

FIGURE IV-17 Site 7 - S.R. 202 Interchange

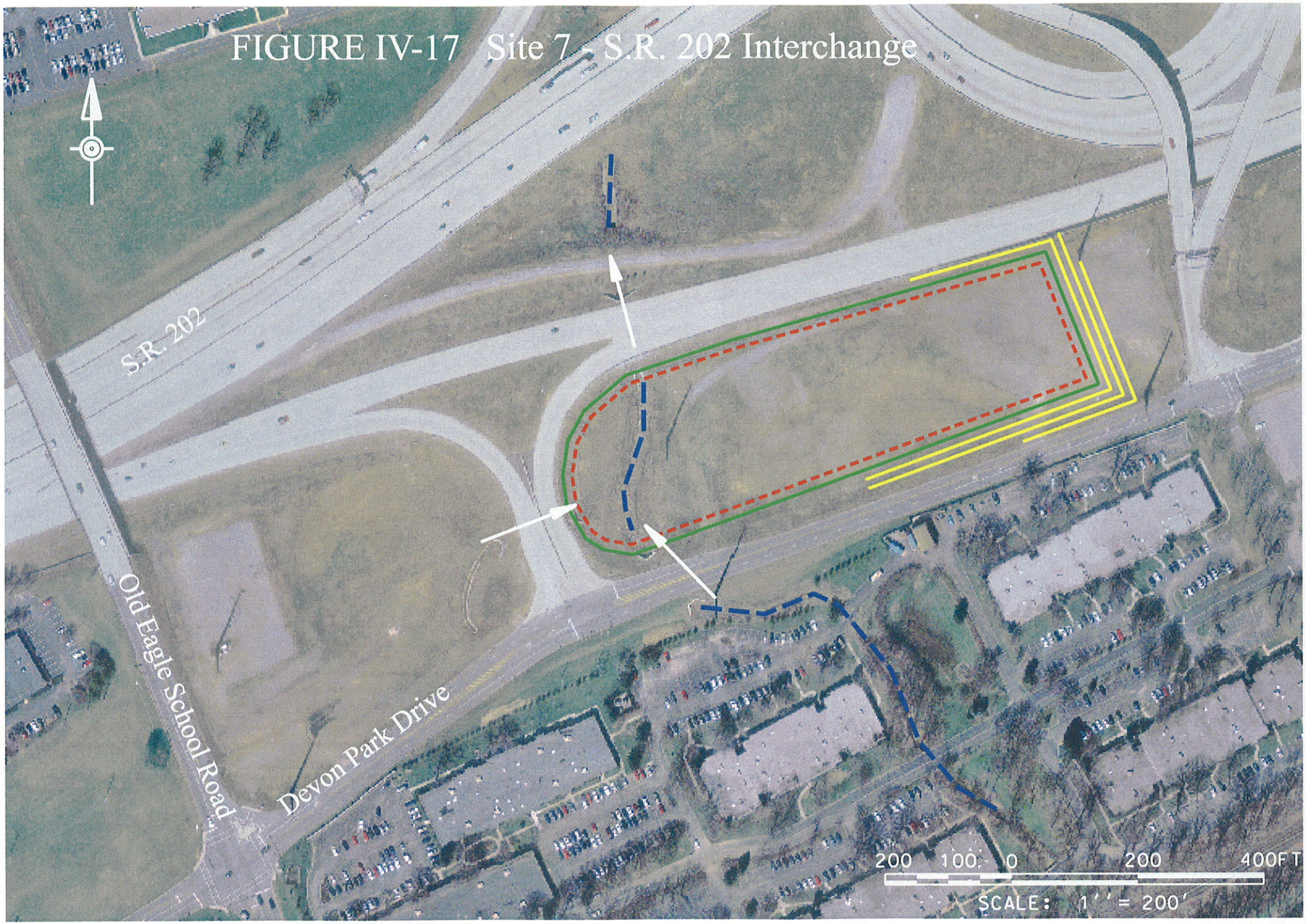


FIGURE IV-18 Richter Property
(looking southwest from Walker Road)

storage, whereas Scenario B only considers grading the area above the channel, thus leaving the existing channel essentially intact. Although both options are physically attainable, Scenario A is considered less environmentally sensitive and will be more difficult to get through the permitting process. In both scenarios, the basin will function as an online facility, receiving all flow from the tributary, before discharging it to the channel below the basin. Since flow from the basin is only being reduced by the conveyance capacity of the proposed culvert under Walker Road, a constant baseflow will remain below the basin if it is constructed. See the aerial photograph provided in Figure IV-I9 for the conceptual site layout and Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process.

As the soils within the area are classified as Hydrologic Soil Group B, the area is anticipated to be a suitable location to construct infiltration facilities which could prove valuable with removing stormwater volume from smaller more frequent precipitation events.

Even without the conceptual storage area proposed by this report the location of this site, in close proximity to a commercial district, makes the parcel an attractive candidate for future commercial development. Any future development at the site should consider implementing innovative stormwater management controls throughout the site to control flooding, prevent streambank erosion, and improve the water quality of the stormwater runoff from the proposed development. BMPs that should be considered as part of the project's stormwater management controls are green roofs, porous paving, impervious surface disconnection, bioretention, riparian buffers, floodplain preservation, and stormwater volume controls, to the fullest extent of the Township's stormwater management standards and criteria and the National Pollution Discharge Elimination System. As part of any future development of the site the Township may want to require the applicant to:

- delineate the 100-year floodplain through the site so the existing floodplain, although not presently determined, can be established and permanently maintained

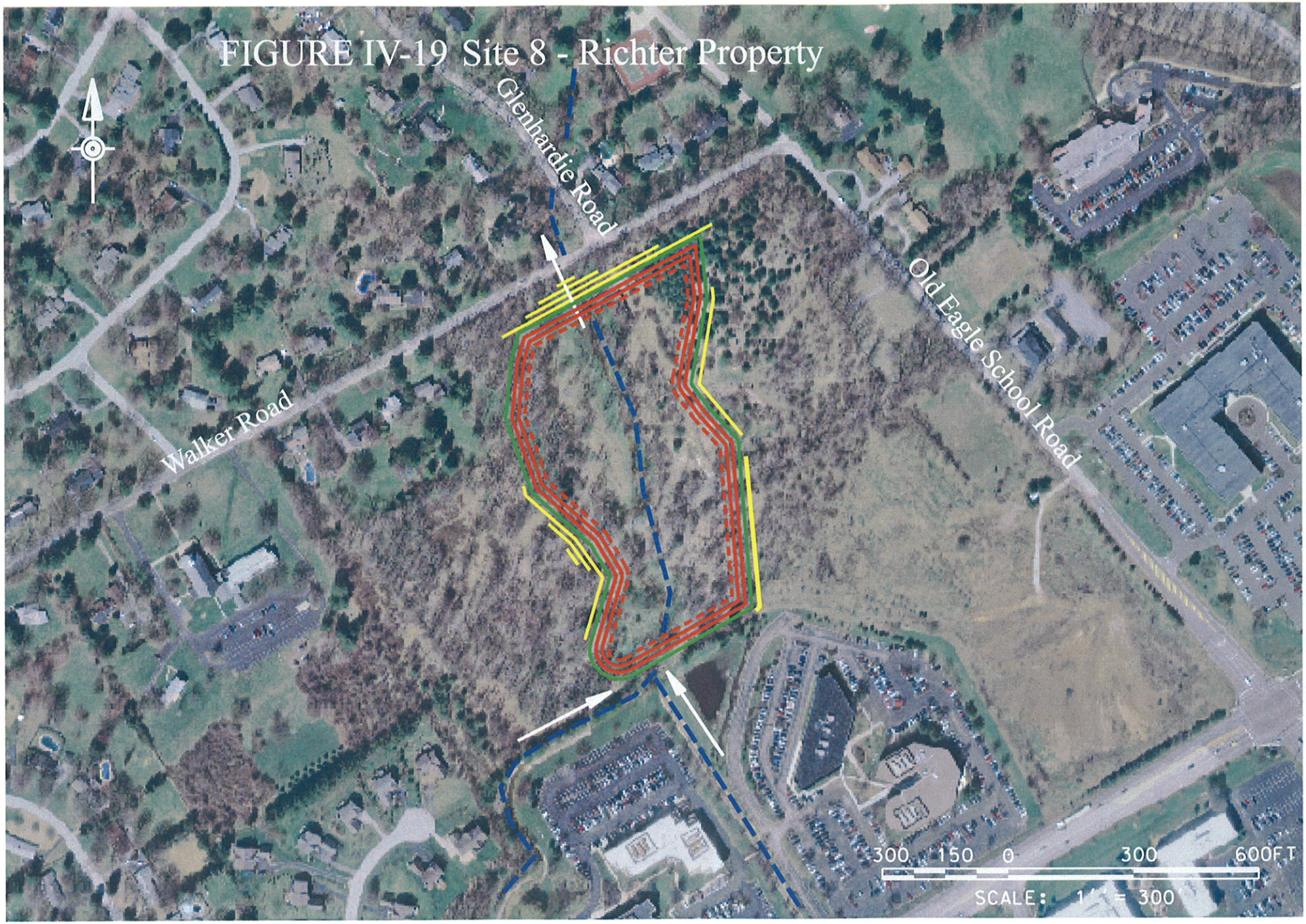


FIGURE IV-19 Site 8 - Richter Property

- stabilize the section of the Trout Creek Tributary located downstream of the site between Glenhardie and Walker Roads, especially if any road improvements are proposed to the respective roads and culvert
- ensure that any modification of the existing Walker Road Culvert maintains, at a minimum, the same amount storage or ponding upstream of the culvert as presently occurs so as to not reduce any attenuation that the existing culvert provides
- use bioengineering techniques in lieu of hard armoring as the preferred method of stabilizing any eroded sections of the streambank
- encourage the use of a treatment train approach to manage post construction stormwater runoff, so stormwater is managed by multiple BMPs placed in succession instead of just one BMP
- require the mapping of existing environmental features on the site including soil types, buffer areas and floodplains, so that these areas can be set aside for infiltration and long term stormwater management needs
- limit the use of curbing and concentration of stormwater
- use numerous smaller BMPs dispersed throughout the site instead of concentrating the BMP at one location to manage post construction stormwater runoff
- encourage minimization of the amount of newly created impervious surface with the application of porous paving and/or parking decks in lieu of standard parking lots

9. Site 9: Devon Park Drive Natural Area (Avonwood Branch)

Tributary: Avonwood Branch

Site Description: This site is located on the north side of Devon Park Drive about two-tenths of a mile east of the intersection of Devon Park Drive with West Valley Road. The site consists of about three-quarters of an acre of undeveloped land on the east side of the Avonwood Branch of the Trout Creek in what appears to be the Philadelphia Electric Company's right-of-way. A photograph of the site is shown in Figure IV-20. Although the size of the site is somewhat small for a regional stormwater management facility, this location is one of only a few sizeable undeveloped areas on the Avonwood Branch available for a stormwater management facility situated adjacent to the stream within this section of the Township, which consists of mostly of office buildings and parking lots.

Proposed Stormwater Management Function: Three different potential stormwater management scenarios were considered for the site. Scenario A considers using the site as a regional stormwater management facility, directing all of the flow from the tributary through the storage area and then discharging it back into the channel below the basin. This configuration places the proposed facility on-line with the Avonwood Branch. However, because of the limited storage volume available with respect to the size of the contributing drainage area, other management scenarios are considered more practical for the site. Scenario B considers reconfiguring the basin such that it would be an off-line facility, only receiving drainage from a portion of the surrounding watershed. Conversely, Scenario C evaluates placing the facility on-line in such a way that only a portion of the flow from the Avonwood branch wood be diverted into the stormwater storage area. Scenario C could be accomplished by placing weir-like diversion structure within the tributary, thereby keeping a majority of the flow in the existing channel. This proposed weir could be designed in such a

way that a majority of the flow would enter the management area in smaller more frequent events while larger stormwater volumes would bypass the storage area.

FIGURE IV-20 Devon Park Drive Natural Area - Avonwood Branch (looking west)

For the analysis the amount of storage was kept equal for each scenario investigated and the orifice controlling the discharge from the stormwater storage was altered in order to maximize the amount of storage within the facility for each scenario investigated. See Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process and Figure IV-21 for an aerial photograph with the proposed grading for conceptual facility.

As the soils within the area consist of a mixture of Hydrologic Soil Group B and D soils, certain select locations at the site may be suitable for infiltration facilities. However, the size of such facilities would be confined to those areas with type B soils.

10. Site 10: Devon Park Drive Natural Area (Weadley Branch)

Tributary: Weadley Branch

Site Description: This site is located about midway between West Valley Road and Old Eagle School Road on the north side of Devon Park Drive and consists of about two-acres of undeveloped land on the west side of the Weadley Branch of the Trout Creek in what appears to be the Philadelphia Electric Company's right-of-way. A photograph of the site is shown on Figure IV-22. This location is considered attractive for a regional stormwater storage facility as it is one of only a few sizeable undeveloped areas on the Weadley Branch in this section of the Township which is undeveloped.

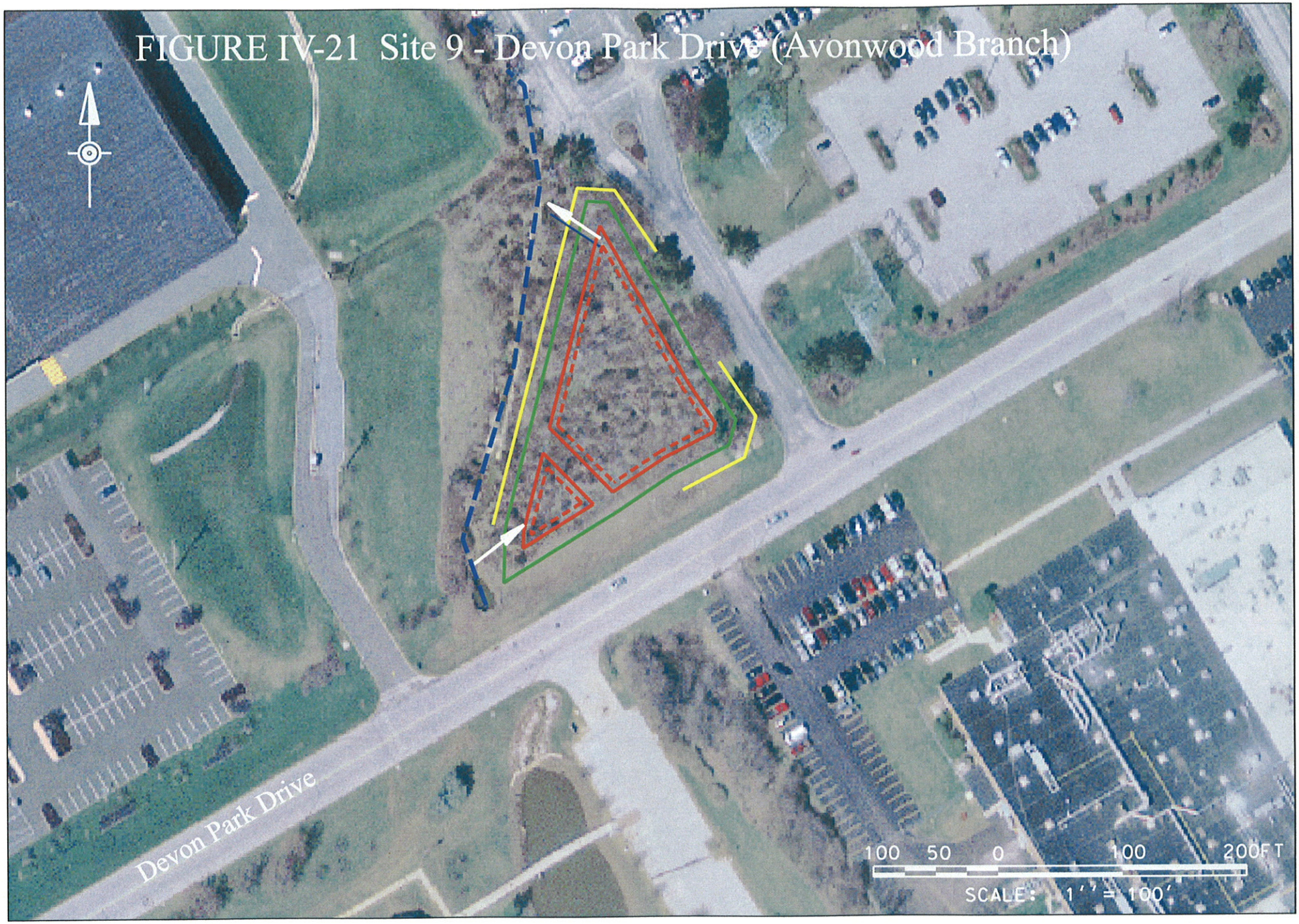


FIGURE IV-21 Site 9 - Devon Park Drive (Avonwood Branch)

FIGURE IV-22 Devon Park Drive Natural Area –Weadly Branch (looking east)

Proposed Stormwater Management Function: Three different potential stormwater scenarios were considered for the site. The first scenario, Scenario A, considered using the site as a regional stormwater management facility, directing all of the flow from the tributary through the storage area and then discharging it back into the channel below the basin. This configuration places the proposed facility on-line with the Weadley Branch. However, because of the limited storage volume available with respect to the size of the contributing drainage area, other management scenarios were considered necessary. Scenario B considers reconfiguring the basin such that the storage area is placed off-line, only receiving drainage from a portion of the surrounding watershed. Scenario C evaluated placing the facility on-line in such a way that only a portion of the flow from the Avonwood branch wood be diverted into the stormwater storage area. This could be accomplished by placing weir-like diversion structure within tributary, thereby keeping a majority of the flow in the existing channel. The diversion device could be designed in such a way that a majority of the flow would enter the management area in smaller more frequent events while larger stormwater volumes would bypass the storage area.

For the analysis the amount of storage was kept equal for each scenario investigated and the orifice controlling the discharge from the stormwater storage was altered in order to maximize the amount of storage within the facility for each scenario investigated.

See the aerial photograph provided in Figure IV-23 for the conceptual site layout and Table IV-5 for physical dimensional data placed in the hydrologic model as part of the evaluation process. As the soils within the area consist of mostly Hydrologic Soil Group B soils with some D soils, infiltration facilities could very likely be incorporated into the design of the stormwater facility to reduce the volume of stormwater runoff during more frequent precipitation events.

FIGURE IV-23 Site 10 - Devon Park Drive (Weadley Branch)

D. Conceptual Stormwater Best Management Practice Evaluation

Table IV-5 contains a description of some of the physical and dimensional data used to represent each of the conceptual stormwater management controls that could potentially be constructed at six of the sites. Whereas only six of the ten sites evaluated proposed BMPs that contained storage facilities sizable enough to affect the rate of flow, either at the site or further downstream of the individual sites, only these six sites were evaluated in the watershed's hydrologic model, with the dimensional data presented in Table IV-5. At four of the sites, several different configurations were evaluated to determine which type of approach would yield the greatest impact to the watershed. Generally, each conceptual BMP was modeled with the maximum amount of storage that could reasonably be attained at a site based upon conceptual grading of the facilities using 5-foot contours of the watershed. This was accomplished to create the maximum benefit to the watershed by mitigating the peak rate of flow within the Trout Creek.

Table IV-6.A and IV-6.B contains output from the hydrologic evaluation of six of the conceptual designs. Several of the designs were evaluated with different BMP configurations to obtain the most effective layout of the BMP to obtain the greatest benefit to the watershed. Whereas two of the major stormwater related problems within the Trout Creek Watershed concern flooding and streambank erosion the 2-year and the 100-year events were selected to measure the effectiveness of the BMPs at reducing the rate of the stormwater runoff both at the site and downstream of the site near the Township line. Reducing the rate of runoff is typically a function of the amount of storage available to provide attenuation, so those conceptual designs which are capable of providing a large amount of storage volume typically perform better than those sites with lesser storage volumes, as demonstrated in Table IV-6.A and IV-6.B.

The performance of the proposed conceptual BMPs where not fully optimized as part of this analysis and the actual performance of the conceptual BMPs modeled in the conceptual design phase of this project will vary depending on the final design of the proposed facilities.

E. Conceptual Stormwater Best Management Practice Volume Control

Volume controls are those controls that are intended to reduce the volume of stormwater runoff discharged to the downstream environment. Although large precipitation events have the potential to generate significant amounts of stormwater runoff volume, on an annual basis it is the frequent runoff from small events that creates the largest portion of the total annual runoff volume. Accurate assessment of volume controls are difficult to model during the conceptual engineering phase of a project as the effectiveness of such controls are highly dependent upon the characteristics of the site where the proposed BMP is constructed. In conceptual engineering many of the physical characteristics of a site which are necessary to accurately assess volume control are not readily available and using values contained in reference materials can result in a subjective performance evaluation that may or may not be difficult to attain in the final design. As these characteristics are difficult to accurately model without on-site testing, volume controls for the conceptual BMPs contained in this report were not modeled as part of this project.

Table IV-5
Physical and Dimensional Data of Conceptual Stormwater Best Management Practices

Site No.	Site Name	Tributary	Scenario	Basin Foot Print (acre)	Configuration	Orifice Size (w x h) (ft)	Elevation - Bottom of Basin (ft)	Total Available Storage (ac-ft)	Drainage Area (acre)	Hydrologic Soils Group	10-year Maximum Stage (ft)	100-year Maximum Stage (ft)
2	Teegarden Park	Contention Lane	A	1.0	on-line	7.5 x 6	237	5.3	292	B	6.56	6.97
			B	1.0	off-line	0.4 x 1	237	5.3	24	B	2.77	6.89
			C	1.0	diversion[1]	6 x 2	237	5.3	292 [2]	B	2.33	6.75
5	Devon Park Drive Open Area	Weadley	A	2.25	off-line	2 x 2	185	24.0	38	D	2.21	3.76
7	S.R. 202 Interchange	Treyburn	A	5.25	on-line	4 x 6	175	37.3	389	D	2.89	6.94
8	Richter Property	Weadley	A	8.0	on-line	11 x 4	130	69.5	753	B	3.89	8.9
			B	8.0	on-line	11.5 x 4	130	44.5	753	B	4.72	9.11
9	Devon Park Drive Natural Area (Avonwood)	Avonwood Branch	A	0.75	on-line	4 x 6	203	3.2	156	B\C\D	3.38	5.92
			B	0.75	off-line	1.25 x 1	203	3.2	16	B\C\D	3.15	6.08
			C	0.75	diversion[1]	2.5 x 1	203	3.2	156 [2]	B\C\D	1.82	6.14
10	Devon Park Drive Natural Area (Weadley)	Weadley Branch	A	1.5	on-line	5.5 x 6	188	7.5	227	B\D	3.46	6.03
			B	1.5	off-line	2.5 x 2	188	7.5	46	B\D	3.1	5.83
			C	1.5	diversion[1]	2.5 x 1	188	7.5	227 [2]	B\D	2.04	6.12

[1] Only a portion of flow diverted from main channel into storage facility via a weir-like structure placed in channel
[2] Entire tributary area flows toward facility but only a portion of flow will enter storage area

Table IV-6.A
2-Year Hydrologic Model Results of Conceptual Stormwater Best Management Practices

Site No.	Site Name	Configuration	2-Year Flow Data (Channel Protection)					
			Site			Downstream		
			Existing (cfs)	w/ BMP (cfs)	Reduction (%)	Existing (cfs)	w/ BMP (cfs)	Reduction (%)
2	Teegarden Park	Online	25	25	0	517	517	0
		Offline	3	1	67	517	517	0
		Diversion	6	6	0	517	517	0
5	Devon Park Drive Open Area	na	36	12	67	517	519	0
7	S.R. 202 Interchange	na	70	19	73	517	466	10
8	Richter Property	Config. A	189	155	18	517	506	2
		Config. B	189	180	5	517	524	-1
9	Devon Park Drive Natural Area (Avonwood)	Online	11	11	0	517	517	0
		Offline	24	7	71	517	518	0
		Diversion	3	3	0	517	517	0
10	Devon Park Drive Natural Area (Weadley)	Online	21	21	0	517	517	0
		Offline	35	18	49	517	519	0
		Diversion	5	4	20	517	517	0

Table IV-6.B
100-Year Hydrologic Model Results of Conceptual Stormwater Best Management Practices

Site No	Site Name	Configuration	100- Year Flow Data (Flood Reduction)					
			Site			Downstream		
			Existing (cfs)	w/ BMP (cfs)	Percent Reduct. (%)	Existing (cfs)	w/ BMP (cfs)	Percent Reduct. (%)
2	Teegarden Park	Online	454	432	5	3077	3077	0
		Offline	64	5	92	3077	3077	0
		Diversion	114	69	39	3077	3077	0
5	Devon Park Drive Open Area	na	84	21	75	3077	3085	0
7	S.R. 202 Interchange	na	406	257	37	3077	2912	5
8	Richter Property	Config. A	735	556	24	3077	2881	6
		Config. B	735	590	20	3077	2940	4
9	Devon Park Drive Natural Area (Avonwood)	Online	204	197	3	3077	3077	0
		Offline	82	14	83	3077	3082	0
		Diversion	51	29	43	3077	3076	0
10	Devon Park Drive Natural Area (Weadley)	Online	294	276	6	3077	3074	0
		Offline	168	53	68	3077	3085	0
		Diversion	73	29	60	3077	3072	0

In lieu of modeling the volume controls, each of the conceptual BMPs presented in this Phase II analysis were evaluated based upon a set of site characteristics and BMP attributes which are considered good indicators of a site's potential for volume control. The four indicators used as part of this analysis are:

- Physical Characteristics- Physical aspects of the prospective sites related to the hydrologic soil group, depth of soil and depth of water table determine the ability of the soil to infiltrate water. Typically, Hydrologic Soil Group A and B soils are better suited for infiltration techniques than C and D soils. Furthermore, deeper soils and soils with deeper water tables are better than shallow soils or those locations with high water tables.
- Facility Size- The footprint or amount of area that a BMP occupies affects the volume a particular facility is able to infiltrate. Throughout the watershed there is a finite depth of soil available to infiltrate stormwater. As the depth of the soil is considered for the most part fixed the only way to increase the amount of infiltration is to maximize the area a facility occupies. Therefore, larger BMP footprints are typically capable of removing more surface runoff and returning it to the ground to recharge the water table than smaller BMPs.
- Loading Ratio- The ratio of the amount of drainage area to the amount of land area a BMP occupies is referred to as the loading ratio. Typically, for volume control facilities such as those that use infiltration, it is best to keep this ratio as small as possible with the optimum ratio not to exceed 5:1. As the loading ratio increases the likelihood of either overwhelming the facility with more water than it can handle or creating maintenance problems increases. Larger loading ratios to a BMP may be acceptable but may require additional maintenance or special provisions such as bypass channel to accommodate the additional flows.
- Impervious Surface- As the percentage or amount of impervious surface is increased within the watershed the volume of stormwater that runs off the land increases and the amount of water that is infiltrate into the ground reduces. Therefore, it is a logical extension that areas with high amounts of impervious surface are more in need of recharge facilities than areas with low amounts impervious surface. Thus it is most beneficial to place recharge or volume control facilities in areas with high amounts of impervious surface than in those areas with a low amount of impervious surface.

To evaluate the potential for volume control at each of the 10 conceptual BMP locations, the four indicators were weighted on a scale of 1 to 10, with a weighting of 10 being most important and a weighting of 1 the least important. Each of the sites was scored on how well they satisfy the individual criterion. The scores varied on a scale of 0 to 100 with the higher scores representing better performance or a more beneficial attribute. The score was multiplied by the weight of the criterion to obtain a gross score. The gross score for each of the criterion was summed together and divided by the sum of the individual criterion weights to achieve an overall weighted rating for each individual site. The end result of this weighted rating process is a comparative value representing the potential for achieving volume control at each of the sites. Table IV-7 contains the weighted rating table used in the analysis.

Table IV-7 Volume Control Rating Table

Site Number		1		2A & C		2B		3		4		5		6		7		8		9A & C		9B		10A & C		10B	
Site Name		Old State Road		Teegarden Park		Teegarden Park		Gateway		Richard Road Culvert		Devon Park Drive Open Area		Devon Park Drive Streetscape		S.R. 202 Interchange		Richter		Devon Park Drive Avonwood Branch		Devon Park Drive Avonwood Branch		Devon Park Drive Weadley Branch		Devon Park Drive Weadley Branch	
Criteria	Weighting	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score	Score	Weight. Score
Physical Characteristics	10	80	800	80	800	80	800	0	0	40	400	40	400	40	400	0	0	60	600	40	400	40	400	40	400	40	400
DA to BMP Ratio	8	0	0	0	0	20	160	100	800	0	0	40	320	60	480	0	0	0	0	0	0	20	160	0	0	0	0
% Impervious Area	5	20	100	40	200	40	200	100	500	60	300	80	400	100	500	40	200	80	400	40	200	100	500	60	300	80	400
BMP Footprint	8	20	160	40	320	40	320	0	0	0	0	60	480	20	160	100	800	100	800	40	320	40	320	40	320	40	320
Total Rating	31		1060		1320		1480		1300		700		1600		1540		1000		1800		920		1380		1020		1120
Weighted Rating		34		43		48		42		23		52		50		32		58		30		45		33		36	

Physical Site Characteristic (soils etc.)

HSG A, Low Water Table	100
HSG B	80
HSG C	40
HSG D, High Water Table	0

BMP Footprint (acres)

+5	100
3-5	80
1.5-3	60
.5-1.5	20
>0.5	0

Drainage Area to BMP Footprint Ratio

3-5	100
5-7	80
7-12	60
12-17	40
17-22	20
+22	0

Imperviousness of Drainag Area

+50%	100
40-50	80
30-40	60
15-30	40
0-15	20

F. Conceptual Stormwater Best Management Practice - Performance

Table IV-8 contains a side by side comparison of the performance data of the 10 conceptual sites evaluated by the study using the project's hydrologic model. Assessing the performance of the conceptual BMPs by examining the percentage of the reduction in flow alone can be misleading. This is because the significance of the flow reduction must always be considered with respect to the amount of flow that a conceptual stormwater BMP is managing. For instance a site that manages 100 cfs of existing conditions flow and reduces it to 75 cfs results in a 25% reduction in flow. However, a second BMP controlling 10 cfs of existing conditions flow and reduces it to 5 cfs results in a 50% reduction in flow. When considering only the percent reduction the second BMP appears the most effective with a 50% reduction in flow. However, it is the first site that provides the most control and depending upon its location in the watershed may be most beneficial to the stream. To compensate for this condition a weighted reduction in flow is provided in Table IV-8, which is calculated by multiplying the percentage of reduction in flow created by the conceptual BMP by the fraction of the existing flow flowing to the BMP, in relation to the existing flow at the Tredyffrin Township line, and multiplying it by a factor of 10. In this way the significance of the flow reduction at one site can be compared directly to the flow reduction created by another conceptual BMP located in a different part of the watershed.

G. Conceptual Stormwater Best Management Practice – Ranking

After completing the performance assessment of the conceptual BMPs with the watershed's hydrologic model, the data was further evaluated in order to rank the conceptual BMPs based upon a series of criteria developed in coordination with the Township. In addition to flood control, erosion control and volume control, the ranking process considered the impact of the conceptual BMPs constructability (accessibility, ease of construction and ability to obtain permits) and public amenity (acceptance by the community, aesthetics and educational value). This evaluation and ranking process is thoroughly described in the Trout Creek Watershed Study –BMP Selection Technical Memo prepared by CH2MHill dated July 2, 2008 and provided in the Appendix A to this report.

The outcome of the ranking process scored six conceptual BMPs as the most beneficial stormwater management projects with the greatest ability to achieve the Township's stormwater management objectives within the watershed. The top six sites are as follows:

- Site 5 - Devon Park Drive Open Area
- Site 2 - Teegarden Park (Offline)
- Site 7 - S.R. 202/Devon Park Drive Interchange
- Site 9 - Devon Park Drive-Avonwood (Offline)
- Site 10 - Devon Park Drive-Weadley (Offline)
- Site 6 - Devon Park Drive Streetscape.

After consulting with the Township the next phase of the project will advance two of these projects into the preliminary design phase of the project. In the preliminary design phase of the project the conceptual BMPs will be further refined to develop plans and engineering analyses that define the size, scope, and intended performance of the two facilities selected by the Township.

TABLE IV-8 Summary of Conceptual Stormwater Best Management Practice Performance

Site Number	Site Name	Configuration	Flood Reduction (100-year event)			Channel Protection (2-year event)			
			Reduction in Peak Flow from Site	Weighted[1] Reduction in Peak Flow from Site	Downstream Reduction in Peak Flow	Reduction in Peak Flow from Site	Weighted[1] Reduction in Peak Flow from Site	Channel Protection Downstream from the site	Volume Control Rating
			(%)	-	(%)	(%)	-	(%)	-
1	Old State Road	na	1	0	0	14	0	0	34
2	Teegarden Park	Online	5	7	0	0	0	0	43
		Offline	92	19	2	67	4	0	48
		Diversion	39	15	0	0	0	0	43
3	Gateway Shopping Center	na	0	0	0	0	0	0	42
4	Richards Road Culvert	na	0	0	0	0	0	0	23
5	Devon Park Drive Open Area	na	21	75	0	67	46	0	52
6	Devon Park Drive Streetscape	na	23	4	0	44	15	0	50
7	S.R. 202 Interchange	na	37	48	5	73	99	10	32
8	Richter Property	Config. A	24	58	6	18	66	2	58
		Config. B	20	47	4	5	17	0	58
9	Devon Park Drive Natural Area (Avonwood)	Online	3	2	0	0	0	0	30
		Offline	83	22	0	71	33	0	45
		Diversion	43	7	0	0	0	0	30
10	Devon Park Drive Natural Area (Weadley)	Online	6	6	0	0	0	0	33
		Offline	68	37	0	49	33	0	36
		Diversion	60	14	0	20	2	0	33

H. Non-Project Specific Recommendations

In addition to the six (6) stormwater retrofit priority sites identified by this report there are additional non-project specific steps that can be taken throughout the Watershed to improve the way stormwater is managed within the Trout Creek watershed. Therefore, the Township is encouraged to continue to improve the way stormwater is managed in the Township by continuing to move forward on the following non-project specific steps:

1. Reduce Existing Impervious Surface Coverage - As indicated in Section II of this report over a third of the Tredyffrin Township section of Trout Creek watershed is comprised of impervious surface. Therefore, the Township is encouraged to seek for any means available to reduce the amount of existing impervious surface or minimize the placement of new impervious surfaces within the Township. To accomplish this objective the Township should encourage owners of existing impervious surface to convert a portion of the surface to pervious pavement or remove unused portions of the impervious surface and converting it back to a vegetated condition. For proposed development the Township should consider low impact design to limit the amount of new impervious surface. Low impact design would consider reduced street widths, porous paving in parking areas, non paved overflow parking, parking structures (parking decks)in lieu of parking lots and shared parking areas where it could be demonstrated that peak parking demand are not concurrent. Green rooftops should be considered as an alternative to standard impervious rooftops to further reduction of rooftop runoff from building structures. Alternative designs of parking islands should consider a sumped design with plantings typical of a Bioretention Area or Rain Garden.

2. Encourage Construction of Stormwater BMPs in Existing Residential and Nonresidential Developments - Large portions of the Township consist of both residential and commercial development that was constructed prior to implementation of current stormwater control methodologies, which address not only localized flooding and drainage but also regional flooding, streambank erosion and water quality issues. Therefore, the Township should continue to promote the implementation of newer stormwater BMPs in existing developments throughout the Township. The Township should encourage all property owners within the Township to seek out ways to improve the management of stormwater runoff. In residential areas the disconnection of impervious surfaces is strongly recommended by redirecting rooftop downspouts and driveway runoff away from storm sewer and gutters and toward pervious surfaces where some of the runoff can be infiltrated. On-lot BMPs such as rain gardens and dry wells are recommended for residential areas while retrofitting of existing stormwater controls such as dry detention basins are recommended for existing nonresidential sites.

3. Enforce Stormwater Management Standards and Criteria – The Township should actively enforce existing and proposed stormwater management ordinances once adopted. The owners of any facilities identified as nuisance facilities or facilities recognized as not functioning as intended, should be required to upgrade the facilities to effectively manage stormwater runoff. Any expansion of impervious surface should require an upgrade of existing facilities to meet current performance standards. The Township should limit any waiver request from the stormwater management standards and criteria to ensure consistent

application of the standards and limit the long term and cumulative effects of poorly managed stormwater runoff throughout the Trout Creek portion of the Township.

4. Stormwater Management Ordinance - Tredyffrin Township should continue to move forward with the development of a Stormwater Management Ordinance to implement flood control, streambank protection, groundwater recharge and water quality standards consistently throughout the Township. The ordinance should require that the post development peak rate of flow not exceed the predevelopment peak rate of flow for the 10 through 100-year storms. To protect streambanks from erosion the ordinance should consider requiring a reduction of the post development 5-year peak rate of runoff to a level that is not greater than the existing condition 1-year flow. Volume controls should be incorporated into a development and redevelopment sites so as to not allow a net increase in the volume of runoff for all storms equal to the 2-year flow or less. All new developments should be required to install BMPs to address nonpoint source pollutant removal. The ordinance should require installation of BMPs to demonstrate the thermal effects from the stormwater runoff are reduced and should promote placement of stormwater management BMPs in a series (treatment train approach) to provide the maximum treatment of the stormwater runoff.

5. Conserve Open Space - A considerable portion of the Township is "built out" with limited open space available for regional stormwater controls or other BMPs to resolve existing stormwater runoff related problems. Therefore, the Township should pursue any and all means of preserving existing open space and should carefully consider the impact of any new development of open space upon the flow of stormwater through the watershed. Whenever possible the Township should encourage redevelopment of existing parcels of land in lieu of converting existing open space to development. The Township should encourage all property owners containing a portion of the Trout Creek or one of its tributaries to permanently establish a natural vegetated buffer along the bank of the creek. A 50-foot width of the buffer from the top of the bank is recommended but can be reduced to as little as 10-feet for small parcels where there are spatial constraints.

6. Continue Proactive Involvement in Development Richter Track – As the Richter parcel is one of a few large parcels of land available for development within the Tredyffrin Township portion of the watershed and is in close proximity to a highly developed portion of the watershed with a large amount of impervious surface, the Township should seek to proactively engage any applicant of large-scale commercial development in these parcels early in the development process. Early interaction is crucial to encourage low impact design principals and practices are incorporated into the design and to ensure that existing problems downstream of the site are not exasperated by the proposed development. A list of stormwater related issues that the Township should consider concerning the development of the Richter properties are listed in Section IV.C.8.

7. Require Application of Infiltration in Areas with Carbonate Geology – Often infiltration practices are immediately discounted in areas with carbonate geology. As a large portion of the Township is underlain with carbonate geology, the initial assessment is that infiltration practices can not be used in a large portion of the Township. This is not an acceptable supposition. Therefore, before any applicant for development applies for a waiver from infiltration or volume controls the township should require the applicant demonstrate through on-site testing and mapping of existing carbonate features that infiltration cannot be physically accomplished at the site or presents an increased hazard if constructed at a

particular site. When infiltration is proposed in an area with carbonate geology, careful attention should be taken to not overload the facility by significantly increasing the loading ratio (drainage area to footprint of BMP) of the facility. With a thick soil mantle, low groundwater table and large distance to an existing carbonate feature, such as sinkhole, surface fault or fissure, the loading ratio can go up to as high as 5:1; however, it is typically best to limit the loading ratio to 3:1 or smaller. Regardless, the Township should adopt stormwater standards for carbonate geologic areas that are consistent with the standards created by the Chester County Water Resource Authority for stormwater management in carbonate geologic regions.

With the application of both the project related and non-project specific recommendations of this report the Township will be able to realize the greatest control of stormwater runoff in the Trout Creek portion of the Township and begin to start the process for some restoration to occur within the watershed.

I. Conclusion

The results of this analysis were presented to select personnel in the in the Township Administration, including the Township Manager, Township Engineer and Public Works Director. Upon careful consideration of the top six ranking projects, which include the following retrofit sites:

- Site 5 - Devon Park Drive Open Area
- Site 2 - Teegarden Park (Offline)
- Site 7 - S.R. 202/Devon Park Drive Interchange
- Site 9 - Devon Park Drive-Avonwood (Offline)
- Site 10 - Devon Park Drive-Weadley (Offline)
- Site 6 - Devon Park Drive Streetscape

The Township selected Site 2 –Teegarden Park and Site 6- Devon Park Drive Streetscape as the two projects it would like to advance into the preliminary engineering phase. These two projects were selected as the top candidate sites for the following reasons:

- Ownership - Both sites are owned by the Township and would not require the purchase of easements or right-of-way which could potentially significantly elevate the cost of implementation.
- Education - Both sites are situated in highly visible locations where citizens of the Township can view and become educated about what stormwater BMPs look like and how they function.
- Site Characteristics – Both sites contain existing characteristics that make them amenable to stormwater management such as usable land area, adequate hydrology, suitable soils, acceptable topography, reasonable proximity to existing problem areas and existing watercourses.
- Future Opportunities - Both sites provide opportunities to implement stormwater BMPs that are new and innovative and a departure from the typical detention basin design.
- Expansion - Both sites can provide a framework or model in which the conceptual BMPs may be partially implemented and then expanded to other portions of the sites; or present an opportunity to place the proposed stormwater BMPs in series with other existing or potential stormwater BMPs.