Stormwater Management Master Plan

Sewanee: The University of the South

SEWANEE
THE UNIVERSITY OF THE SOUTH

Contents

Executive Summary

Sewanee: The University of the South has undertaken this Stormwater Management Master Plan as part of their commitment to natural resources and sustainable practices. Reinforced by University stakeholders throughout the process, Sewanee would like to prioritize comprehensive planning before implementation of significant development projects. Stormwater management and the protection of natural resources are critical elements of a sustainable comprehensive planning process. The importance of protecting natural resources is particularly evident within the Domain (Sewanee's entire 13,000-acre property), where over 90 percent of the property is a diverse natural habitat. The three developed watersheds within the "inner" Domain represent over 1,400 acres and are the primary focus of this Stormwater Management Master Plan (SMMP). The three project watersheds that contain the central campus and Sewanee Village drain outward from the plateau through the natural lands (the "Greater Domain"), as illustrated in Figure ES-1.

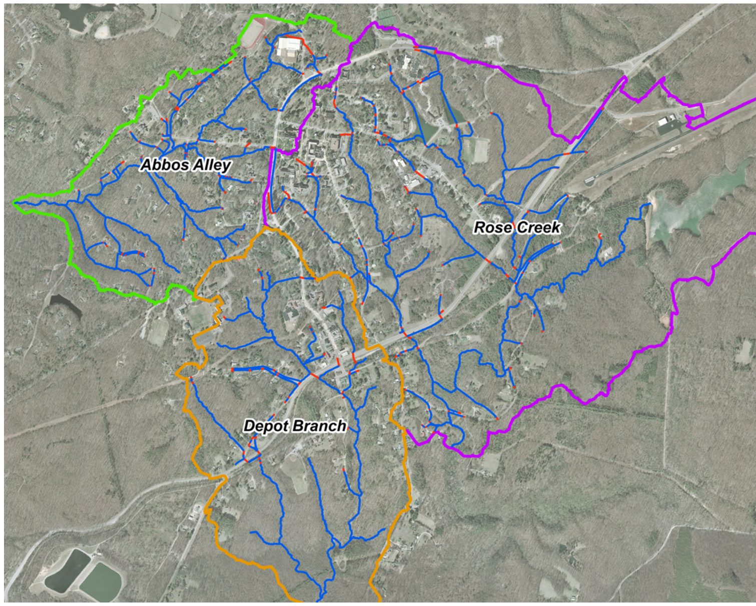


Figure ES-1: Project Watershed Overview

Unmitigated development, compared to natural land cover conditions, will negatively impact receiving streams and the downstream natural habitat that surrounds the study area. To plan for the impacts of future development from a stormwater perspective, this SMMP explores existing stormwater trends within the three project watersheds, suggests improvements to system-wide stormwater management, identifies five high-value projects, and recommends stormwater management guidelines for future development projects within the Domain.

Historical stormwater management practices and existing problems within the project area were reviewed to identify common issues that will continue to negatively impact the health of the receiving streams if not addressed. The study found that large roofs, parking lots, and general areas of impervious land cover, which do not allow infiltration of rainfall into the soil, have been commonly installed without appropriate stormwater management facilities to intercept the increases in runoff before entering the receiving stream. A stormwater model was developed to estimate the impacts of development on the stormwater drainage network throughout the three project watersheds. The estimated flows indicate undersized pipes under many roads that would lead to probable nuisance flooding. Stream velocities from higher-than-natural flows were predicted by the model and observed in the field to erode stream banks in localized areas within the project watersheds. The existing flooding and erosion problems would be exacerbated with future unmitigated development upstream. The study also found that vegetated stream buffers are not maintained in select areas and some structures are installed dangerously close to stream banks.

Holistically, the impacts to the observed natural stream network are localized and do not appear to be approaching poor urban-stream status. Relatively low-density development within the Domain's watersheds have protected the stream network from passing a "point-of-no-return," despite its negligible stormwater management practices. This is a positive message that reinforces current comprehensive planning efforts and the implementation of improved stormwater management practices within the Domain. Through implementing proper stormwater management the University can succeed in protecting the surrounding natural habitat while allowing higher-density future development.

Introduction

Figure 1-1: Stream within the Sewanee Domain

Sewanee: the University of the South, is recognized for its distinctive academic campus architecture atop the southern Cumberland Plateau. The campus represents less than five percent of the University's larger, 13,000-acre property called the Domain. The Domain also contains non-academic facilities such as single-family homes, the Sewanee Inn, golf course, and commercial properties. Most of the commercial properties are located along University Avenue and US Route 41A in the "Sewanee Village." Planned growth within the Village strives to encourage denser commercial and residential development in a town-centric fashion promoting community and connectivity. In contrast to the developed environment, more than 90 percent of the Domain is Southern Appalachian Forest with pristine natural habitat and a rich biodiversity.

As an influencer of future generations, environmental stewardship and sustainability are priorities for the University as established by the core principles of the 2011 Campus Master Plan to "plan a holistic approach to sustainable initiatives." Encouraging planned growth within the Domain while protecting the surrounding natural habitat is the primary driver for the creation of this Stormwater Management Master Plan (SMMP).

Considering the University's priorities, the SMMP provides specific guidance for accomplishing initiatives proposed within the 2013 Sustainability Master Plan for implementing stormwater management measures and protecting the surrounding watersheds. The University has not historically required extensive stormwater management practices for development projects within the Domain. While the land can absorb some low-density development, recent planning efforts and sustainability initiatives have recognized the need for an intentional change in practice. Much of this is due to anticipated development, particularly within the Village. This SMMP provides the University with a deliberate stormwater management approach to ensure the existing stormwater problems are effectively addressed and future development preserves the downstream natural habitat.

> A core principle of the 2011 Campus Master Plan was to "plan a holistic approach to sustainable initiatives."

Stormwater Management Master Plan (SMMP) Organization

This SMMP document is organized into five sections:

1. **Data Collection and Review**
   Summary of the background data collected and reviewed providing the foundation for the analysis

2. **Existing System Modeling**
   Existing stormwater system analysis, given terrain, infrastructure inventory, and land use within the studied watersheds and identification of stormwater issues

3. **Existing System Improvements**
   Recommended improvements based on field data, stakeholder input, and the existing system modeling; includes conceptual design of five high priority projects

4. **Near-term Project Stormwater Management Plan**
   Review and example application of enhanced stormwater guidelines to an actual campus project

5. **Stormwater Management Guidelines for Future Projects**
   Review of stormwater management goals for campus, a best practices toolbox for Sewanee, and stormwater guideline recommendations for future development projects within the Domain

1. Data Collection and Review

1.1. GIS Data

Several important pieces of GIS data were obtained from the University to provide background data for the study. These data include the following:

- Watershed Boundaries: Estimated boundaries of Rose Creek, Depot Branch, and Abbo's Alley watersheds
- Digital Elevation Model (DEM): Elevation data created from the collection of LiDAR points
- Contours: Contour data for each watershed created from the DEM
- LiDAR Streams: Estimated stream location polyline file for each watershed
- ArcHydro Intermediates: Intermediate data output from ArcHydro processing
- Culverts: Polyline files of conduits and culverts in each watershed
- Nodes: Point files of nodes and junctions in each watershed
- Watershed ArcMap Documents: Map documents with compiled data listed previously

1.2. Background Data

Numerous studies and plans regarding the campus landscape, environmental conditions, and future development have previously been conducted by consultants as well as students. Regarding the general context of the campus landscape, campus policies/goals, and future development plans, the following studies/documents were reviewed:

- 2011 Campus Master Plan
- 2012 Strategic Plan
- 2013 Sustainability Master Plan
- 2014 Sewanee Village Action Plan
- 2016 Sewanee Village Implementation Plan
- 2016 Strategic Plan Assessment

The *Stormwater Analysis for the Domain of the University of the South* (Senior Project 2011) serves as a particularly useful student project with regards to the SMMP. The project included individual contributions from hydrology, soil, and water quality groups. The non-forested watersheds included in the study are all within the SMMP project watersheds. Locally collected data have been valuable throughout SMMP process including the following information contained in the student project:

- Locations of poor stream conditions and erosion
- Peak flow relationship between forested and non-forested watersheds within the Domain
- Average infiltration rates and depths of soils in forested and non-forested areas within the Domain

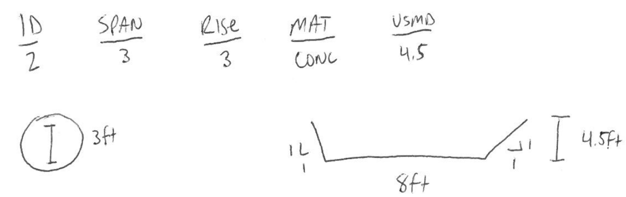


Figure 1-2: Example Notes from Field Data Collection

Figure 1-3: Culvert Visited during Field Data Collection

1.3. Field Data Collection

To complement GIS data obtained from the University, BWSC conducted field data collection on some of the stormwater inventory. These culverts were selected because their rise and/or span were greater than one foot and were expected to support large runoff quantities. In total, 30 culverts and adjacent open channels were visited in the field. For the culverts, details about their material, rise, span, barrels were recorded. For the open channels, bank slopes and bed width were recorded. Applicable photographs and notes were taken of the culverts and open channels.

Measurements were used to populate point and line shapefiles with spatial data corresponding to their real-world locations to update the GIS inventory of culverts received by the University. Photographs taken in the field were also made into a point shapefile with appropriate spatial placement.

1.4. Stakeholder input meeting

A workshop was conducted as part of the data collection process that included University representatives from Landscape Planning & Operations, Academics (Professor of Hydrology), Lease Management, Office of Environmental Stewardship and Sustainability, Vice Chancellor's Office (Special Assistant overseeing Sewanee Village implementation), Facilities Management, and Domain Management. The diversity of stakeholder participation was valuable in identifying SMMP goals from the University's perspective and resulted in the following:

- Protect and enhance the downstream habitat (outer Domain and beyond)
- Engage in comprehensive stormwater planning before development
- Consider historical mistakes
- Mitigate non-buildable parcels and increase leasehold stock, where possible
- Consider effect of site-specific maintenance on the greater Domain
- Include public education of environmental stewardship

In addition to the stakeholder goals for the SMMP, the workshop provided an opportunity to gather institutional knowledge from individuals who were intimately familiar with existing campus stormwater issues and historical practices within the Domain. Specific locations of known stormwater issues within the project area were identified during the meeting and related GPS point files for many of these were later shared from Sewanee staff.

1.5. Findings

During the field data collection effort and discussions with project stakeholders, several recurring stormwater issues were noted within developed areas of the Domain: undersized or clogged stormwater pipes, structures located near stream banks, a lack of stormwater management (e.g. detention) for roofs and parking lots, and localized stream erosion. Despite these problems, many of the stream corridors throughout the Domain maintain their natural function and habitat due to the upstream watershed not exceeding detrimental development limits. As development increases and land use transitions from fields and forests to impervious surfaces (sidewalks, roads, parking, and roofs), rainfall has less ability to infiltrate soils or be intercepted by vegetation causing the increase in stormwater to overload the natural carrying capacity of the stream system. This is commonly found in urban environments, and the streams downstream of the Village are in danger of exceeding this limit. A primary goal of this master plan is to ensure these streams remain protected as development increases within the Domain.

Figure 1-4: Partially Clogged Headwall South of Print Services Building.

Instances of isolated flooding are usually the result of undersized or clogged pipes. The upstream sides of these pipes are typically headwalls or drop inlets that collect runoff from a larger drainage area. In large storm events, the initial runoff volume is too great for these relatively small pipes. In some instances, the pipe is restricted due to being partially or fully clogged with debris or sediment and is a simple maintenance issue.

Another issue was the lack of retention and detention for runoff coming from roofs and parking lots throughout the developed areas within the Domain. In areas like the Tennessee Williams Center parking lot and behind Spencer Hall, unmitigated runoff is causing localized erosion. This occurs because there is significantly reduced infiltration of rainfall causing the runoff volume to be greater and the peak runoff flow rate to be higher. The resulting higher velocities and longer periods of high stream flow erode the soil along banks. Stream erosion can damage property, topple trees, increase the sediment load of the stream, and clog pipes.

Figure 1-5: Erosion near Alabama Avenue

2. Existing System Modeling

2.1. Introduction

Existing stormwater conditions within the three project watersheds must be established before developing recommended improvements or drafting stormwater guidelines for growth within the Domain. To analyze the existing conditions, a stormwater model (Figure 2-1) was developed using a stormwater management model (SWMM) that estimates existing stormwater runoff (hydrology) based on the land characteristics and the resulting performance (hydraulics) of the stormwater system. The following section summarizes the general process of the stormwater modeling and the results of the existing system analysis.

Document Terminology:

Stormwater System
stormwater drainage network containing open-channel and closed-pipe conveyance

Open-Channel
stormwater conveyance channel that could be a man-made ditch or natural stream

Closed-Pipe
stormwater conveyance pipe or culvert typically made from concrete, corrugated metal, or plastic

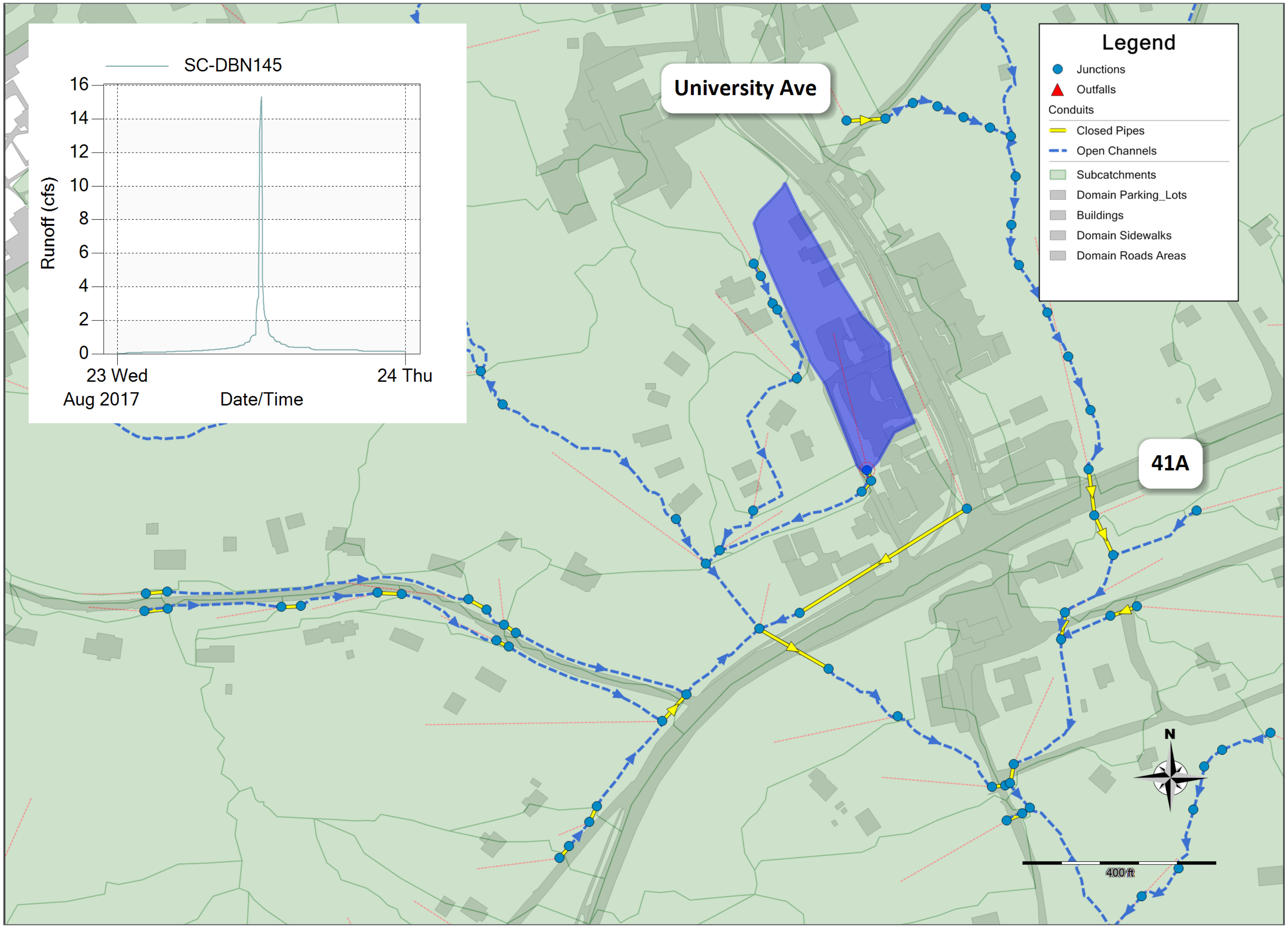


Figure 2-1: Sewanee SWMM Model Example

2.2. Hydrology

Land use, terrain data, stormwater infrastructure data, and terrain-derived stream data provided by the University were the foundation for defining the stormwater network for the project watersheds. In areas where the terrain-derived stream connectivity was unclear, Natural Resources Conservation Services (NRCS) stream data were used for defining the natural stream network. A GIS-based, continuous stormwater conveyance network that contains both closed-pipe and open-channel sections was developed for this task. The created stormwater network defines the general drainage patterns for the project watersheds.

Subcatchments within each of the three project watersheds were delineated based on the stormwater network connectivity, terrain data, and conduit data to determine the drainage areas contributing to specific points within the stormwater system. The system inflow-point for each drainage area was determined from aerial imagery, field data, and GIS data. Generally, the level of detail for subdividing each watershed was based on capturing drainage areas upstream of pipes with greater than 12-inch diameters, representative drainage areas for stream tributaries, and drainage areas for significant buildings and parking lots. The 1,450 acres of total watershed area was subdivided into 349 modeled subcatchments with an average subcatchment size of four acres.

> Stormwater runoff refers to rainfall that is not intercepted by vegetation or infiltrated into the soil, instead flows over land and through the stormwater drainage network to a receiving stream.

In addition to drainage area, certain land characteristics impact stormwater runoff. Stormwater runoff refers to rainfall that is not intercepted by vegetation or infiltrated into the soil but instead flows over land and through the stormwater drainage network to a receiving stream. Accordingly, land use and the amount of impervious area (e.g. roads, parking lots, roofs, sidewalks) significantly impact the volume of runoff within a drainage area due to the lack of infiltration occurring over impervious areas. For pervious areas, where infiltration can occur, the type of land cover and soil type impact the infiltration rate and the resulting volume of rainfall converted to runoff. Additionally, the land cover and slope of the drainage area impact the rate at which the runoff volume reaches the stormwater network and the receiving stream. The stormwater runoff volumes (rainfall not infiltrated) and runoff rates (time to reach stormwater system) impact the hydraulics of the stormwater network and the receiving streams.

2.3. Hydraulics

Spatial and physical data for conduits and inlets within the project area were provided in the University's stormwater inventory. Some infrastructure was spatially adjusted based on stream files, aerial imagery, road files, and elevation data. Project site visits and quality control review suggested varying degrees of confidence between watersheds in the inventoried closed-pipe stormwater system. Accordingly, assumptions were documented for pipe sizes and invert elevations to create logical connectivity and slope within the network. The amount and rate of flow entering the stormwater system is estimated from the hydrologic calculations described in the previous subsection. The resulting flooding and capacity of the system to handle the flows are based on the hydraulic calculations within the model. The hydraulic calculations are based on the pipe or open-channel geometry, slope, minor losses from entering/exiting the pipes, and estimated roughness.

2.4. Existing Stormwater Conditions

The stormwater model was used to estimate the existing hydrologic and hydraulic conditions for the three project watersheds. The analysis results are illustrated in terms of level of service, erodibility, and unit runoff.

Level of Service Analysis

For this stormwater analysis, the term "level of service" refers to the maximum design-storm event that a given pipe has capacity to convey without causing flooding. For stormwater systems, it is not necessarily a design flaw for a pipe to surcharge during infrequent rainfall events, so the identification of an existing problem is limited to flooding identified as flow exiting the system for closed-pipe drainage systems (e.g. grate inlets and catch basins) or overtopping a road for culverts between open channels. To determine the existing level of service for pipes within the three watersheds, the 24-hour rainfall events for the statistical 1-year, 2-year, 5-year, 10-year, and 25-year storms were simulated within the model. The total amount of rainfall per 24 hours for each design storm increases as the probability of occurrence decreases. The total rainfall amounts per 24-hour design storm for Sewanee, Tennessee is summarized in Table 2-1.

Table 2-1: Total Rainfall Amounts for 24-Hour Design Storms in Sewanee, TN

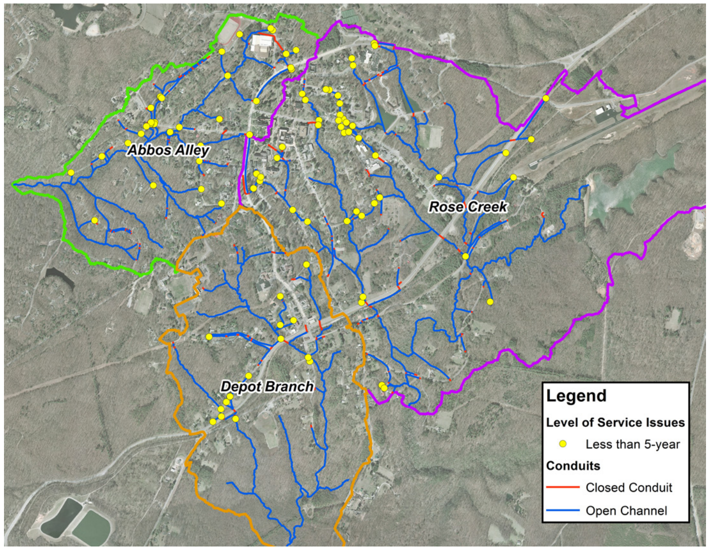
Design Storm	Total 24-hr Rainfall (in.)
1-year	3.38
2-year	4.04
5-year	4.93
10-year	5.62
25-year	6.58

A majority of modeled pipes within the University's stormwater system were estimated to flood during large events (10-year+), which is anticipated from historical construction practices, local construction standards, and traffic counts. However, some clustered areas of flooding indicate extent and frequencies that are probable nuisance areas which will worsen with additional, unmitigated upstream development. To illustrate the results from the level of service analysis, Figure 2-2 indicates areas exhibiting flooding during the 5-year, 24-hour design event.

As indicated in Figure 2-2, the areas of clustered flooding and a low level of service include:

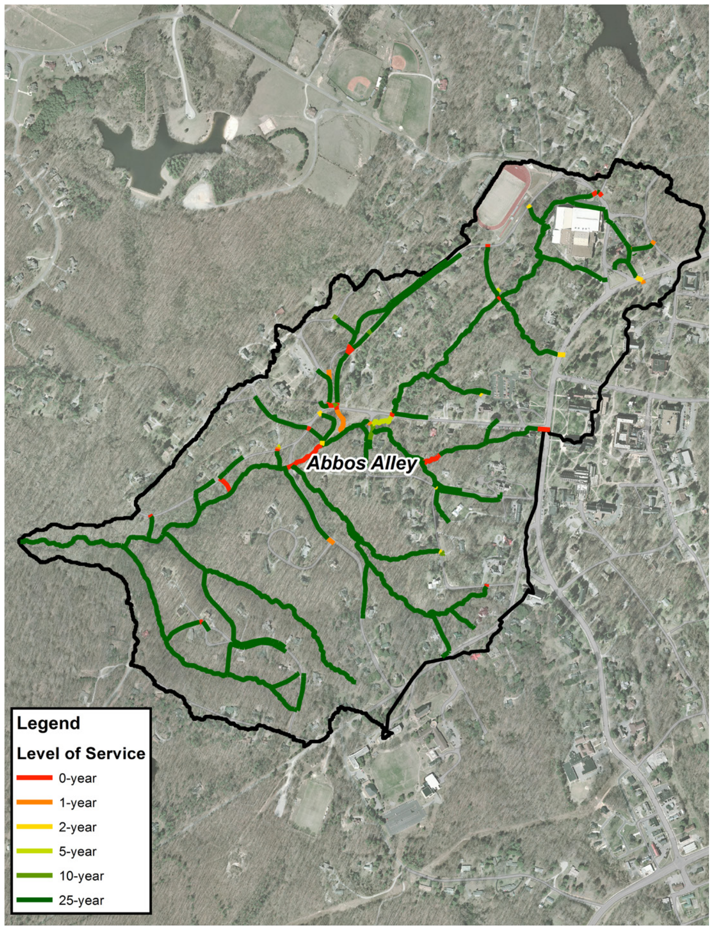
- Abbo's Alley: the culverts below South Carolina Avenue between Florida Avenue and North Carolina Avenue
- Depot Branch: the culverts along US-41A at University Avenue
- Rose Creek: the culverts at the intersection of Georgia Avenue and Mississippi Avenue

Figure 2-2: 5-Year Level of Service Overview



A GIS-based database (geodatabase) was submitted with the project deliverables to provide spatial reference for an individual pipe's level of service for the stormwater system. The level of confidence in the results should factor the data source included in the geodatabase. Development projects within the Domain, road improvements, or similar that impact the stormwater system can reference the geodatabase for existing deficient areas. Levels of service for specific pipes within the individual project watersheds are illustrated in Figures 2-3 through 2-5.

Figure 2-3: Abbo's Alley Level of Service Overview



Stormwater design uses statistical storms, which are based on historical rainfall data for the geographical location and are a measure of design risk. A 2-year event has a 50 percent (1÷2) statistical probability and a 25-year event has a four percent (1÷25) probability of occurring in a single year. Example applications:

- A culvert under a residential road might be designed for a 10-year rainfall event with acceptable consequences of intermittent detours throughout the years.
- An access road to a regional hospital or a fire station is commonly designed for the 500-year rainfall event as a critical facility that cannot afford frequent flooding issues.
- The lower the acceptable flood risk in stormwater design, the higher the project cost. An elevated road with larger pipes to handle less frequent, larger storm events require higher construction cost.

Stream Erodibility

The function of a stormwater system and stream network extends to more than level of service and flooding. Erodibility is another indicator of a system's health that impacts infrastructure and, more significantly, the natural stream network. When stormwater runoff results in high velocities within the stormwater network, erosion can occur in the open-channel portions of the system. As flow velocity increases, so does the erodibility of the stream banks. A 2-year rainfall event was used to gauge erodibility within the stream network using the stormwater model. Natural stream channels form to contain more frequent wet-weather flow events that correspond to the approximate 2-year flow frequency. In healthy-functioning stream systems, stream flows resulting from storms greater than the 2-year rainfall will typically overtop banks and enter the floodplain. Accordingly, the peak velocities were estimated within the stormwater network using the model during a 2-year, 24-hour rainfall simulation to identify the level of erodibility. The level of erodibility is based on literature and industry standards. For this study, the level of erodibility is identified as stream velocities higher than 4 feet per second (ft/s) having moderate probability for erosion ("Erodible") and stream

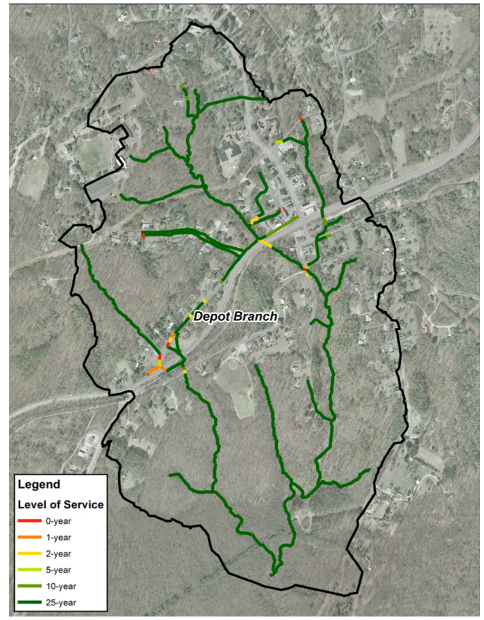
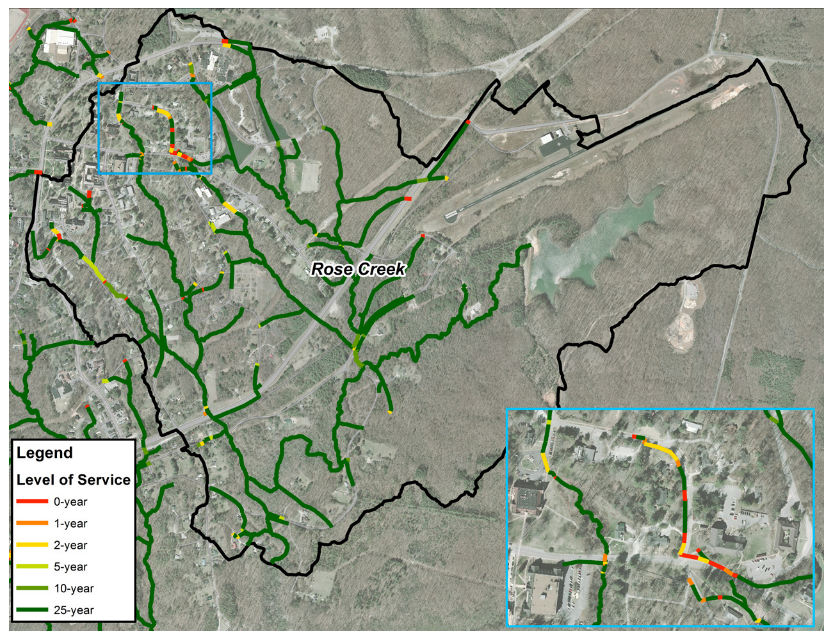


Figure 2-4: Depot Branch Level of Service Overview

Figure 2-5: Rose Creek Level of Service Overview



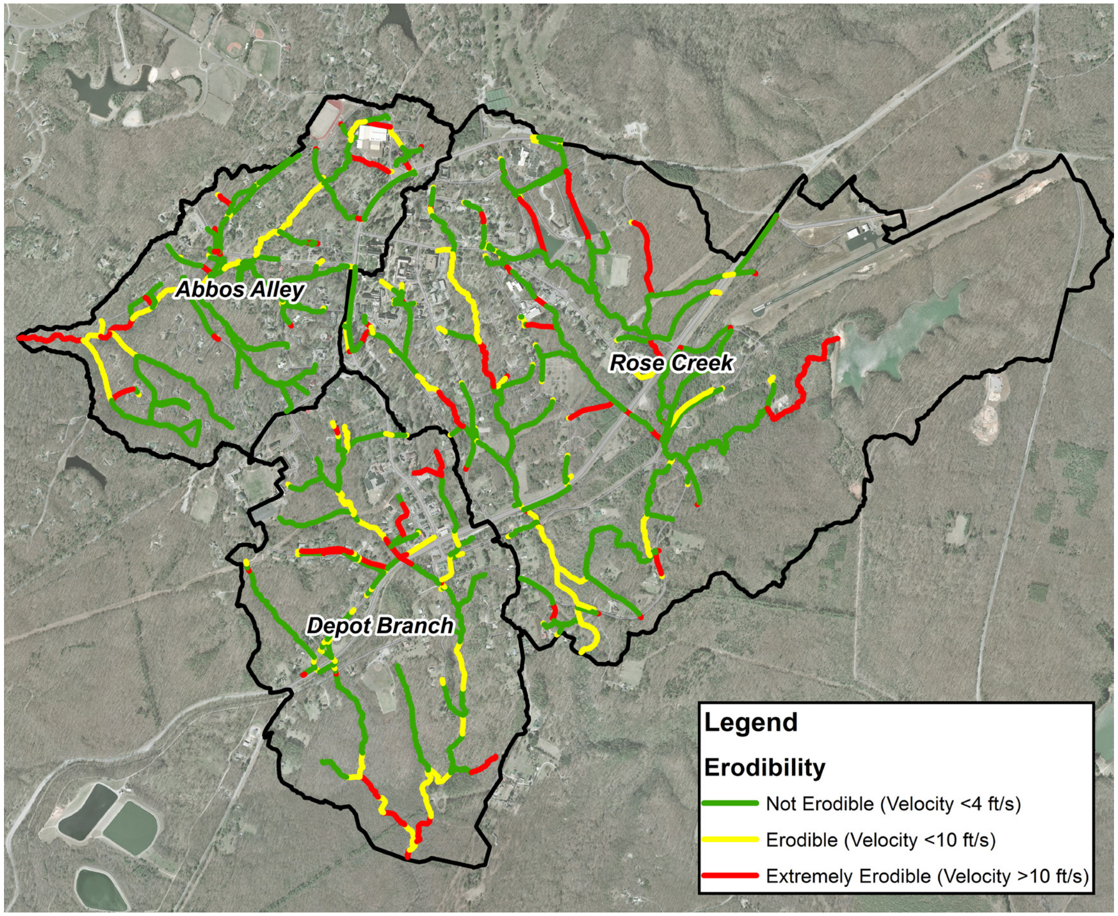


Figure 2-6: Overview of Erodibility in Open Channels

velocities of greater than 10 ft/s having high probability for erosion ("Extremely Erodible"). Figure 2-6 illustrates areas within the project watersheds that indicate velocities susceptible to stream erosion.

Streams downstream of the Fowler Center and denser developed areas near central campus were confirmed to have localized areas of erosion during field visits. It should be noted that Figure 2-6 indicates estimated peak velocity and the resulting probability for erosion. Areas in the most downstream portions of each watershed may be misleading as a stormwater problem. Soils tend to become thinner near plateau margins, the lower reaches of the streams tend to be entrenched in bedrock and contribute little to soil erosion in spite of increased flow velocities. The downstream stream reaches, which represent high-slope areas exiting the plateau, naturally experience high velocities.

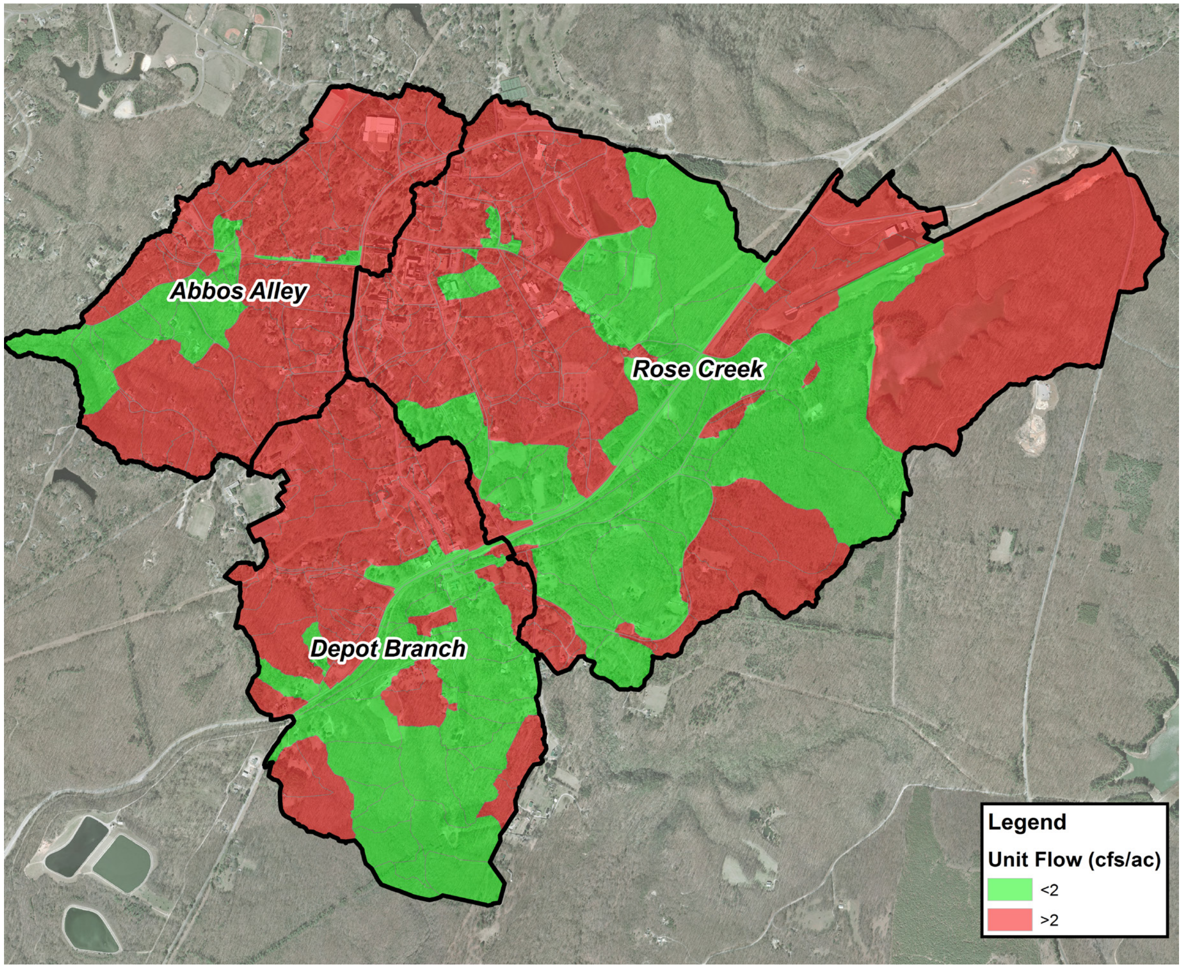


Figure 2-7: Unit Flow in Each Subcatchment (during 2-year rainfall event)

Unit Flow

A high unit flow rate is a simplified indicator of surface areas in a subcatchment having low infiltration rates, and therefore high runoff rates. During a storm, runoff begins sooner and the peak runoff rate is higher than in a subcatchment with a lower unit flow. Figure 2-7 illustrates the estimated unit flow rate of each subcatchment during the 2-year, 24-hour rainfall simulation.

Subcatchments with high unit flow are concentrated around developed areas within the Domain, such as central campus, the Village, and residential areas. The relationship between impervious area and stormwater will be further discussed in the following sections.

3. Existing System Improvements

3.1 Introduction

This section progresses from existing stormwater conditions to the related recommended improvements for each watershed within the project area. The recommendations are first outlined by system-wide improvements for commonly identified stormwater problems; next, a method for prioritizing watersheds within the Domain is introduced; finally, five high-value projects are presented. The high-value projects include a stormwater review for the Sewanee Village and four conceptual designs for areas that were identified collaboratively through stakeholder workshops and the initial findings from the existing conditions analysis.

3.2 System-wide Improvements

The existing conditions analysis identified common stormwater system deficiencies within the project watersheds:

- Pipes within the stormwater system that exhibit upstream flooding during smaller, more-frequent storms;
- Streams have areas of localized erosion and bank failure; and
- Existing impervious areas from roofs, roads, and parking lots often are the source of the issue from the increase from natural runoff conditions and the lack of stormwater management facilities to mitigate the impact.

Accordingly, the impact of future development upstream of problem areas needs to be considered, and existing problems would be exacerbated without an improvement to stormwater management practices. The following subsections outline four cost-effective recommendations for addressing existing stormwater problems that can be incrementally implemented to improve the health of the watersheds, benefit the downstream habitat, and potentially mitigate impacts from future development.

Large Impervious Area Stormwater Management

The installation of stormwater control facilities, such as detention ponds or bioretention areas (vegetated detention area with infiltration component), can reduce flooding and stream erosion. Properly sized stormwater control facilities can mimic natural runoff conditions and allow future development to continue with fewer negative impacts to the stormwater system and receiving streams. Accordingly, the optimal design size for a stormwater control facility addresses the change in stormwater runoff volume and peak flow rates from impervious areas compared to pre-developed conditions.

Within the three project watersheds there are several instances of large existing parking lots and roofs with adjacent available land that can be used to incorporate control facilities like bioretention areas, underground detention chambers, or traditional detention facilities (when site conditions do not permit infiltration). Retrofitting current areas with new stormwater control facilities may provide cost-effective opportunities to reduce existing flooding and erosion problems. Where practical, oversizing new stormwater control facilities can mitigate downstream impacts from development where stormwater management may be more difficult. When the soil allows, stormwater control facilities that include an infiltration component, such as a bioretention area, are recommended. Infiltrating a portion of the detained stormwater assists in reducing the total volume of runoff released to the stream to improve water quality and stream health.

Compared to a forested area, one-third of an acre of impervious surface contributes over 500,000 gallons of additional runoff to the stormwater system in an average rainfall year. In addition to an increase in runoff volume, higher peak runoff rates introduce erodible stream flow velocities to the system. Mitigation of runoff from larger impervious areas is a cost-effective method for reducing flooding and erosion within the downstream system. By prioritizing larger areas of impervious area, fewer stormwater control facilities can make a big impact. Additionally, it is more efficient to maintain a few, large facilities compared to many, small facilities. To allow for flexibility on potential retrofit locations, one-third of an acre was chosen as the benchmark to illustrate large impervious areas within the project area. A recommended prioritization method for selecting locations will be introduced later within this Section (Subsection 3.3). Figure 3-1 highlights impervious areas larger than one-third of an acre.

Note that five existing bioretention basins are also shown in Figure 3-1. Some of these may be adequately sized for the upstream impervious areas, whereas others may provide future upsizing opportunities. Regardless, areas without an existing downstream stormwater control facility should be prioritized over areas with existing facilities.

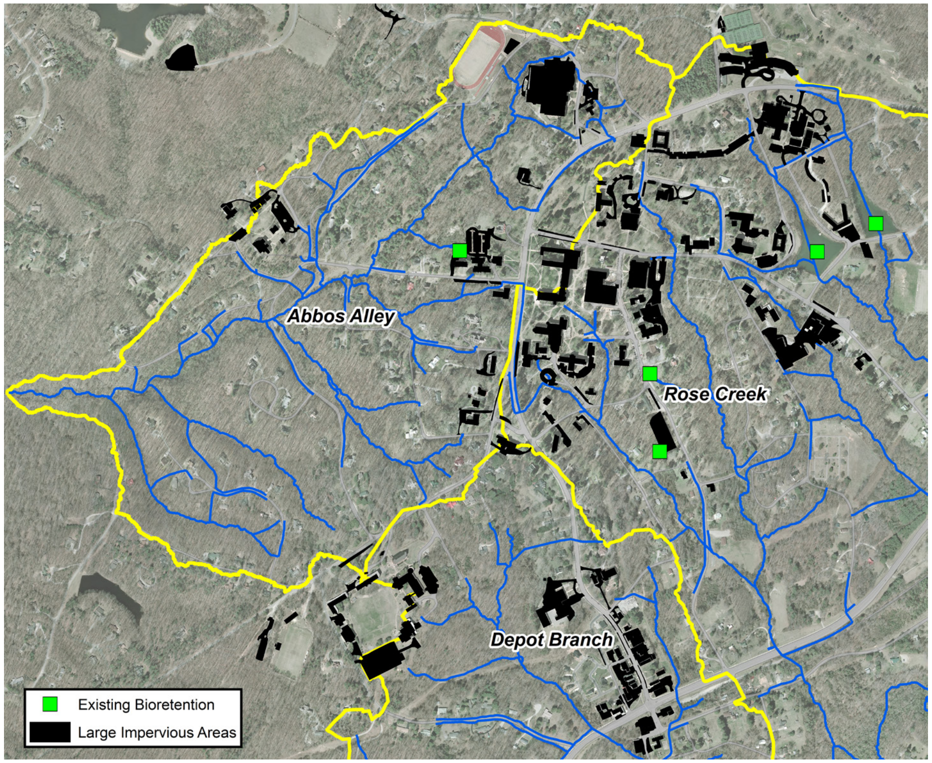


Figure 3-1: Large Impervious Areas within Domain

Downspout Disconnection

Another retrofit opportunity to improve existing conditions within the project watersheds is roof downspout disconnection. This simple process can significantly impact runoff volume by sending roof runoff into pervious lawns, landscaping, or wooded areas instead of through a pipe or gutter directly to the stormwater system. Allowing roof runoff to infiltrate as much as possible before entering the stormwater system is a cost-effective method for incrementally mitigating downstream impacts from development. For smaller roofs or large lawns, roof runoff associated with most rainfall events can be completely contained before it enters the stormwater system.

Downspout disconnects work effectively by adhering to a few standard design features. The downspouts should not discharge onto an impervious surface and should not flow towards the foundation of a building or an adjacent structure. Lawns and gardens are very suitable discharge areas for downspouts. The infiltration rate can be improved by adding soil with increased permeability to the discharge area. Spreading the flow at the mouth of the disconnected downspout with stone filters or level spreaders will reduce the velocity of the flow and discourage localized erosion.

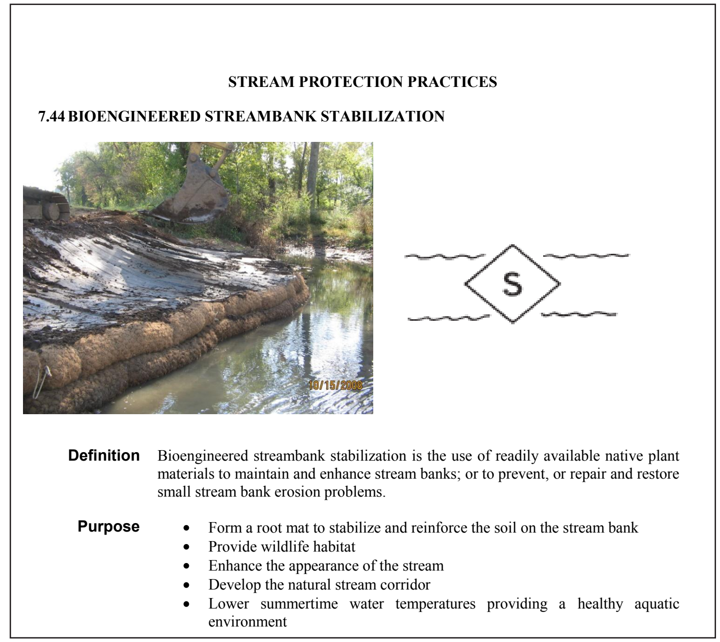
Pipe Upsizing

This SMMP does not recommend upsizing the flooding stormwater pipes throughout the Domain. Upsizing a single pipe under a flooding road or walkway often represents a “near-sighted” solution to localized flooding – an individual road flooding may be solved by upsizing the pipe underneath it; however, the downstream peak stream flows will negatively increase as a result from the removal of the bottleneck. It is better, from a system-wide perspective, to address the increased volumes

Upsizing a single pipe under a flooding road or walkway often represents a “near-sighted” solution to localized flooding – an individual road flooding may be solved by upsizing the pipe underneath it; however, the downstream peak stream flows will negatively increase as a result from the removal of the bottleneck.

and peak flows that cause flooding through upstream detention and infiltration. The treatment of the symptom versus the cause approach to localized flooding was identified as a negative past practice within the Domain during the stakeholder workshops.

Considering the above qualification that pipe upsizing should not be performed on a system-wide scale, there are critical transportation routes that should remain open during storm events from an emergency vehicle access or traffic-count point of view. Highway 41A and University Avenue are two examples of roads that should remain open during most rainfall events. It is recommended to properly size pipes under these critical roads when transportation-driven improvement projects occur. Combining the processes of upsizing pipes with routine road maintenance and road construction can decrease the inconvenience to the community and is a cost-effective construction process. A hydraulic analysis for sizing the pipe to the appropriate design storm should also include a downstream impact analysis. Significant increases in downstream flows should be mitigated with designed floodplain storage or new stormwater control facilities installed within the watershed.


STREAM PROTECTION PRACTICES

7.44 BIOENGINEERED STREAMBANK STABILIZATION

Definition Bioengineered streambank stabilization is the use of readily available native plant materials to maintain and enhance stream banks; or to prevent, or repair and restore small stream bank erosion problems.

Purpose
- Form a root mat to stabilize and reinforce the soil on the stream bank
- Provide wildlife habitat
- Enhance the appearance of the stream
- Develop the natural stream corridor
- Lower summertime water temperatures providing a healthy aquatic environment

Figure 3-2: Streambank Stabilization Excerpt from the Tennessee Erosion and Sediment Control Handbook

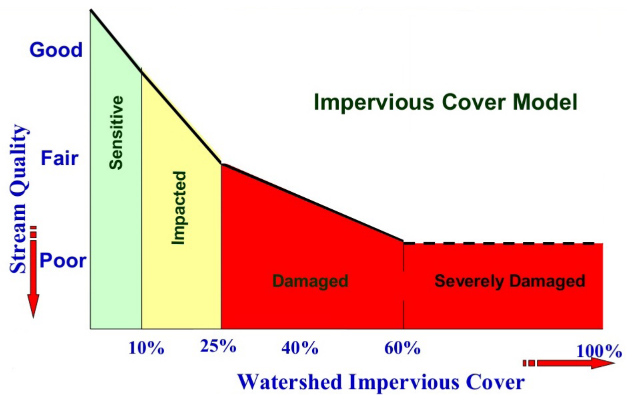
Stream Restoration and Bank Stabilization

Stream restoration and bank stabilization practices are recommended improvements to restore eroded stream channels that have been impacted by increased runoff conditions. The ideal goal of stream restoration is to return streams to a natural equilibrium regarding capacity, vegetation, and connection to the floodplain during larger storm events. It is recommended to address erosion after the upstream flow imbalance within the watershed has been addressed. When severe eroded stream conditions threaten structural failure to an adjacent building or utility, bank stabilization is sometimes the only near-term option to protect assets over the preferred full stream restoration approach. A bioengineered bank stabilization that includes a vegetation component is supported by the regulatory community over hard armoring (e.g. rip-rap, gabion baskets). An overview of bioengineered bank stabilization is provided in Figure 3-2 from the Tennessee Erosion and Sediment Control Handbook (TDEC 2012).

3.3 Watershed Prioritization

While there are several existing areas of the three project watersheds that need runoff mitigation, the severity of need varies. Development and urbanization within watersheds has been connected to the deteriorating health of streams for decades. The primary factors are increased exposure to pollutants and the significant shift in the balance between soil infiltration and stream flows. Impervious land cover significantly reduces the amount of rainfall that is filtered through the soil and recharges the groundwater; instead, this untreated runoff reaches the receiving stream at a much higher rate compared to natural conditions. The Center for Watershed Protection quantified the correlation between a watershed's percentage of impervious land cover to stream quality as illustrated in Figure 3-3.

Figure 3-3: Impervious Cover and Stream Quality (Center for Watershed Protection 2003)



According to the Center for Watershed Protection, streams with drainage areas containing less than 10-percent impervious cover are considered "good" quality streams that are sensitive to an increase in impervious area. Streams with drainage areas of 10- to 25-percent impervious cover trend towards "fair" quality and are measurably impacted by the impervious cover. As quality deteriorates, streams with drainage areas exceeding 25 percent impervious cover approach "poor" conditions. These are typically non-supporting, urban streams. This is somewhat intuitive as it is commonly observable that streams within natural forests are healthier than streams in a medium-density neighborhood, which are both healthier than a stream through a heavily-paved, urban area.

Despite a majority of the Domain being natural forests, there are several streams within the three project watersheds that are estimated to approach "fair" quality and one stream past the benchmark, approaching "poor." The watersheds containing higher proportions of impervious area are near central campus and the Sewanee Village. For the project area, Figure 3-4 provides an overview of the major stream's estimated quality based on impervious cover within each watershed.

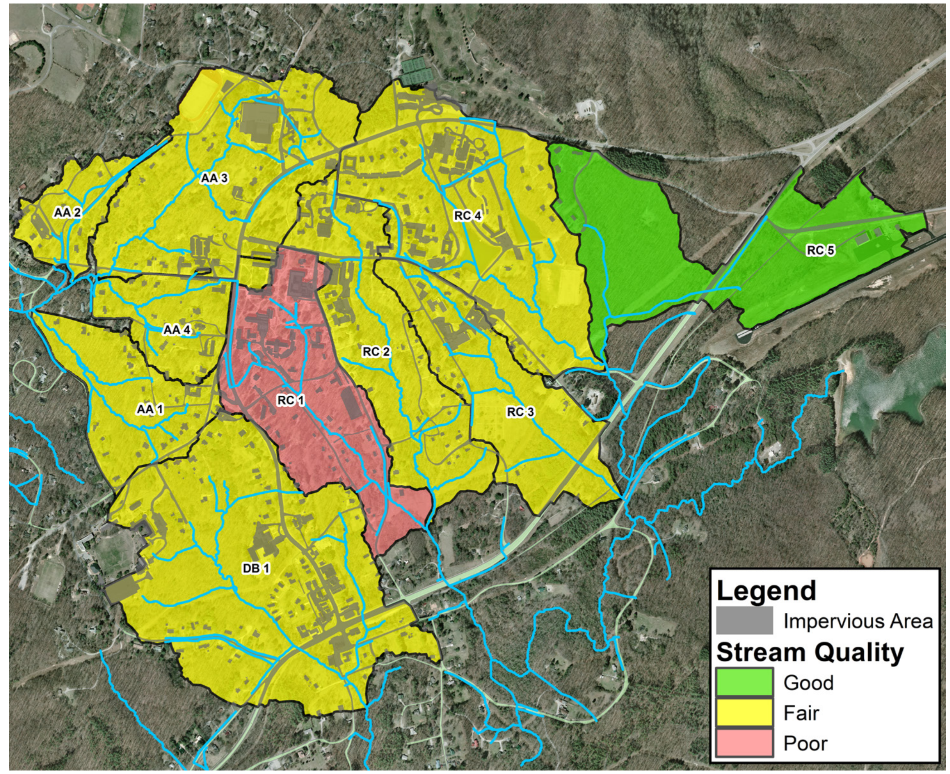


Figure 3-4: Stream Quality Based on Watershed Impervious Cover

Based on existing impervious cover, a majority of the streams within the project's watersheds have an estimated quality between "good" and "fair." This includes the Depot Branch stream receiving runoff from the Sewanee Village (DB 1). Within the project area, historically low-density development has helped preserve the health of the overall stream network and natural habitat within the Domain. By recognizing the proposed future development within the Domain, this SMMP is an effort by the University to concentrate on stormwater management and foster the protection of natural resources.

When selecting areas for stormwater improvement projects, a recommended method for prioritizing locations is to use this concept of stream quality and watershed impervious cover to guide the rankings. For example, there is one stream (RC 1) with an impervious watershed percentage that exceeds the "fair" quality benchmark. This watershed, along with DB 1, should float to the top for prioritization when funding for stormwater improvements becomes available or a new development project has a cost-effective opportunity for oversizing a proposed stormwater control facility within the watershed. Due to the proposed near-term significant increase in development density for the Sewanee Village, it is recommended to include the DB 1 watershed with a similar priority as RC 1, despite the difference in impervious percentage. It is a highly visible development project that should be mitigated from a stormwater perspective to protect the downstream habitat. Additionally, in the current Sewanee Village Implementation Plan there are multiple proposed structures within low-lying areas near the confluence of multiple drainage areas. Stormwater improvements within this watershed will reduce, but not eliminate, the probability of future property damage due to flooding or erosion within Sewanee Village.

As indicated in Table 3-1, many of the project streams have comparable levels of impervious cover within their watersheds. Considerations for community significance, such as central campus location or public access, may override the suggested impervious-based two through six priority watersheds. Watersheds RC 3, AA 1, and RC 5 have healthier levels of impervious cover and should objectively follow the other areas in urgency for stormwater improvements from a stream-quality perspective.

Partial Watershed	Total Area (ac)	Existing Imp. %	Phase 1 Imp. %	Watershed Priority
RC 1	64.6	26	26	1
DB 1	135.0	17	22	1
RC 4	94.8	20	20	2
AA 3	82.4	18	18	3
AA 2	18.5	17	17	4
AA 4	26.7	16	16	5
RC 2	60.3	15	15	6
RC 3	52.1	12	12	7
AA 1	35.8	10	10	8
RC 5	80.3	7	7	9

Table 3-1: Watershed Impervious Summary and Potential Priority

3.4 Five High-Value Projects

The following project overview pages describe five high-value projects (Figure 3-5) that were identified in collaboration with the project stakeholders. Of the five projects, four are conceptual designs for specific areas within the studied watersheds, with the fifth project serving as a broader stormwater review of the Sewanee Village Implementation Plan. Specific components of each conceptual design, such as bioretention, vegetated swales, etc., will be further defined in Section 5 of the SMMP. General local conditions and known constraints were considered during the project development; however, infiltration tests and thorough site investigations must be performed for the detailed design and more accurate opinions of probable construction costs. Conservatively broad planning-level costs are provided based on unit cost ranges, but they should be considered an order-of-magnitude cost outlook due to the uncertainties of subsurface conditions and the variation of specific features included in the detailed design.

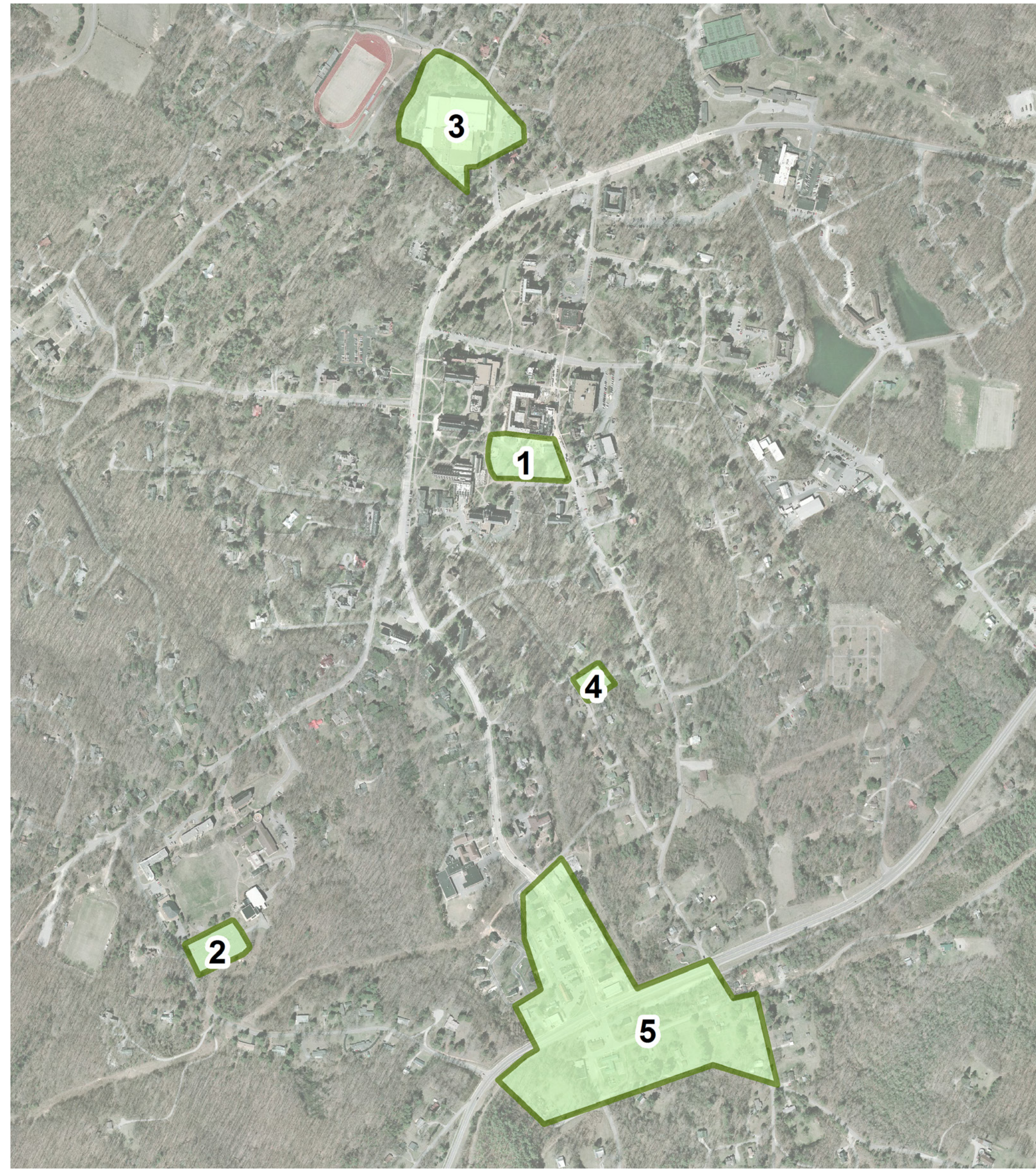


Figure 3-5: Five High-Value Projects Overview

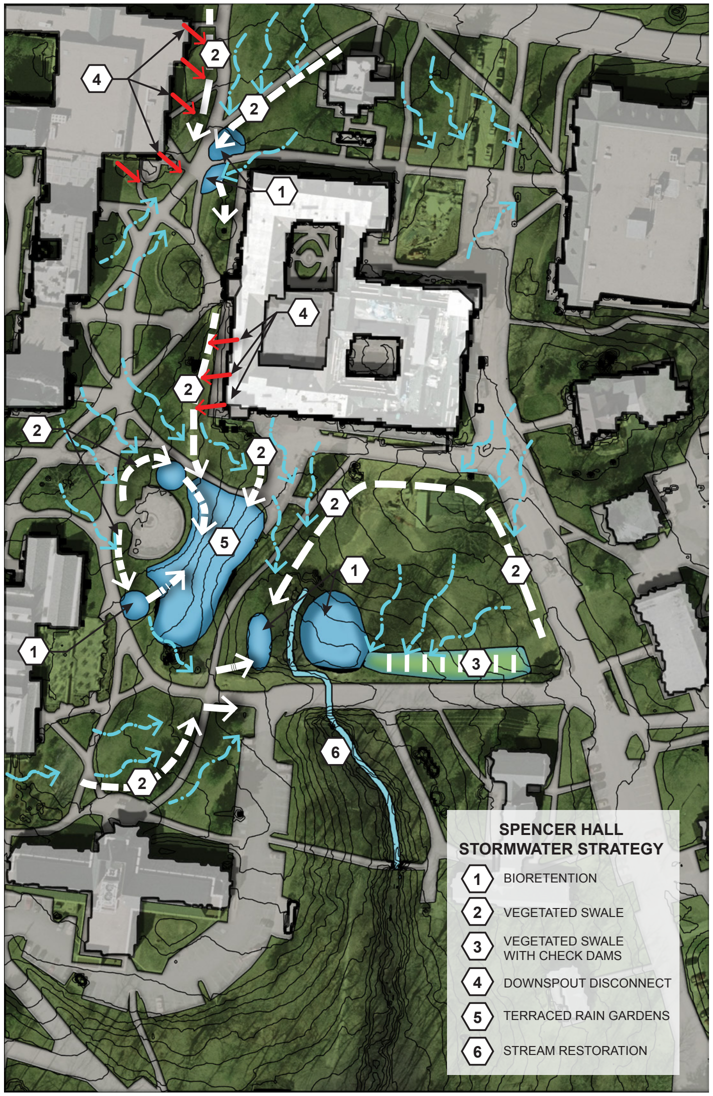


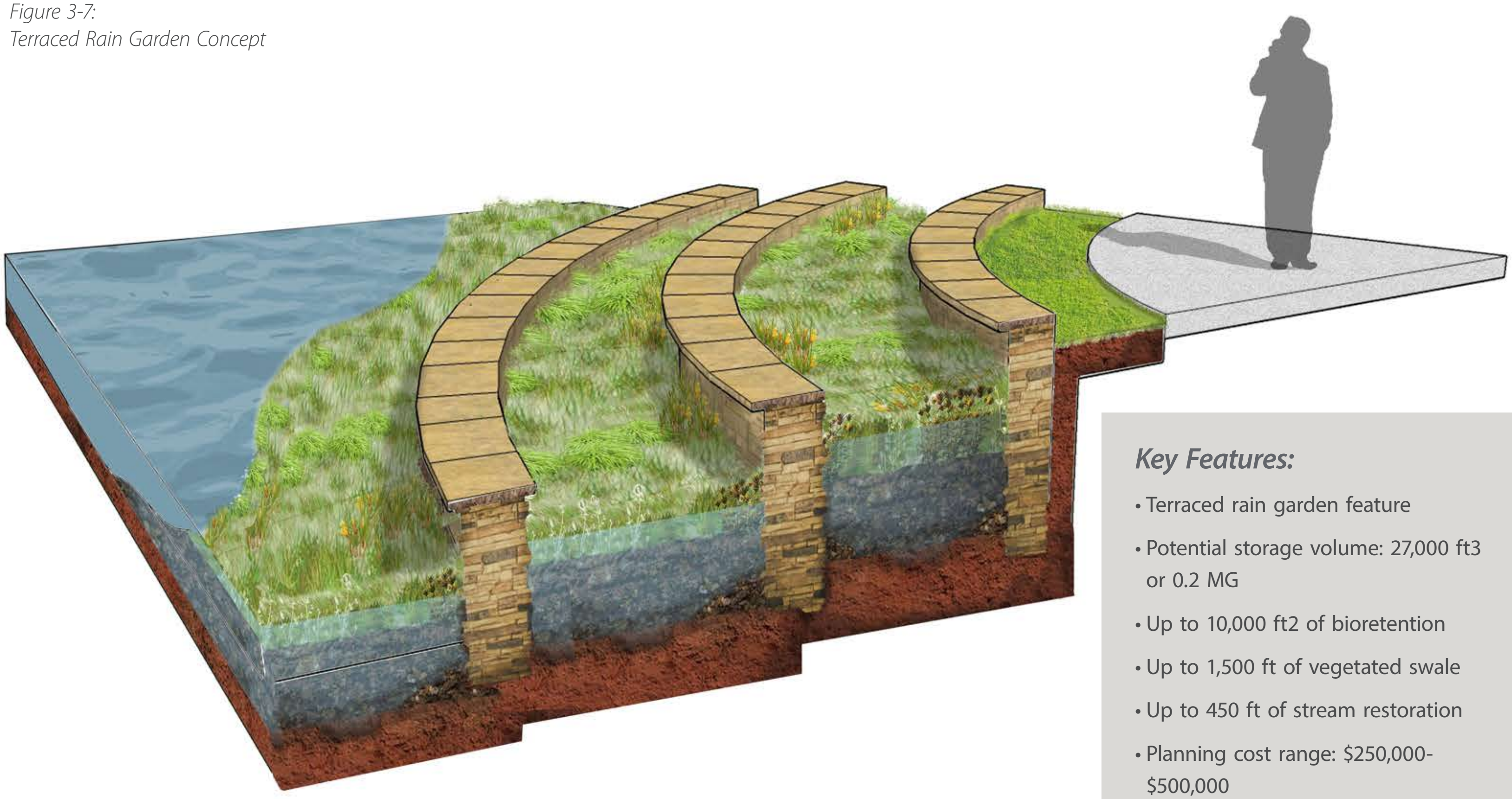
Figure 3-6:
Spencer Hall Conceptual Design

High Value Project 1 – Spencer Hall

The green-space south of Spencer Hall (Figure 3-6) has become a highly trafficked outdoor common area that also serves as the confluence to multiple drainage areas, including Spencer Hall, the Chapel, and portions of McClurg Dining Hall. The project is in the upstream portion of a top-priority watershed with localized flooding and erosion issues. The goals of the multi-faceted stormwater improvements are to make a functional, aesthetic, and educational area while maintaining pedestrian connectivity.

The area can feature a terraced rain garden (Figure 3-7), multiple bioretention areas, and vegetated swales to detain runoff in a treatment train or stair-step approach that maximizes the retention and slows the rate that runoff reaches the stream. Once peak flows have been mitigated, there is an opportunity for stream restoration at the downstream boundary of the project.

Figure 3-7:
Terraced Rain Garden Concept



Key Features:

- Terraced rain garden feature
- Potential storage volume: 27,000 ft3 or 0.2 MG
- Up to 10,000 ft2 of bioretention
- Up to 1,500 ft of vegetated swale
- Up to 450 ft of stream restoration
- Planning cost range: $250,000-$500,000
- Annual maintenance: $12,000-$17,000

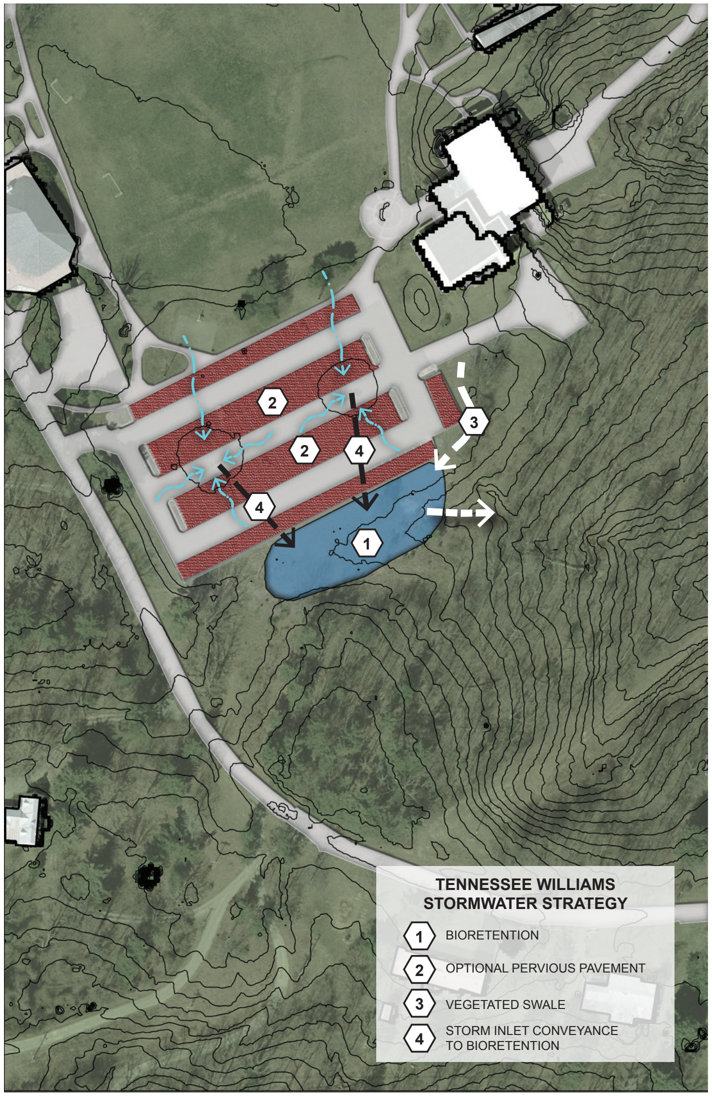


Figure 3-8: Tennessee Williams Center Conceptual Design

High Value Project 2 – Tennessee Williams Center Parking Lot

The Tennessee Williams Center parking lot (Figure 3-8) presents one of the highest benefit-cost ratios of any identified project. Located in and around an expansive parking lot with no current stormwater management, the project is in the headwaters of a top-priority watershed (draining to the Village area), with downstream land available. Due to the construction access and available space, this project could provide a cost-effective opportunity for oversizing a stormwater management facility to account for development within the watershed that has more difficult stormwater management options.

The parking lot is a destination for visitors to the Tennessee Williams Center, which might be encouragement to replace a portion of the parking spaces with pervious material, such as pavers, during the next resurfacing cycle. While the optional pervious pavement is a more expensive stormwater storage alternative than bioretention, it is a visible demonstration of an alternative method for managing stormwater on campus.

Key Features

(does not include optional pervious pavement):

- Potential storage volume: 36,000 ft^3 or 0.3 MG
- Up to 13,000 ft^2 of bioretention
- Up to 200 ft of vegetated swales
- Planning cost range: $150,000-$350,000
- Annual maintenance: $12,000-$17,000
- Site excavation and access needs to be coordinated with adjacent historical homestead site
- Existing infrastructure under parking lot can be used to convey stormwater to bioretention

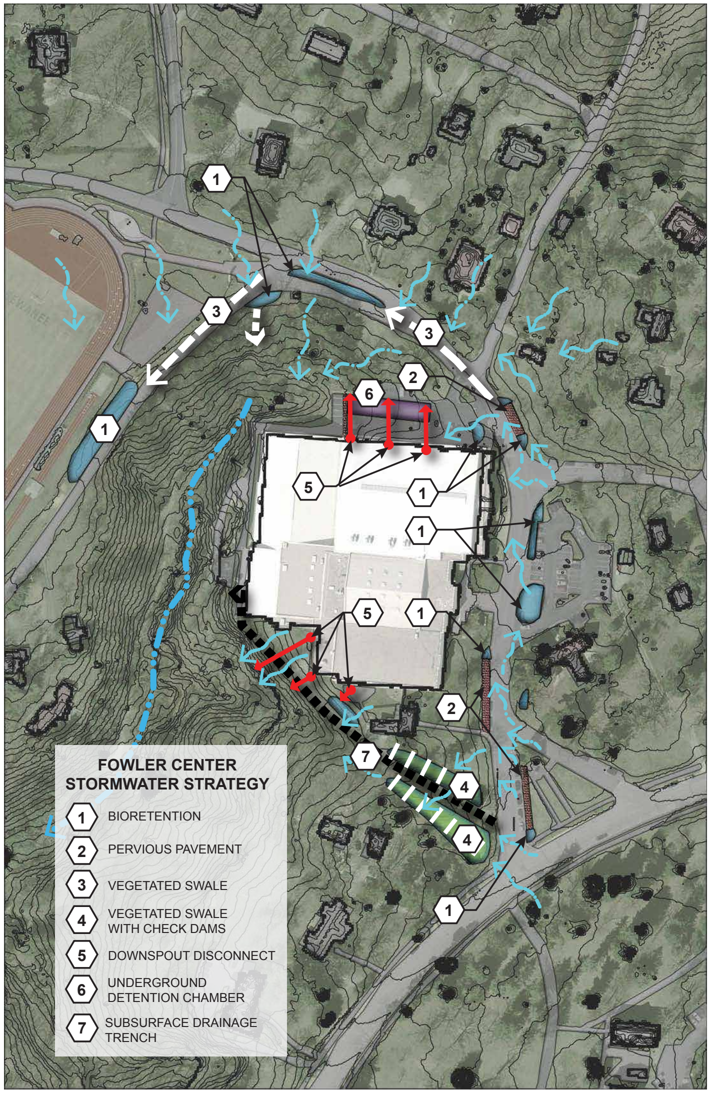


Figure 3-9: Fowler Center Conceptual Design

High Value Project 3 – Fowler Center

The Fowler Center is situated in the headwaters of Abbo's Alley and represents an extensive impervious area with no existing stormwater management. Runoff from the large (approximately two-acre) athletic facility roof and surrounding asphalt causes erosion as it rushes down the steep slopes to the stream. Within the stream channel, there are multiple areas of failing banks from the increase in flows.

The proximity to the top of the slope makes it difficult to install a single, large stormwater control facility. Instead, mitigation measures should be piecemealed in the available areas, as illustrated in Figure 3-9. The most cost-effective runoff to intercept and infiltrate is from the parking lot to the east of the building that contributes to the same drainage system. Swales and check dams above ground and potentially within a trench along the gravel drive to the south could slow flows before entering the valley. To the north of the building, there is potential to disconnect downspouts and install an underground detention chamber under the existing asphalt.

Key Features:

- Potential Storage Volume: 52,000 ft3 or 0.4 MG
- Up to 10,000 ft2 of bioretention
- Up to 850 ft of vegetated swales
- Up to 8,200 ft2 of pervious pavement
- Up to 4,200 ft2 of underground storage
- Planning Cost Range: $500,000-$1,000,000
- Annual maintenance: $14,000-$18,000
- Historic spring to south of site must be protected in design and during construction
- Subsurface drainage trench - potential design could be a perforated HDPE pipe with outlet control to provide linear storage and infiltration

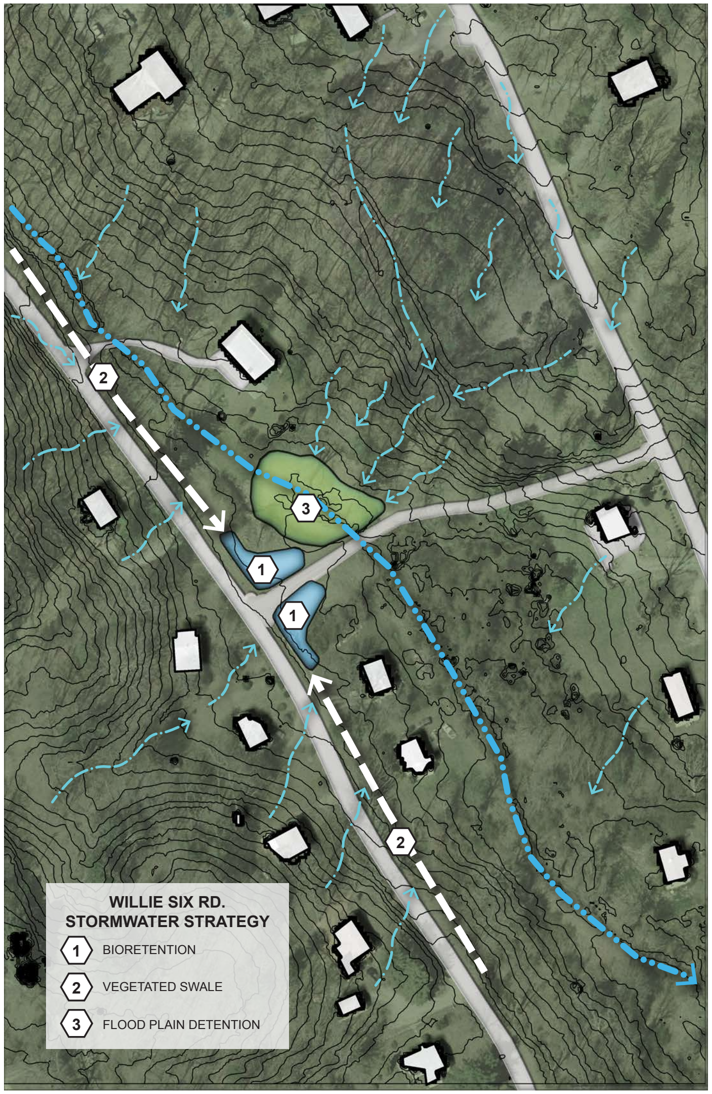
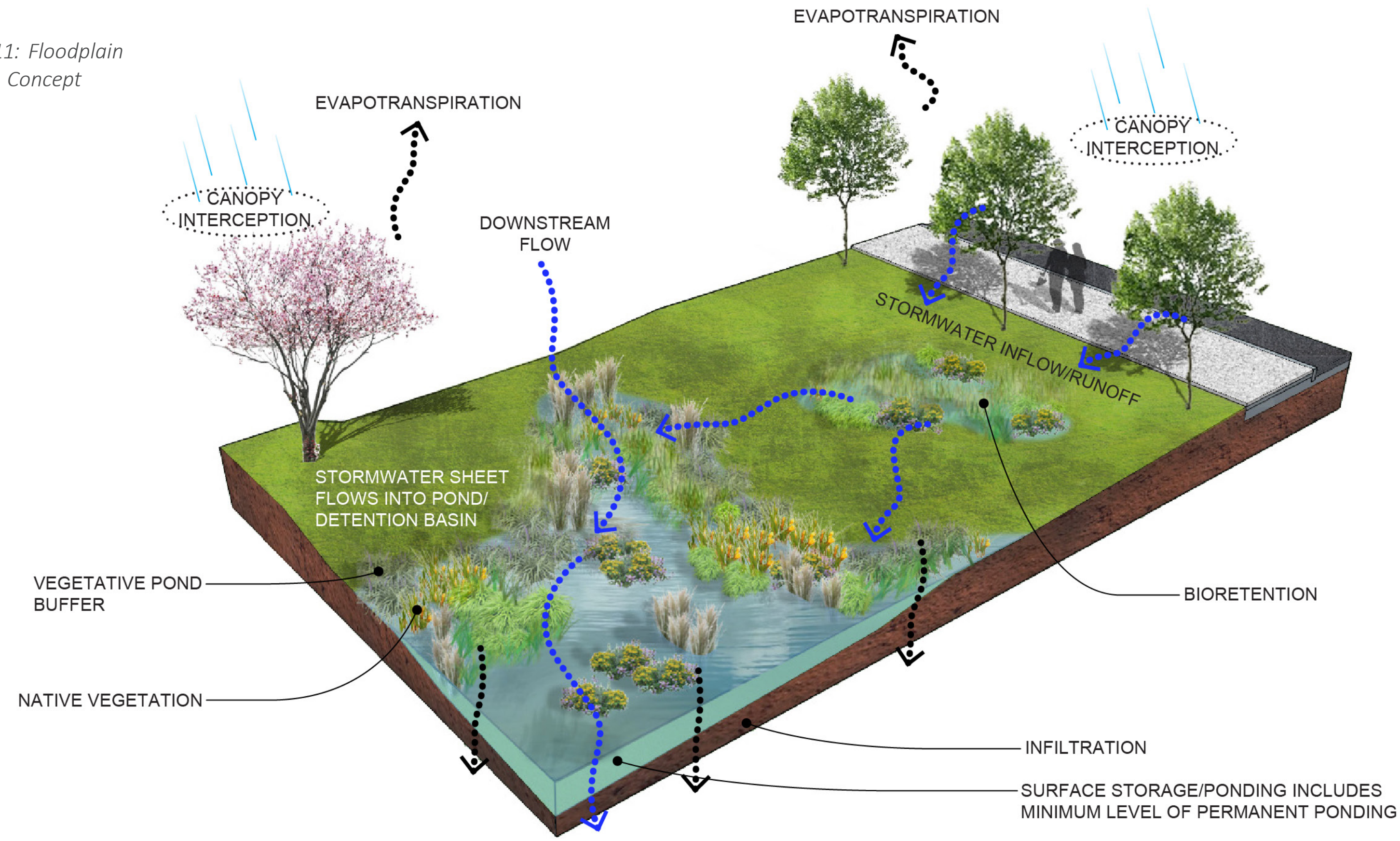


Figure 3-10: Willie Six Road Conceptual Design

High Value Project 4 – Willie Six Road

The Willie Six Road site (Figure 3-10) is adjacent to a stream with a relatively large drainage area that contains dense development in the upstream headwaters. Because of the large contributing area, low-lying properties downstream form Shedd Lane are prone to flooding. To mitigate the flooding for smaller, more-frequent storm events, the site can host floodplain detention adjacent to the stream (Figure 3-11) and two bioretention areas along Willie Six Road to retain local road and yard runoff. These improvements will mitigate flooding and is a visible demonstration project. However, the site is not large enough to eliminate flooding during larger storm events. A combination of upstream runoff reduction projects would be required to further improve flooding conditions.

Figure 3-11: Floodplain Detention Concept



Key Features:

- Potential storage volume: 21,000 ft3 or 0.16 MG
- Up to 4,800 ft2 of bioretention
- Up to 700 ft of vegetated swale
- Up to 8,800 ft2 of floodplain detention
- Planning cost range: $125,000-$250,000
- Annual maintenance: $10,000-$14,000
- Site excavation and access needs to be coordinated with adjacent historical homestead site

High Value Project 5 – Stormwater Review of Sewanee Village Implementation Plan

The Sewanee Village Implementation Plan (Figure 3-12) aims to connect development between the University of the South and the Sewanee Village. The plan calls for a connection between existing and new parks, a set of architectural guidelines for construction of new buildings in the Village and enhanced connectivity between existing and future roadways and paths. The plan provides a vision for a cohesive town-center environment that increases the availability of retail and residential leaseholds that by nature will increase development density of the Village.

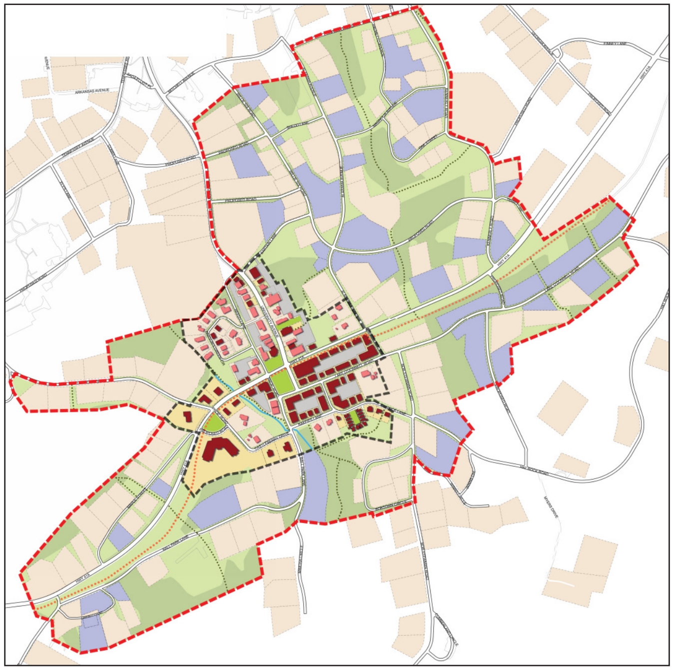


Figure 3-12: Sewanee Village Implementation Plan

Phase 1 of the Village Implementation Plan calls for the construction of additional homes and businesses roughly concentrated around the intersection of Highway 41A and University Avenue. Along with spurring the growth of the local economy, this development will also cause an impact to the area's stormwater runoff characteristics. Based on the building and parking lot footprints illustrated in the Phase 1 Village Implementation Plan, new construction in the area will lead to an impervious area increase of approximately 250 percent (from 5.3 acres to 13.4 acres). This increase is illustrated in Figure 3-13, where the left panel represents the current impervious areas and the right panel represents the proposed impervious areas after implementation of Phase 1.

The stormwater model that was developed for the study was used to compare stormwater impacts of the proposed Phase 1 Village Implementation Plan. Considering the change in land over conditions within the Phase 1 boundary, the stormwater runoff volume was estimated to increase by 0.2 to 0.4 million gallons (MG) for the modeled storms. A summary of the stormwater runoff volume increases for various statistical rainfall events is provided in Table 3-2.

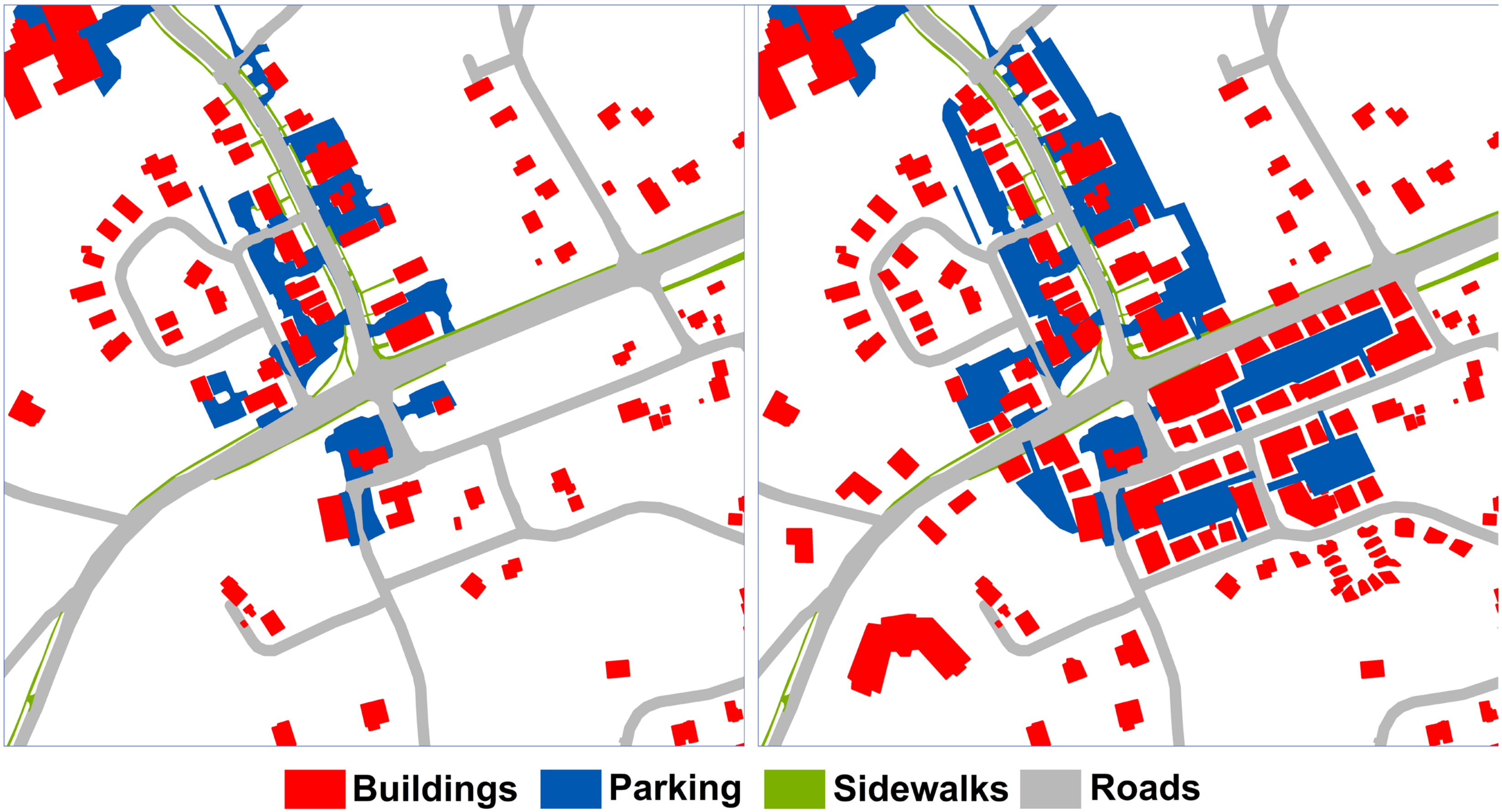


Figure 3-13: Sewanee Village Phase 1
Impervious Area Increase

Similarly, peak stormwater flows from the Phase 1 Village area were also impacted by this increase in development. Complete implementation of Phase 1 was estimated to increase the peak stormwater runoff in the Phase 1 drainage areas between 4 percent and 30 percent for the modeled storm events (Table 3-3).

Table 3-2: Runoff Volume Summary - Phase 1 Village Implementation Plan

1 – Statistical design frequency (e.g. 25-year storm has a 4% probability of occurring in a given year [1-year 25-year])

2 – Water quality event assumed to be 1.0 inch of rainfall (based on TDEC standard)

Total Runoff Volume (MG)					
Design Storm[1]	**Pre-Development**	**Existing Conditions**	**Phase 1**	**Increase from Pre-Development to Phase 1**	**Increase from Existing Conditions to Phase 1**
Water Quality[2]	0.06	0.19	0.39	0.33	0.20
1-year	3.01	3.68	3.93	0.92	0.25
2-year	4.01	4.77	5.08	1.07	0.31
5-year	5.42	6.36	6.66	1.24	0.30
10-year	6.57	7.61	7.95	1.38	0.34
25-year	8.25	9.4	9.81	1.56	0.41
Average	**4.55**	**5.34**	**5.64**	**1.08**	**0.30**

Table3-3: Runoff Peak Flow Summary - Phase 1 Village Implementation Plan

Average Peak Runoff (cfs)					
Design Storm	**Pre-Development**	**Existing Conditions**	**Phase 1**	**Increase from Pre-Development to Phase 1**	**Increase from Existing Conditions to Phase 1**
Water Quality	0.11	0.21	0.28	143.2%	29.7%
1-year	5.09	6.68	7.22	41.8%	8.1%
2-year	7.58	9.60	10.25	35.3%	6.8%
5-year	11.42	13.97	14.75	29.1%	5.5%
10-year	14.79	17.71	18.56	25.5%	4.8%
25-year	19.88	23.24	24.17	21.5%	4.0%
Average	**9.81**	**11.90**	**12.54**	**49.4%**	**9.8%**

Table 3-3 summarizes the average peak runoff increases in the Phase 1 Village drainage areas. Higher peak runoff values signify higher flow rates entering the receiving streams and increase the potential for erosion. Figure 3-14 illustrates the estimated increase in flow experienced by the receiving stream immediately downstream of the Village area during the 2-year storm event (approximate bank-full event).

The Phase 1 Village drainage areas do not represent the entire watershed for the illustrated stream; however, the development is estimated to increase peak flows within the stream by almost 10 percent for the illustrated scenario. The increase will exacerbate existing flooding and erosion problems in the area if mitigation measures are not incorporated into the planning.

Many areas within the Sewanee Village are already prone to disruptive flooding due to existing low-lying terrain and undersized pipes located at the confluence of two large watersheds. A 100-year event was modeled to illustrate areas of potential flooding as shown in Figure 3-15.

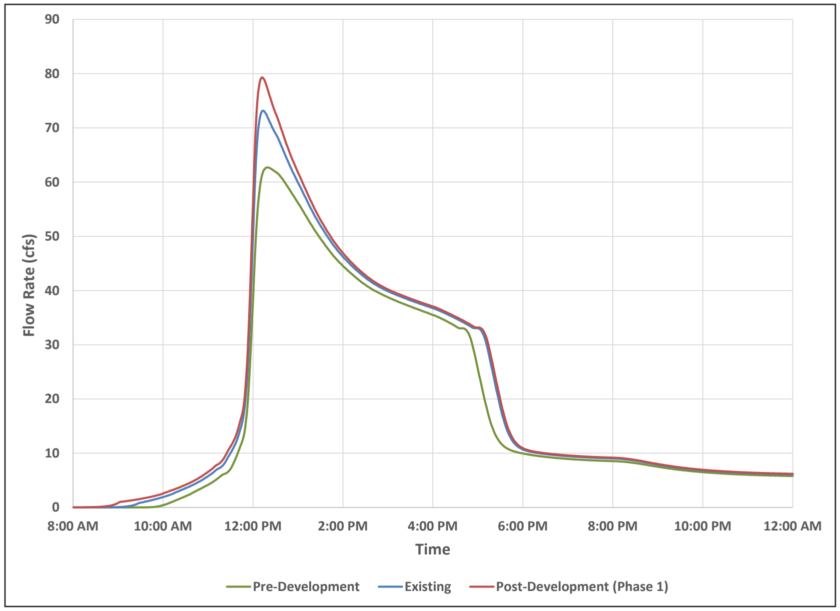


Figure 3-14: Stream Flow Downstream of Phase 1 Sewanee Village (2-year, 24-hour storm)

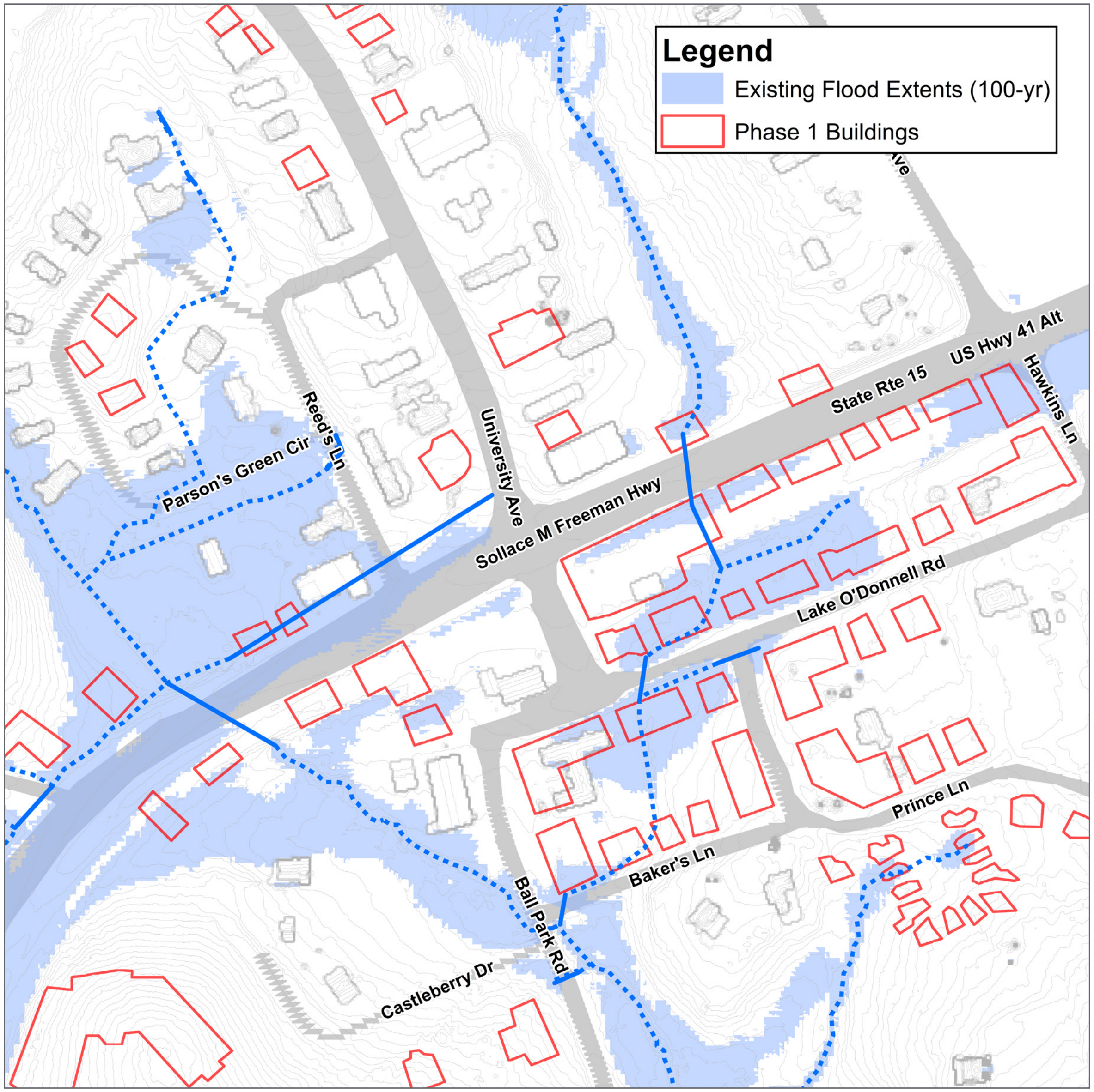


Figure 3-15: Village Area Flooding Overview (100-year, 24-hour storm)

The proposed footprint of several buildings in Phase 1 intersect with areas that show flooding from the 100-year storm. Existing inundation conditions notably fill floodplain areas south of Sartain Road, south of Parson's Green Circle, across Lake O'Donnell Road at the intersection of Prince Lane, and behind IvyWild and Cross Roads Café. The increased impervious footprint due to development in Phase 1 will likely increase flooding extents. If culverts are extended to pipe the flow through the development, the loss of storage within the existing floodplains will negatively impact downstream flood extents.

Recommendations

The Village Implementation Plan provides a valuable vision for the area architecturally and for encouraging a town-centric, connected theme for development. Natural resources, existing terrain, and drainage patterns were not prioritized when developing the original plan. As a result of collaboration between this study's project team and the Village planners, modifications are being made to the Village Implementation Plan to account for existing conditions. From a development-cost perspective the terrain and drainage conditions should be included in the planning process in addition to transportation connectivity and natural resources (e.g. wetlands, champion trees). If structures must be constructed in flood-prone areas, proper flood-proofing should be included in the design to minimize future property damage.

To protect the downstream habitat from the Phase 1 Village implementation, the additional runoff volume incurred from the increase in impervious area should be mitigated. As previously mentioned, complete implementation of Phase 1 would result in a 250 percent, or 8.1 acre, increase in impervious surface area within the Village. It is recommended that stormwater control facilities are installed to retain the TDEC water quality event (1-inch rainfall) volume resulting from the 8.1-acre impervious area increase. This corresponds to approximately 0.2 MG of runoff volume. It is optimal to retain this volume within the Phase 1 Village area before reaching the stream. If it is not feasible to install this volume of infiltration within the Village, an alternative stormwater control facility within the same Depot Branch Watershed, such as the Tennessee Williams Center parking lot improvement, could be installed to accommodate the deficiency.

4. Near-Term Project Stormwater Management Plan

As illustrated by the high-value projects in the previous section, various stormwater strategies can be implemented to store large volumes of runoff to reduce the impact of development. A properly defined strategy to control stormwater runoff from future development can align stormwater management practices with the goal of protecting the receiving streams and downstream habitat. While the previous sections presented solutions to prioritized areas of Sewanee, the goal of this section is to provide an example of how stormwater management solutions can be applied to an actual project to reduce downstream flooding and erosion within the Domain. This section details current and proposed conditions at a project site and how stormwater strategies can be used to mitigate the impacts of the project.

4.1 Project Overview

To demonstrate a near-term project stormwater management plan, the study will use the University Commons Improvement Plan as an example project. The improvement project is upstream of the Willie Six Road priority area discussed in Section 3, so stormwater management improvements to the project could positively impact a known flooding area within the Domain. The two drainage areas contributing to the University Commons project area are illustrated in Figure 4-1.

The University Commons Phase 1 plans include the construction of new building additions, a new parking lot, and various landscaping improvements within the South Basin in Figure 4-1. The proposed project is projected to increase the impervious area in the South Basin by 27 percent, or approximately 20,000 ft^2, which will increase runoff volume from the site. While the increased runoff volume may have little adverse effect on site, it will cause additional

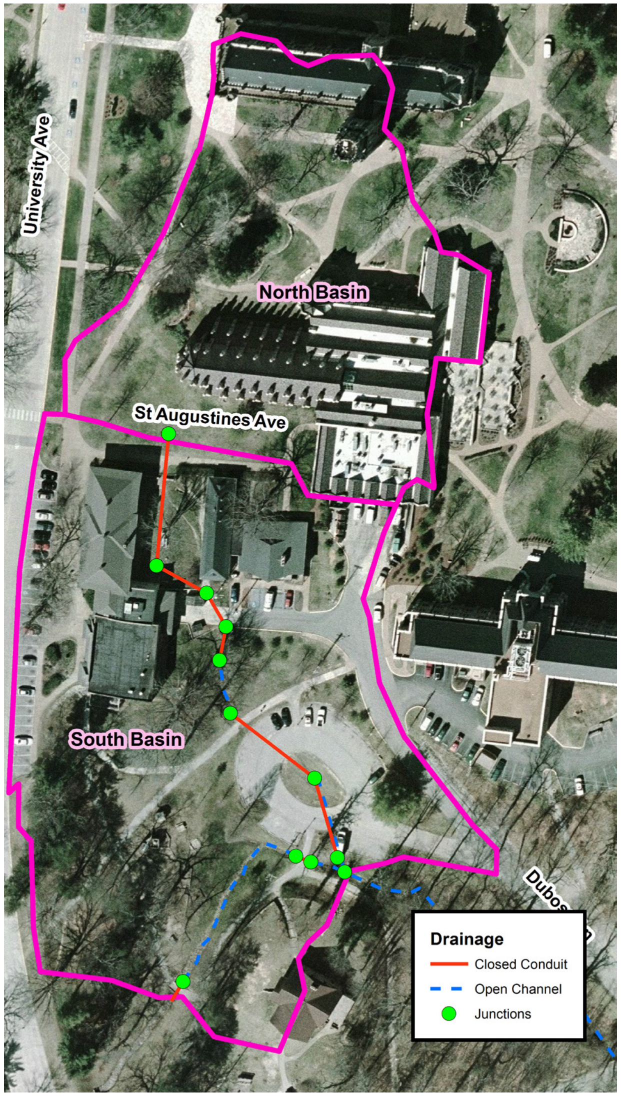


Figure 4-1: Drainage Areas Contributing to the University Commons Project

flooding and erosion downstream to a stream already known to intermittently flood properties. A summary of the estimated increase in impervious area is included in Table 4-1.

Table 4-1: University Commons Project Impervious Area Summary

	Total Drainage Basin Area (ft^2)	Existing Impervious Area (ft^2)	Future Impervious Area (ft^2)	Existing Impervious Coverage Percentage	Future Impervious Coverage Percentage	% Increase in Impervious Area
South Basin	162,460	72,537	92,162	45%	57%	27%
North Basin	98,192	50,664	50,664	52%	52%	(No Change)
Total	260,652	123,202	142,827	47%	55%	16%

In natural environments, stream banks and floodplains have adapted to drainage patterns and typically do not experience significant erosion by reaching a flow and sediment equilibrium. When land coverage experiences significant change, the infiltration rate of soil can be impacted. The prevention of infiltration over large areas of land can cause significant increases in the volumes of rainfall that reach the streams. When larger runoff volumes with higher flow rates enter these streams, they can overwhelm the natural capacity of a stream channel and cause more frequent flooding and erosion. Therefore, non-natural land coverage impacts should be mitigated with stormwater control. In order to prevent harmful stream impacts resulting from the proposed near-term project, a stormwater control facility that can reduce the runoff volume and peak runoff rate is recommended a stormwater management plan.

4.2 Stormwater Impacts of the Near-Term Project

To determine the size of the near-term project's stormwater control facility, the amount of stormwater runoff must first be calculated. One of the more effective standards for runoff control design is the Water Quality Volume (WQ_v), which is the amount of rain that should be detained to capture the first-flush of runoff and remove a majority of pollutants exiting a site. If an area has not experienced rainfall for more than 72 hours; pollutants on the ground, on roads, and in parking lots can be washed away during the first-flush rainfall event. It has been determined that these pollutants are nearly completely washed away after one inch of rainfall in this region of Tennessee and is the standard used by TDEC. Therefore, the runoff from one inch of rainfall is the proposed standard to be used for the WQ_v for the near-term project.

To convert one inch of rainfall into a volume that can be managed in a stormwater control facility, a standard formula for calculating WQ_v has been provided by the American Society of Civil Engineers:

$$WQ_v = P \times R_v \times A \text{ where}$$

$$P = \text{Precipitation, in feet} = \tfrac{1}{12} \text{ x Precipitation (inches)}$$

$$R_v = \text{Runoff Coefficient} = 0.05+0.009\ (I)$$

$$I = \text{Impervious Coverage Percentage } (0 \geq I \geq 100)$$

$$A = \text{Total Runoff Area, in square feet}$$

This formula results in a runoff volume in cubic feet that should be controlled in order maintain water quality. As previously mentioned, the value for precipitation is one inch of rainfall. The impervious coverage percentage and total runoff area are found in Table 4.1. For example, the WQ_v for the North Basin would be calculated as follows:

$$WQ_v = P \times R_v \times A \text{ where}$$

$$WQ_v = (1/12\ ft) \times (0.05 + 0.009\ [52 \text{ percent impervious}]) \times (98{,}192\ ft^2)$$

$$WQ_v = 4{,}238\ ft^3$$

Stormwater control facilities can provide mitigation for runoff that is more than just pollutant reduction. While the WQ_v represents the pollutant-heavy first flush, it also represents the most frequently occurring rainfall depths and 80 to 90 percent of storm events within an average year will be controlled by a facility sized for the WQ_v.

Stormwater control facilities can also be sized for larger storm events, such as the 1-year or 25-year design storms. The larger the storm, the greater the impact on downstream erosion and flooding control. However, the resulting facility will need to be larger and more expensive for the less-frequent rainfall events. These larger storms lead to increased runoff volumes that are complicated to calculate by hand. Therefore, runoff volumes and peak flows from larger storms are typically estimated using stormwater management models (SWMM) or less accurate simplified equations (e.g. rational method). A more-common method within SWMM assigns an NRCS curve number to calculate infiltration. Curve numbers are unique to each subbasin and are composite values from the land cover and soil type. Curve numbers range from 25 to 100 with a subbasin's ability to infiltrate decreasing as the curve number increases. For the two basins in the near-term project area, the curve numbers increase with Phase 1 development. The curve numbers for these subbasins are shown in Table 4-2. Note that the "Pre-Development" curve number represents the curve numbers based on forested land coverage with the Domain's most-common soil type (hydrologic soil group C).

	Pre-Development	Existing	Post-Development
South Basin Curve Number	70	84.7	87.6
North Basin Curve Number	70	86.4	86.4

Table 4-2: Near-term Project Curve Number Summary

Runoff Volumes (ft^3)

North Basin	Pre-Dev	Current	Post-Dev
1-inch	409	4,238	4,238
1-year	12,030	18,714	18,714
25-year	32,081	42,775	42,775
South Basin	**Pre-Dev**	**Current**	**Post-Dev**
1-inch	677	6,160	7,622
1-year	18,714	28,071	30,745
25-year	52,132	68,173	72,183
Total	**Pre-Dev**	**Current**	**Post-Dev**
1-inch	1,086	10,398	11,860
1-year	30,745	46,785	49,459
25-year	84,213	110,948	114,958

Table 4-3: Near-term Project Runoff Volume Summary

These curve numbers were used in SWMM to calculate runoff volumes for the 1-year storm and the 25-year storm within the two subbasins. For Sewanee, the 1-year, 24-hour design storm is estimated to have a depth of 3.38 inches of rainfall and the 25-year, 24-hour storm produces 6.58 inches of rainfall. Runoff volumes for the hand-calculated WQ_v storm and the SWMM-estimated 1-year and 25-year storms are summarized in Table 4-3.

When planning a stormwater control facility, several factors may be considered to determine what level of runoff volume to treat. If cost or space is limited, focusing on smaller volumes may be the best option. If the impervious area contributing to increased runoff is limited, a small control facility may be sufficient to mitigate the increased runoff. However, controlling larger runoff volumes, especially at an upstream area like that found in the near-term project, can significantly benefit downstream conditions. If runoff is controlled in the headwaters of a watershed, the entirety of the stream will experience a lower risk of flooding and erosion. For the near-term project, various levels of runoff control were explored.

4.3 Stormwater Management Alternatives

The recommended location for a stormwater control facility with the near-term project would be under the proposed parking lot associated with the University Commons.

The parking lot has a large footprint and is a lower elevation between the project drainage areas and the receiving drainage network. The available footprint under the parking lot is approximately 17,500 ft^2. By looking at the elevations of the proposed parking lot, there is potentially three feet of space underneath the lot that can be used for storage and potentially more with excavation. A figure of the maximum potential footprint is shown in Figure 4-2.

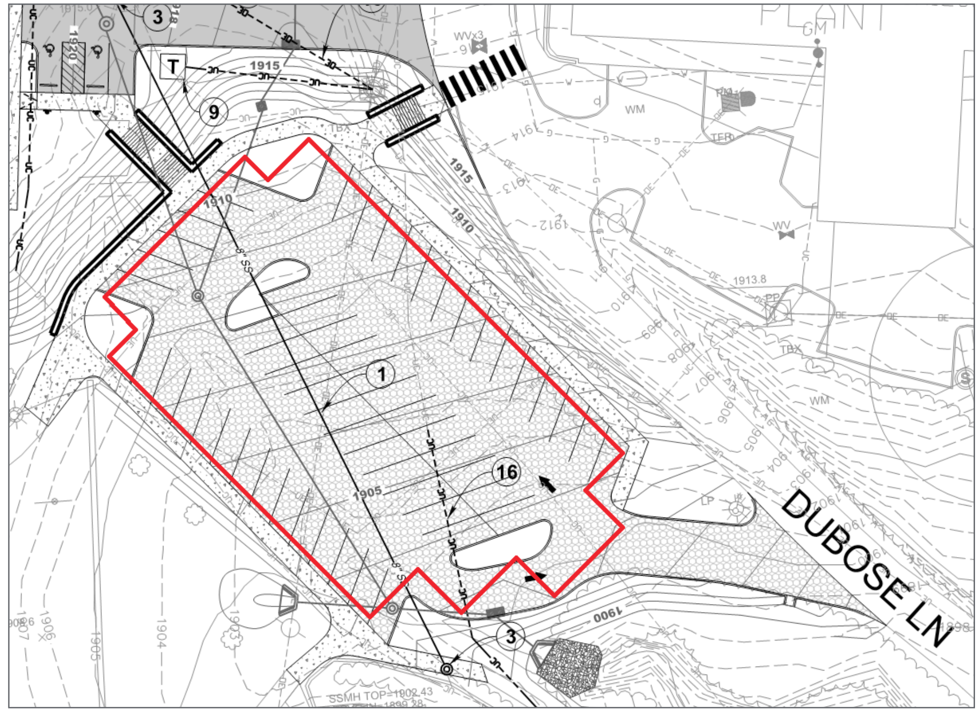


Figure 4-2: Potential footprint of Proposed Stormwater Control Facility

During a project workshop, it was noted that there are known conflicts from both a sanitary sewer main and telecommunications associated with the adjacent server hub. These utility conflicts would need to be included in the project coordination and design. Also, for infiltration the subsurface soil conditions would need to be investigated for the ability to infiltrate the volume of retained stormwater; otherwise, temporary detention for reducing downstream peak flows would be the only option. Three stormwater management scenarios were explored for the near-term project with increasing levels of performance and resulting facility size.

Scenario A

For Scenario A, the stormwater control facility was sized to hold the first inch of runoff from the projected 27 percent increase in impervious area only within the South Basin. This retention volume is calculated to be approximately 1,500 ft^3 and can be contained underneath the proposed parking lot in a relatively small storage footprint. As the maximum depth of a control facility is three feet, there are many potential solutions to Scenario A. An easy solution is a series of large diameter perforated pipes that would receive runoff from the parking lot and upstream stormwater drainage. Using three, 50-foot long half pipes of three-foot diameter would be sufficient to hold the Scenario A runoff. This solution would have a footprint of about 1,000 ft^2 leaving much of the available subsurface area unused. This alternative could easily avoid the identified utility conflicts.

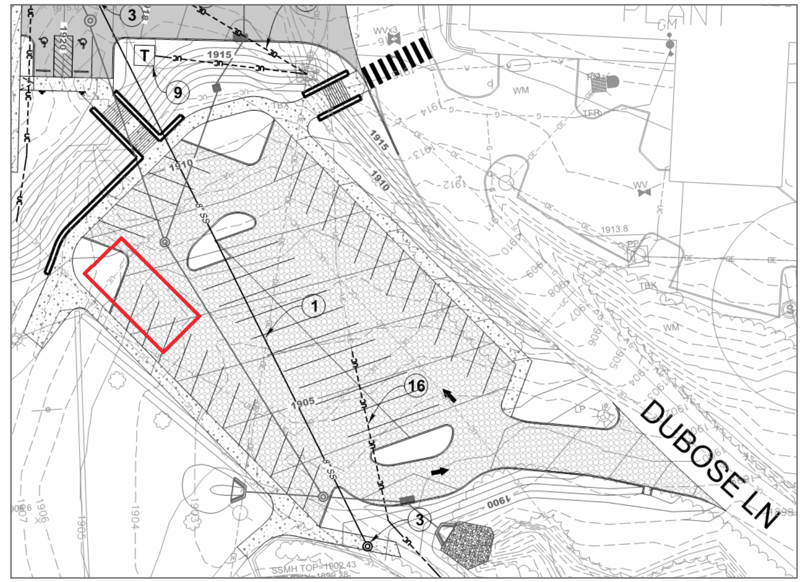


Fig 4-2A: Scenario A footprint

Scenario B

While Scenario A focused on the WQ_v runoff from new impervious areas, Scenario B was proposed to hold the first inch of runoff from all impervious surfaces within the South Basin compared to pre-development conditions. This retention volume is calculated to be approximately 7,000 ft^3 and is a more expansive version of the solution suggested in Scenario A. As this increased control facility footprint would be about 4,500 ft^2, Scenario B provides an effective solution without using the entire available footprint.

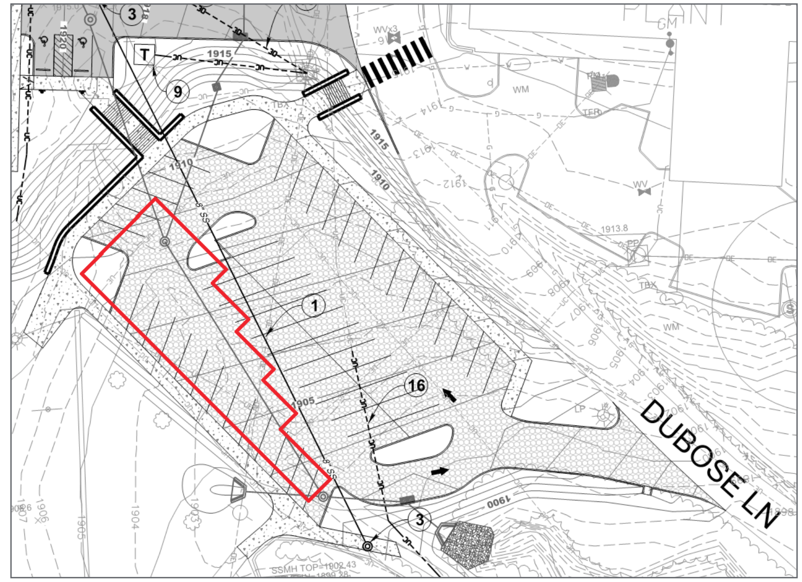


Fig 4-2B: Scenario B footprint

Scenario C

To further limit the impact of runoff on flooding and erosion downstream, the proposed stormwater facility could be designed to effectively return the runoff from the entire drainage area (North and South Basins) to pre-development levels. This can be achieved by controlling all runoff volume above the pre-development levels. As shown in Scenarios A and B, there is plenty of surface area to allow for a large control facility. By using the previously mentioned maximum footprint of 17,500 ft^3, the maximum storage volume was calculated to be about 31,000 ft^3. This volume was determined using a similar method to Scenarios A and B: a facility of large diameter pipes. Scenario C would provide capacity for a much larger storm and could control about 31,000 ft^3 of runoff through 15, 130-foot long three-foot diameter half pipes. Shown below in Table 4-4, Scenario C would adequately address the increase in runoff from the 25-year storm compared to pre-development conditions.

Design Storm	Total Increase in Pre-Development Runoff (ft^3)
1-inch	10,774
1-year	18,714
25-year	30,745
10-year	5.62
25-year	6.58

Table 4-4: Summary of Increase in Runoff from Pre-Development Conditions (North Basin + South Basin)

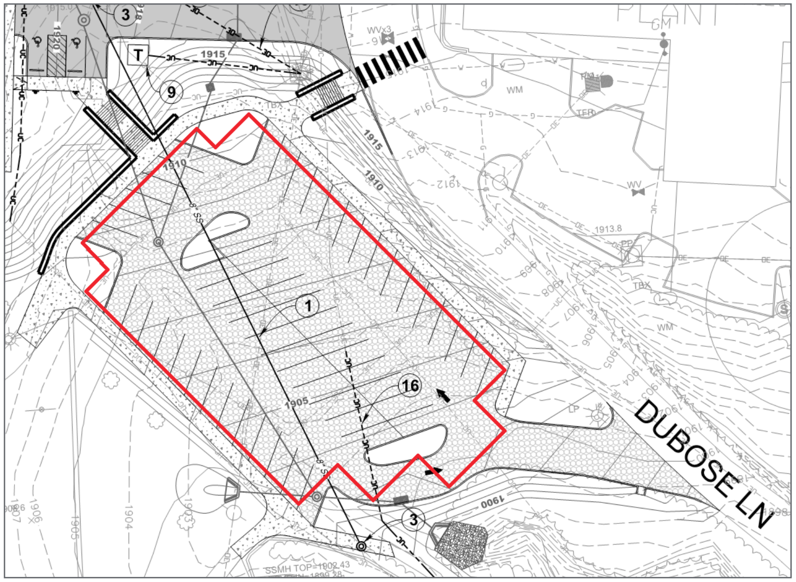


Fig 4-2C: Scenario C footprint

4.4 Conclusion

The specific sub-surface site conditions will limit the available footprint of the proposed stormwater control facility, but there is the potential to minimize the impact of development in this portion of the watershed. Due the project location in the headwaters of a watershed with known downstream flooding issues, it is recommended to investigate installing some stormwater management components as part of this project. The proposed parking lot of the University Commons Project could be a practical location for installing a stormwater control facility for the watershed. As illustrated in Section 3 of the SMMP, this watershed is a top-priority area for future stormwater improvements within the Domain.

5. Stormwater Management Guidelines for Future Projects

Consistent with the identified priorities for the Stormwater Management Master Plan, future development within the Domain should follow practical stormwater guidelines to ensure preservation of the downstream natural habitat. As the single property owner for the Domain, the University can practice a more holistic approach to development and stormwater management than most communities. Because of this flexibility, planning around the existing terrain and natural resources provides cost-efficiencies for stormwater management and site construction.

The recommended Stormwater Management Guidelines for the University are a balance between the strong commitment to protect the area's natural habitat and the desire to increase its lease inventory and encourage a more cohesive town-center within the Sewanee Village. Several factors contributed to the development of the recommended stormwater management guidelines for the University, including:

- Advanced stormwater practices and current ordinances practiced in other Tennessee municipalities
- Historical stormwater practices and guidelines in smaller communities and similarly-sized institutions
- Familiarity with stormwater design standards within the regional engineering community
- Stringent enough guidelines to protect the downstream resources
- Balanced guidelines to not discourage development due to additional project costs, yet fit Sewanee's culture

Considering the listed factors and common practices within the Domain, long-term guideline recommendations were developed for the University. By using these guidelines in future development and redevelopment projects, the impact of flooding and erosion can be minimized within the Domain. The recommended stormwater management guidelines include a minimum stormwater management **Performance Criteria** for future development design, a Domain-specific **Stormwater Strategy Toolbox**, and **Stormwater Management Guidelines** that facilitate the protection of the 90+ percent of natural habitat within the Domain.

5.1 Performance Criteria

To create a comprehensive and industry-aligned minimum stormwater management performance criteria, the criteria for other municipalities in Tennessee were reviewed. The municipalities referenced were Chattanooga, Nashville, Franklin, and Hendersonville. The municipalities differ from Sewanee by all being Municipal Separate Storm Sewer System (MS4) permittees with more stringent requirements for their stormwater regulations than Sewanee, Tennessee (or Franklin County). However, they are a good example of advanced stormwater regulations to consider while developing applicable stormwater management guidelines. The criteria for the different municipalities shared similarities and are compared in Table 5-1.

Table 5-1: Tennessee Municipalities Stormwater Performance Criteria Comparison

	Water Quality	Channel Protection	Overbank Flood Protection
Chattanooga	Retain 100% of runoff from 1-inch rainfall event. If runoff reduction is not met, remove 80% of TSS from 1-year event minus the runoff reduction volume.	See Overbank Flood Protection	Peak runoff rates must be no higher than those from pre-development peak runoff for 1-YR through 25-YR
Nashville	Retain 100% of runoff from 1-inch rainfall event. If runoff reduction is not met, remove 80% of TSS from the first 1.1-inches of rainfall from a site.	See Overbank Flood Protection	No construction, whether by private or public action, shall be performed in a manner that will have a negative impact on stormwater quantity or quality in its vicinity or in other areas whether by flow restrictions, increased runoff, or by diminished channel or overbank storage capacity.
Franklin	Retain 100% of runoff from 1-inch rainfall event. If runoff reduction is not met, remove 80% of TSS from 1-year event minus the runoff reduction volume.	See Overbank Flood Protection	Peak runoff rates must be no higher than those from pre-development peak runoff for 1-YR through 25-YR
Hendersonville	Retain 100% of runoff from 1-inch rainfall event. If runoff reduction is not met, remove 80% of TSS.	See Overbank Flood Protection	Must be capable of conveying the runoff from a 25-YR storm; Peak runoff rates must be no higher than those from pre-development peak runoff for 25-YR; collector roads must not be inundated by 100-YR storm

Recommended Performance Criteria

Considering the goals of the SMMP, a practical performance standard that is understood by the regional design community, and the right balance between development and stormwater management, the following performance criteria is recommended for future development within the Domain:

- Retain 100% of runoff volume from 1-inch of rainfall based on a project's proposed impervious surface area. The volume should be estimated using the following industry-standard calculation (example application provided in Section 4):

$$WQ_v = P \times R_v \times A \text{ where}$$

$$P = \text{Precipitation, in feet} = \tfrac{1}{12} \times \text{Precipitation (inches)}$$

$$R_v = \text{Runoff Coefficient} = 0.05+0.009\ (I)$$

$$I = \text{Impervious Coverage Percentage } (0 \geq I \geq 100)$$

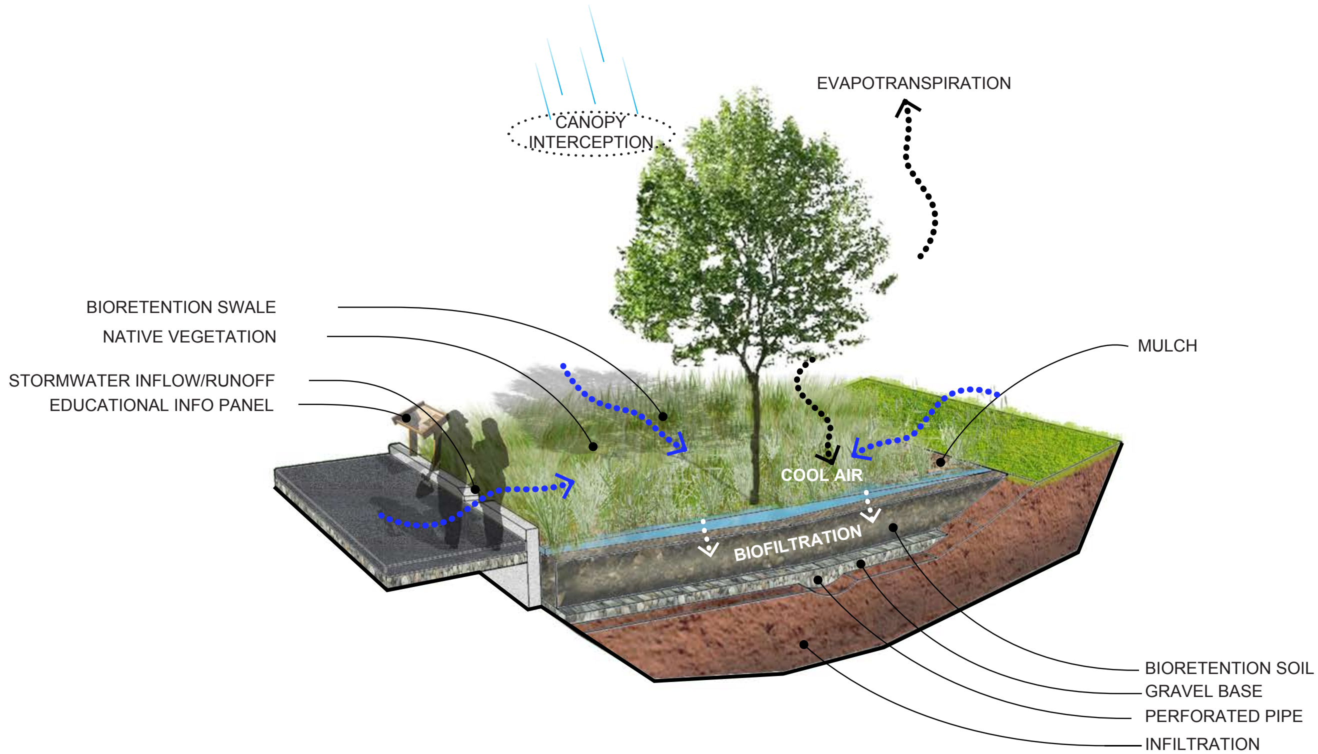
$$A = \text{Total Runoff Area, in square feet}$$

- If the proposed project site limits the ability to retain 100% of the 1-inch runoff volume due to land availability or soil conditions, account for the equivalent storage volume on a more-feasible site within the same watershed. This can be done by either retrofitting an existing impervious area or incorporated the additional volume into another near-term project's stormwater control facility design.

5.2 Stormwater Strategy Toolbox

Stormwater management strategies (also referred to as Best Management Practices [BMPs]) were reviewed for applicability to the local conditions throughout the Domain. Five specific strategies are recommended for stormwater management to mitigate development-related increases in runoff volume and peak flows for the University: bioretention areas, vegetated swales, downspout disconnection, underground detention chambers, and pervious pavement. Where soil conditions do not allow for proper stormwater infiltration, traditional detention with slow release to the stormwater system is recommended. Each stormwater strategy is summarized in the next few pages in terms of general application, benefits, and high-value project areas where the strategy applies. A good resource for more technical details about the strategies is Nashville's Best Management Practices Manual[1].

1 Nashville Best Management Practice (BMP) Manual: https://www.nashville.gov/Water-Services/Developers/Stormwater-Review/Stormwater-Management-Manual/Best-Management-Practices.aspx



Bioretention Areas

Bioretention areas allow for shallow detention and lower peak runoff flow rates, runoff volumes, and filters runoff through an engineered soil and stone media. This stormwater strategy would be suitable for Sewanee because its size can vary, it can be visually appealing with landscaping, and it is one of the more cost-effective strategies to apply when you have available land adjacent to impervious areas. When soil conditions allow, bioretention can infiltrate retained stormwater volumes. Otherwise, underdrains will be required and the facility will provide a detention and filtration function.

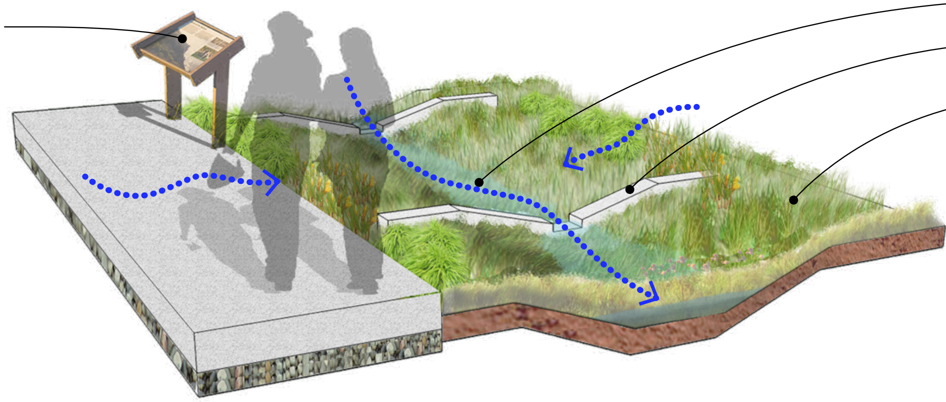
This strategy can provide stormwater runoff mitigation benefits to each of the four high-value project areas identified in Section 3. A list of benefits of bioretention basins is shown below:

Bioretention Area Benefits:

- Available land
- Cost effective
- Improves water quality
- Provides volume and peak flow reduction
- Adds to landscape
- Visual stormwater management application

Applicable High-Value Project Areas:

- Fowler Center Roof and Parking Lot
- Spencer Hall Quad
- Tennessee Williams Center Parking Lot
- Willie Six Road



Vegetated Swale

Vegetated Swales convey and treat the stormwater via infiltration and vegetation along the way. Peak runoff rates can be reduced through vegetated swales by conveying flows slower than a traditional pipe; check dams can be installed to further temporarily hold and filter flows along the route. This strategy would be suitable for Sewanee because it allows peak runoff rate to be reduced in areas where more surface area-intensive solutions are not feasible. Vegetated swales can be installed to connect a series of stormwater strategies, such as multiple disconnected downspouts could converge to a vegetated swale that routes stormwater to a bioretention area for multi-faceted methods for slowing down and treating stormwater from impervious surfaces before entering the stream network.

This strategy can provide stormwater runoff mitigation benefits to each of the four priority areas in Sewanee. A list of benefits of vegetated swales is shown below:

Vegetated Swale Benefits:

- Conveys stormwater
- Slows velocity
- Increases infiltration time
- Provides additional filtration and flow control
- Cost-effective solution
- Visual stormwater management application

Applicable Priority Areas:

- Fowler Center
- Spencer Hall
- Tennessee Williams Center
- Willie Six Road

Downspout Disconnect

Downspout Disconnection is a non-structural BMP that calls for the disconnection of downspouts to the storm sewer system. By releasing roof runoff onto lawns or over gravel, the peak runoff rate and runoff volume from roofs into the drainage system are reduced. This BMP would be suitable for Sewanee because many downspouts are currently routed through pipes directly connected to the stormwater system that could be disconnected for a cost-effective improvement.

This BMP can provide stormwater runoff mitigation benefits for multiple buildings within the project watersheds. A list of benefits of downspout disconnects is shown below:

Downspout Disconnection Benefits:

- Distributes runoff from roofs
- Lowers peak runoff rate
- Encourages infiltration and filtering of stormwater
- Cost-effective solution

Applicable Priority Areas:

- Fowler Center
- Spencer Hall

Underground Detention Chamber

An underground detention chamber works by routing runoff through a storage facility rather than immediately releasing it to a stream. This reduces the peak flow rates and volume (if infiltration can occur) of the stormwater runoff. This stormwater strategy would be suitable for Sewanee because these underground detention chambers can fit underneath parking spaces without disturbing additional surface area. Bioretention or traditional detention are more cost-effective stormwater management strategies when available, but underground detention is an alternative strategy when there is minimal available land.

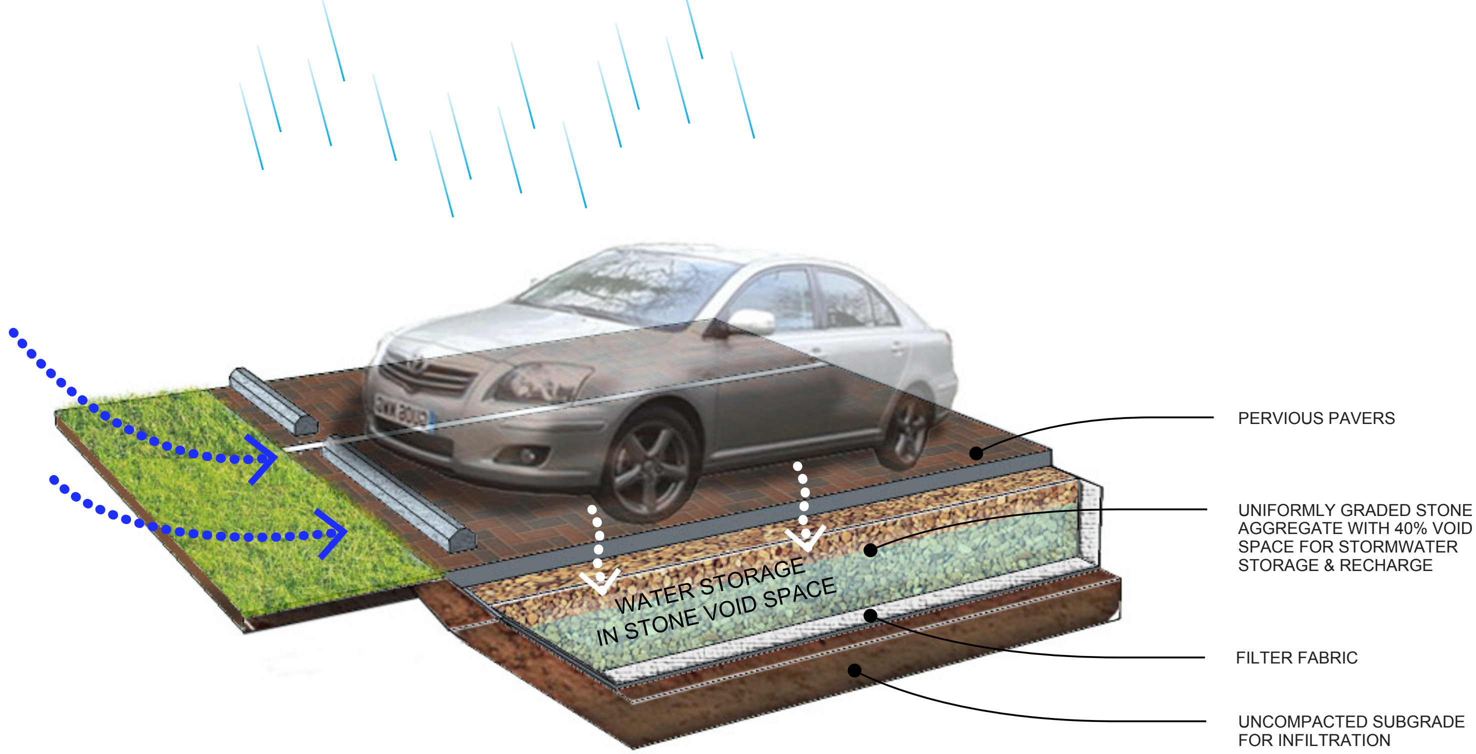
This strategy can provide stormwater runoff mitigation benefits for the Fowler Center and the University Commons projects. A list of benefits of underground detention is shown below:

Underground Detention Chamber Benefits:

- Allows surface parking or travel function to continue on the surface
- Reduces peak runoff
- Can provide water quality improvement and volume reduction if soil conditions allow infiltration

Applicable Priority Areas:

- Fowler Center Roof and Parking Lot
- University Commons Project (Near-term Project)



Pervious Pavement

Pervious pavement allows stormwater to infiltrate into subsurface storage or infiltrate rather than travel over the traditional asphalt or concrete pavement. This reduces the impact of impervious surfaces and reduces runoff volume and peak runoff rates. This strategy would be suitable for Sewanee because it does not require additional surface area to construct. Pervious pavement can be combined with underground detention chambers. Similar to underground detention, bioretention or traditional detention are more cost-effective stormwater management strategies when available.

This BMP can provide stormwater runoff mitigation benefits in limited applications for two of the four high-value projects. A list of benefits of pervious pavement is shown below:

Pervious Pavement Benefits:

- Requires no additional surface area
- Can be designed attractively
- Visual stormwater management application

Applicable Priority Areas:

- Fowler Center Roof and Parking Lot
- Tennessee Williams Center Parking Lot

5.3 Stormwater Management Guidelines

There are many solutions to managing stormwater that do not involve the implementation of structural stormwater facilities. One of the more effective methods of managing stormwater is to leave surfaces and soil in their natural condition, surrounding development to maintain the area's ability to infiltrate and filter runoff. Considering local conditions and the goals of the SMMP, best practices from industry standards and other Southeastern communities were compiled to develop a list of recommended Stormwater Management Guidelines for Future Development within the Domain. The Recommended Stormwater Management Guidelines include:

- Maintain undisturbed, vegetated buffer of 30-ft from top of bank on all streams within the Domain to maintain their ability to infiltrate and to maintain stabilization of stream banks. This is consistent with TDEC's minimum state-wide standard.
- Plan to redevelop already disturbed areas that are underutilized, rather than developing undisturbed land.
- Construct drives and walkways with pavers, gravel, or other pervious media to limit reduction of the soils' infiltration rate.
- Direct roof downspouts to vegetation or natural areas draining away from structures rather than connecting to the stormwater system or to impervious surfaces.
- Limit development on slopes where existing vegetation and soils limit erosion.
- Preserve natural vegetation and trees, including critical root zone on project sites where possible.
- Take advantage of existing terrain on site so that the natural drainage patterns of stormwater are kept as intact where possible.
- Limit areas of access for heavy machinery during construction so that soil is not compacted.
- Avoid channeling runoff to impervious ditches or down driveways so that runoff is given time to infiltrate.
- Maintain sheet flow of runoff from impervious surfaces so that velocity remains low and surface area is maximized for infiltration.
- Build on soils that have low infiltration rates where option is available.

Mosquito Frequently Asked Questions (FAQs)

Will these stormwater strategies create an issue with mosquitos? When properly maintained, stormwater control facilities do not sustain mosquito populations. To breed successfully, mosquitos need shallow (less than 3 feet) water that has been standing for at least seven days. All strategies recommended in this SMMP should be designed to retain stormwater for a maximum of three days.

How will we prevent mosquitos over time? If litter and debris are regularly removed, erosion is routinely repaired, and re-vegetation occurs when necessary, these stormwater strategies will not support mosquito populations.

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