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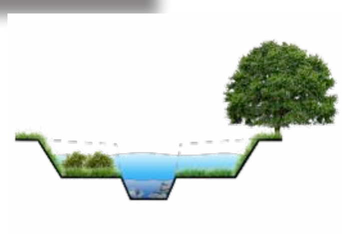

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# CHAPTER 1
## *Introduction*

# Executive Summary:

The Town of Bath has experienced drainage problems and flooding for decades due to the unique topography of this region. The Town is drained by Warm Springs Run which navigates through the Town Center and eventually empties into the Potomac River. Warm Springs Run is constricted through town and often backs up and swells out of its banks at various locations. Several studies and projects have been conducted over the years dealing with flooding in the Warm Springs Run Watershed, however, this study builds upon the existing information, creating a "Comprehensive Planning Document" intended to focus on opportunities for implementation of green infrastructure practices. These practices will emphasize treatment of water quality within the watershed while contributing to the overall reduction of runoff volume as well.

*Context Map*

The study provides an overview of green infrastructure practices and gives site specific examples as well as general conceptualizations of projects that would be likely to have major positive impacts for the water quality and quantity of runoff entering and within the Town. It examines different regions of the watershed and helps to identify needs within various areas in and upstream of the Town.


*Fairfax Street in June of 2014.*

Another aspect of the study is the identification of various methods of implementation. It can be financially unfeasible to develop and construct pure stormwater management projects no matter the need, however the Town has explored other avenues available to afford said projects. For instance, many projects can be retrofit for green stormwater management as a part of initial construction for other purposes and routine site maintenance such as paving an existing parking lot. In these instances, the cost burden of the stormwater practices are spread over the entire project and substantial savings can be accomplished by sharing costs such as mobilization.

*Berkeley Springs State Park*

The intended result of the following study is to be used as an educational tool for the public and to serve as a prioritized project list that can be used as a guide to carry out various green stormwater projects, which will improve the life and well-being of the citizens of Bath and the Warm Springs Run Watershed.

# Introduction:

*Bridge on Fairfax Street.*


*Flooding on US 522 in September of 2012.*

*Flooding on Fairfax Street in September of 2012.*

Warm Springs Run is an 11.8 mile stream located in Morgan County of the eastern panhandle of West Virginia. The stream is a tributary of the Potomac River and is a part of the Chesapeake Bay Watershed. The entire Warm Springs Run watershed has a drainage area of 9,682 acres, however, the focus area of this study contains the upper portion of the watershed, extending through the lower end of town. The drainage area of the study is 3664 acres.

The Town of Bath was founded in 1776 and is the county seat of Morgan County. Bath and the general area surrounding it are also known as Berkeley Springs which is named after the natural springs in the area. The higher density development of this area is mainly focused around Warm Springs Run and U. S. Route 522 which runs adjacent to the run for nearly its entire span. The high density of development within and upstream of the Town of Bath contributes to flash flooding following heavy storm events. The stream is not wide or deep enough to accommodate the high water flows during such events and much of the natural floodplain has been developed, therefore the out of bank events overflow into urban areas.

To help control/alleviate this problem a series of stormwater control dams were built in the late 50's and early 60's. These dams were constructed at strategic areas around the watershed. The dams are over fifty years old but they have been well maintained and are still serving a crucial role of alleviating flood waters during heavy storm events.

While the dams help a great deal there are a number of areas upstream from the Town of Bath that have seen very high concentrations of development over the time since their construction. The general area including and surrounding Morgan Square for example has 350,000 $ft.^2$ of impervious surface that is introduced into the stream within a very short section of Warm Springs Run.

# Goals & Objectives:

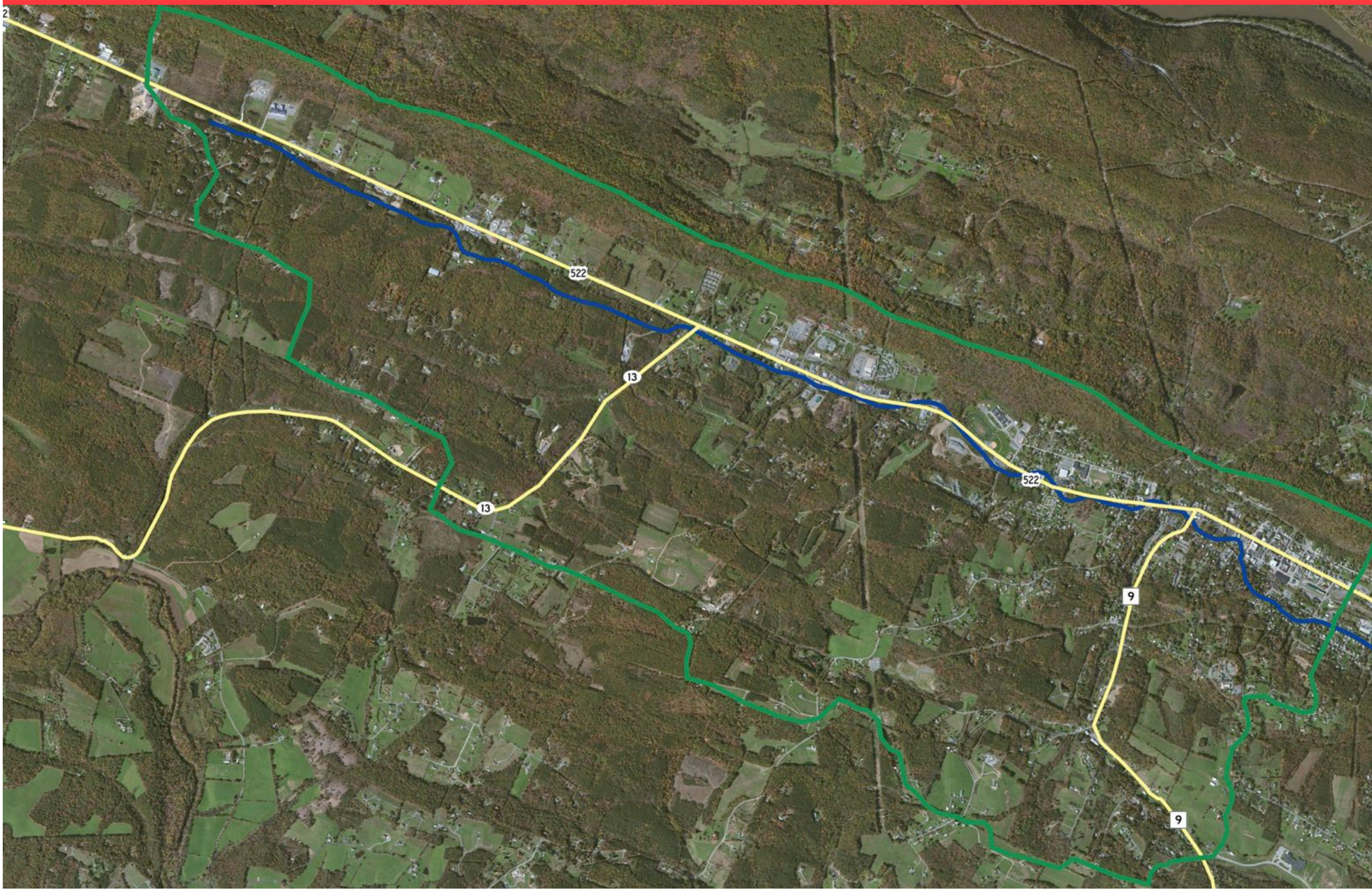
## Goals:

- Improve the water quality in the watershed and positively impact downstream receiving waters.
- Manage stormwater quantities and reduce damages from water quantities and flooding.
- Educate on the importance of green infrastructure to the watershed and the environment.

## Objectives:

- Reduce the amount of impervious surface.
- Reduce the water pollution and sediment runoff.
- Install stormwater BMPs throughout the watershed to create sustainability chains and positively affect water quality while reducing runoff.
- Educate businesses and residents on the importance of green infrastructure through demonstration projects on public land.
- Encourage green infrastructure development on private land through successful projects implemented on public land.
- Educate and encourage planners and project developers to manage stormwater on site and throughout the watershed.

# CHAPTER 2
## *Existing Conditions*



# Watersheds:

## Chesapeake Bay Watershed:

The Chesapeake Bay Watershed is the largest estuary in North America. The watershed covers 64,000 square miles and includes more than 100,000 rivers and streams. The watershed includes parts of six different states and also the District of Columbia. The land to water ratio of the watershed is a staggering 14:1 (the most of any coastal watershed in the world).

Almost 18 million people live within the watershed. More than 300 species of fish, shellfish and crab species and a wide array of other wildlife call the Bay home.

The Chesapeake Bay holds more than 15 trillion gallons of water and is fed by 50 major tributaries. The largest of these are the Susquehanna, Potomac, Rappahannock, Yurk, and James Rivers.

*Aerial view of Washington, D.C. (Potomac & Anacostia Rivers)*

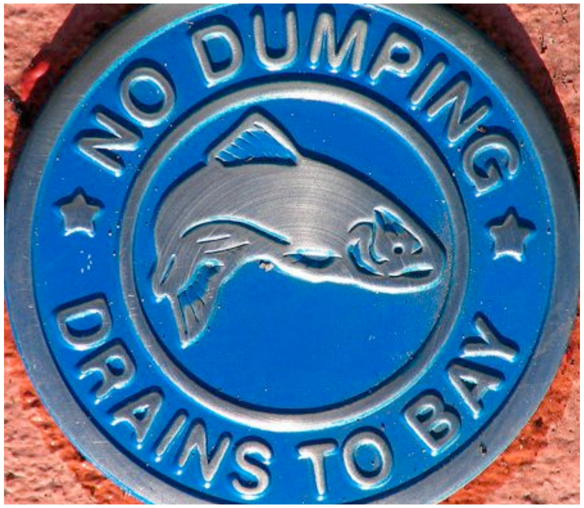
*Osprey (Pandion haliaetus)*

## Potomac River Watershed:

The Potomac River Watershed is a sub watershed of the Chesapeake Bay Watershed. The watershed covers 14,760 square miles and includes four states and the District of Columbia. The major tributaries are the Shenandoah, South Branch, Monocacy, Savage, Cacapon, Anacostia, and Occaquan Rivers. Around 6.11 million people live in this watershed with the majority of that number being located in the D.C. metropolitan area. The Potomac River has an average water flow of 7 billion gallons per day.

## Why is this important?

Stormwater runoff within a watershed ultimately drains to bodies of water. Water that drains from a roof in Berkeley Springs, WV will drain primarily into Warm Springs Run. However, this water will also end up in the Potomac River, the Chesapeake Bay, and the Atlantic Ocean. Considering the downstream impacts should be a major part of all types of development. Poor development practices will lead to further problems not only in a primary watershed but everywhere downstream of the source.

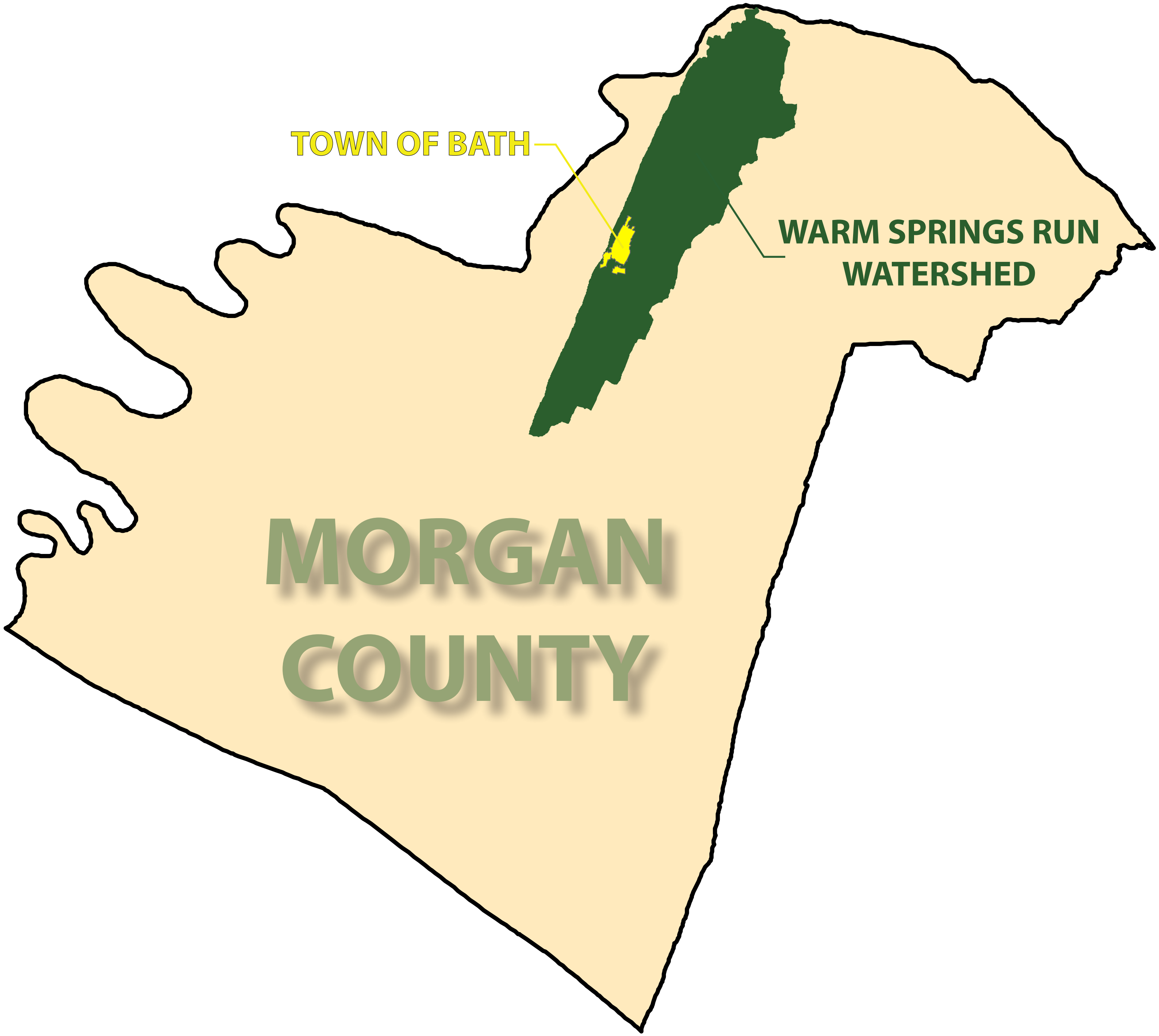



## Context Map:

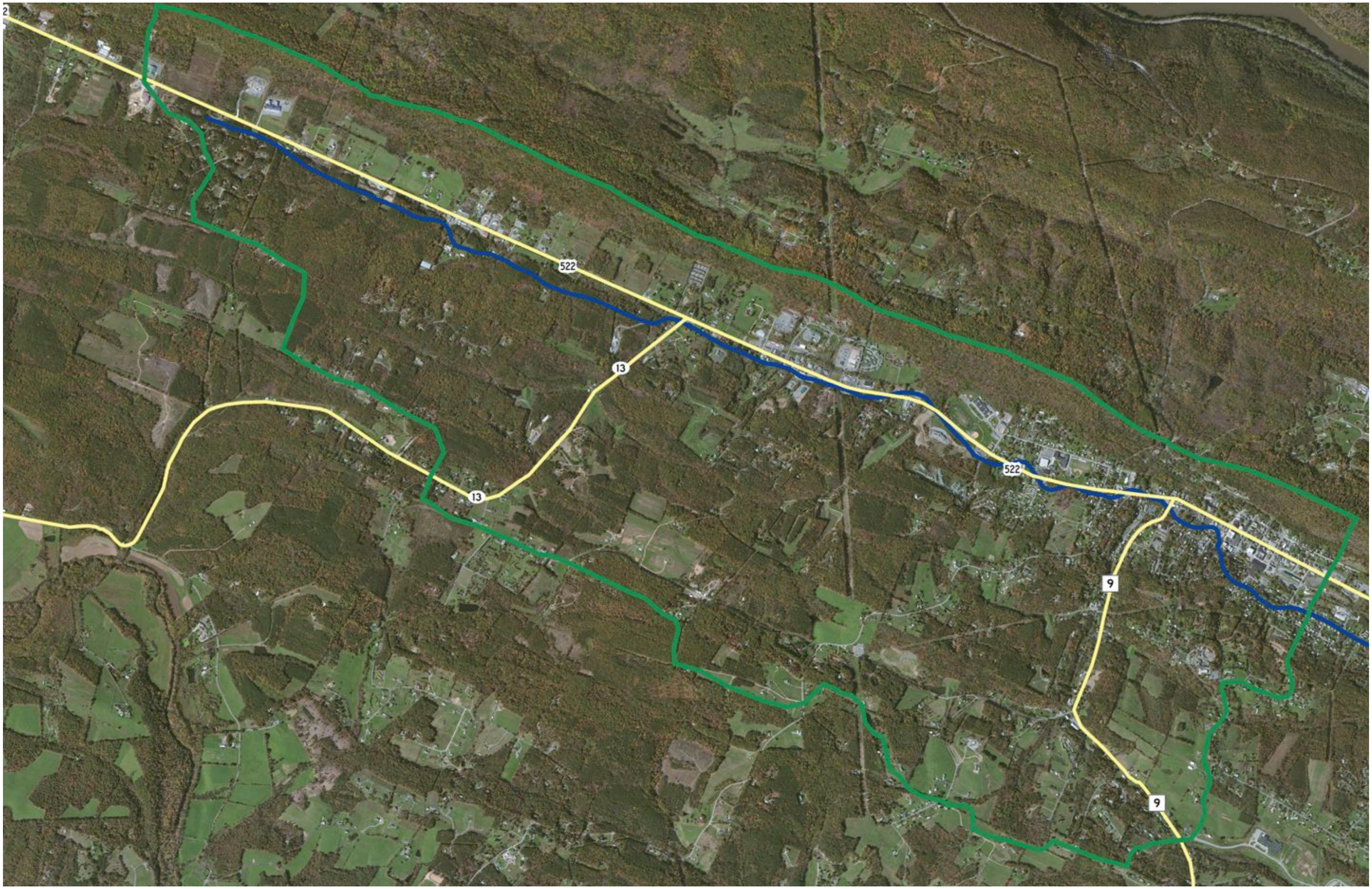

MICHIGAN
MASSACHUSETTS
NEW YORK
CONNECTICUT
PENNSYLVANIA
NEW JERSEY
CHESAPEAKE BAY WATERSHED
OHIO
DELAWARE
WEST VIRGINIA
KENTUCKY
VIRGINIA

## Context Map:

## Study Area:



# Upper Warm Springs Run Watershed:




## Legend:

Upper Watershed Boundary

Major Roads

Warm Springs Run

# Upper Warm Springs Run Watershed:

## Study Area:

This map and the previous context maps highlight the area of interest for this plan. The Warm Springs Run watershed lies completely within Morgan County in the eastern panhandle of West Virginia.  This plan is analyzing the upper part of the watershed that is the more developed portion around the Town of Bath, WV. Warm Springs Run Watershed is a part of the Potomac River Watershed; a sub basin of the Chesapeake Bay Watershed. Our study area covers a 4.7 mile stretch of Warm Springs Run and 3,664.6 acres of drainage area.

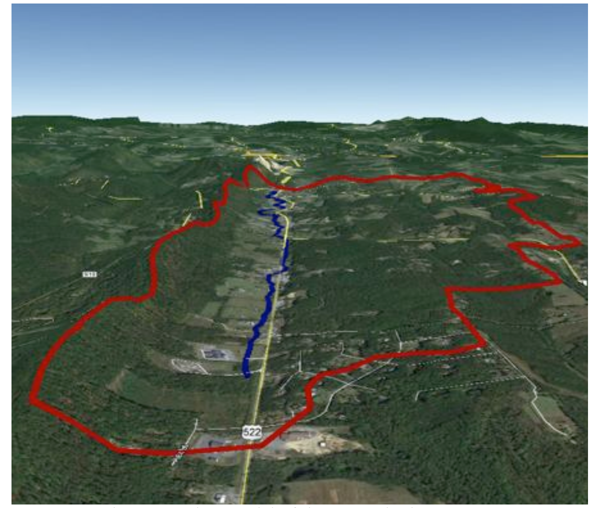
U.S. Route 522 and WV Route 9 run through the watershed as well as a number of county roads and city streets. These roads account for a large amount of impervious surface in the watershed that contribute to stormwater runoff and water quality pollution.


*U.S. 522 and WV 9. Berkeley Springs, WV.*

## Topography:

The model pictured to the right shows the topography within the watershed and the surrounding area. The western side of the stream is made up of a large ridge that surface flows into the stream. This is opposite of the eastern side of the stream where there are several valleys and bottlenecks that produce concentrated points of flow into the run.

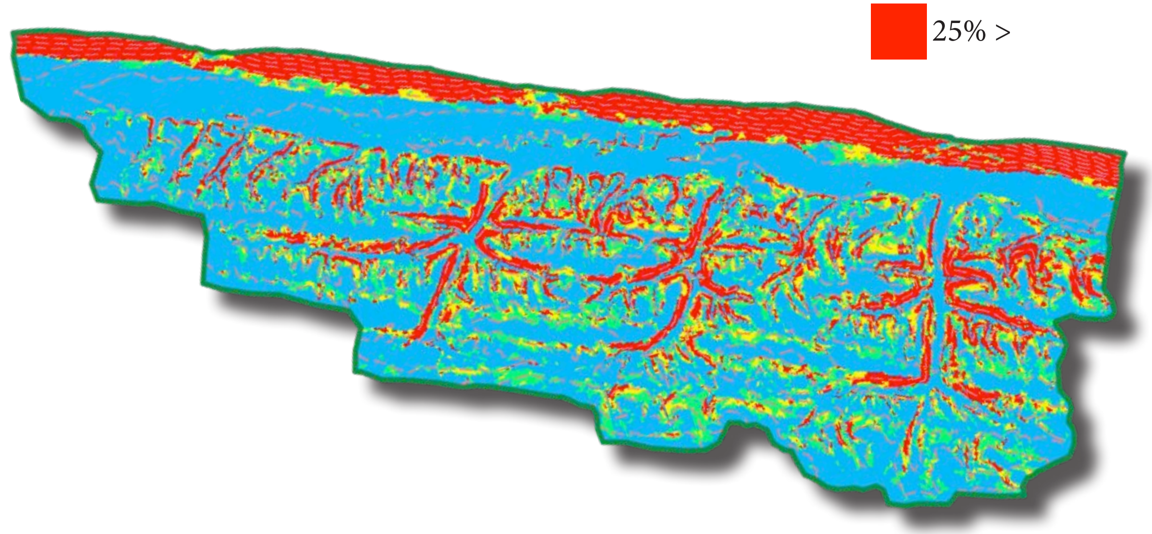
The model pictured below is a slope analysis of the watershed study area. This map highlights some of the major flow corridors in the watershed and points out some of the key areas to focus on in the implementation portion of this effort. The slope analysis is based off of USGS Topographic Contours.



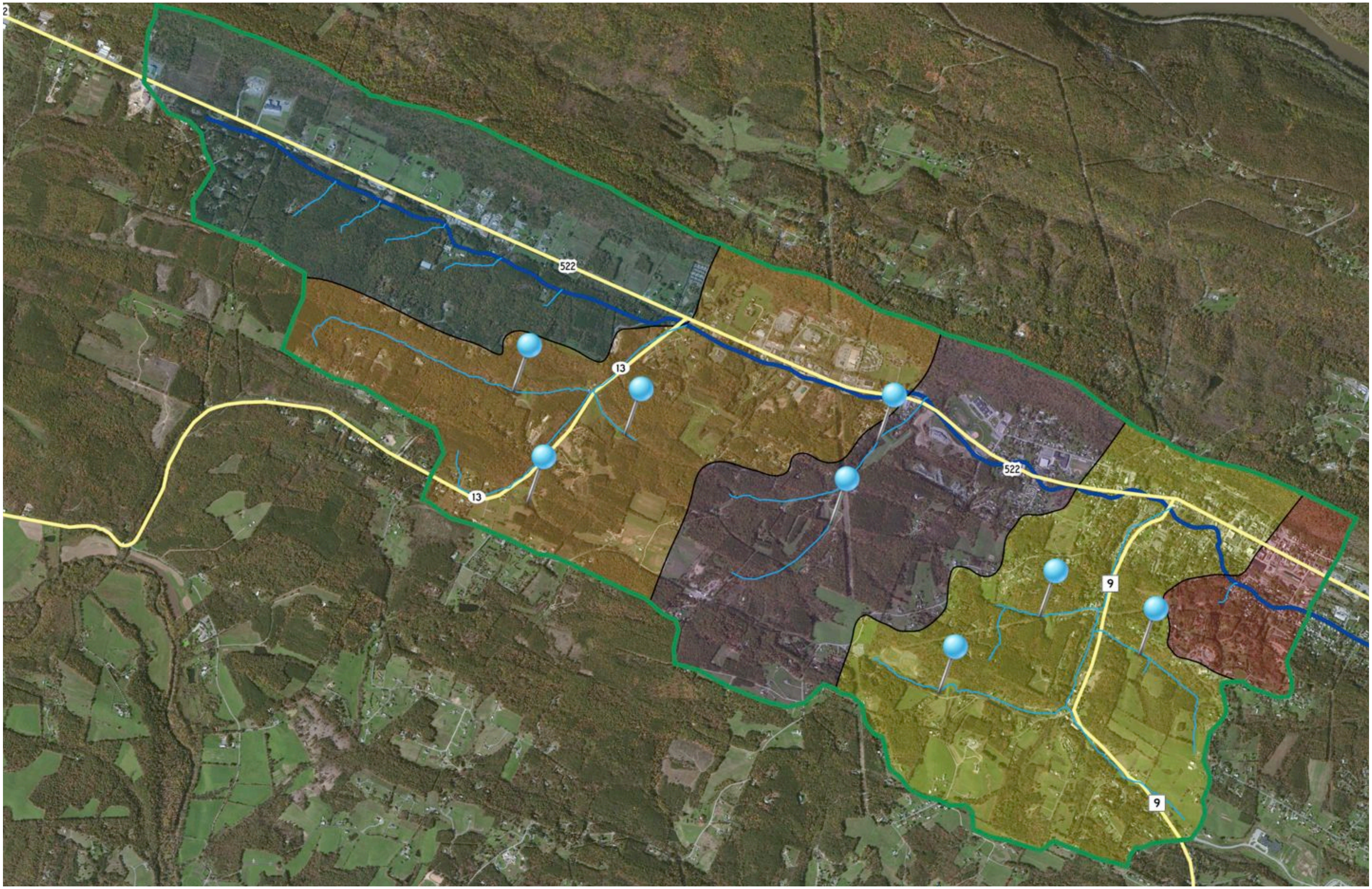

*Exaggerated topographic model of the watershed.*

### Slope Analysis Legend:

- 0-15%
- 15-20%
- 20-25%
- 25% >



## Sub Watershed Basins:




### Legend:

Sub Area One
Sub Area Two
Sub Area Three
Sub Area Four
Sub Area Five
Drainage Paths
Stormwater Control Dam
Warm Springs Run
Upper Watershed Boundary
Major Roads

# Sub Watershed Basins:

Page 13 shows the different drainage areas of the study area. There are five major areas within the upper watershed of varying sizes.

Drainage Area:
Sub Area 1 = 165.5 AC
Sub Area 2 = 949.7 AC
Sub Area 3 = 755.0 AC
Sub Area 4 = 932.3 AC
Sub Area 5 = 862.1 AC
Total = 3664.6 AC

Within each of the sub areas the major flow paths have been highlighted. These flow paths are where the highest concentration of water moves through the watershed. Also shown on the map are the eight flood control dams built between 1955 and 1961. These dams control stormwater from over 1,000 acres upstream from the Town of Bath and are able to hold back approximately 90 million gallons of water.

*Structure Four Dam and Stormwater Pond. Berkeley Springs, WV.*

*Aerial view of a portion of Sub Area One.*

## Sub Area 1-2:

Sub Areas 1-2 have the highest development percentages in comparison to their overall size. The town limits are almost completely within these two areas with a small portion dipping into Sub Area 3. Shown in the picture above is the existing and former CSX rail yards which have been identified as a brownfield site. Areas like this can be larger redevelopment projects through the brownfield development processes.

## Sub Area 3-4:

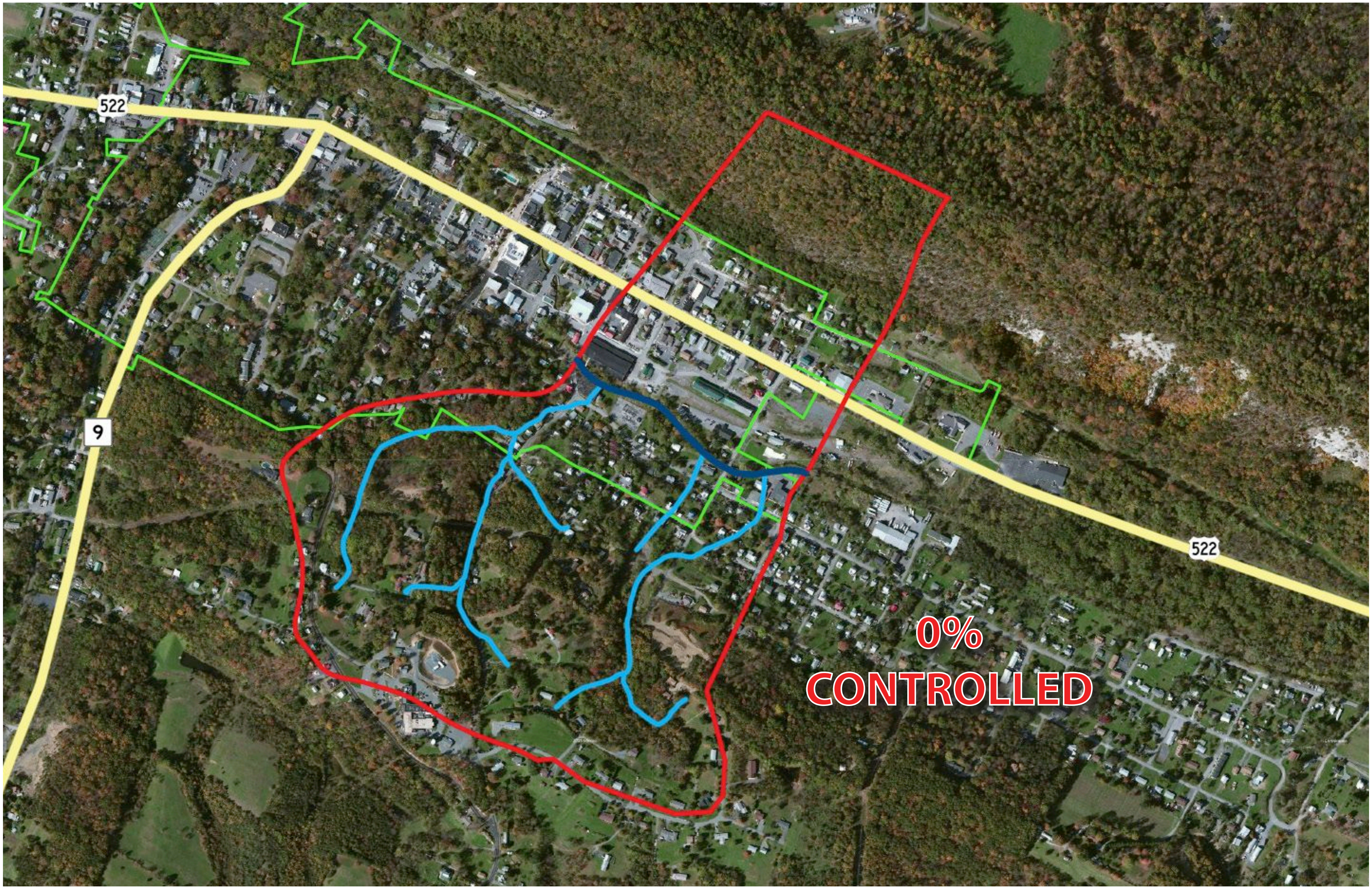
Sub Areas 3-4 have large amounts of development near the run but are relatively forested and undeveloped in their upper reaches. Berkeley Springs High School and Widmyer Elementary are in Sub Area 3 which represent opportunities for green infrastructure on public land. The development that is in Sub Area 4 is privately owned land but covers some very problematic areas within the watershed. The developed areas around the shopping center is an area where large amounts of runoff dump into the stream within a stretch of a few hundred feet.

*Large field located next to the run in Sub Area Four.*

## Sub Area 5:

Sub Area 5 consists of primarily undeveloped land with a few small portions of concentrated development. This area is where the origin of Warm Springs Run is located and provides opportunities for some upper reach controls to prevent downstream problems in the more problematic sub areas. A lot of the areas directly adjacent to the stream are open land available for benching techniques or reforesting projects.

## Sub Area One:




### Legend:

Sub Area One

Warm Springs Run

Town of Bath

Major Road

Drainage Paths

# Sub Area One Description:

Sub Area 1 is the portion of the study area furthest downstream. This area runs approximately from Independence Street northward to George Street and has the highest development percentage in comparison to its size. This area receives a high level of flow during storm events because of its location downstream of the most developed areas of the overall watershed.

A little less than half of this sub area is within the town limits. The western side of Warm Springs Run consists of single family residential and pockets of industrial and commercial sites. One significant area of impervious surface is the behind old train depot and is the location of the existing and former CSX Rail Yards. While listed as a brownfield by the WVDEP there is still potential for redevelopment of this site.

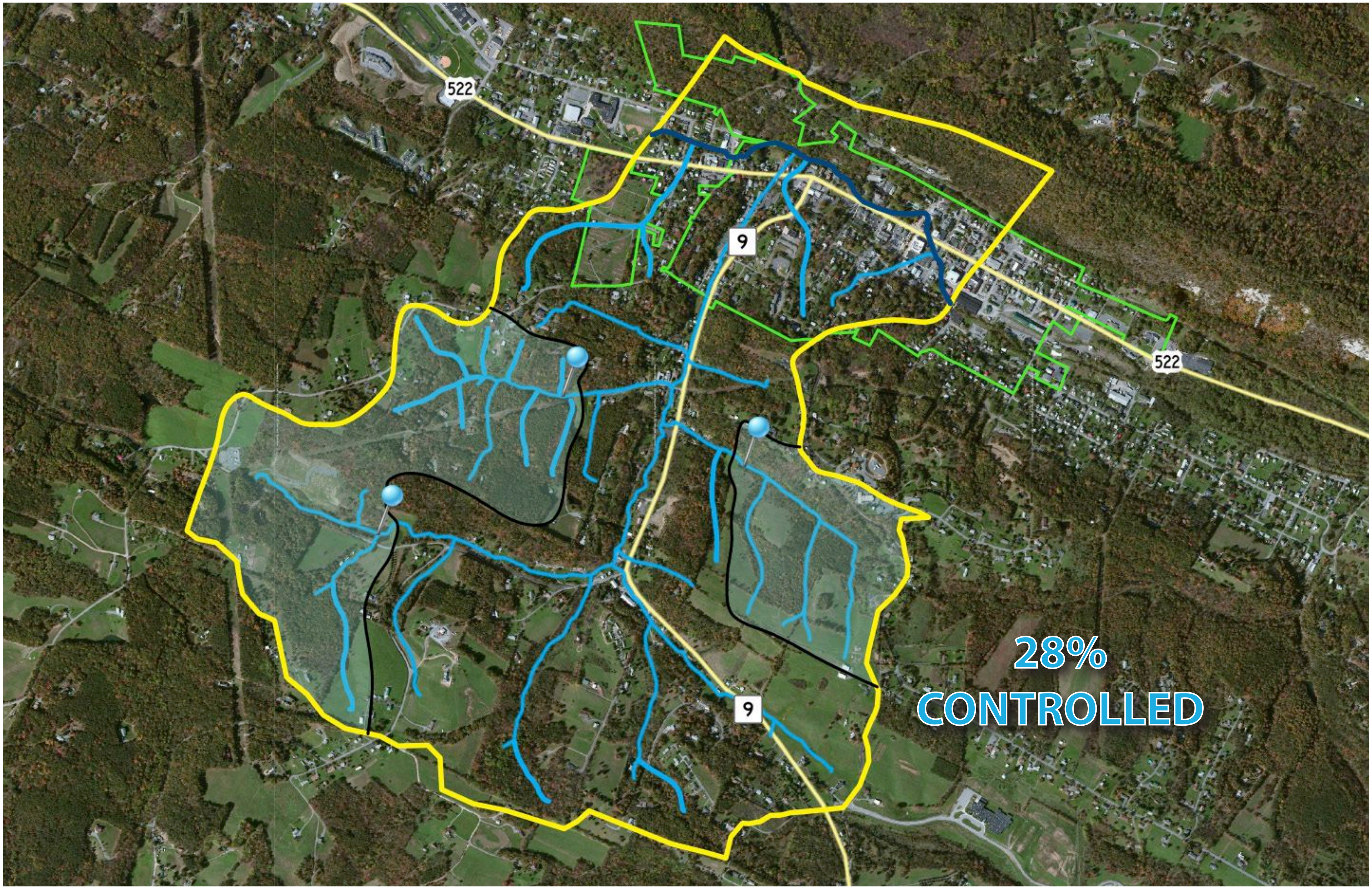
Outside the town limits consists of mostly steep slopes and highly vegetated land leading up to the ridge and the watershed boundary. The eastern side of Warm Springs Run is less densely developed consisting of mostly single family residential and a few industrial sites. Near the eastern boundary of the watershed is the site of the Old War Memorial Hospital. This site tallies a lot of impervious surface and is in a position of upper reach controls which can alleviate pressure on this sub area.

*Old Berkeley Springs Train Depot.*

*Existing and former CSX Rail Yards site.*

*Old War Memorial Hospital.*

## Sub Area Two:




**Legend:**

- Sub Area Two
- Warm Springs Run
- Stormwater Control Dam
- Town of Bath
- Major Road
- Drainage Paths
- Dam Controlled Areas (28% of area)

# Sub Area Two Description:



Sub Area Two stretches along Warm Springs Run approximately from Greenway Cemetery and the high school athletic fields northward to Independence Street. This sub area can be a problematic portion of the watershed due to the high density of development in proximity to Warm Springs Run and the amount of concentrated flow points east of the run. This sub area has three stormwater control dams in the upper reaches that control 28% of the sub area.

Most of the Town of Bath lies within this sub area which consists of some pockets of single family residential development and large bands of commercial and industrial sites. The remainder of the sub area consists of Greenway Cemetery and farmland. The cemetery is mostly pervious surface but does have a few access roads counting as impervious surface. The cemetery also lies in a valley with a drainage area of over 30 acres.

Outside the town limits lies largely undeveloped land with around half of that land having tree canopy coverage. WV Route 9 runs through a valley from the top of the sub watershed into the town. This valley represents a portion of the uncontrolled land in this sub area and with the expanse of land adjacent to the road it presents opportunities for future stormwater management projects.

*Narrow portion of the stream behind the County Courthouse.*

*Morgan County Public Library.*

*Gravel parking lot located on Fairfax Street.*

## Sub Area Three:

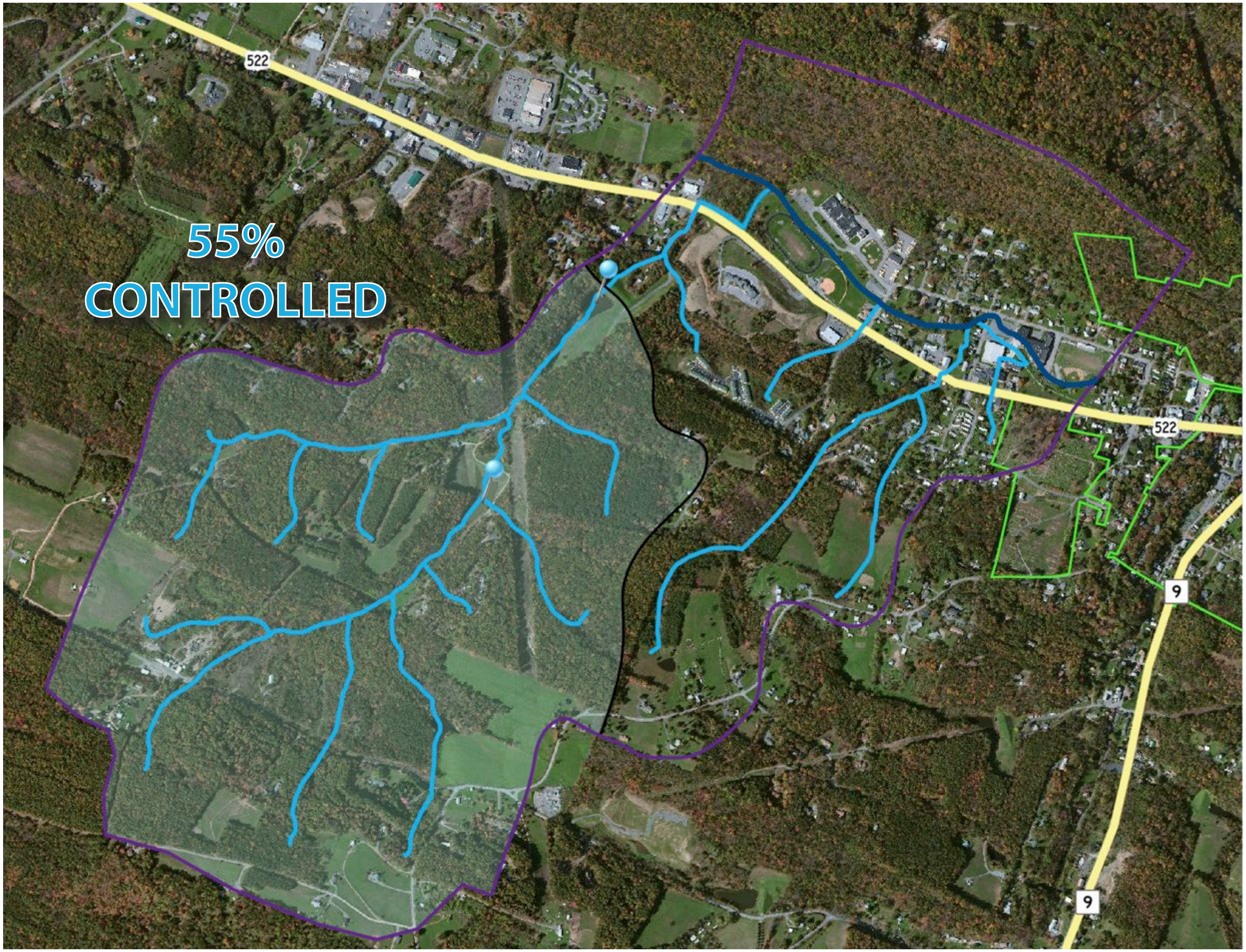



*Figure 3.3*

## Legend:

Sub Area Three
Warm Springs Run
Stormwater Control Dam
Town of Bath
Major Road
Drainage Paths
Dam Controlled Areas (55% of area)

## Sub Area Three Description:

Sub Area Three stretches from just south of Sugar Hollow Road northward to Greenway Cemetery and the high school athletic fields. This area has a relatively low development percentage that consists mostly of single family residential, a pocket of multi-family residential, commercial, and educational land. The educational land is Berkeley Springs High School and Widmyer Elementary School which take up approximately 35 acres of land directly adjacent to Warm Springs Run. These sites currently have no stormwater control in place.

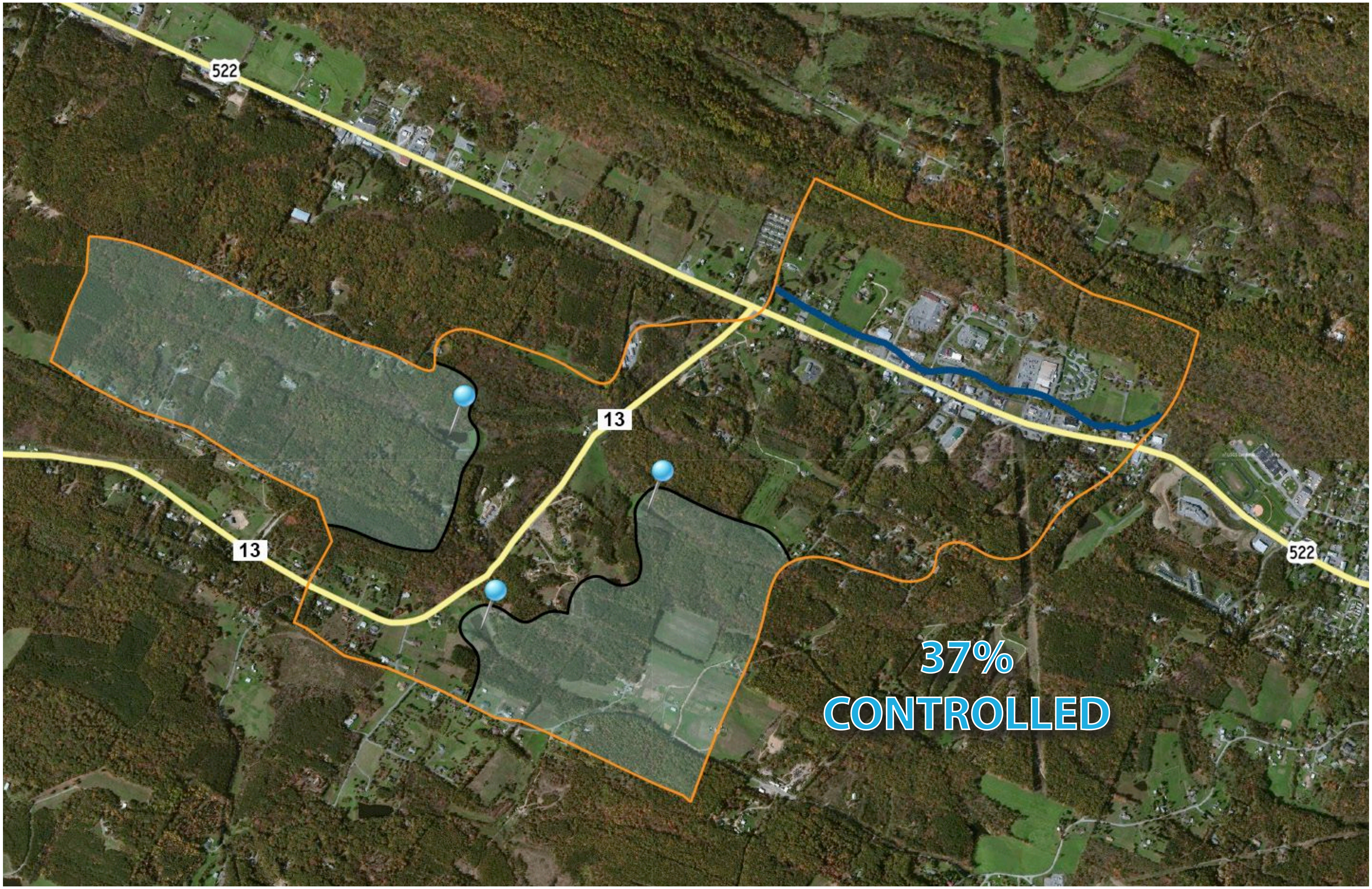
Across U.S. 522 from the elementary school is an expanse of cleared land ready for development that currently has one site constructed. This area is controlled by a stormwater management facility. The rest of this sub area consists of mostly undeveloped land with good canopy coverage. There are two stormwater control dams in this sub area which control 55% of the sub area.


*Widmyer Elementary & Commercial Development.*


*Berkeley Springs High School.*


*Commercial development stormwater management facility.*

## Sub Area Four:




### Legend:

- Sub Area Four
- Major Road
- Warm Springs Run
- Drainage Paths
- Stormwater Control Dam
- Dam Controlled Areas (37% of area)

# Sub Area Four Description:



Sub Area Four stretches from Winchester Grade Road northward to Sugar Hollow Road. There is also a piece of the sub area which extends south of Winchester Grade Road back into a valley that contributes to the sub area.

A large percentage of the sub area especially in the upper reaches is undeveloped with good tree canopy coverage. However the areas adjacent to Warm Springs Run and U.S. 522 are highly developed and contain a lot of impervious surfaces. The stretch along U.S. 522 between Winchester Grade Road and the Sub Area 3 boundary are densely developed with few checks to manage the stormwater before introduction into Warm Springs Run.

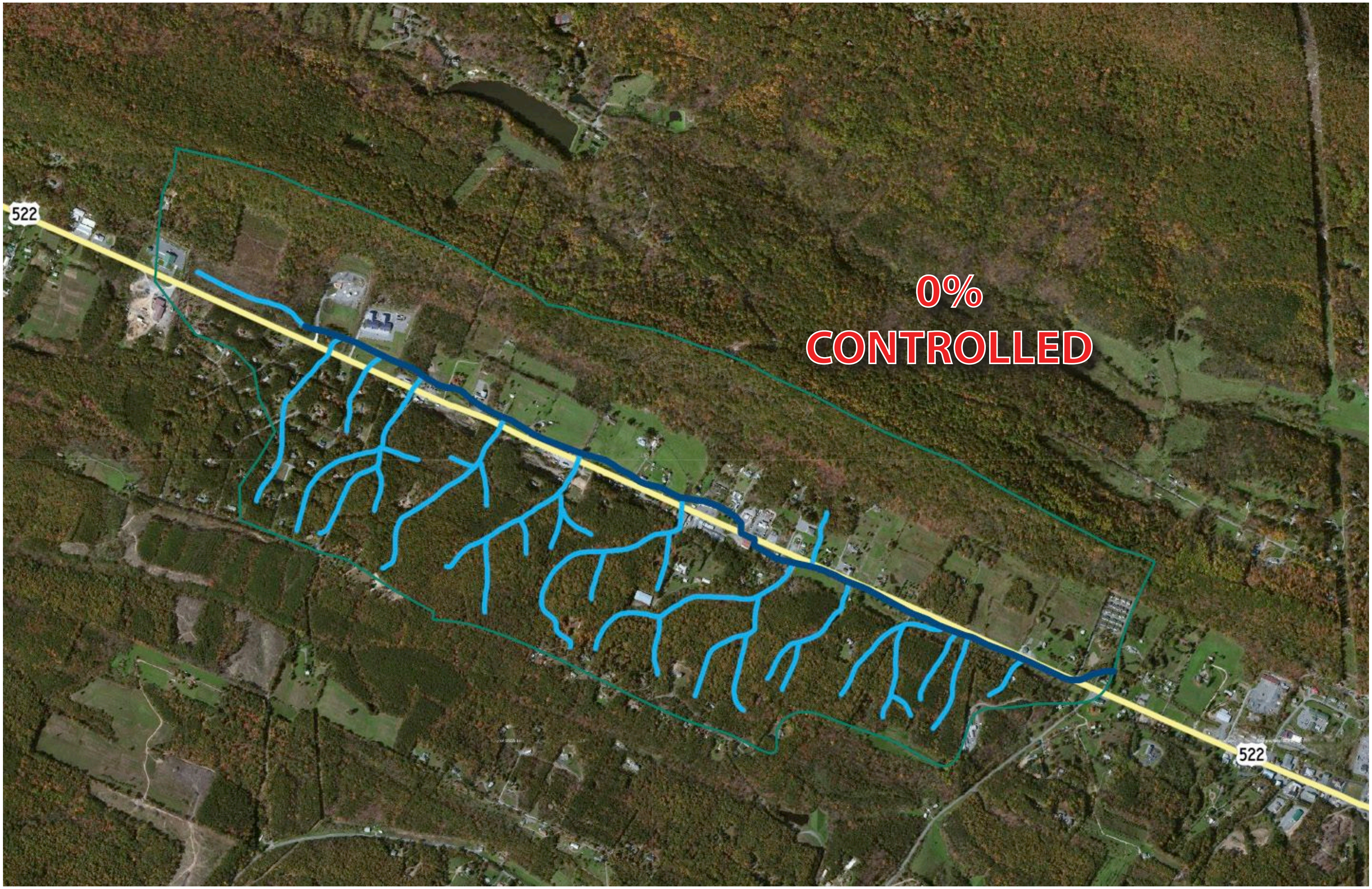
The sub area has two stormwater control dams which control 37% of the land accounting for most of the upper reaches.

*Storm inlet that drains directly into Warm Springs Run.*

*Pollution in Sub Area 4.*

*Morgan Square and surrounding area.*

## Sub Area Five:




### Legend:

Sub Area Five
Warm Springs Run
Major Road
Drainage Paths

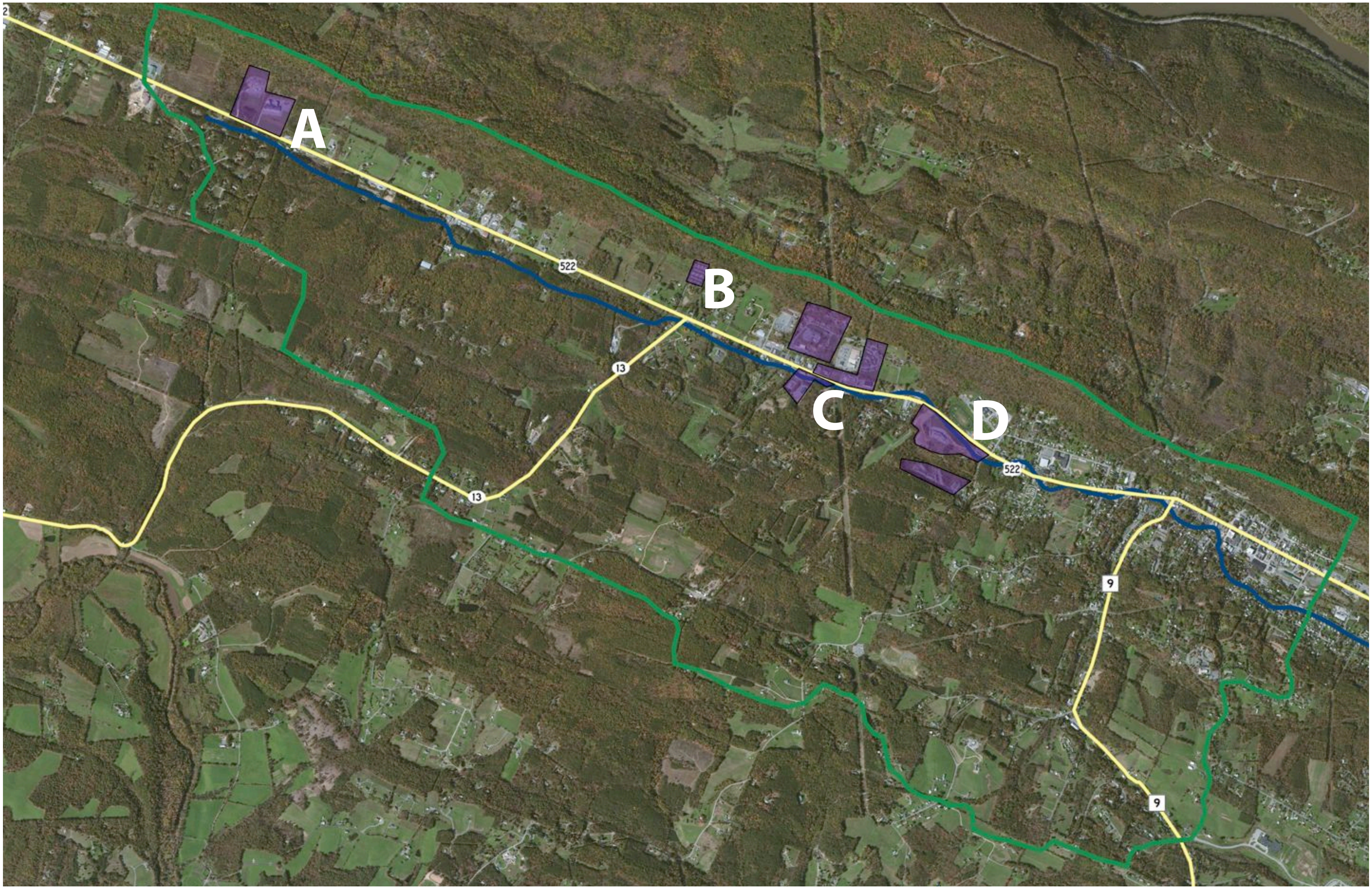
## Sub Area Five Description:

Sub Area Five is the furthest upstream in the study area and the starting point location of Warm Springs Run. This sub area consists of mostly undeveloped land with good tree canopy coverage. The development in this area is mostly single family residential with a few commercial sites.

The topography of this sub area exhibits several valleys that create concentrated points of flow and present opportunities for upper reach controls. There is also an expanse of land adjacent to the run in this sub area that presents opportunities for vegetation installs or larger stormwater management facilities. Anything that can be done in this sub area to improve water quality and reduce flow will have positive impacts on the rest of the watershed.

*A birds eye view showing the typical makeup of Sub Area 5.*

## Major Development (Past 25 Years):




### Legend:

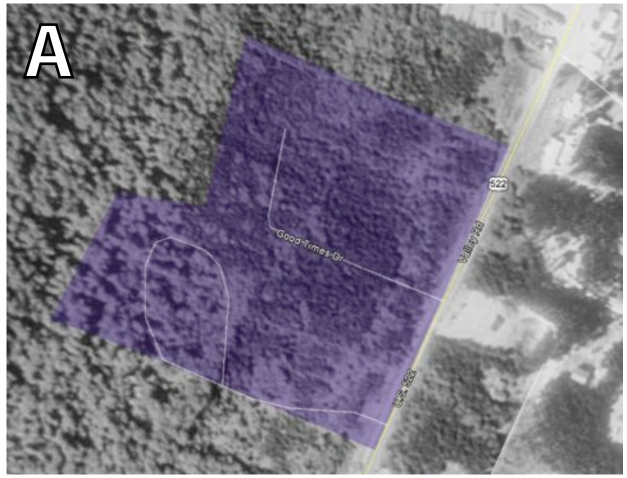
- Major Development Area
- Upper Watershed Boundary
- Warm Springs Run
- Major Roads

### Developed Acres:

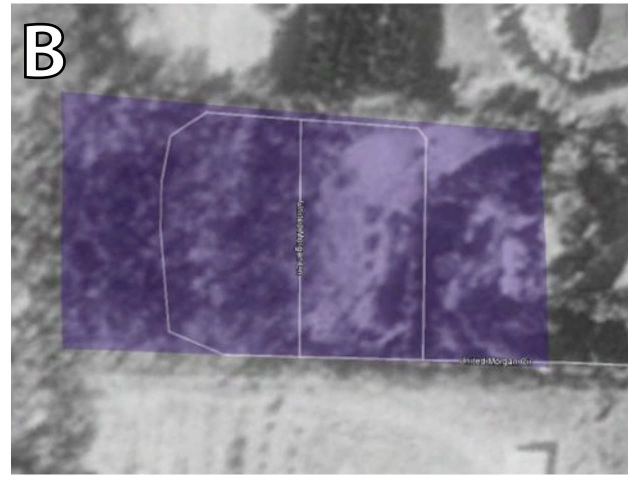
Residential = 31.55 Acres
Commercial = 40.80 Acres
Industrial = 11.00 Acres

## Major Development (Past 25 Years):

This map focuses on the major development that has taken place in the watershed over the last 25 years. All of these changes have taken place within proximity to Warm Springs Run and involve a large amount of added impervious surface. There are various smaller changes that have taken place as well but these areas are the highlights of development. Only a few of these developments have stormwater controls on site. These land development activities have disturbed the natural vegetation and topography and replaced them with homes, roads, and graded sites. This has decreased the amount of surface that is able to absorb precipitation and increased the amount of surface runoff in the watershed. The following diagram demonstrates the adverse effects of development on stormwater runoff.




Area of forested land that has been cleared for a commercial retail site and an industrial staging area.




A housing complex with seventeen buildings has been developed on this site. The majority of the land around this development remains unchanged.


The shopping center development off of U.S. 522 is one of the larger changes within the watershed in the past 25 years. Some buildings were in place at the 25 year mark but the highlighted shows additional development.


This land was cleared for a commercial services and office space development as well as some multi-family housing units.

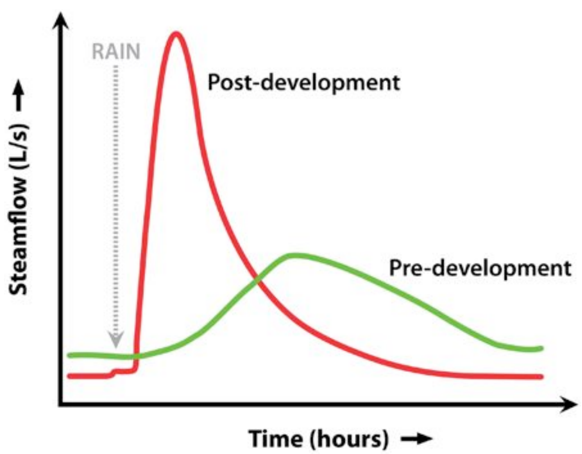



*Photo courtesy of www.learnnc.org*

## Unpaved or Gravel Roads:

There are a number of unpaved roads or driveways within the study area. This is an important factor when considering stormwater management due to them being a high source of pollution and runoff. Erosion of unpaved roadways occurs when soil particles are loosened and carried away from the roadway base, ditch, or road bank by water, wind, traffic, or other transport means. Exposed soils, high runoff velocities and volumes, sandy or silty soil types, and poor compaction increase the potential for erosion.

In 2000 The EPA released a manual titled Gravel Roads: Maintenance and Design Manual. This report analyzes these roads and provides detailed information about maintenance, drainage, design specifications, dust control and stabilization, and innovations. A section of this manual deals with the consideration for paving gravel roads.

*"The decision to pave is a matter of trade-offs. Paving helps to seal the surface from rainfall, and thus protects the base and subgrade material. It eliminates dust problems, has high user acceptance because of increased smoothness, and can accommodate many types of vehicles such as tractor-trailers that do not operate as effectively on unsurfaced roads.*

*In spite of the benefits of paved roads, well maintained gravel roads are an effective alternative. In fact, some local agencies are reverting to gravel roads. Gravel roads have the advantage of lower construction and sometimes lower maintenance costs. They may be easier to maintain, requiring less equipment and possibly lower operator skill levels. Potholes can be patched more effectively. Gravel roads generate lower speeds than paved surfaces. Another advantage of the unpaved road is its forgiveness of external forces..."*

Summary of when to pave a gravel road:

- After developing a road management program.
- When the local agency is committed to effective management.
- When traffic demands it.
- After standards have been adopted.
- After considering safety and design.
- After determining the costs of road preparation.
- After comparing pavement costs, pavement life and maintenance costs.
- After comparing users costs.
- After weighing public opinion.

*** The full document can be viewed at http://water.epa.gov/polwaste/nps/gravelroads_index.cfm

# CHAPTER 3
## *Concept Plans*

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## Concept Plans Introduction:

This chapter outlines a number of concept plans that propose stormwater management practices throughout the study area. These locations were selected based on the criteria of existing land use, amount of impervious surface, proximity to the run or point of high water flow, and feasibility based on opportunity to incorporate with already planned projects. This study utilizes a retrofit philosophy that if a project is being planned then what is being done or can be done to incorporate green infrastructure in a way that it does not impact the goal of construction and is cost effective to the owner. The main point of these concept plans is to designate opportunities within the watershed where green infrastructure could be most effective. While these plans point out some obvious things that could be done to improve each site there are a number of solutions to improve on site stormwater management for each of them.

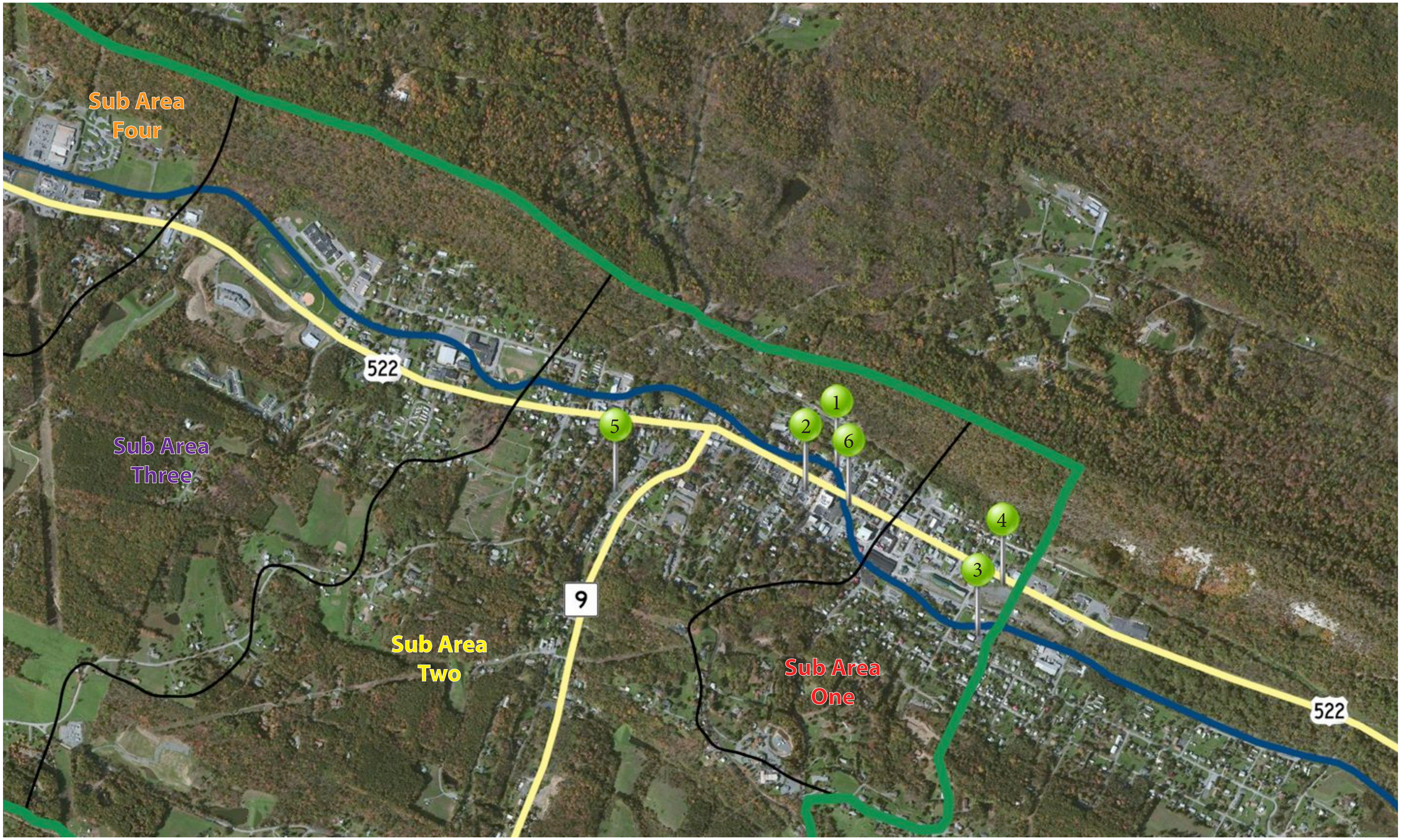
## Section One:

The opportunities listed in this section have an estimated breakdown of cost to perform the construction project with traditional methods as well as a cost to incorporate green infrastructure. These estimates also include a cost benefit summary which replaces traditional stormwater management methods with green infrastructure while also reducing associated design and construction fees with two different projects becoming one. These projects are either planned or potential both providing us the opportunity to give a detailed breakdown of cost with comparison.

## Section Two:

The projects in this section have specific sites selected and give a generic breakdown of the estimated project cost. There may be retrofit opportunities available at these sites in the future but they have not been identified at this time. These concepts are meant to generate awareness of where potential impacts could be made throughout the study area. These concepts may also act as example projects that could be translated to similar sites across the watershed.

## Section 1 - Site Locations:




**Legend:**

- Watershed Boundary
- Warm Springs Run
- Major Road
- Sub Area Boundaries

## Section 1 - Site Locations:

1. Fairfax & Washington Streetscape - Fairfax St. / Washington St.
2. Fairfax Street Parking Lot - 77 Fairfax Street
3. Morgan County Board of Education - 247 Harrison Avenue
4. Train Depot - 342 N Washington Street
5. Biser Street Park - Biser Street
6. County Courthouse Parking Lot - N Mercer Street

*Train Depot*


*Biser Street Park*

*Washington Street*


*Fairfax Street Parking Lot*

| Streetscape Project Total | |
|---|---|
| Washington & Fairfax Streetscape | $565,437.00 |
| Fairfax Resurfacing | $1,156,267.00 |
| Additional Miscellaneous Cost | $125,000.00 |
| **Project Total** | **$1,846,704.00** |

| Green Infrastructure | |
|---|---|
| Permeable Pavers | $14,960.00 |
| Silva Cells | $33,640.00 |
| 4" Pipe | $455.00 |
| Inlet Connections | $750.00 |
| Landscaping | $3,800.00 |
| **Materials Total:** | **$53,605.00** |

| Without Green Infrastructure | |
|---|---|
| Regular Pavers | $14,280.00 |
| No Planter Box | -$8,000.00 |
| Concrete Instead of Silva Cells | $11,270.00 |
| Landscaping | $3,800.00 |
| **Materials Total:** | **$21,350.00** |

| Cost Benefit Summary | |
|---|---|
| With Green Infrastructure | $53,605.00 |
| Without Green Infrastructure | $21,350.00 |
| Cost Difference | $32,255.00 |

*These numbers only reflect the portion of the project related to green infrastructure. $21,350.00 reflects the number required to replace the silva cell system with traditional construction practices.

## Fairfax Streetscape - Fairfax Street

| Parking Lot Resurfacing Project | |
|---|---|
| Stone | $5,000.00 |
| Asphalt | $34,000.00 |
| Earthwork | $8,000.00 |
| Pavement Striping | $1,500.00 |
| Traditional Stormwater Management | $6,500.00 |
| Concrete Curb | $16,000.00 |
| **Materials Total:** | **$71,000.00** |
| | |
| Mobilization | $5,000.00 |
| Contingency | $7,000.00 |
| Survey / A&E | $12,000.00 |
| **Total:** | **$95,000.00** |

| Bio Swale Construction | |
|---|---|
| Stone | $5,500.00 |
| Soil Media | $2,000.00 |
| Underdrain | $2,000.00 |
| Plants | $4,000.00 |
| **Materials Total:** | **$13,500.00** |
| | |
| Mobilization | $1,500.00 |
| Contingency | $1,500.00 |
| Survey / A&E | $2,000.00 |
| **Total:** | **$18,500.00** |

| Cost Benefit Summary | |
|---|---|
| Parking Lot Paving Project | $95,000.00 |
| Green Infrastructure | $18,500.00 |
| If completed together initially: | $108,500.00 |
| (Savings from design fees, mobilization, contingency & GI) | *Savings of $5,000.00 |
| Treated Acres | 0.3 |
| Cost of Green Infrastructure Per Treated Acre | $45,000.00 |

## Parking Lot - 77 Fairfax Street

| Parking Lot Paving Project | |
|---|---|
| Aggregate Base (2" assumed existing) | $14,000.00 |
| Asphalt Base Course | $32,500.00 |
| Asphalt Wearing Course | $27,000.00 |
| Striping | $1,500.00 |
| Traditional Stormwater Management | $4,000.00 |
| Separation Fabric | $4,500.00 |
| **Materials Total:** | **$83,500.00** |
| | |
| Mobilization | $5,000.00 |
| Contingency | $8,000.00 |
| Survey / A&E | $15,000.00 |
| **Total:** | **$111,500.00** |

| Green Infrastructure | |
|---|---|
| Vegetated Swale | $1,000.00 |
| Rain Garden (Soil media, stone, plants, drain, etc.) | $10,000.00 |
| Cistern (tank, downspout connection) | $5,000.00 |
| **Materials Total:** | **$16,000.00** |
| | |
| Mobilization | $1,500.00 |
| Contingency | $1,500.00 |
| Survey / A&E | $5,000.00 |
| **Total:** | **$24,000.00** |

| Cost Benefit Summary | |
|---|---|
| Parking Lot Paving Project | $111,500.00 |
| Green Infrastrucutre | $24,000.00 |
| If completed together initially: | $130,500.00 |
| (Savings from design fees, mobilization, contingency, & GI) | *Savings of $5,000.00 |
| Treated Acres | 0.3 |
| Cost of Green Infrastructure Per Treated Acre | $53,000.00 |

# Morgan County BOE - 247 Harrison Avenue

| Train Depot Renovation Total | |
|---|---|
| Exterior Renovations | $516,000.00 |
| **Total:** | **$516,000.00** |

| Stormwater | |
|---|---|
| Curb and Gutter | $13,500.00 |
| Type E Storm Inlet | $3,300.00 |
| Gutters and Downspouts | $8,100.00 |
| Trench Drain | $15,700.00 |
| Rain Garden | $16,000.00 |
| **Total:** | **$56,600.00** |

| Cost Benefit Summary | |
|---|---|
| Building Renovation Total | $516,000.00 |
| Green Infrastrucutre | $16,000.00 |
| Treated Acres | 0.3 |
| Cost of Green Infrastructure  Per Treated Acre | $55,000.00 |

*Green infrastructure portion of the project is only 3% of total project cost.

## Train Depot - 342 N Washington Street

| Athletic Court Resurfacing | |
|---|---|
| Basketball Courts - (2) | $20,000.00 |
| Tennis Courts - (2) | $20,000.00 |
| **Total:** | **$40,000.00** |
| | |
| Mobilization | $3,000.00 |
| Contingency | $4,000.00 |
| **Grand Total:** | **$47,000.00** |

| Rain Garden Construction | |
|---|---|
| Rain Garden (soil media, stone, plants, drain, etc.) | $3,000.00 |
| **Total:** | **$3,000.00** |
| | |
| Mobilization | $1,000.00 |
| Survey / A&E | $1,500.00 |
| Contingency | $1,000.00 |
| **Grand Total:** | **$6,500.00** |

| Cost Benefit Summary | |
|---|---|
| Athletic Court Resurfacing | $47,000.00 |
| Green Infrastrucutre | $6,500.00 |
| If completed together initially: | $52,500.00 |
| (Savings from design fees, mobilization, contingency & GI) | *Savings of $1,000.00 |
| Treated Acres | 0.5 |
| Cost of Green Infrastructure Per Treated Acre | $6,000.00 |


9
BISER STREET
Proposed
Rain Garden
Proposed
Drainage

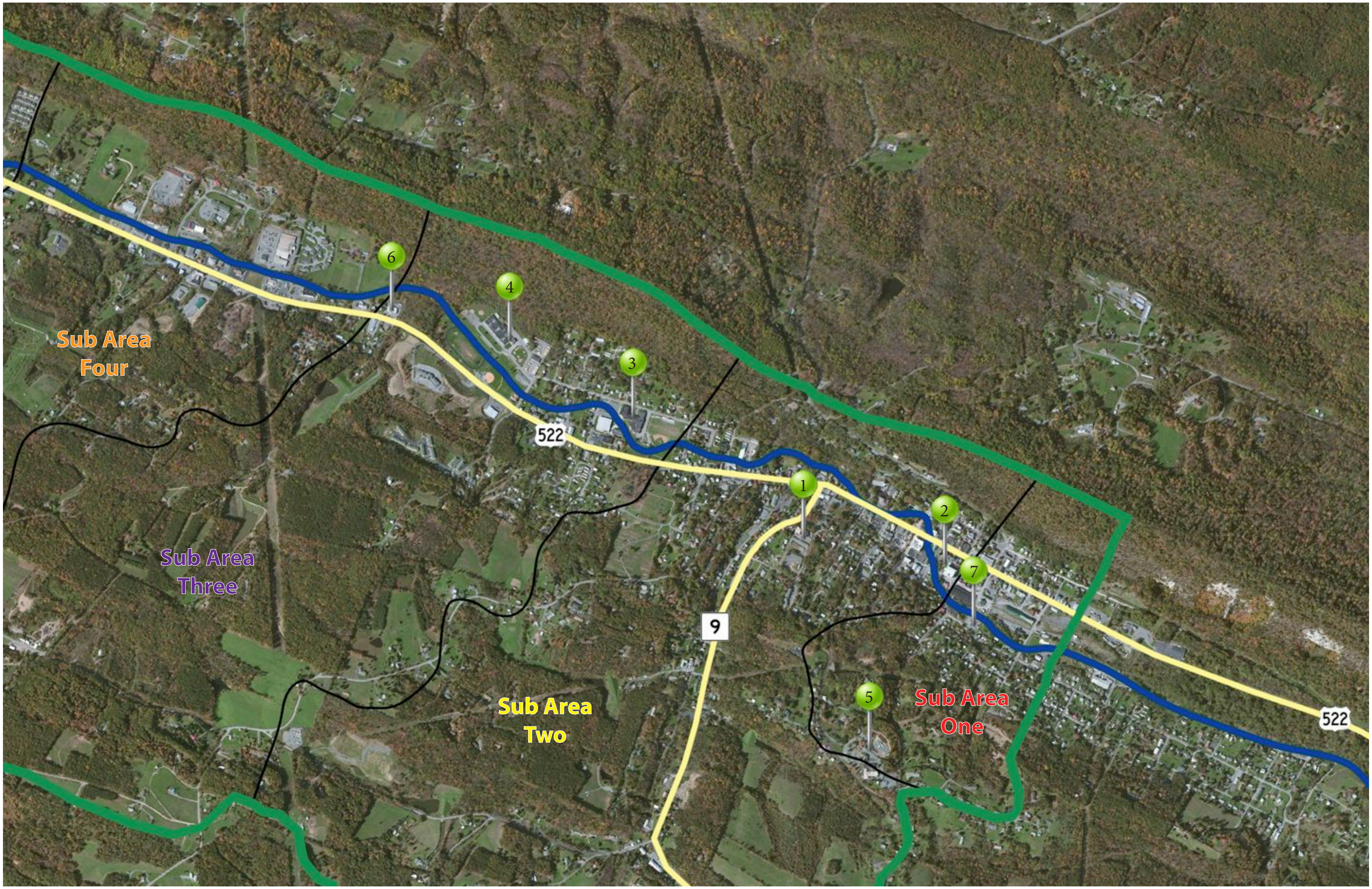
| Parking Lot Paving Project | |
|---|---|
| Asphalt Milling | $4,000.00 |
| 1" Scratch Course | $12,000.00 |
| Asphalt Wearing Course | $23,000.00 |
| Concrete Curb | $3,500.00 |
| Striping | $1,500.00 |
| **Materials Total:** | **$44,000.00** |
| | |
| Mobilization | $2,500.00 |
| Contingency | $4,000.00 |
| Survey / A&E | $8,000.00 |
| **Total:** | **$58,500.00** |

| Green Infrastructure | |
|---|---|
| Rain Garden (Soil media, stone, plants, drain, etc.) | $10,000.00 |
| **Materials Total:** | **$10,000.00** |
| | |
| Mobilization | $1,500.00 |
| Contingency | $1,000.00 |
| Survey / A&E | $2,000.00 |
| **Total:** | **$14,500.00** |

| Cost Benefit Summary | |
|---|---|
| Parking Lot Resurfacing Project | $58,500.00 |
| Green Infrastructure | $20,000.00 |
| If completed together initially: | $70,500.00 |
| (Savings from design fees, mobilization, contingency, & GI) | *Savings of $2,500.00 |
| Treated Acres | 0.4 |
| Cost of Green Infrastructure Per Treated Acre | $25,000.00 |

# County Courthouse Parking Lot - N Mercer Street

# Section 2 - Site Locations:




## Legend:

Watershed Boundary
Warm Springs Run
Major Road
Sub Area Boundaries

## Section 2 - Site Locations:

**1.** Community Center / Bike and Skate Park - College & Dawson Streets
**2.** Public Library & Ice House - 138 Independence Street
**3.** Berkeley Springs High School - 149 Concord Avenue
**4.** Widmyer Elementary School - Myers Road
**5.** BRCTC / Old War Memorial Hospital - 109 War Memorial Drive
**6.** Morgan County EMS - 1258 Valley Road
**7.** Sub Station - 113 Harrison Avenue

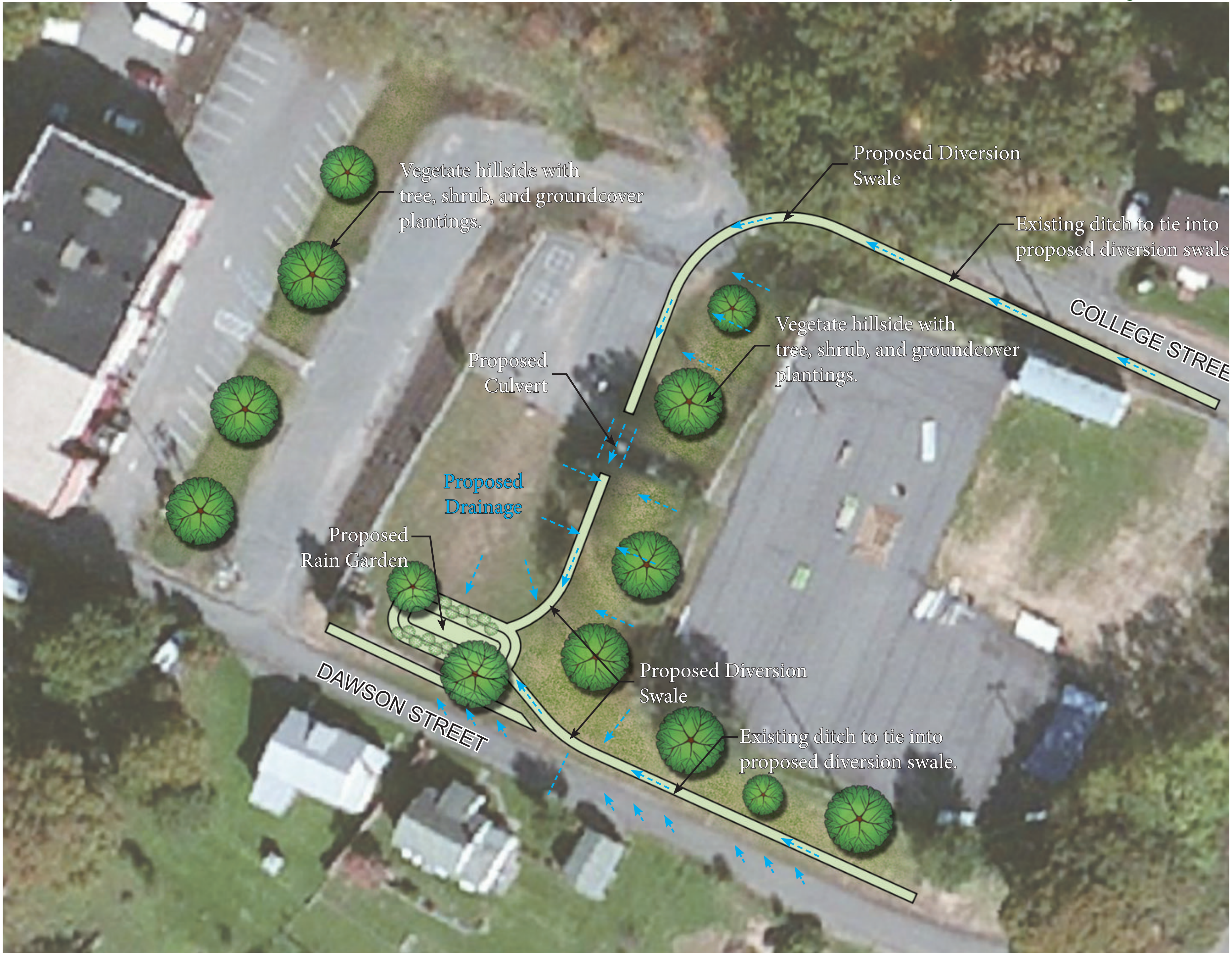
*Berkeley Springs High School.*

*Area behind the Old War Memorial Hospital.*

*Widmyer Elementary School.*

*Lot behind the Ice House and Public Library.*

| Typical Cost | |
|---|---|
| Rain Garden | $10-$30 Square Foot |
| 12" HDPE Pipe | $55 Linear Foot |
| Tree | $250-400 each |
| Shrub | $30-$80 each |
| Perennial / Grass | $15-$30 each |
| Earthwork | $10-$15 Cubic Yard |
| Survey / A&E | $10,000.00 |
| Contingency | $5,000.00 |
| **Estimated Cost:** | **$60,000.00** |


Vegetate hillside with tree, shrub, and groundcover plantings.
Proposed Diversion Swale
Existing ditch to tie into proposed diversion swale
COLLEGE STREET
Vegetate hillside with tree, shrub, and groundcover plantings.
Proposed Culvert
Proposed Drainage
Proposed Rain Garden
Proposed Diversion Swale
DAWSON STREET
Existing ditch to tie into proposed diversion swale.

| Typical Cost | |
|---|---|
| Permeable Pavers | $220 Square Yard |
| 4" Perforated Storm Drain Pipe | $40 Linear Foot |
| 12" HDPE Pipe | $55 Linear Foot |
| Extensive Green Roof | $15-$30 Square Foot |
| Cistern | $1,000-$10,000 |
| Rain Garden | $10-$30 Sqaure Foot |
| Tree | $250-400 each |
| Shrub | $30-$80 each |
| Perennial / Grass | $15-$30 each |
| Asphalt Repair | $70 Square Yard |
| Curb Demolition | $10 Linear Foot |
| Earthwork | $10-$15 Cubic Yard |
| Survey / A&E | $50,000.00 |
| Contingency | $11,000.00 |
| **Estimated Cost** | **$200,000.00** |


Extensive Green Roof
Proposed Roof Drainage
Existing Parking Lot Drainage
Vegetated Swale
Passive Recreation Park
Proposed Rainwater Cistern
Convert to Permeable Staff Parking Spaces
Proposed Rain Garden

| Typical Cost | |
|---|---|
| Earthwork | $10-$15 Cubic Yard |
| Rain Garden | $10-$30 Square Foot |
| Cistern | $1,000-$10,000 |
| Planter Box | $2,000-$5,000 each |
| Downspout Connections | $35 Linear Foot |
| Survey / A&E | $25,000.00 |
| Contingency | $7,000.00 |
| **Estimated Cost** | **$105,000.00** |

522
Proposed Flood Bench
CONCORD AVENUE
Proposed Planter Box (TYP)
Proposed Rain Garden
Proposed Stormwater Cistern (TYP)
522
Proposed Parking Drainage
Existing Roof Drainage
JOHN STREET

| Typical Cost | |
|---|---|
| Earthwork | $10-$15 Cubic Yard |
| Tree | $250-$450 each |
| Shrub | $30-$80 each |
| Perennial / Grass | $15-$30 each |
| Aggregate Trail | $8 Square Yard |
| Earthwork | $10-$15 Cubic Yard |
| Survey / A&E | $25,000.00 |
| Contingency | $6,000.00 |
| **Estimated Cost** | **$90,000.00** |

## Widmyer Elementary - Myers Road

| Typical Cost | |
|---|---|
| Earthwork | $10-$15 Cubic Yard |
| Stormwater Inlet | $3,000 each |
| 12" HDPE Pipe | $55 Linear Foot |
| Spillway | $3,000 - $10,000 |
| Plantings | $3,000 |
| Survey / A&E | $20,000.00 |
| Contingency | $5,000.00 |
| **Estimated Cost** | **$85,000.00** |

# BRCTC - Old War Mem. Hospital - 109 War Memorial Drive

| Typical Cost | |
|---|---|
| Rain Garden | $10-$30 Square Foot |
| 12" HDPE Pipe | $55 Linear Foot |
| Plantings | $2,000.00 |
| Asphalt Wearing Course | $125 Ton |
| Survey / A&E | $10,000.00 |
| Contingency | $2,000.00 |
| **Estimated Cost** | **$35,000.00** |

## Morgan County EMS - 1258 Valley Road

| Typical Cost | |
|---|---|
| Earthwork | $10-$15 Cubic Yard |
| Rain Garden | $10-$30 Square Foot |
| Bioswale | $10-$30 Square Foot |
| Plantings | $3,000 |
| Survey / A&E | $10,000.00 |
| Contingency | $5,000.00 |
| **Estimated Cost** | **$65,000.00** |

## Sub Station - 113 Harrison Avenue

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# CHAPTER 4
## *Generic Plans*

## Generic Plans Introduction:

The plans in this chapter are generic and are not related to a specific site in the watershed. On the contrary these plans could relate to any number of sites including existing or planned development. The purpose of these plans are to provide conceptual guidelines of the opportunities that may be realized now or in the future.

## Generic Plan #1 Description:

Generic Plan #1 is for a flood bench. This concept would apply to areas where there is an expanse of undeveloped land upstream of the Town of Bath. A flood bench creates an overflow section adjacent to the stream that allows the stream to expand during times of peak flow. By expanding the stream channel the water is slowed during times of peak flow alleviating pressure on the system downstream.

To help stabilize the stream banks these areas should be heavily planted or seeded with a grass mix of native plant species. The vegetation will create wildlife habitat and absorb chemicals in runoff increasing the water quality.

*Photo courtesy of www.farmprogess.com*

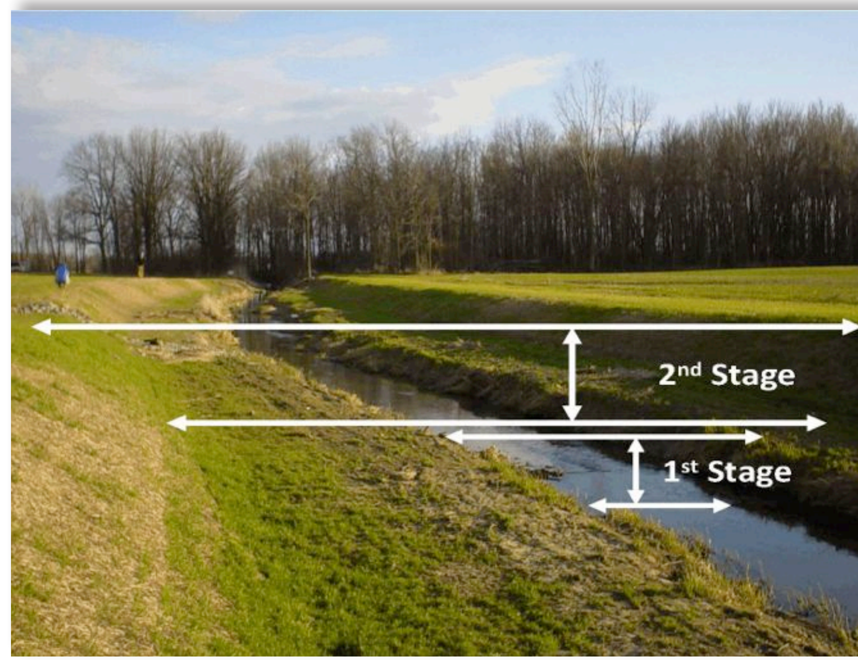
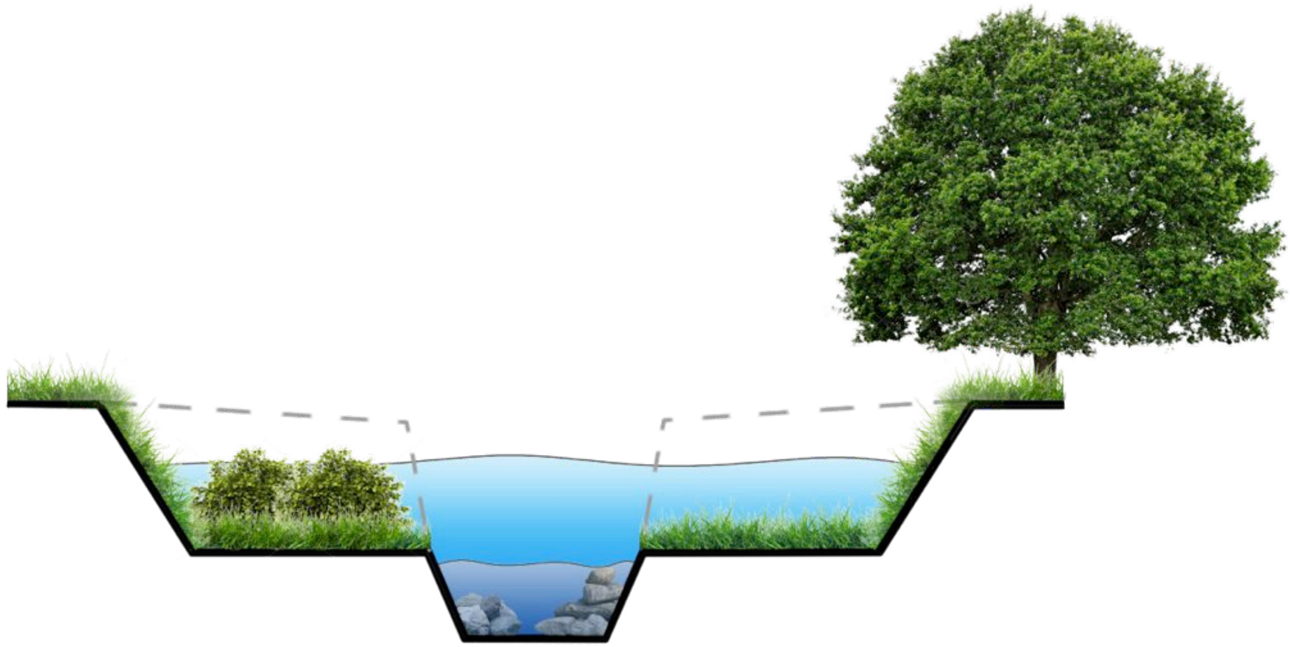


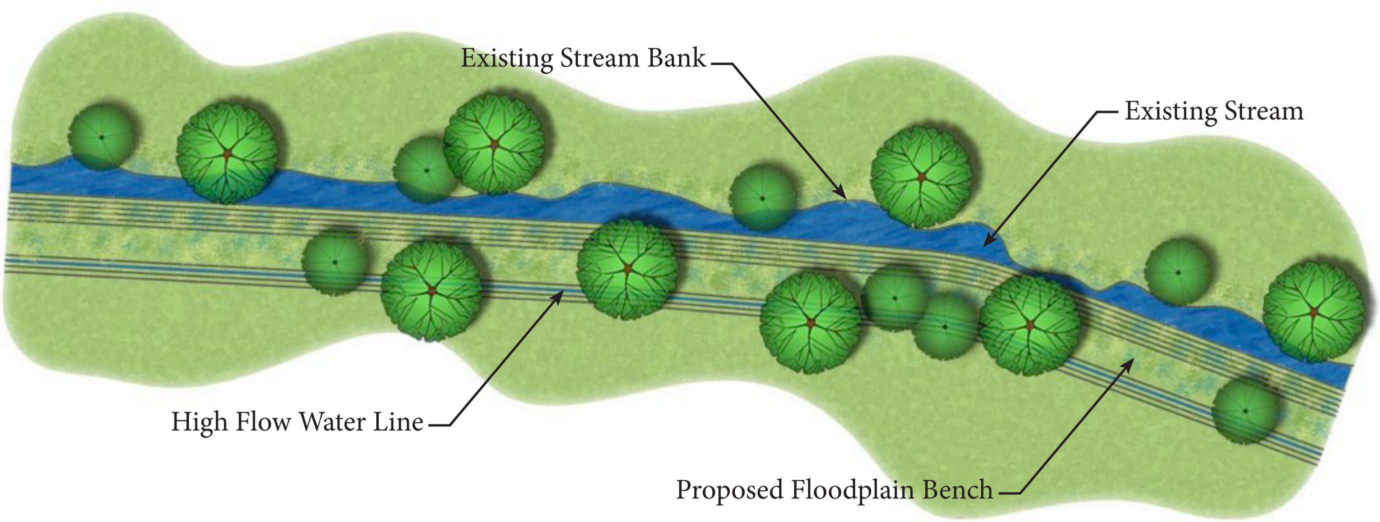

*Photo courtesy of www.conservationregistry.org*

## Flood Bench





**Section View**




**Plan View**

## Generic Plan #2 Description:

Generic Plan #2 is for a stormwater control pond or detention pond. These are constructed ponds meant to hold back extremely large volumes of water and alleviate pressure on the system during storm events. These ponds have a spillway that empty water into the watershed once the water level has reached a certain point but are designed to hold back water for several storms. The ponds also serve better water quality by containing sediments within the pond as the water sits over time. These are large projects that involve lots of earthwork and heavy machinery. As shown on the plan they are ideal in places where if the topography were bridged or dammed a pond would form.

The pictures below (left) shows an existing stormwater pond in the watershed and the topography around the pond (right).

*Photo courtesy of www.bing.com*

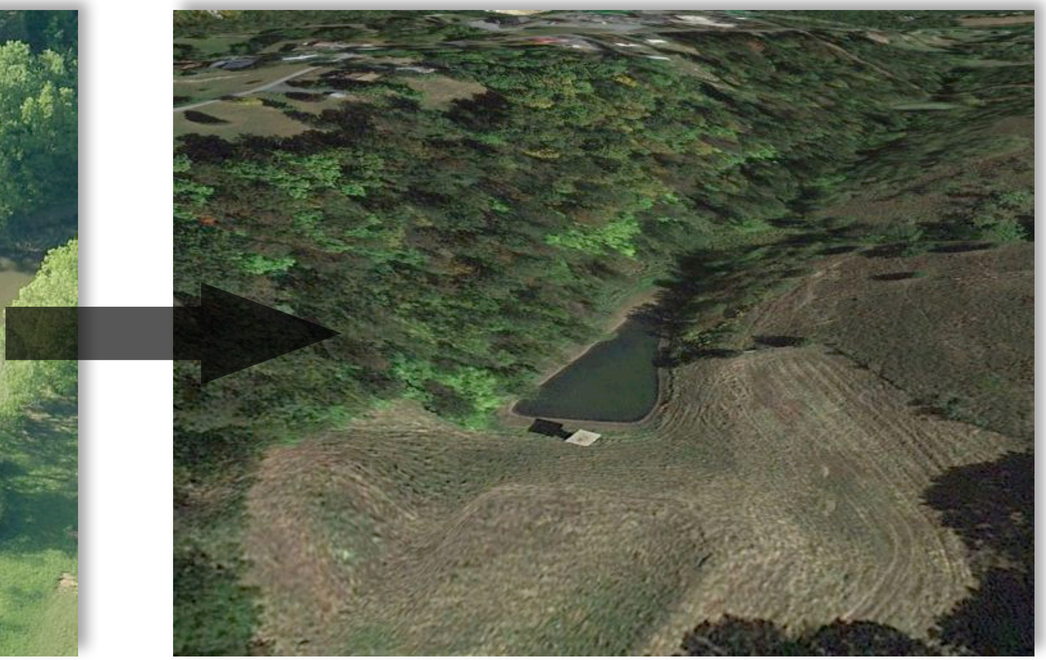
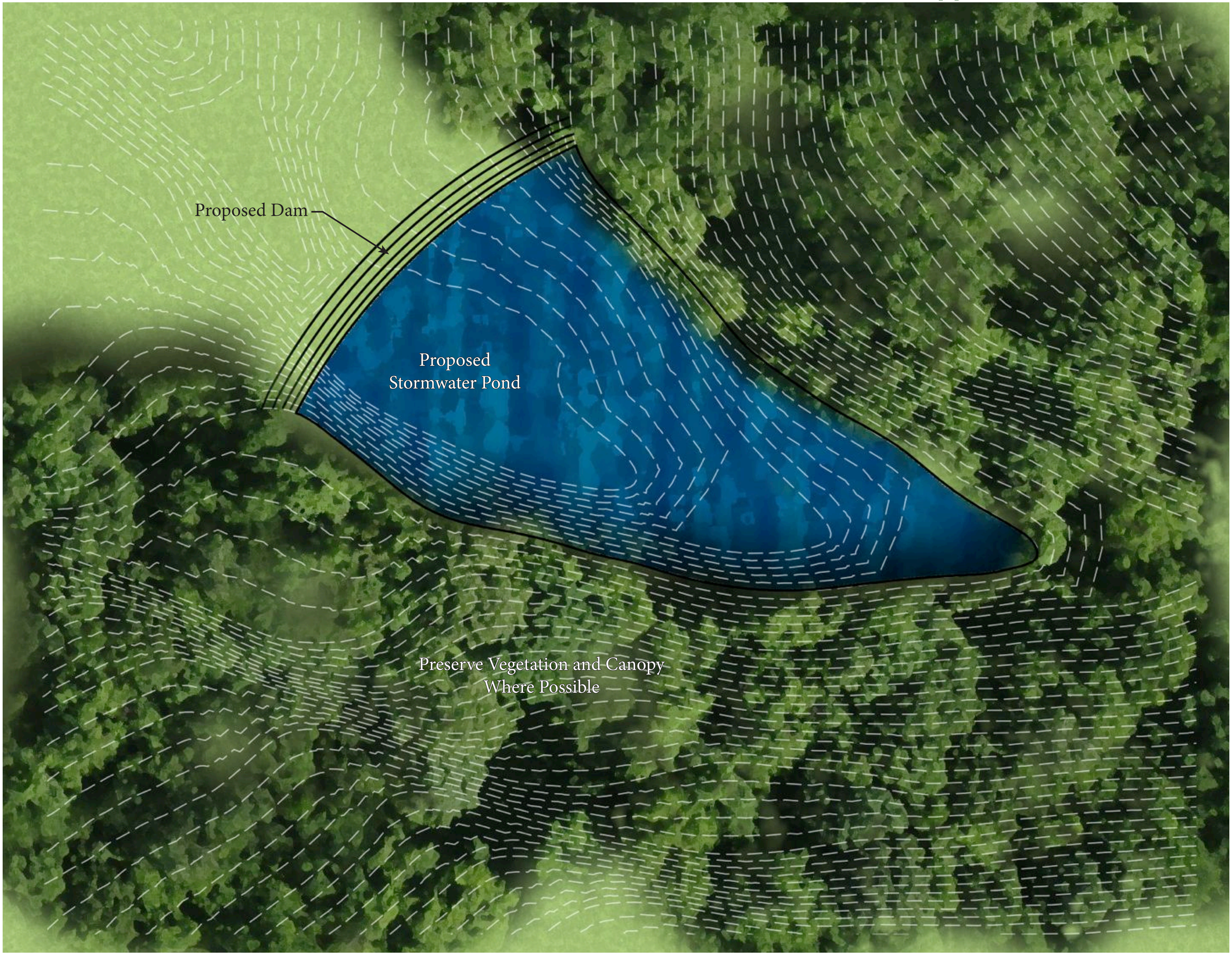


*Photo courtesy of Google Earth*

# Upper Reach Control Pond



## Generic Plan #3 Description:

Generic Plan #3 is for a constructed wetland that would serve as a stormwater treatment facility and double as a public park and trail system. Wetlands perform many functions that are beneficial to both humans and wildlife. One of their most important functions is water filtration. As water flows through a wetland, it slows down and many of the suspended soil solids become trapped by vegetation and settle out. Other pollutants are transformed to less soluble forms taken up by plants or become inactive.

*Photo courtesy of www.wetlandcenter.com*

*Photo courtesy of www.wetlandcenter.com*

# Constructed Wetland / Public Park & Trail

GENERIC PLANS

## Generic Plan #4 Description:

Generic Plan #4 demonstrates how green infrastructure practices could be incorporated in a commercial retail or restaurants sites. These practices could be installed on existing sites or incorporated into new development. The plan demonstrates how water stormwater should be managed on site before emptying into the watershed. This can be done through the use of inlets, bioswales, vegetated swales, and other conveyance means leading to a retention facility such as a rain garden. Commercial buildings typically have large roofs that contribute a large amount of impervious surface. This surface could be reduced through the use of extensive green roof panels. Water that is not treated by the green roof could be connected to a nearby rain garden instead. As with any site vegetation and canopy cover should be either maintained as much as possible or restored in any new development.

*Photo courtesy of www.inhabitat.com*

*Photo courtesy of www.bluegreenbldg.org*


Rain Garden
Bioswale
ADJACENT STREET
Direct Roof Drainage
To Rain Garden
Retail Store
or Restaurant
(1 Story Building)
Extensive
Green Roof
Direct Pavement Draiange
to Bioswale or Rain Garden

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# CHAPTER 5

## *Summary & Conclusions*

## Summary:

This study has taken a comprehensive look at the upper watershed of Warm Springs Run to analyze where and how it may be effective to implement green infrastructure practices. The introduction described the history of problems leading to the need for this report. The existing conditions analyzed the watersheds topography, hydrology, and development to pinpoint where implementation may be most effective. The concept plans and generic plans chapters provide ideas for implementation of BMPs that serve the purpose of flood control, water quality improvement, and enhancing community lifestyle and amenities.

## Conclusions:

The most important thing to take away from this study is that no individual project will solve the flooding and water quality issues of the upper watershed. However, a chain of effectively located and designed projects working together would certainly start to make a difference. A project as small as a resident diverting their 1,500 square foot roof to rain barrels makes a difference. Imagine if an entire neighborhood of thirty homes did this. That is over an acre of impervious surface that is controlled during storm events.

The importance of education on this matter is a general first step. The general public is typically unaware of the vast amount of green alternatives to traditional construction methods. As seen in the concept plans the cost effectiveness will vary. However there are definitely situations where green infrastructure will be cheaper than traditional construction methods and every project should be evaluated with an eye for green infrastructure improvement.

## Recommendations:

- Determine short and long range projects based on immediate feasibility versus long term feasibility.
- Develop an online presence dedicated to a green infrastructure initiative promoting the importance and educating the public on current and future efforts.
- Establish and maintain inter agency partnerships to facilitate green infrastructure projects. (Town of Bath, Region 9, Warm Springs Run Watershed Association, Morgan County Planning Commission, WVDEP, etc.)
- Develop or enhance existing community service and volunteer based programs catered toward the green infrastructure effort. (Tree plantings, design charrettes, adopt a highway or stream programs, youth learning experiences, etc.)
- Review town and county ordinances to ensure new development will follow necessary requirements for managing their stormwater on site.
- Facilitate a rain barrel program that offers a media for local artist. Rain barrels would be installed in locations accessible to the public view and artist could paint the rain barrels with a new theme every year. A walking tour could be organized as a public event or a map would be available through the online presence for green infrastructure.
- Organize meetings to review progress toward the goals and objectives of this study as well as newly identified goals and objectives.
- Incorporate green infrastructure into any publicly funded project where cost effective and utilize these as demonstration projects.

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# CHAPTER 6

## *Green Infrastructure Glossary*

# Bioswale:

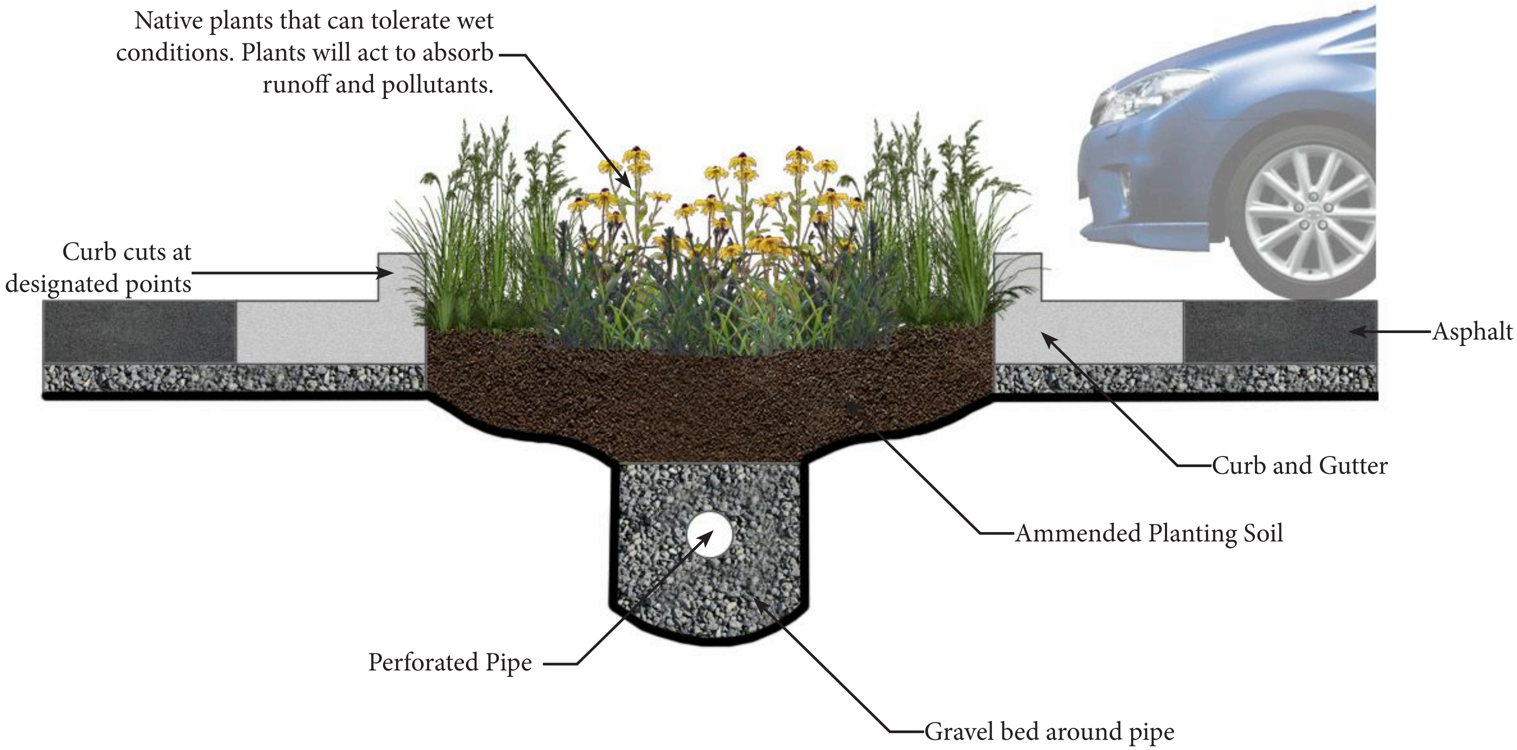



*Photo courtesy of http://lacreekfreak.wordpress.com*

*Photo courtesy of www.watershedco.com*

## Information:

A bioswale is a vegetated channel that provides treatment and retention as it conveys stormwater within or away from a site. These swales slow, infiltrate, and filter stormwater flows. These features typically work best in coordination with streets and parking lots but can be implemented in a variety of locations. A fine textured and water resistant grass is ideal for the vegetation of the swale. Pollutant removal efficiency varies greatly depending on the specific plants involved, so the vegetation should be selected with pollution control objectives in mind. Native plants should be the palette for plant selection.

## Benefits:

- Reduction of peak flows.
- Removal of pollutants.
- Promotion of runoff infiltration.
- Lower capital costs.
- Aesthetic value added to typically concrete/asphalt areas.

## Maintenance:

- Mulching.
- Debris and litter removal.
- Plant health evaluation.
- Repair erosion areas as needed.
- General inspection to become aware of potential issues with the functionality of the swale.

## Limitations:

- Impractical in areas with very flat grades, steep topography, or poorly drained soils.
- Can have erosion problems when volumes are too high.
- Can attract mosquitoes if there is standing water.
- Improper base soils can lead to drainage issues as well as plant health problems.

*Photo courtesy of www.asla.org*

*Photo courtesy of www.landperspectives.com*

*Photo courtesy of lacreakfreek.wordpress.com*

# Rain Garden:

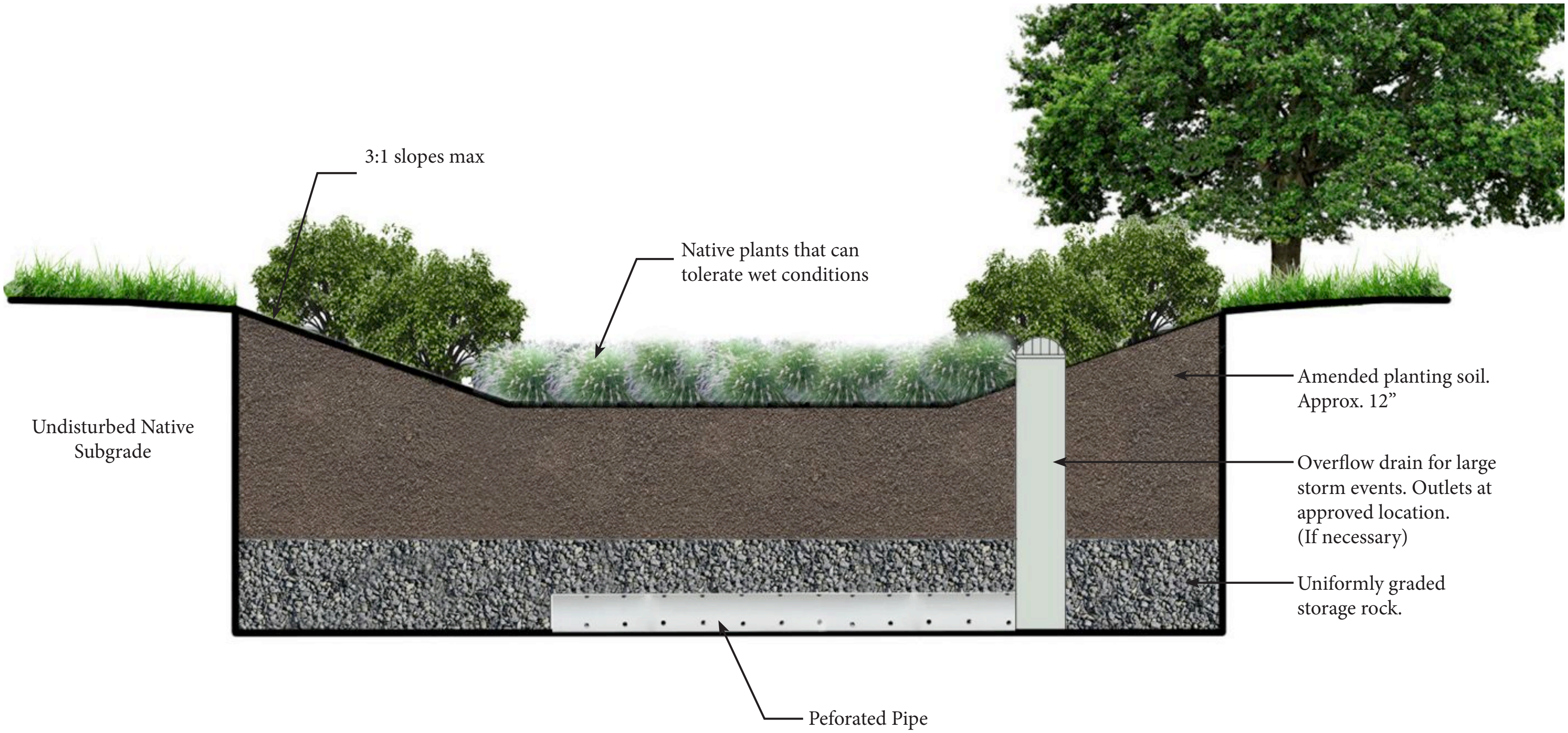



*Photo courtesy of blogs.webster.edu*

*Photo courtesy of www.asla.org*

## Information:

Rain gardens are landscape areas that double as a way to treat stormwater. They are typically located next to or within parking lots and in other small pockets of urban areas. The areas are shallow depressions that receive surface or directed runoff. During storm events water ponds in these areas until it percolates into the ground. Rain gardens can be equipped with overflow drains for larger storm events that produce a higher flow.

## Benefits:

- Improves the quality of downstream water bodies.
- Reduction of peak flows.
- Removal of pollutants.
- Promotion of runoff infiltration.
- Lower capital costs.
- Aesthetic value added to typically concrete/asphalt areas.

## Maintenance:

- Mulching.
- Debris and litter removal.
- Plant health evaluation.
- Repair erosion areas as needed.
- General inspection to become aware of potential issues with the functionality of the rain garden.

## Limitations:

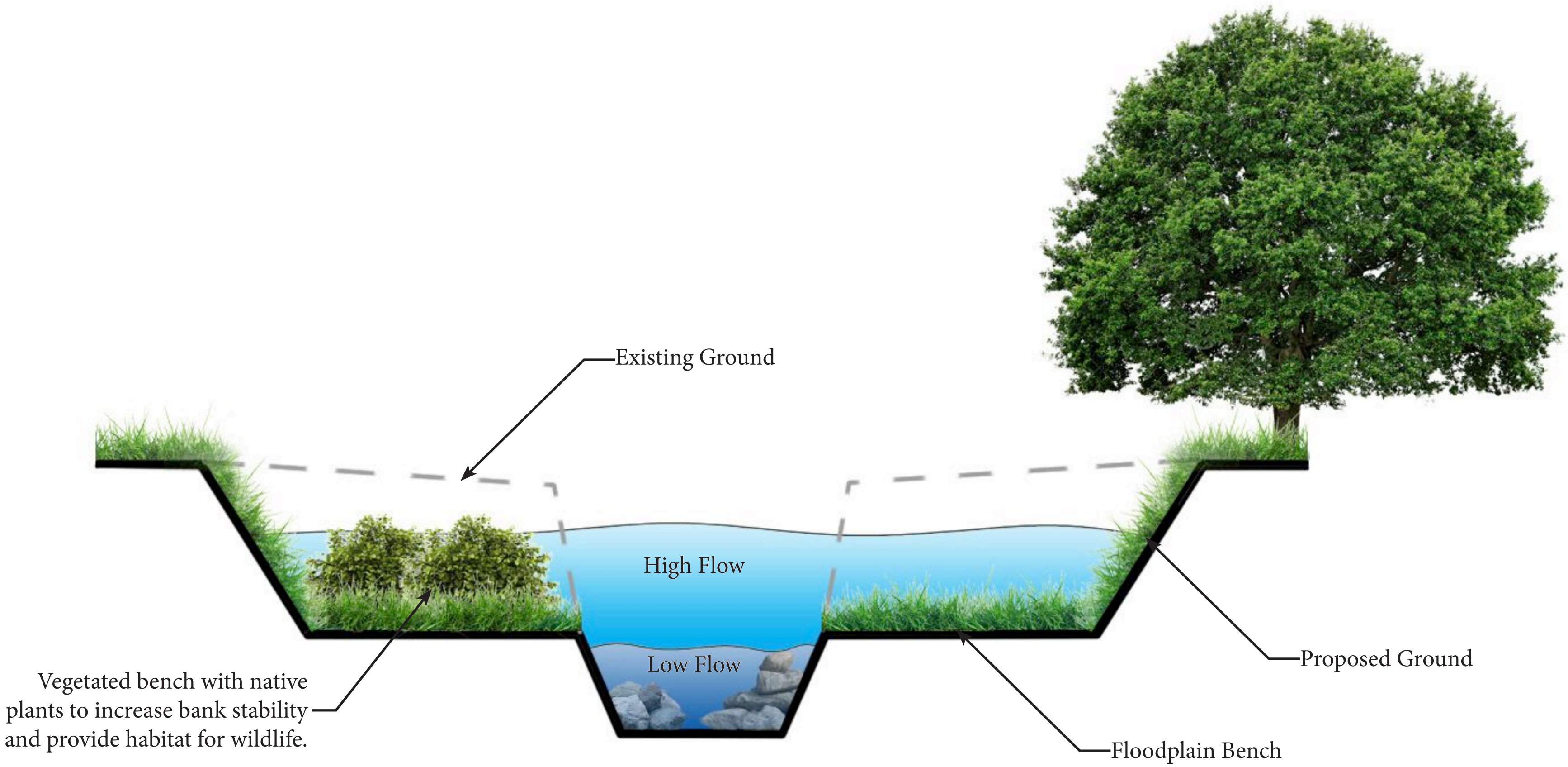
- Not applicable in areas where the water table is within 6 feet of the ground surface.
- In colder climates the soil may freeze preventing infiltration.
- Not ideal in areas with slopes greater than 20%.
- Clogging can be an issue if the BMP is receiving high amounts of sediment from adjacent areas.

*Photo courtesy of www.ferncreekdesign.org*

*Photo courtesy of www.extension.iastate.edu*

*Photo courtesy of www.sfbetterstreets.org*

# Floodplain Bench:



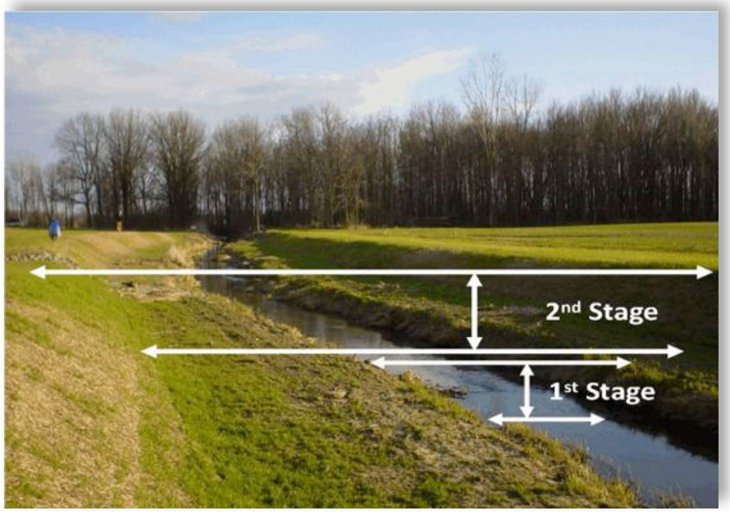




*Photo courtesy of www.conservationregistry.org*

*Photo courtesy of www.conservationregistry.org*

## Information:

A floodplain bench is a modification to an existing stream that adds benches serving as floodplains within the channel. The benches can be vegetated with grass mixes or heavily planted which increases the wildlife habitat in and around the stream and provides natural erosion control. These stream expansions create overflow areas in parts of the stream that provide extra storage during larger storm events. This storage will help to control flooding in the primary location of the bench as well as downstream.

## Benefits:

- Nutrient and sediment removal.
- Increased capacity of the stream.
- Mitigates downstream flooding.
- Improves bank stability and reduced erosion.
- Improved stream habitat.
- Nutrient and sediment removal.

## Maintenance:

- Landscape maintenance where necessary though the point would be to allow these areas to naturalize.
- General inspection associated with this type of installation.

## Limitations:

- This type of project will require some space because of the widening of the stream channel. Therefore it will be best used in the less urban areas of the watershed.

*Photo courtesy of www.engineering.purdue.edu*

*Photo courtesy of www.farmprogess.com*

*Photo courtesy of www.eatoncd.org*

# Rain Barrel / Cistern:


*Photo courtesy of www.stormsaver.com*

*Photo courtesy of www.coolcleveland.com*


*Photo courtesy of www.watrnews.com*

## Information:

Rain barrels and cisterns collect water to be reused for various purposes. These units are placed outside of buildings and positioned to where the buildings gutter system will empty stormwater into the unit. Cisterns are larger tanks that can collect high volumes of water and be pumped back into a building for re-use in non-potable situations such as flushing a toilet. Both of these units provide a source of chemically untreated water that is great for use in gardens and landscapes.

## Benefits:

- Reduce peak flow during smaller storm events.
- Provide a free source of water as a cost savings.
- Provides chemically untreated or "soft water".
- Will reduce on site runoff and helps with drainage issues.
- Can be decorated or stylized to fit in any location.
- Can be a small or large project good for any budget.
- A great do it yourself project.
- 1" of rain on a 1,000 SF roof yields 623 gallons of water.

## Maintenance:

- If you do not have a filter for a rain barrel then it should be emptied every 5 to 7 days to prevent mosquitoes from breeding.
- Remove any debris that has collected around the lid.
- Routinely clean the inside.
- Check overflow hose and connections.
- Disconnect and winterize you rain barrel before cold weather.
- Clean roof and gutters to minimize the amount of debris.

## Limitations:

- Barrels and cisterns can only hold so much water and during long periods of rain events will become less useful.
- Roofs should be evaluated before harvesting rainwater. Roofs with treated cedar shakes, old tar and gravel, old asbestos shingle should not be used in harvesting processes.
- Lower water pressure than with a spigot.


*Photo courtesy of www.betterground.org*

*Photo courtesy of www.seattledrainservice.org*

*Photo courtesy of www.cbtrust.org*

# Infiltration Trench:

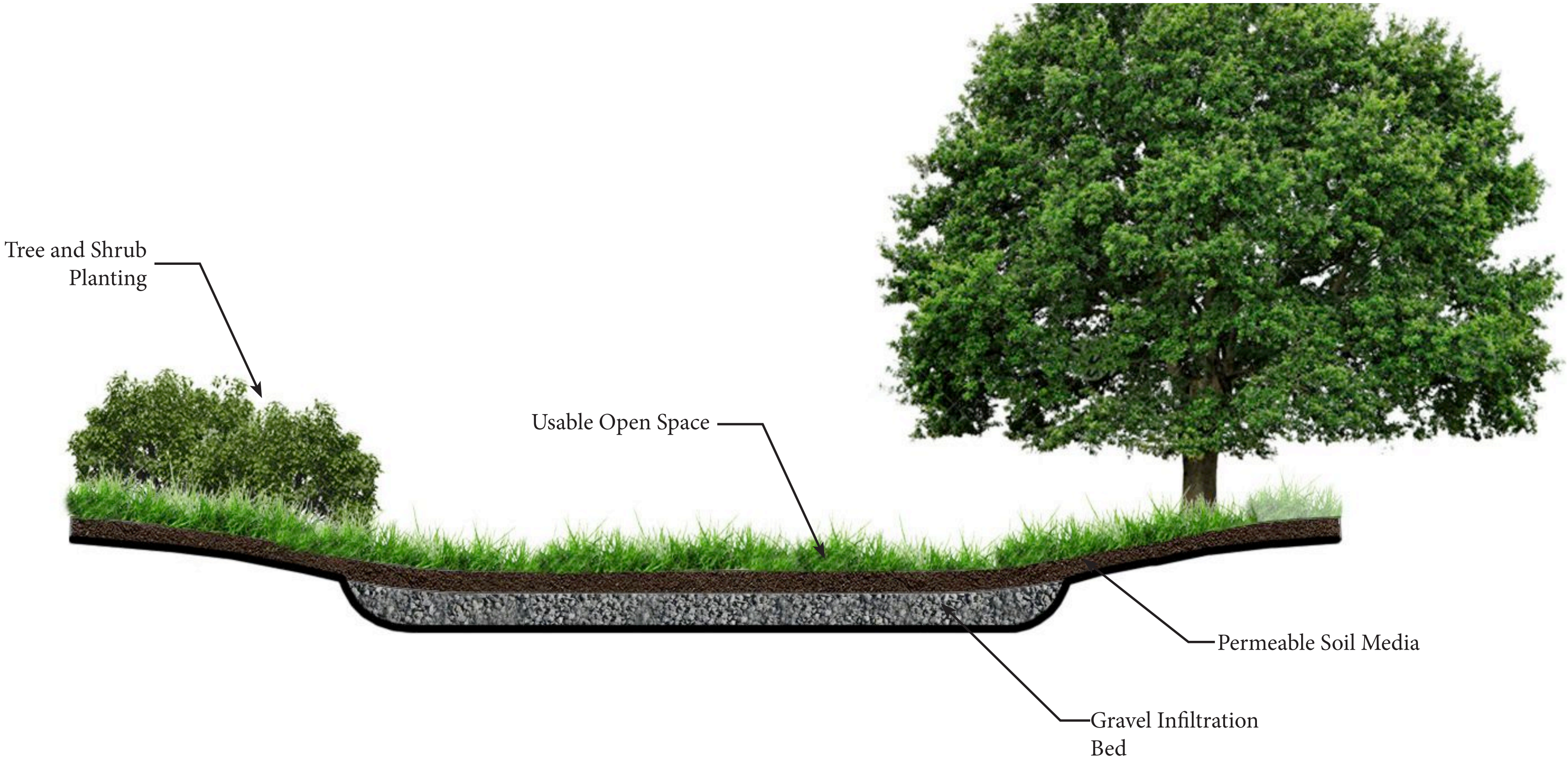




*Photo courtesy of www.temple.edu*


*Photo courtesy of www.water.epa.gov*

## Information:

Infiltration trenches are rock filled pits with no discharge outlets. During a storm event water is collected in these trenches and released into the soil through infiltration. These trenches are often best used in coordination with other types of BMPs to help control the peak flow into the trench as well as filter out some of the sediment in the runoff. Infiltration trenches can be noticeable or disguised as an open space. They vary greatly in size depending on the amount of water they are intended to receive.

## Benefits:

- Does not have to eliminate usable space.
- Can vary in size and accommodate a large amount of runoff if necessary.
- Increases ground water recharging.

## Maintenance:

- Routine inspection to ensure proper functionality.
- Potential for clean out in the event of chemical spills or clogging.

## Limitations:

- Can become clogged by sediments in stormwater runoff.
- If covered it is hard to inspect whether the BMP is clogged.
- Not typically used as a stand alone BMP.
- Sites are limited depending on native soils and location of groundwater table.
- In cold climates they can become ineffective if the surface freezes and prevents water from entering.

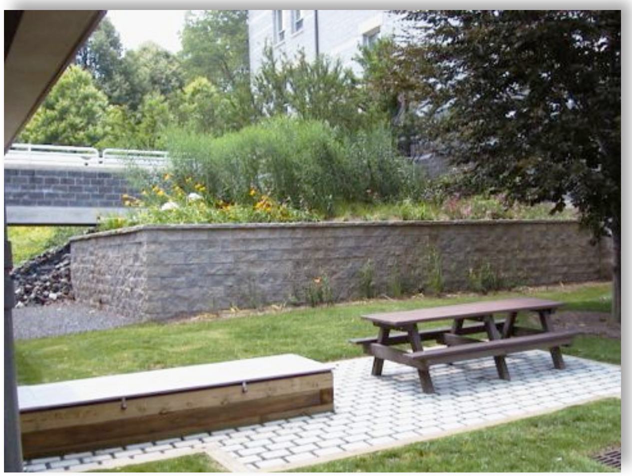


*Photo courtesy of www.engineering.purdue.edu*


*Photo courtesy of www.susdrain.org*


*Photo courtesy of www.susdrain.org*

# Extensive Green Roof:

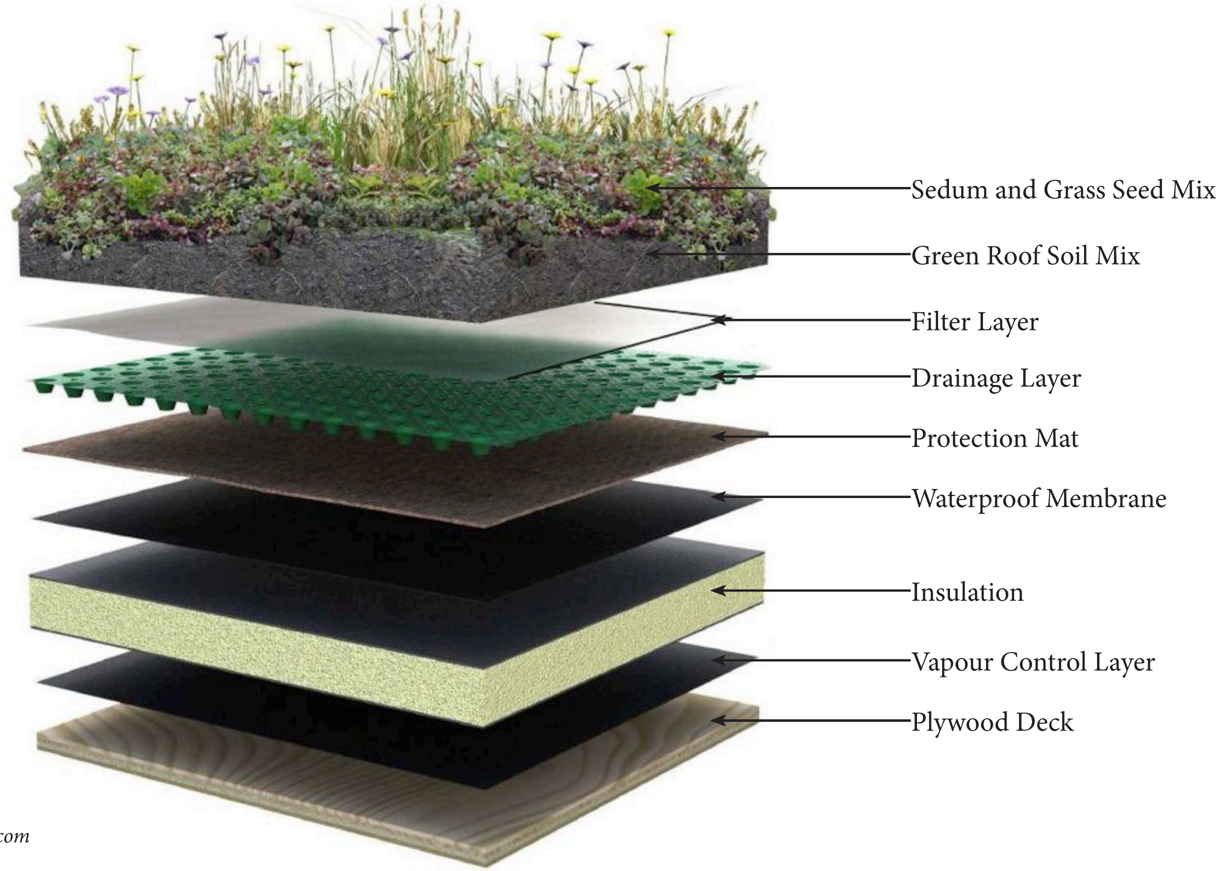



*Photo courtesy of www.midstateltd.com*

*Photo courtesy of www.greenroofs.com*

*Photo courtesy of www.greenrooftechnology.com*

## Information:

Extensive green roofs are thin layers of living vegetation installed on roofs of various styles either sloped or flat. This type of application is shallow (usually 6 inches or less) and not like intensive green roofs which can be used for plazas or recreation spaces. As shown in the diagram these roofs are made up of many layers serve drainage, plant nourishment, protection of underlying roof, waterproofing, and insulation. These projects can be implemented in new build or post build situations.

## Benefits:

- Controls stormwater runoff.
- Improves water quality.
- Applicable in almost any setting commercial or residential.
- Prolongs the life of roofing materials.
- Adds aesthetics to a typically bland feature.

## Maintenance:

- Initial plant establishment aid for the first two years.
- Inspections at least twice a year to ensure proper functionality and plant health.
- Checking drainage outlets for debris clogs.

## Limitations:

- Requires a specialty contractor with proper experience.
- It may be difficult to incorporate them into some roofs because of the architectural style of the building.
- These types of green roofs are not designed for load bearing like intensive green roofs.

*Photo courtesy of www.engineering.greenrooftechnology.com*

*Photo courtesy of www.firestonebpe.com*

*Photo courtesy of www.caseytrees.org*

# Pervious Pavement:

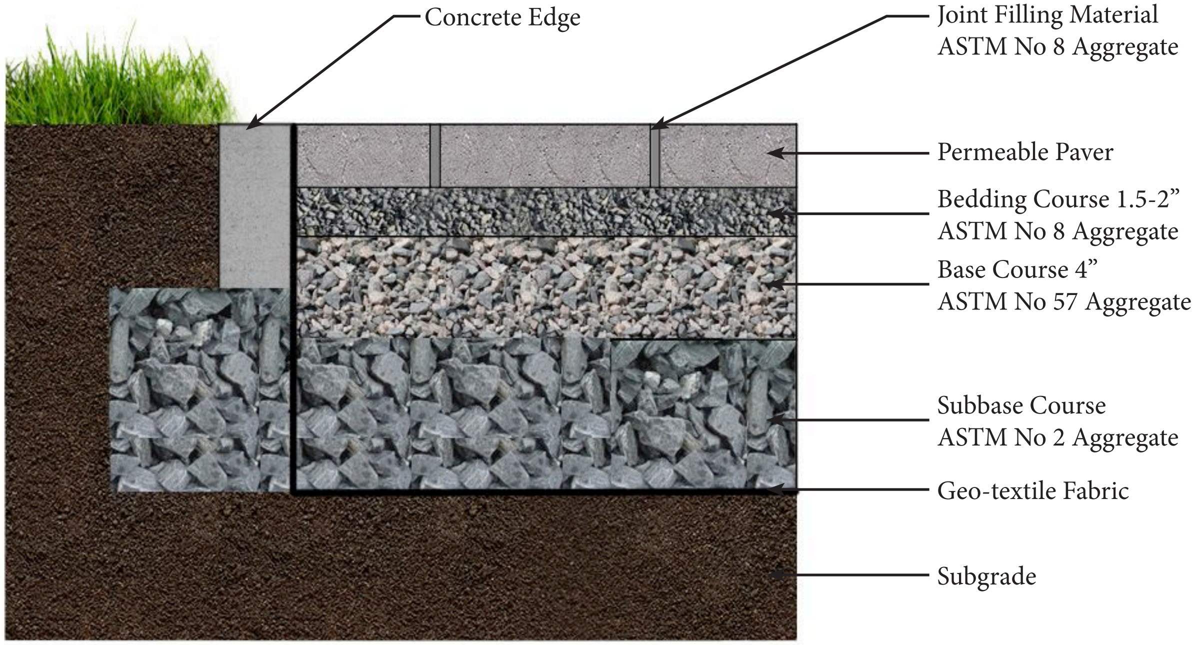



*Photo courtesy of www.gulfcoastpavers.com*

*Photo courtesy of www.icpi.org*

## Information:

Pervious pavement comes in a few different forms. There are pervious forms of asphalt and concrete as well as permeable interlocking pavers and open celled interlocking pavers. These types of pavement turn typically impervious surfaces into areas where water is allowed to seep into the ground rather than running off into storm drains or waterways. This type of pavement can be used in a variety of areas including streetscapes, parking lots, parks, and residential settings.

## Benefits:

- Controls stormwater runoff.
- Comes in a variety of materials, styles, and colors.
- Helps retain water on a given property which will aid the landscapes of that property.
- Open cell pavers maintain a grassy appearance.

## Maintenance:

- Remove sediment from surface the could potentially clog the pavements porosity.
- Monitor regularly to ensure the surface is properly draining.
- For permeable pavers, joint material that may wash out should be added when necessary.
- Open celled pavers will need mowed.
- Porous asphalt and concrete can be filled with patching mixes unless more than 10% of the surface needs repaired.

## Limitations:

- These areas should not receive stormwater from unstabilized landscape areas because of the amount of sediment that will wash onto them. They are best used in coordination with other bmps.
- These types of pavement are best used on slopes less than 5%.
- Snow removal can be hazardous to pavers specifically. Plows can catch corners and pull them up.
- These types of pavement are not good for areas where they will be subject to constant heavy loads.

*Photo courtesy of www.unilock.com*

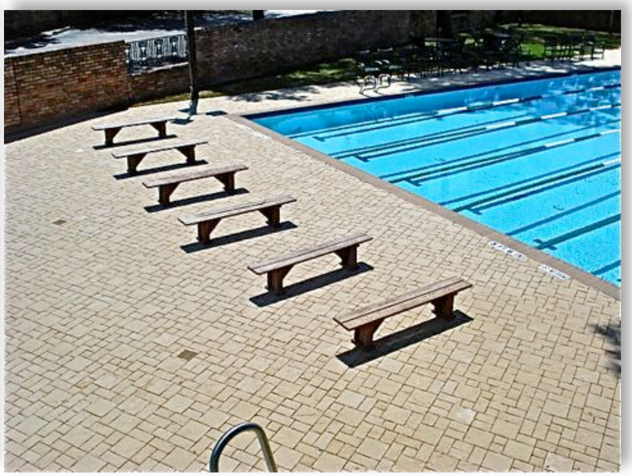


*Photo courtesy of www.gulfcoastpavers.com*

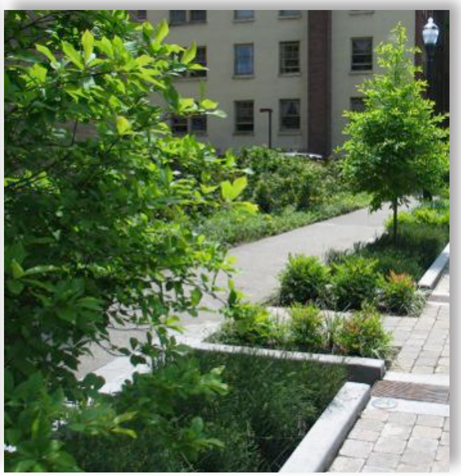
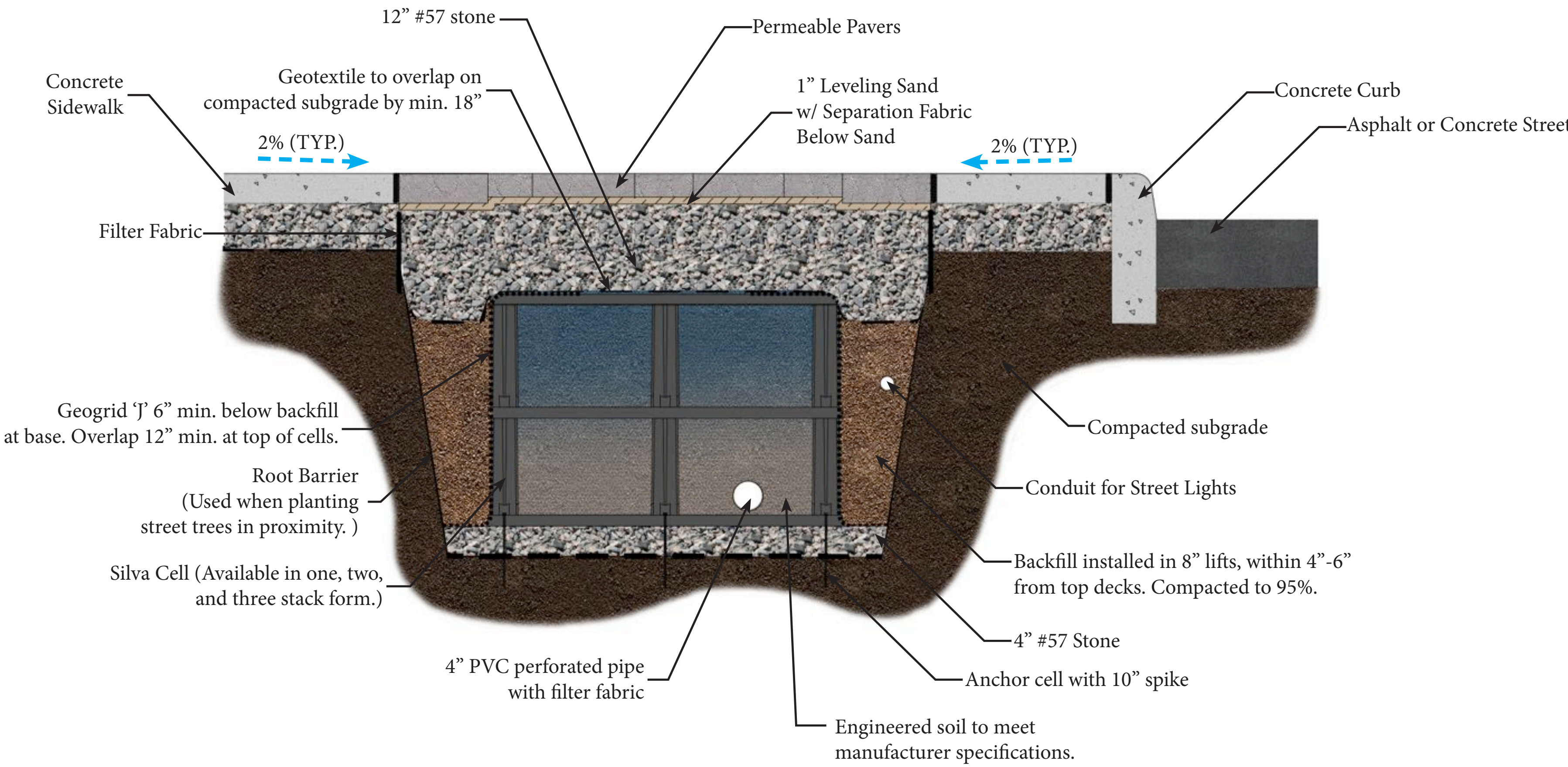


*Photo courtesy of www.water.epa.gov*

# Silva Cell:


12” #57 stone
Permeable Pavers
Concrete Sidewalk
Geotextile to overlap on compacted subgrade by min. 18”
1” Leveling Sand w/ Separation Fabric Below Sand
Concrete Curb
Asphalt or Concrete Street
2% (TYP.)
2% (TYP.)
Filter Fabric
Geogrid ‘J’ 6” min. below backfill at base. Overlap 12” min. at top of cells.
Compacted subgrade
Root Barrier (Used when planting street trees in proximity. )
Conduit for Street Lights
Silva Cell (Available in one, two, and three stack form.)
Backfill installed in 8” lifts, within 4”-6” from top decks. Compacted to 95%.
4” #57 Stone
4” PVC perforated pipe with filter fabric
Anchor cell with 10” spike
Engineered soil to meet manufacturer specifications.

## Information:

Silva cells are modular suspended pavement systems that use soil volumes to support large tree growth and provide powerful on-site stormwater management. Each cell is comprised of a frame and a deck and each holds 10 cubic feet of soil. They can be stacked one, two, or three cells high before the are topped with a deck. They can spread as wide as needed for a variety of project uses. Each unit is comprised of 92% void space, making it easy to accommodate utilities and expansion of street tree roots.

## Benefits:

• Store large volumes of water underground.
• Street trees can grow larger and healthier because their roots can expand into the system.
• Can be used in different applications both urban and rural.
• Excellent for streetscape renovations.
• Can support multiple types of paving.
• Can accept roof water through piping into the system.

## Maintenance:

• Most maintenance associated with silva cells will be inspection of the pavement surface that is overlaid onto the cells or any pipe connections distributing into the cells to ensure proper usage.
• To help avoid future disturbance of the Silva Cell system the location of the system should be accurately recorded at the time of construction and incorporated into an as-built drawing.
• Any machinery exceeding H-20 Loading should not be used on top of any pavement with underlying silva cells.

## Limitations:

• While the system can accommodate underground utilities care must be taken during future utility work not to damage these systems. Once close enough to the system excavation must be done by hand to not damage the cells.
• The size of the system depends on the amount of water that can be held. A rule of thumb in that each cell can hold 2 cubic feet of water so small systems may reach a cap during large storm events.


*Photo courtesy of www.deeproot.com*


*Photo courtesy of www.deeproot.com*


*Photo courtesy of www.deeproot.com*

## Sources:

***Web:***

- www.inhabitat.org
- www.water.epa.gov
- www.cbf.org
- www.nrcs.usda.gov
- www.dep.wv.gov
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- www.caseytrees.org
- www.greenroofs.com

***Print:***

- Warm Springs Run Watershed Assessment. Warm Springs Watershed Association. 2010
- Comprehensive Watershed Based Management Plan for Warm Springs Run. Warm Springs Watershed Association 2012.

***both available @ http://warmspringswatershed.webs.com/