GRAND VALLEY STATE UNIVERSITY

STORM WATER MANAGEMENT PLAN

ALLENDALE CAMPUS

PREPARED FOR:
GRAND VALLEY STATE UNIVERSITY
ALLENDALE, MICHIGAN

JULY 2007
PROJECT NO. G06834
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LIST OF ABBREVIATIONS/ACRONYMS

BMP  best management practice
CMI  Clean Michigan Initiative
EEG  Environmental Education Grants
EPA  U.S. Environmental Protection Agency
FTC&H  Fishbeck, Thompson, Carr & Huber, Inc.
GIS  Geographic Information Systems
GVSU  Grand Valley State University
MDEQ  Michigan Department of Environmental Quality
MSIRF  Movement Sciences and Indoor Recreation Facility
MUCC  Michigan United Conservation Clubs
NOC  Notice of Coverage
NPDES  National Pollutant Discharge Elimination System
NPS  Nonpoint Source
NRCS  Natural Resource Conservation Service
PAH  polycyclic aromatic hydrocarbon
SESC  Soil Erosion and Sedimentation Control
SWAG  Storm Water Advisory Group
SWMM  Storm Water Management Model
SWMP  Storm Water Management Plan
USFWS  U.S. Fish and Wildlife Service
PURPOSE

This study was conducted to address the concerns of GVSU with regards to storm water and soil erosion control on campus. A Storm Water Advisory Group (SWAG) representing the GVSU community was assembled to aid in the discussion and brainstorming of solutions to the storm water and soil erosion problems. In addition to the SWAG meetings, a webpage was created on the GVSU blackboard website to help communication with faculty by posting information for their review.

Data used for the development of this report was compiled through many sources, including: site visits, previous Storm Water Management Plans, flow monitoring and rainfall data compiled by GVSU faculty and Geographic Information Systems (GIS). This data was scrutinized to ensure its accuracy before using in the storm water management plan.

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INTRODUCTION

The Allendale Campus of Grand Valley State University (GVSU) was founded in 1960 and has developed to include 75 buildings, approximately 4.5 miles of roads, over 12,000 parking spaces, an extensive underground infrastructure, a golf course, and numerous athletic fields. Prior to the 1990s, the philosophy surrounding storm water management was flood prevention; storm water systems were designed to route water away from buildings and structures. These storm sewer systems routed water to the ravine edges and allowed the runoff to drain down to the streams leading to the Grand River. As the campus developed, the amount of runoff to the ravines increased and lead to severe erosion in the ravines.

A 1998 Storm Water Management Plan (SWMP), and a 2002 update to the SWMP, established strategies for storm water disposal and flood control, while preventing erosion and improving storm water quality. GVSU has implemented several alternatives, including construction of new storm sewers, open channel conveyance systems, streambank stabilization measures, energy dissipation and grade control structures, detention basins, and reestablishment of slope failures.

Current storm water management initiatives are focused on restoring the campus storm water runoff to predevelopment conditions. The efforts include developing alternatives for a sustainable approach to long-term storm water runoff that will restore historic drainage patterns, educate existing and future students on the importance of storm water management, and create better ecosystems within the campus ravines and receiving waters. These initiatives will be incorporated into the University's overall goals for sustainability on campus.

This report includes background information on the impacts of storm water runoff at the Allendale Campus, analysis of the campus storm water system and hydraulic modeling, evaluation of potential storm water improvements, and a recommended SWMP.

STORM WATER IMPACTS

This section addresses both observed and potential storm water impacts associated with the 40-year history of the GVSU Allendale Campus and proposed changes to the Campus Master Plan. Figure 1 illustrates the existing storm water impact areas on campus that will be discussed in this report.

BACKGROUND

The storm water drainage patterns on campus can be divided into two major catchments, East Campus and West Campus, with Campus Drive the approximate drainage divide. East Campus drains into a number of ravines that outlet directly to the Grand River. West Campus drains west and north across
Lake Michigan Drive (M-45) to Ottawa Creek, a tributary of the Grand River. Surficial soils are predominantly clay and are classified as Hydrologic Soil Group C by the Natural Resource Conservation Service (NRCS) as shown in Figure 2.

A map of presettlement vegetation and hydric soils, Figure 3, shows the campus was once primarily a forest of beech and sugar maple trees. Over time, this area was deforested and converted to agricultural usage. Since the addition of GVSU, the campus has changed from an agricultural to more of an urbanized area, with pervious cover being converted to impervious cover. These changes in land usage associated with human involvement have had a significant impact on the hydrologic characteristics of the watershed.

THE RELATIONSHIP BETWEEN STORM WATER RUNOFF AND THE ENVIRONMENT

Urban development can have a profound influence on water resources in terms of water quality, groundwater recharge, stream stability and floodplain protection. Degradation of water resources is typically brought about by hydrologic changes in the watershed, fluctuations in temperature, and increases in pollutant loading and transport associated with development. These effects are well documented by Schueler, et al., and summarized here from the Maryland Storm Water Design Manual.

HYDROLOGY

The hydrology of a site changes during the initial clearing and grading that occurs during construction. In many cases, trees, meadow grasses, and even agricultural crops that had intercepted and absorbed rainfall are removed, and natural depressions that had temporarily ponded water are graded to a uniform slope. In addition, roof tops, roads, parking lots, driveways, and other impervious surfaces no longer allow rainfall to soak into the ground. Consequently, most rainfall is converted directly to storm water runoff. The volume of storm water runoff increases sharply with impervious cover. For example, a 1-acre parking lot can produce 16 times more storm water runoff than a 1-acre meadow each year (Schueler, 1994). The increase in storm water runoff can be too much for the existing natural drainage system to handle. As a result, the natural drainage system is often “improved” to rapidly collect runoff and quickly convey it away (using curb and gutter, enclosed storm sewers, and lined channels). The storm water runoff is subsequently discharged to downstream waters such as streams, rivers, and lakes (Schueler, 1987).

On the GVSU campus, increased imperviousness and the related storm sewer system appear to be the major contributor to the degradation of downstream ravines, as further described in the “stream protection” subsection. Increased runoff has also contributed to localized flooding, when downstream infrastructure is not sized adequately or maintained to safely convey the design discharge.
CHANGES IN HYDROLOGY

The volume and rate of storm water runoff from the campus has increased due to the increased imperviousness of the GVSU landscape, the loss of a wooded canopy, and a change in the drainage patterns through the construction of storm sewers. The campus storm sewer system has redirected and concentrated runoff, which has had a significant impact on the receiving natural drainage system. Generation of storm water runoff from pervious areas has also increased, since the campus was developed through the loss of depression storage, and interception by the conversion of woods to agricultural field and agricultural field to graded lawn. Figures 4 and 5 are aerial photos of the GVSU campus from 1955 and 2004, which show the significant increase in impervious surfaces from the agricultural usage to today.

LOCALIZED FLOODING

Due to inadequate capacity of onsite conveyance systems, localized flooding is presently a problem in several locations. Three building locations that experience chronic flooding are Copeland Living Center, Robinson Living Center, and the Children’s Center. The Meadows Golf Course has also encountered ongoing drainage problems as a result of the continued development of the campus. The extent and frequency of flooding in these areas is discussed below.

Copeland and Robinson Living Centers
The low areas west of the entrance to the Copeland and Robinson Living Centers, shown in Appendix 1, Photograph 1, flood during minor storm events. Large storm events have flooded the buildings, resulting in significant cleanup and maintenance costs. The 2008 Academic Building construction project includes the installation of a backflow preventer within the existing storm sewer system, as well as additional site improvements designed to direct runoff away from these building entrances.

Children’s Center
The playground south of the Children’s Center near West Campus Drive also experiences flooding. An existing detention basin, shown in Appendix 1, Photograph 2, is undersized and inadequate for the contributing drainage area, which includes most of Parking Lot H. The outlet from the detention basin is a 15-inch pipe, which does little to restrict flow. Flooding of the Children’s Center becomes a problem when runoff exceeds the capacity of the 15-inch outlet pipe and causes detention basin water levels to back up into the playground area.
Meadows Golf Course

The Meadows Golf Course, located along 48th Avenue and West Campus Drive, regularly experiences drainage problems. The southern portion of the golf course, along West Campus Drive, has seen the largest increase in storm water runoff due to the development of the southwest part of the campus and inadequate detention facilities upstream. As a result of the increased runoff, the golf course has installed a system of underdrains and small ditches, to help convey the water into ponds and eventually north into a ravine that crosses M-45 and outlets to Ottawa Creek. However, the increased runoff regularly exceeds the capacity of the existing drainage system.

Jacobs Drain

Storm water runoff from the majority of the golf course drains west into Jacobs Drain located along 48th Avenue and flows north across M-45 and outlets to Ottawa Creek. Jacobs Drain is an established Ottawa County drain. Drain reconstruction was necessary in 2005 to increase capacity, which alleviated flooding associated with an inadequate drain outlet. Appendix 1, Photographs 3 and 4, show Jacobs Drain before and after reconstruction.

WATER QUALITY

Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown from adjacent areas. Additionally, in the winter time, large quantities of salt used to deice the roadways are deposited onto impervious surfaces. During storm events, these pollutants quickly wash off and are rapidly delivered to downstream waters. Some common pollutants found in urban storm water runoff include nutrients, suspended solids, organic carbon, bacteria, hydrocarbons, trace metals, pesticides, chlorides, thermal impacts, and trash and debris (Schueler, 1987).

The storm sewer collection systems provide little or no treatment of storm water runoff before it is conveyed offsite. Wet detention ponds provide a high level of treatment for all but the most soluble pollutants. Sensitive ecosystems that may react dramatically to increases in urban pollutant loads (i.e., algal blooms in lakes from increased nutrients) are not directly impacted by storm water runoff from campus since most of the drainage is routed directly to the Grand River. However, improvement to runoff water quality is important to mitigate the impact to any receiving water course. Temperature fluctuations commonly associated with increased pollutant loading may be negatively affecting the downstream ravine ecosystems. Currently, GVSU faculty are collecting data in the ravine systems which should help reveal the impact water quality and temperature fluctuations have had on the ecosystem. This study will also help create a base line with which to compare future assessments against to help evaluate the effectiveness of storm water management.
GROUNDWATER

A net decrease in groundwater recharge rates can be expected in urban watersheds, because development creates impervious surfaces that prevent natural recharge. Thus, during prolonged periods of dry weather, stream flow may sharply diminish. Urban land uses and activities can also degrade groundwater quality if storm water runoff is directed into the soil without adequate treatment. Certain land uses and activities are known to produce higher loads of metals and toxic chemicals, and are designated as storm water hotspots. Soluble pollutants, such as chloride, nitrate, copper, dissolved solids, and some polycyclic aromatic hydrocarbons (PAHs) can migrate into groundwater and potentially contaminate wells (Schueler, 1995).

The heavy soils predominant across campus make it unlikely that this was a significant groundwater recharge area. However, groundwater seeps are observed at exposed banks of the downstream ravines that receive storm water runoff from campus. The soils also lower the risk of groundwater contamination from campus activities that might generate more soluble pollutants, when evaluating storm water strategies that provide for a longer storm water/soil contact time and promote infiltration.

STREAM PROTECTION

Storm water runoff is a powerful force that influences the geometry of streams. After development, both the frequency and magnitude of storm flows may increase dramatically. Consequently, urban stream channels experience more bankfull and sub-bankfull flow events each year than they had prior to development. Development greatly increases the frequency that a stream exceeds the critical discharge rate (the discharge rate associated with bankfull flow) that corresponds to the onset of channel erosion and enlargement. As a result, the stream bed and banks are exposed to highly erosive flows more frequently and for longer periods. Streams typically respond to this change by increasing cross-sectional area to handle the more frequent and erosive flows, either by channel widening or down cutting, or both. This results in a highly unstable phase where the severe bank erosion and habitat degradation is possible. In this phase, the stream channel often experiences some of the following changes:

- Rapid stream widening
- Increased streambank and channel erosion
- Decline in stream substrate quality (through sediment deposition and embedding of the substrate)
- Loss of pool/riffle structure in the stream channel
- Degradation of stream habitat structure
The decline in the physical habitat of the stream, coupled with lower base flows and higher storm water pollutant loads, has a severe impact on the aquatic community. Recent research has shown the following possible changes in stream ecology:

- Decline in aquatic insect and freshwater mussel diversity
- Decline in fish diversity
- Degradation of aquatic habitat (Schueler, 1995)

All of the drainage courses downstream from campus are experiencing some level of degradation from concentrated storm water flows at storm sewer outfalls, or the cumulative effects of increases in the rate and volume of runoff. A storm water management strategy that results in a reduction in both rates and volumes would have the most positive impact on ravine and channel stability.

RAVINE EROSION

The Little Mac, Calder, and Ravine Apartments ravines have experienced the most severe erosion in the past. Following is a brief description of the storm water impacts on each of these ravines.

Little Mac Ravine
The Little Mac Ravine has undergone the most dramatic change since GVSU first began construction activities on the Allendale Campus. The majority of the east campus runoff has been redirected into this ravine resulting in increased erosion. In the past, riprap and energy dissipation structures have been used to stabilize the streambed. The majority of the riprap has moved downstream, while the larger riprap that has remained in place has broken up, rendering it less effective. Examples of erosion in Little Mac Ravine are shown in Appendix 1, Photographs 5 and 6.

Calder Ravine
The Calder Ravine has also seen an increase in runoff from the development of the southeast area of campus. The problems associated with the increased runoff and resulting erosion are tree loss, streambank instability, and slope instability. In 2002 and 2006, large riprap was lowered into the ravine by helicopter in an effort to stabilize the outlet. Appendix 1, Photographs 7 and 8, show some examples of erosion within Calder Ravine.

Ravine Apartments Ravine
The Ravine Apartments Ravine, located on the north portion of campus along M-45, exhibits severe erosion with few measures in place to reduce the rate of erosion. Accelerated erosion can be seen at all the outlet pipes into the ravine, with the worst being a 48-inch pipe with the last section of pipe having
fallen into the ravine. Appendix 1, Photograph 9, shows the severe erosion occurring in the ravine at the 48-inch outlet pipe.

**SLOPE STABILITY**

Erosion of these ravine systems has weakened the stability of the ravine slopes, causing concern for the structural integrity of the neighboring buildings. Slope failures requiring repair have occurred just north of Lake Ontario Hall and southeast of Parking Lot N. Appendix 1, Photographs 10 and 11, show the instability of the slopes in these repaired areas. GVSU faculty have determined which structures are most vulnerable to slope instability through the use of a preliminary risk assessment model. They concluded that the buildings most at risk are those within 50 feet of a slope angle greater than 35 degrees, which includes Kirkpatrick, Copeland, Robinson, Kistler, and Hoobler Living Centers, and Lake Ontario Hall (Womble, et al.). A more refined algorithm that takes into account the outcrop of the lower sand aquifer was identified as important for future assessments. These high risk areas are indicated on Figure 1.

**OTTAWA CREEK**

The ravine systems north of M-45 discharge to Ottawa Creek, which is located approximately ¼ mile north of M-45 and is a tributary to the Grand River. Ottawa Creek is a county drain (established prior to 1927) under the jurisdiction of the Ottawa County Drain Commissioner. The contributing GVSU drainage area to the Ottawa Creek watershed is a fraction of the total watershed area. Extensive development has occurred within the Ottawa Creek watershed outside of the development occurring on GVSU property. Property owners along Ottawa Creek have stated to GVSU faculty that the creek once supported good-sized fish, but none have been observed in recent years. The degradation of Ottawa Creek cannot be solely attributed to the development of GVSU, but rather all developments within the watershed. Field observations of Ottawa Creek indicate that while erosion is evident, it is not on the order of the severe erosion in the ravines east of campus. Appendix 1, Photographs 12 and 13, show Ottawa Creek and the confluence of the GVSU drainage system with Ottawa Creek. Although the ravines and Ottawa Creek floodplain provide adequate capacity from a flooding perspective, ostensibly, the potential exists for degradation of these watercourses with increases in storm water runoff.

**FLOODPLAIN PROTECTION**

Flow events that exceed the capacity of the stream channel may spill out into adjacent floodplains. These are termed “overbank” floods, and can damage property and downstream drainage structures when urban development increases the peak discharge rates; because, impervious surfaces generate greater runoff volumes, and drainage systems deliver it more rapidly to a stream or river. Overbank floods are ranked in terms of their statistical return frequency. For example, a flood that has a 1% chance of
occurring in any given year is termed a “100-year” flood. While some overbank flooding is inevitable and even desirable, the historical goal of drainage design has been to avoid increases in the level of the 100-year floodplain. Floodplains are natural flood storage areas and help to attenuate downstream flooding. Floodplains may also be very important habitat areas, encompassing riparian forests, wetlands, and wildlife corridors.

State regulated floodplains are located adjacent to the GVSU campus along Ottawa Creek and the Grand River. The GVSU campus is situated well above the 100-year flood elevation of the Grand River and is not at risk from regional flooding. The impacts from campus storm water management on the floodplain of the Grand River is negligible, however, increases in discharge rates or volumes could have a measurable impact on Ottawa Creek and its floodplain. The existing ravines have more than adequate capacity to convey flood flows without flooding of buildings or infrastructure improvements.

SUMMARY OF STORM WATER IMPACTS

The major problems associated with storm water runoff on the GVSU Allendale Campus are a result of an increase in the intensity and duration of storm water runoff and the subsequent accelerated erosion in the ravines. This increase in storm water runoff is a consequence of constructing additional impervious buildings, roads, and parking areas. A change in the drainage patterns during development of the campus has also increased the amount of concentrated storm water runoff that is entering the ravines. The urbanization of the area has caused degraded water quality as a result of the pollutants typically associated with storm water runoff, and localized flooding occurs on the campus due to inadequate storage or conveyance capacity.

ANALYSIS

HYDROLOGIC AND HYDRAULIC MODELING

The hydrologic and hydraulic characteristics of the storm water collection system and drainage patterns at the Allendale Campus were analyzed using the Storm Water Management Model (SWMM) Version 5.0 developed by the U.S. Environmental Protection Agency (EPA). This modeling software is well suited for evaluating the existing conditions on campus and assessing the effectiveness of various storm water improvement alternatives. Input parameters for the EPA SWMM Model and the methodology used for the hydrologic and hydraulic analysis are included in Appendix 2.

The existing conditions model was calibrated using flow monitoring data compiled by Dr. Peter Wampler, Assistant Professor of Geology. Dr. Wampler developed a rating curve from five measured data points at stream gage “B” in Little Mac ravine to calculate peak discharge based on the measured stage height of
the stream. This rating curve was used to estimate the peak discharge for the July 17, 2006, rain event. This rain event was entered into the computer model to be able to compare to the calculated peak discharges. The peak discharge computed from the model was slightly higher than the value computed from the rating curve. It is presumed that assumptions made with both the rating curve and the computer model account for the majority of the error between the two techniques. Minor adjustments affecting the runoff travel time of the subcatchments were made to the EPA SWMM Model to more closely correlate to the measured data.

The EPA SWMM Model was run for a range of storm events to provide hydrographs of storm water discharge versus time for several of the subcatchments on campus. Figure 6 illustrates the existing drainage subcatchments that were included in the model. The model was also applied to compare existing runoff patterns to presettlement and agricultural conditions. Appendix 3 shows the hydrographs for all the major outlets on campus associated with these development scenarios for the 2-year and 25-year frequency rainfall events. These hydrographs illustrate the significant increase in both the peak flow and runoff volume in subcatchments that outlet to the ravines on East Campus. The hydrographs for the runoff from the golf course (Appendix 3, GC-OUT) actually show a decrease in the existing rate and volume of runoff compared to the agricultural usage, because of the diversion of storm water from this subcatchment to East Campus and the additional storage volume created with the development of the golf course.

EVALUATION OF IMPROVEMENT ALTERNATIVES

The evaluation of storm water management alternatives for the GVSU Allendale Campus focuses primarily on controlling erosion, preventing flooding, and improving storm water quality. These goals can best be achieved by efforts that will control the intensity and frequency of runoff from impervious areas that have contributed to erosion problems and localized flooding. The following four storm water management approaches were identified to achieve these goals:

- Divert storm water away from erodable soils and flood prone areas
- Provide extended storage and slow release of storm water runoff
- Implement best management practices (BMPs) that will provide onsite storage and water quality benefits
- Implement storm water conveyance improvements with structural erosion control measures

STORM WATER DIVERSION

There has been an ongoing effort to divert storm water away from unstable slopes and areas with significant erosion problems. Storm water was intercepted in the vicinity of Parking Lots M and N in 2002
and conveyed to a stabilized outlet south of the Calder Art Center to address problems of slope stability at the prior outlets. Ongoing building construction, such as the Movement Sciences and Indoor Recreation Facility (MSIRF), has provided opportunities to divert additional runoff away from impacted areas. The extent to which storm water can be diverted away from the ravines is limited by topography and the layout of the existing storm water collection system. This alternative remains a viable option for the Allendale Campus, when the existing conveyance system is capable of handling the additional runoff without contributing to flooding and additional erosion as a result of the diversion.

**STORAGE AND SLOW RELEASE OF STORM WATER RUNOFF**

The detention or retention of storm water runoff can be an effective strategy to reduce the rate of discharge from a drainage system. The reduction in volume of runoff will depend on the amount of evaporation, evapotranspiration, and infiltration of storm water runoff that occurs. The Hydrologic Soil Group Map for the Allendale Campus, Figure 2, shows that the soils on the campus have low permeability and the potential for direct infiltration of runoff into the groundwater is limited. Extended detention of storm water can reduce the rate of runoff to the rate that occurred during presettlement if adequate storage volume is available.

The amount of storage volume required depends not only on the infiltration capacity of the soils, but also on the design storm event. Research indicates that more frequent rainfall events (1- to 2-year frequency) provide the channel forming flow of a water course (XXXX,XXXX). Accelerated erosion in these natural drainage systems occurs during the more frequent events because of the increase in runoff intensity and volume associated with increases in impervious surfaces. Therefore, providing extended detention and storage volume for more frequent rainfall events is vital to controlling erosion. Onsite storage systems such as swales and rain gardens can provide adequate storage for the more frequent rainfall events, resulting in erosion control while providing additional water quality benefits.

It is also important to address the more extreme storm events, such as the 25-year or 100-year storms. Providing detention for these events is essential to reduce flooding if adequate conveyance capacity is not available. Storage and slow release appears to be an effective strategy for the Allendale Campus at locations where onsite systems with adequate storage volume can be constructed. The largest available area for storage of storm water appears to be in the southwest portion of the campus in the vicinity of the radio tower. The storage system could be designed around the existing infrastructure and incorporate wetlands and other wildlife habitat with water quality features.
BEST MANAGEMENT PRACTICES

The selection and design of urban BMPs is influenced by many of the factors listed below:

- Effectiveness of pollutant removal
- Cost
- Maintenance
- Ease of implementation
- Community acceptance
- Location of the BMP in regard to the downstream receiving water
- Slope of the site
- Soils
- Elevation of the groundwater table
- Size of the drainage area
- Amount of space required for installation

Appendix 4 includes a fact sheet on several BMPs containing descriptions, benefits, limitations, applications, maintenance, design life, basis for cost and cost estimate, pollutant removal efficiencies, and references. This section is a general approach to BMP selection. The above factors should be evaluated in greater detail prior to BMP installation.

The feasibility of constructing onsite BMPs on the Allendale Campus will vary based on the extent of existing development, topography, and the existing storm water collection system. A BMP Application Matrix recommended for consideration during future GVSU projects is included as Table 1. The BMP Application Matrix provides information on the storm water control category, potential water quality benefits, application (existing or future), and the feasibility of construction in each of the subcatchments.

A BMP Benefits Calculator was also developed to help quantify the hydrologic benefits that would occur from the installation of onsite BMPs. The BMP Benefits Calculator computes the revised hydrograph that would occur after installation of various BMPs for five different rainfall events (1-year, 2-year, 10-year, 25-year, and 100-year). An example of the BMP Benefits Calculator output is included in Appendix 5.

Figure 7 is an illustration of the application of possible BMPs on a representative portion of the Allendale Campus. The actual layout of the BMPs would depend on site constraints, existing facilities, and landscaping.
STORM WATER CONVEYANCE AND EROSION CONTROL

The existing storm water collection system on campus consists of a network of storm sewers and catch basin inlets that discharge runoff to various outlets as shown in Figure 6. Extremely high velocities that have accelerated the rate of erosion and contributed to slope instability have been observed at the storm sewer outlets into the ravines. Trees and other vegetation that have stabilized the ravines in the past have been adversely affected, thereby contributing to the instability of many of the drainage channels and slopes. In an attempt to prevent accelerated erosion, structural armoring using rock riprap has been placed at some outlets and along steep drainage channels, but has had only limited success. Gabion weir check dams have also been placed in the drainage channel to slow the rate of flow and reduce erosion. In many locations, placement of rock and other materials is difficult because of limited access to the ravines for construction equipment. Placement of large riprap by helicopter has proven to be an effective strategy for construction in areas with limited accessibility. The high construction and maintenance costs and the impact to the ecosystem are negative factors associated with this alternative.

RECOMMENDATIONS

The recommended SWMP for the Allendale Campus consists of a combination of the available improvement alternatives. Ongoing conveyance improvements and structural erosion control measures are necessary to maintain adequate drainage in the developed areas of campus. Installation of BMPs should be investigated throughout the campus and particularly in conjunction with campus development and improvements. The major component of the recommended plan consists of the diversion of runoff away from the East Campus ravines to a system of wetlands, ponds, and BMPs on West Campus, which will provide adequate storage to limit the discharge rate to predevelopment levels.

STORM WATER CONVEYANCE AND EROSION CONTROL

There are a number of drainage systems on campus that function well as designed, and analysis shows that they should continue to do so. Many of these systems provide adequate storm water conveyance and have erosion control measures in good working order. However, these systems require ongoing inspection and maintenance to ensure that the erosion control measures can function as designed. The use of structural measures for erosion control will remain necessary at some locations on campus. It is recommended that GVSU budget approximately $75,000 annually for maintenance and installation of erosion control measures in the drainage systems.

It should be noted that the drainage system near the Ravine Apartments exhibits characteristics of accelerated erosion and should be a high priority for structural erosion control measures. A large portion of the contributing drainage area will be diverted as part of the MSIRF project, but the existing erosive
conditions should be addressed. Any future erosion control measures should be reviewed by the SWAG to determine the best course of action.

STORM WATER BMPS

Numerous storm water BMPs have already been installed on campus in conjunction with various construction projects. Current projects also include plans for integrated storm water BMPs, such as porous pavement, green roofs, grassed swales, tree planting, wetlands, rain gardens, storm water reuse (irrigation), wet ponds, dry ponds, and sediment basins. GVSU should continue to look for these opportunities in association with other projects. The tools that have been developed with this SWMP can help to screen the feasible BMPs, and quantify the potential hydrologic and water quality benefits that would result.

RADIO TOWER WETLAND COMPLEX

Analysis of the existing drainage system shows that runoff from approximately 38.4 acres of parking lots and developed areas that currently drain to East Campus ravines can be intercepted and diverted to a proposed wetland complex on West Campus. This will help to reverse the historical trend of routing as much runoff as possible to the East Campus ravines. The predevelopment, existing, and proposed future drainage divide between East and West Campus is shown on Figure 8. The contributing drainage area diverted from East Campus to this wetland complex is shown on Figure 9. A conceptual illustration of the proposed Radio Tower Wetland Complex is shown on Figure 10. The goal of this wetland will be to reduce the runoff and associated erosion in the ravines on East Campus while providing the storage and water quality benefits necessary to avoid downstream impacts to West Campus. The significant change in the runoff at outlet A-OUT on East Campus that would result from diverting runoff to the wetland complex is shown in Appendix 3. Construction of this project would also help to mitigate potential wetland impacts associated with the future development of athletic facilities in this area. The estimated project cost for establishment of the Radio Tower Wetland Complex is $1,590,165. An itemized cost estimate is included in Appendix 6.

IMPLEMENTATION

PERMITS AND REGULATORY REQUIREMENTS

Permits are required from the Michigan Department of Environmental Quality (MDEQ) to dredge or fill a state-regulated wetland under Part 303, Act 451, PA 1994, which may govern work proposed for the Radio Tower Wetland Complex. As mentioned previously, this work may be counted as wetland mitigation for filling of other wetland areas on campus in conjunction with campus improvement projects. Work
within the bottomlands of an Inland Lake or Stream (i.e., portions of some ravines, Jacobs Drain, Ottawa Creek, the Grand River) is regulated under Part 301, Act 451, PA 1994. Also, any excavation within 500 feet of an Inland Lake or Stream is regulated (exemptions include noncontiguous excavation above the water table). Work within a floodplain of a watercourse with greater than a 2-square mile drainage area (i.e., Grand River, Ottawa Creek) is regulated under Part 31, Act 451, PA 1994.

The Ottawa County Drain Commissioner requires a permit for all work proposed within the right-of-way of an established county drain (i.e., Jacob’s Drain, Ottawa Creek), or for proposed storm water connections. Review and approval will also be required from the Ottawa County Drain Commissioner office prior to changing drainage district boundaries through diversion of storm water.

A Soil Erosion and Sedimentation Control (SESC) permit under Part 91, Act 451, PA 1994, will be required from the Ottawa County Drain Commissioner for earth disturbances of greater than 1 acre or within 500 feet of an Inland Lake or Stream. A Notice of Coverage (NOC) will also be required under the National Pollutant Discharge Elimination System (NPDES) program for construction sites with earth disturbances of 5 acres or more. This program also requires a certified storm water operator for all sites with earth disturbance of 1 acre or more.

**FUNDING OPPORTUNITIES**

Annual funding is critical to helping develop a long term data set that will improve the understanding of storm water runoff and the success of future BMPs. Following is a brief review of typical grants and organizations that provide funding opportunities.

**NPS GRANTS**

Michigan’s Nonpoint Source (NPS) Program assists local units of government; nonprofit entities; and other state, federal, and local partners to reduce NPS pollution. The basis of the program is watershed management; therefore, the projects funded are to develop watershed management plans or to implement nonpoint source activities in MDEQ approved watershed management plans. Section 319 Implementation Funds derive their name from Section 319 of the federal Clean Water Act of 1972. Since 319 funds are granted by the federal government, they have been more stable than the Clean Michigan Initiative (CMI) Program.

MDEQ Environmental Science and Services Division utilizes funding from Section 319(h) of the federal Clean Water Act, and from the Clean Michigan Initiative NPS Pollution Control Grants and Clean Water Fund.
ENVIRONMENTAL EDUCATION GRANTS

The purpose of the Environmental Education Grants (EEG) is to provide financial support for projects that design, demonstrate, or disseminate environmental education practices, methods, or techniques. Projects must focus on one of the following: (1) improving environmental education teaching skills; (2) educating teachers, students, or the public about human health problems; (3) building state, local, or tribal government capacity to develop environmental education programs; (4) educating communities through community-based organization; or (5) educating the public through print, broadcast, or other media.

Non-federal government match of 25 percent is required.

Contact Information:
U.S. EPA, Environmental Education Grant Program, 202-260-8619
Website: www.epa.gov/enviroed/grants.html

U.S. FISH AND WILDLIFE SERVICE

The USFWS supports large and small wetland projects. Grants are 1:1 matching funds of up to $1 million for wetland restoration projects.

EPA 5-STAR GRANT

The EPA 5-Star Grant involves five entities (students, conservation corps, corporations, landowners, and government agencies), who provide environmental education through projects that restore wetlands. The program provides challenge grants, technical support, and opportunities for information exchange to enable community-based restoration projects. The grants are typically small, around $10,000, but they are accessible to the general public and are flexible to meet the grantees needs. In most cases, a school would be able to get this grant for environmental education programs.

PRIVATE ORGANIZATIONS

NATURE CONSERVANCY

The Nature Conservancy is a well known and very selective conservation organization. They identify exemplary sections of land from across the world that are unique and threatened. They are also an
advocacy group and promote educational activities and projects which help conserve unique natural heritage sites. To learn more about the Nature Conservancy, go to http://nature.org/.

MICHIGAN AUDUBON SOCIETY

The Audubon Society is an organization that has been working to conserve habitats in the U.S. for over 100 years. John James Audubon described and painted birds. The Michigan Audubon Society is Michigan’s oldest conservation organization, conceived in 1904. They have sanctuaries and nature centers, as well as other outreach and educational material that is available throughout the state. See their website for more information: http://www.michiganaudubon.org/index.html.

MICHIGAN UNITED CONSERVATION CLUBS

The MUCC has a membership that is interested in acting locally to conserve natural resources and use them wisely. They are an advocacy group and lobby in Michigan. More information is available at http://www.mucc.org/.

EDUCATIONAL OPPORTUNITIES

Several academic programs on campus use the campus ravines and ongoing storm water management practices in classroom curriculum, including the biology, geology, and engineering departments. Examples include ongoing flow monitoring in the campus ravines, research on plant and animal ecosystems, erosion of the ravine slopes, and monitoring of the campus rain gardens, wetlands, and porous pavement parking lots.

Implementation of additional storm water initiatives will provide additional educational opportunities for faculty and students, and assist the University in their ongoing efforts to promote sustainability on campus.

OPERATION AND MAINTENANCE

As with any storm water management system, ongoing maintenance is required for proper operation of the wetland complex. Subsequent to the installation of wetland seed and plant material, a maintenance and monitoring program should be conducted for a period of three years. Site conditions should be assessed at appropriate times of the year for the presence of invasive and exotic species. Appropriate treatment measures would be prescribed and completed, which may include herbicide treatment by a licensed professional, mechanical cutting, mowing, and hand pulling.

07/26/2007 • DRAFT
U:\PROJECTS\06834\REPORT\SWMP_ALLENDALE_2007_JULY_2007.DOC
Maintenance for individual BMPs is given in the BMP fact sheets found in Appendix 4. Prior to beginning construction on any of the storm water projects, GVSU should consider adopting a maintenance plan and budget that specifies who is responsible for maintenance and how often it is performed. Following a maintenance plan is essential for the continuing effectiveness of the SWMP.
Figures
Grand Valley State University

Storm Water Management Plan

HYDROLOGIC SOIL GROUP

LEGEND

- GVSU OWNERSHIP
- RIVERS AND STREAMS
- HYDROLOGIC SOIL GROUP
  - A- HIGH INFILTRATION
  - B- MEDIUM INFILTRATION
  - B/D- IMPROVED/NATURAL CONDITION
  - C- LOW INFILTRATION
  - D- VERY LOW INFILTRATION
  - NO DATA

BASE MAP, GVSU 2003.
WATER COURSES, MICHIGAN CENTER FOR GEOGRAPHIC INFORMATION FRAMEWORK.
SOILS, NRCS SSURGO SOILS 24K, OTTAWA COUNTY.

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PRESETTLEMENT VEGETATION/
HYDRIC SOILS

BASE MAP, GVSU 2003.
WATER COURSES, MICHIGAN CENTER FOR GEOGRAPHIC
INFORMATION FRAMEWORK.
LAND COVER CIRCA 1800, MICHIGAN DEPARTMENT
OF NATURAL RESOURCES.
SOILS, NRCS SSURGO SOILS 24K, OTTAWA COUNTY.

LEGEND

GVSU OWNERSHIP
RIVERS AND STREAMS
HYDRIC SOILS
LAND COVER CIRCA 1800
BEECH-SUGAR MAPLE FOREST
MIXED HARDWOOD SWAMP
LAKE/RIVER
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<th>Pollutant Removal Effectiveness</th>
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<td>Flow Rate Reduction</td>
<td>Storm Water Retention</td>
<td>Storm Water Detention</td>
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H = High (>50% Efficiency)  
M = Medium (20 - 50% Efficiency)  
L = Low (<20% Efficiency)
Appendix 1
Localized Flooding

Photograph 1 - Low area in front of Robinson Living Center

Photograph 2 - Children’s center detention basin
Jacobs Drain Reconstruction

Photograph 3 - Jacob’s Drain looking south before reconstruction

Photograph 4 - Jacob’s Drain looking south after reconstruction
Little Mac Ravine

Photograph 5 - Little Mac ravine at flow control structure looking downstream

Photograph 6 - Erosion in Little Mac Ravine
Calder Ravine

Photograph 7 - Erosion around gabion check dam in Calder Ravine

Photograph 8 - Erosion within Calder Ravine
Ravine Apartments Ravine

Photograph 9 - 48” outlet to Ravine Apartments Ravine
Slope Instability

Photograph 10 - Slope instability North of Lake Ontario Hall

Photograph 11 - Slope Instability South of parking lot N
Confluence with Ottawa Creek

Photograph 12 - Confluence of ravine drainage area with Ottawa Creek

Photograph 13 - Ottawa Creek looking downstream
Appendix 2
METHODOLOGY FOR HYDROLOGIC AND HYDRAULIC ANALYSIS USING EPA SWMM 5.0

RAINFALL DATA
Rainfall data use for synthetic distributions analysis was obtained from the *Rainfall Frequency Atlas of the Midwest*, Floyd A. Huff and James R. Angel, 1992, for a 24-hour duration using the Michigan SCS Triangular Unit Hydrograph distribution. Rainfall amounts are tabulated below:

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<td>Peak Intensity (inches/hr)</td>
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Calibration Event
The existing-conditions model was calibrated using the July 17, 2006 rainfall event with the distribution and accumulation of rainfall recorded at the Grand Valley State University Allendale campus. A total recorded rainfall of 3.69 inches fell over approximately 1 hour 45 minutes. The rainfall data used to calibrate the existing conditions EPA SWMM Model is provided in Table A1 of this Appendix.

HYDROLOGIC ANALYSIS

Drainage Area
The subcatchments were delineated using topographic and utility maps of campus. Subcatchment areas used in the hydrologic analysis of the existing campus are provided in Table A2 of this Appendix.

Catchment Width
The subcatchment width value is the characteristic width of the overland flow path for sheet flow runoff. An initial estimate of the characteristic width was found by dividing the subcatchment area by the average maximum overland flow length. The maximum overland flow length is the distance flow travels from the inlet to the furthest drainage point of the subcatchment. Once the model was run successfully, some of the width numbers were adjusted as necessary to calibrate the EPA SWMM model. Width values used in the hydrologic analysis of the existing campus are provided in Table A2 of this Appendix.

Percent Slope
The average percent slope of the subcatchment is calculated by dividing the change in ground surface elevation by the overland flow path length. The ground surface was determined from GIS contour data over the entire campus. Slopes used in the hydrologic analysis of the existing campus are provided in Table A2 of this Appendix.

Percent Impervious
The percent of impervious cover of the drainage area determined from GIS mapping. The areas used to determine impervious cover include building roofs, parking lot and road pavement, concrete walks and ponds. The percent imperviousness used in the hydrologic analysis of the existing campus are provided in Table A2 of this Appendix.

Impervious & Pervious “n”
The Manning’s Roughness coefficient, n, for overland flow over the impervious and pervious portions of the subcatchment. The coefficient used for all subcatchments is 0.013 for impervious areas and 0.4 for pervious areas.
**Impervious & Pervious Depression Storage**

The depth of depression storage on the impervious and pervious portions of the subcatchment. This parameter is used to estimate the amount of rainfall that must occur before runoff is generated from the subcatchment. The values used for all subcatchments are 0.075 inches for impervious areas and ranges between 0.1 inches and 0.3 inches for pervious areas.

**Percent Zero Impervious**

The percent of the impervious area with no depression storage. Commonly referred to as directly connected impervious area. The percent zero imperviousness used in the hydrologic analysis of the existing campus are provided in Table A2 of this Appendix.

**HYDRAULIC ANALYSIS**

**Hydraulic Input**

The hydraulic input for the existing conditions model was obtained from numerous surveys conducted by FTC&H for the master utility mapping. Input parameters required for the analysis are conduit shape, size, length, invert elevation and Manning’s roughness coefficient.

**ASSUMPTIONS**

The model was setup to analyze the impact of a single storm event. As a result, the effects of groundwater were assumed to be negligible for the event. In order to analyze the effects of groundwater, the model would need to be run for a long term simulation. In order to do this, several additional parameters related to groundwater flow would need to be defined, data for which may not be readily available.

It was also assumed that the impact of the smaller pipes in the storm sewer collection system would have very little impact on the flow rate and volume of storm water runoff leaving campus. As a result, the entire storm sewer collection system was not analyzed in the computer model, rather just the trunk storm sewers to the outlet points. The purpose of the computer model was not to identify the adequacy of small storm sewer networks, but rather to determine the impact of runoff on the ravines.
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### Table A2 - Hydrologic Input Parameters

**Storm Water Management Plan**  
Grand Valley State University, Allendale Campus

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<td>11.01</td>
<td>440</td>
<td>1.0</td>
<td>56.3</td>
<td>90.0</td>
</tr>
<tr>
<td>D-1</td>
<td>59.62</td>
<td>950</td>
<td>4.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GC-1</td>
<td>178.27</td>
<td>1260</td>
<td>0.6</td>
<td>6.4</td>
<td>100.0</td>
</tr>
<tr>
<td>GC-2</td>
<td>42.65</td>
<td>920</td>
<td>1.3</td>
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<td>0.0</td>
</tr>
<tr>
<td>GC-3</td>
<td>61.24</td>
<td>1200</td>
<td>1.2</td>
<td>9.2</td>
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</tr>
<tr>
<td>GC-4</td>
<td>18.75</td>
<td>750</td>
<td>1.5</td>
<td>39.0</td>
<td>85.0</td>
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<tr>
<td>GC-5</td>
<td>8.81</td>
<td>515</td>
<td>2.2</td>
<td>68.2</td>
<td>98.0</td>
</tr>
<tr>
<td>GC-6</td>
<td>16.47</td>
<td>750</td>
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<td>GC-7</td>
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<td>M45-1</td>
<td>21.01</td>
<td>680</td>
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<td>2.4</td>
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<td>9.66</td>
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<td>5.32</td>
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<td>1.1</td>
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<td>78.0</td>
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<td>M45-5</td>
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<td>900</td>
<td>1.4</td>
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<td>M45-6</td>
<td>16.63</td>
<td>520</td>
<td>0.6</td>
<td>47.5</td>
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<tr>
<td>M45-7</td>
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<td>280</td>
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<td>29.0</td>
<td>50.0</td>
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<td>M45-8</td>
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<td>43.4</td>
<td>87.0</td>
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<td>435</td>
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<td>46.0</td>
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<td>NE-1</td>
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<td>63.3</td>
<td>75.0</td>
</tr>
<tr>
<td>NE-2</td>
<td>67.57</td>
<td>1050</td>
<td>3.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>S-1</td>
<td>13.30</td>
<td>850</td>
<td>0.5</td>
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<td>50.0</td>
</tr>
<tr>
<td>S-2</td>
<td>82.13</td>
<td>995</td>
<td>3.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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Appendix 3
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<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drainage Area (acres)</strong></td>
<td>6.82</td>
<td>6.82</td>
<td>41.09</td>
<td>14.11</td>
<td>-66%</td>
<td>107%</td>
</tr>
<tr>
<td><strong>% Impervious</strong></td>
<td>0%</td>
<td>0%</td>
<td>58.3%</td>
<td>58.2%</td>
<td>-66%</td>
<td>107%</td>
</tr>
<tr>
<td><strong>Curve Number</strong></td>
<td>70</td>
<td>80</td>
<td>88</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2-yr Peak Runoff (cfs)</strong></td>
<td>0.38</td>
<td>1.38</td>
<td>43.55</td>
<td>14.67</td>
<td>-66%</td>
<td>3761%</td>
</tr>
<tr>
<td><strong>2-yr Total Volume (ac-ft)</strong></td>
<td>0.27</td>
<td>0.50</td>
<td>6.52</td>
<td>2.23</td>
<td>-66%</td>
<td>732%</td>
</tr>
<tr>
<td><strong>25-yr Peak Runoff (cfs)</strong></td>
<td>3.61</td>
<td>8.71</td>
<td>92.33</td>
<td>31.26</td>
<td>-66%</td>
<td>766%</td>
</tr>
<tr>
<td><strong>25-yr Total Volume (ac-ft)</strong></td>
<td>1.09</td>
<td>1.49</td>
<td>13.44</td>
<td>4.62</td>
<td>-66%</td>
<td>325%</td>
</tr>
</tbody>
</table>

**2-yr HYDROGRAPH**

**25-yr HYDROGRAPH**
## B-OUT

<table>
<thead>
<tr>
<th></th>
<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area (acres)</td>
<td>126.40</td>
<td>126.40</td>
<td>131.07</td>
<td>104.09</td>
<td>-21%</td>
<td>-18%</td>
</tr>
<tr>
<td>% Impervious</td>
<td>0%</td>
<td>0%</td>
<td>29.6%</td>
<td>22.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve Number</td>
<td>70</td>
<td>80</td>
<td>79</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>2.42</td>
<td>7.21</td>
<td>46.75</td>
<td>23.53</td>
<td>-50%</td>
<td></td>
</tr>
<tr>
<td>2-yr Total Volume (ac-ft)</td>
<td>3.24</td>
<td>7.63</td>
<td>12.73</td>
<td>8.34</td>
<td>-35%</td>
<td></td>
</tr>
<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>17.49</td>
<td>41.12</td>
<td>142.78</td>
<td>82.05</td>
<td>-43%</td>
<td></td>
</tr>
<tr>
<td>25-yr Total Volume (ac-ft)</td>
<td>17.05</td>
<td>25.32</td>
<td>32.04</td>
<td>22.97</td>
<td>-28%</td>
<td></td>
</tr>
</tbody>
</table>

### 2-yr HYDROGRAPH

- **Presettlement**
- **Agricultural**
- **Existing**
- **Future**

### 25-yr HYDROGRAPH

- **Presettlement**
- **Agricultural**
- **Existing**
- **Future**

---

J:\06834.REPT\SWMP_Apps2and3.xls

<table>
<thead>
<tr>
<th></th>
<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area (acres)</td>
<td>69.38</td>
<td>69.38</td>
<td>93.87</td>
<td>93.87</td>
<td>0%</td>
<td>35%</td>
</tr>
<tr>
<td>% Impervious</td>
<td>0%</td>
<td>0%</td>
<td>22.5%</td>
<td>0%</td>
<td>22.5%</td>
<td>22.5%</td>
</tr>
<tr>
<td>Curve Number</td>
<td>70</td>
<td>80</td>
<td>77</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>1.60</td>
<td>4.80</td>
<td>22.70</td>
<td>22.70</td>
<td>0%</td>
<td>1319%</td>
</tr>
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<td>2-yr Total Volume (ac-ft)</td>
<td>1.99</td>
<td>4.40</td>
<td>8.18</td>
<td>8.18</td>
<td>0%</td>
<td>311%</td>
</tr>
<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>11.60</td>
<td>27.42</td>
<td>66.24</td>
<td>66.24</td>
<td>0%</td>
<td>471%</td>
</tr>
<tr>
<td>25-yr Total Volume (ac-ft)</td>
<td>9.80</td>
<td>14.19</td>
<td>21.02</td>
<td>21.02</td>
<td>0%</td>
<td>115%</td>
</tr>
</tbody>
</table>

**2-yr HYDROGRAPH**

![2-yr HYDROGRAPH](image1)

**25-yr HYDROGRAPH**

![25-yr HYDROGRAPH](image2)
**D-OUT**

Presettlement | 1960 Land Usage | 2007 Land Usage | Future | % change 2007 to Future | % change Presettle to Future
---|---|---|---|---|---
Drainage Area (acres) | 59.62 | 59.62 | 59.62 | 59.62 | 0%
% Impervious | 0 | 0 | 0 | 0 | 0%
Curve Number | 70 | 70 | 70 | 70 | 0%
2-yr Peak Runoff (cfs) | 1.54 | 1.54 | 1.54 | 1.54 | 0%
2-yr Total Volume (ac-ft) | 1.82 | 1.82 | 1.82 | 1.82 | 0%
25-yr Peak Runoff (cfs) | 11.66 | 11.66 | 11.66 | 11.66 | 0%
25-yr Total Volume (ac-ft) | 8.61 | 8.61 | 8.61 | 8.61 | 0%

**2-yr HYDROGRAPH**

- Presettlement
- Agricultural
- Existing
- Future

**25-yr HYDROGRAPH**

- Presettlement
- Agricultural
- Existing
- Future
### Land Usage

<table>
<thead>
<tr>
<th>Year</th>
<th>Presettlement</th>
<th>1960</th>
<th>2007</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>% change</td>
<td>15%</td>
<td>226%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% change</td>
<td>15%</td>
<td>160%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% change</td>
<td>16%</td>
<td>341%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% change</td>
<td>28%</td>
<td>924%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% change</td>
<td>4%</td>
<td>461%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Drainage Area (acres)

<table>
<thead>
<tr>
<th>Year</th>
<th>Presettlement</th>
<th>1960</th>
<th>2007</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>118.62</td>
<td>412.57</td>
<td>337.04</td>
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<td></td>
</tr>
</tbody>
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### Impervious

<table>
<thead>
<tr>
<th>Year</th>
<th>% Impervious</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0%</td>
</tr>
<tr>
<td>1960</td>
<td>0%</td>
</tr>
<tr>
<td>2007</td>
<td>11.8%</td>
</tr>
</tbody>
</table>

### Curve Number

<table>
<thead>
<tr>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>15%</td>
<td>226%</td>
</tr>
<tr>
<td>84</td>
<td>15%</td>
<td>1609%</td>
</tr>
<tr>
<td>76</td>
<td>16.8%</td>
<td>924%</td>
</tr>
</tbody>
</table>

### 2-yr Peak Runoff (cfs)

<table>
<thead>
<tr>
<th>Future</th>
<th>2-yr Peak Runoff (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>24.37</td>
</tr>
</tbody>
</table>

### 2-yr Total Volume (ac-ft)

<table>
<thead>
<tr>
<th>Future</th>
<th>2-yr Total Volume (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.50</td>
<td>24.37</td>
</tr>
</tbody>
</table>

### 25-yr Peak Runoff (cfs)

<table>
<thead>
<tr>
<th>Future</th>
<th>25-yr Peak Runoff (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.05</td>
<td>113.52</td>
</tr>
</tbody>
</table>

### 25-yr Total Volume (ac-ft)

<table>
<thead>
<tr>
<th>Future</th>
<th>25-yr Total Volume (ac-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.77</td>
<td>25-yr Total Volume (ac-ft)</td>
</tr>
</tbody>
</table>

### 2-yr HYDROGRAPH

- Presettlement
- Agricultural
- Existing
- Future

### 25-yr HYDROGRAPH

- Presettlement
- Agricultural
- Existing
- Future
## M45-OUT

<table>
<thead>
<tr>
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<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Preset to Future</th>
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</thead>
<tbody>
<tr>
<td>Drainage Area (acres)</td>
<td>62.41</td>
<td>71.17</td>
<td>85.89</td>
<td>63.75</td>
<td>-26%</td>
<td>2%</td>
</tr>
<tr>
<td>% Impervious</td>
<td>0%</td>
<td>0%</td>
<td>36.3%</td>
<td>34.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve Number</td>
<td>70</td>
<td>80</td>
<td>82</td>
<td>81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>1.41</td>
<td>4.49</td>
<td>58.59</td>
<td>42.05</td>
<td>-28%</td>
<td>2882%</td>
</tr>
<tr>
<td>2-yr Total Volume (ac-ft)</td>
<td>1.77</td>
<td>4.44</td>
<td>10.04</td>
<td>7.09</td>
<td>-29%</td>
<td>301%</td>
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<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>10.12</td>
<td>25.41</td>
<td>135.63</td>
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<td>876%</td>
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<td>8.77</td>
<td>14.45</td>
<td>23.14</td>
<td>16.62</td>
<td>-28%</td>
<td>90%</td>
</tr>
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</table>

### 2-yr HYDROGRAPH

![2-yr Hydrograph](image1.png)

### 25-yr HYDROGRAPH

![25-yr Hydrograph](image2.png)
### NE-OUT

<table>
<thead>
<tr>
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<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
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</thead>
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<td>104.74</td>
<td>104.74</td>
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<td>12%</td>
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<td>0%</td>
<td>22.5%</td>
<td>22.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve Number</td>
<td>70</td>
<td>70</td>
<td>77</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>2.54</td>
<td>1.94</td>
<td>20.45</td>
<td>20.45</td>
<td>0%</td>
<td>705%</td>
</tr>
<tr>
<td>2-yr Total Volume (ac-ft)</td>
<td>2.91</td>
<td>2.26</td>
<td>7.95</td>
<td>7.95</td>
<td>0%</td>
<td>174%</td>
</tr>
<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>19.23</td>
<td>14.64</td>
<td>64.54</td>
<td>64.54</td>
<td>0%</td>
<td>236%</td>
</tr>
<tr>
<td>25-yr Total Volume (ac-ft)</td>
<td>13.58</td>
<td>10.67</td>
<td>21.97</td>
<td>21.97</td>
<td>0%</td>
<td>62%</td>
</tr>
</tbody>
</table>

#### 2-yr HYDROGRAPH

![2-yr Hydrograph](image)

#### 25-yr HYDROGRAPH

![25-yr Hydrograph](image)
**N-OUT**

<table>
<thead>
<tr>
<th></th>
<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Presettle to Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area (acres)</td>
<td>36.40</td>
<td>34.35</td>
<td>17.95</td>
<td>17.95</td>
<td>0%</td>
<td>-51%</td>
</tr>
<tr>
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<td>0%</td>
<td>0%</td>
<td>21.1%</td>
<td>21.1%</td>
<td>0%</td>
<td>26%</td>
</tr>
<tr>
<td>Curve Number</td>
<td>70</td>
<td>80</td>
<td>76</td>
<td>76</td>
<td>0%</td>
<td>23%</td>
</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>1.03</td>
<td>3.05</td>
<td>7.02</td>
<td>7.02</td>
<td>0%</td>
<td>582%</td>
</tr>
<tr>
<td>2-yr Total Volume (ac-ft)</td>
<td>1.15</td>
<td>2.27</td>
<td>1.41</td>
<td>1.41</td>
<td>0%</td>
<td>23%</td>
</tr>
<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>7.87</td>
<td>17.46</td>
<td>16.38</td>
<td>16.38</td>
<td>0%</td>
<td>108%</td>
</tr>
<tr>
<td>25-yr Total Volume (ac-ft)</td>
<td>5.33</td>
<td>7.14</td>
<td>3.93</td>
<td>3.93</td>
<td>0%</td>
<td>-26%</td>
</tr>
</tbody>
</table>

---

**2-yr HYDROGRAPH**

- Presettlement
- Agricultural
- Existing
- Future

**25-yr HYDROGRAPH**

- Presettlement
- Agricultural
- Existing
- Future
## S-OUT

<table>
<thead>
<tr>
<th></th>
<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
<th>% change 2007 to Future</th>
<th>% change Preset to Future</th>
</tr>
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<tbody>
<tr>
<td>Drainage Area (acres)</td>
<td>88.25</td>
<td>88.25</td>
<td>95.43</td>
<td>95.43</td>
<td>0%</td>
<td>8%</td>
</tr>
<tr>
<td>% Impervious</td>
<td>0%</td>
<td>0%</td>
<td>6.0%</td>
<td>6.0%</td>
<td>0%</td>
<td>8%</td>
</tr>
<tr>
<td>Curve Number</td>
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<td>72</td>
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</tr>
<tr>
<td>2-yr Peak Runoff (cfs)</td>
<td>1.97</td>
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<td>8.31</td>
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<td>2-yr Total Volume (ac-ft)</td>
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<td>4.12</td>
<td>4.12</td>
<td>0%</td>
<td>66%</td>
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<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>14.08</td>
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<td>27.18</td>
<td>27.17</td>
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<td>93%</td>
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<td>25-yr Total Volume (ac-ft)</td>
<td>12.36</td>
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<td>15.49</td>
<td>15.49</td>
<td>0%</td>
<td>25%</td>
</tr>
</tbody>
</table>

### 2-yr HYDROGRAPH

- Presettlement
- Agricultural
- Existing
- Future

### 25-yr HYDROGRAPH

- Presettlement
- Agricultural
- Existing
- Future

---
### Drainage Area

<table>
<thead>
<tr>
<th>Presettlement</th>
<th>1960 Land Usage</th>
<th>2007 Land Usage</th>
<th>Future</th>
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<tr>
<td>Drainage Area (acres)</td>
<td>253.09</td>
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<td>0%</td>
<td>0%</td>
</tr>
<tr>
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### Runoff Calculations

<table>
<thead>
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<th>Future</th>
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<td>2.81</td>
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<td>2-yr Total Volume (ac-ft)</td>
<td>4.24</td>
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<tr>
<td>25-yr Peak Runoff (cfs)</td>
<td>17.34</td>
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<tr>
<td>25-yr Total Volume (ac-ft)</td>
<td>27.98</td>
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</tr>
</tbody>
</table>

### 2-yr Hydrograph

- Presettlement
- Agricultural
- Existing
- Future

### 25-yr Hydrograph

- Presettlement
- Agricultural
- Existing
- Future
Appendix 4
Porous Pavement

**Type:** Structural, Treatment Control BMP

**Description:** A permeable pavement surface, often built with a underlying stone reservoir that temporarily stores surface runoff before it infiltrates into the subsoil or is released from the site.

**Benefit:** Removal of fine particulates and soluble pollutants through soil infiltration, attenuation of peak flows, reduction in the volume of runoff leaving the site and entering storm sewers, reduction in soil erosion, and groundwater recharge.

**Limitations:** Should only be used in low to medium traffic areas, has a high rate of failure mainly attributed to the pavement having a tendency to clog if improperly installed or maintained.

**Applications:** Medium traffic areas are the ideal application. Suitable for most regions of the country, but cold climates present special challenges.

**Maintenance:** Ensure that paving area is clean of debris and sediments and dewateres between storms. Vacuum sweep frequently to keep surface free of sediments.

**Design Life:** 20 years

**Basis for Cost Estimate:**

**Cost:**
- **Capital Cost:** $2-$8/sft
- **Maintenance Cost:** $200/acre/year

Calculate annualized cost per acre:

Annual Capital Cost = 

Annual Maintenance Cost =

**Pollutant Removal Efficiencies:**
- 95% of total suspended solids (5)
- 65% of total phosphorous (5)

**Pollutant Removal:**
- Calculate Annualized Pollutant Removal per Acre:
  - **TSS Load from 1 acre Site =**
  - **Reduction =**
  - **P Load from 1 Acre Site =**
  - **Reduction =**

**References:**
1.
2.
Green Roofs

Type: Structural, Treatment Control BMP

Description: Building rooftops planted with vegetation. Defined as intensive or extensive depending on the thickness of the soil layer and the plant species supported.

Benefit: Green roofs improve the building’s thermal insulation and energy efficiency, have increased durability and lifespan compared to conventional roofs, and reduce the peak discharge of storm water from roof tops, thereby reducing storm sewer loading, stream bank erosion and flooding.

Limitations: Require drought tolerant plant species or an irrigation system to sustain vegetation. Buildings must be designed to manage the increased load associated with a green roof.

Applications: Can be applied to new construction or retrofitted to existing construction. They are applicable on residential, commercial and industrial buildings with up to a 20 percent slope.

Maintenance: Green roofs need to be monitored regularly to ensure the vegetation survives. Maintenance is similar to any other landscaped area which may include weeding and irrigating during exceptionally dry periods. Other roof maintenance similar to a conventional roof should be expected.

Design Life:

Basis for Cost Estimate:

Cost: Capital Cost: Range from $5.00/sft to $20.00/sft

Maintenance Cost:

Calculate annualized cost per acre:

Annual Capital Cost =

Annual Maintenance Cost =

Pollutant Removal Efficiencies:

Pollutant Removal: Green roofs have the potential to reduce discharge of pollutants such as nitrogen and phosphorous due to soil microbial processes and plant uptake. However, the primary purpose of green roofs is to reduce the peak discharge rate from roof tops, not pollutant removal. The majority of pollutant removal is accomplished when green roofs are used in conjunction with other BMP’s.

References:
1.
2.
Bioretention (Rain Garden)

Type: Structural, Treatment Control BMP

Description: Shallow landscaped depressions used to promote infiltration and evapo-transpiration of storm water runoff. A rain garden combines shrubs, grasses, and flowering perennials in depressions that allow runoff to pool for only a few days after a rain.

Benefit: Achieves fine to coarse particulate pollutant removal, removes nutrients, may enhance the quality of downstream water bodies, and may beautify a neighborhood.

Limitations: Soils adequate for infiltration are required, cold climates may reduce evapo-transpiration and infiltrative capacity, not suitable for slopes greater than 20% (2), pretreatment (sediment basin) needed in high sediment load areas, and cannot be used to treat a large drainage area (>5 acres).

Applications: Use for drainage areas ≤ 5 acres (3), at storm sewer outfalls, and to collect overland flow.

Maintenance: Remove and dispose of sediment, trash, and debris, repair erosion, re-vegetate, and weed, water, and mulch.

Design Life: Assumed 25 years, based on rain gardens installed in the early 1990s in Prince George County, MD which are still functioning.

Basis for Cost Estimate: A rain garden holds and treats the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site. Typical maintenance costs are comparable to those of typical landscaping required for a site.

Cost: Capital Cost: $4/sft

Maintenance Cost: Assume $100/year.

Calculate annualized cost per acre:
Assume 60% Impervious. Capital costs annualized over design life at 4% interest rate.
Volume = (0.5 inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft
Maximum ponding depth is 6 inches (0.5 foot) (2).
Area of Bioretention =1,089 cft/0.5 ft = 2,178 sft

Annual Capital Cost = ($4/sft) * (2,178 sft) = $8,712 * 0.064 = $557

Annual Maintenance Cost = $100

Pollutant Removal Efficiencies:

Pollutant Removal: 90% of total suspended solids. (3)
75% of total phosphorous. (3)

Pollutant Removal: Calculate Annualized Pollutant Removal per Acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 90% = 0.072 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 75% = 0.413 lb

References:
1. Storm Water Technology Fact Sheet Bioretention, 1999
3. Rain Gardens, Beautiful Solutions for Water Pollution
Dry Pond (Sediment Basin)

Type: Structural, Treatment Control BMP

Description: Man-made depression in the ground where runoff water is collected and stored for the minimum amount of time to allow suspended solids to settle out. May have inlet and outlet structures to regulate flow.

Benefit: Achieves medium to coarse particulate pollutant removal by temporarily ponding water, may recharge groundwater, and can provide flood control by including additional flood detention storage.

Limitations: Frequent maintenance required, significant land use requirement, provides only moderate pollutant removal effectiveness, soils adequate for infiltration required if retention is used in design of sediment basin.

Applications: Use for large drainage areas (≥ 1 acre), at storm sewer outfalls, may be included with detention pond, and to collect overland flow.

Maintenance: Remove and dispose of sediment, trash and debris, and repair erosion.

Design Life: Assume 50 years, same as wet pond.

Basis for Cost Estimate: Pond holds the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site.

Cost:
Capital Cost: $0.60/cft of storage volume excluding land purchase. (3)
Maintenance Cost: 7% of capital cost/year. (3)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital costs annualized over design life at 4% interest rate.
Volume = (½ inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft

Annual Capital Cost = ($0.60/cft) * (1,089 cft) = $653.40 * 0.04 = $26.14 = $26

Annual Maintenance Cost = 7% of capital cost = $653.40 * 7% = $45.74 = $46

Pollutant Removal Efficiencies:
50% of Total Suspended Solids (5)
<20% of Total Phosphorous (5)

Pollutant Removal: Calculate Annualized Pollutant Removal per Acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 50% = 0.04 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 20% = 0.11 lb

References:
1. Rouge River National Wet Weather Demonstration Project, 2001
2. Costs of Urban Stormwater Control, 2002
Wet Pond

Type: Structural, Treatment Control BMP

Description: Constructed basins that have a permanent pool of water with emergent wetland vegetation around the bank designed to capture and remove particulate matter and dissolved nutrients. It generally has inlet and outlet structures to regulate flow.

Benefit: Achieves fine to coarse particulate pollutant removal, removes nutrients, decreases potential for downstream stream bank erosion, may create local wildlife habitat, and can be used as a water source for an irrigation system.

Limitations: Frequent maintenance required, significant land use requirement, may need supplement water to maintain water level, potential nuisance (mosquito, odor), may cause increase in water temperature, and can be a safety hazard.

Applications: Use for large drainage areas (≥ 1 acre), at storm sewer outfalls, and to collect overland flow.

Maintenance: Remove and dispose of sediment, trash and debris, and repair erosion. Manage vegetation and inspect for invasive plant species.

Design Life: 50 years (3,6)

Basis for Cost Estimate: Pond holds the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site.

Cost: Capital Cost: $1/cft of storage volume, excluding land purchase. (3)

Maintainance Cost: 5% of capital cost/year. (3)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital cost annualized over design life at 4% interest rate.
Volume = (0.5 inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft
Annual Capital Cost = ($1/cft) * (1,089 cft) = $1,089 * 0.04 = $44
Annual Maintenance Cost = 5% of capital cost = $1,089 * 5% = $54

Pollutant Removal Efficiencies:

- TOD, 80% of total suspended solids (5)
- P, 50% of total phosphorous (5)

Pollutant Removal:

- TSS Load from 1 Acre Site = 0.08 ton/year
  Reduction = 0.08 ton * 80% = 0.064 ton/year

- P Load from 1 Acre Site = 0.55 lb/year
  Reduction = 0.55 lb * 50% = 0.275 lb/year

References:
1. Rouge River National Wet Weather Demonstration Project, 2001
2. Costs of Urban Stormwater Control, 2002
**Constructed Wetland**

**Type:** Structural, Treatment Control BMP

**Description:** Excavated basin with irregular perimeters and undulating bottom contours into which wetland vegetation is placed to enhance pollutant removal from storm water runoff.

**Benefit:** Achieves fine to coarse particulate pollutant removal, removes nutrients, decreases potential for downstream stream bank erosion, and creates local wildlife habitat.

**Limitations:** Frequent maintenance required, significant land use requirement, needs supplement water to maintain water level, potential nuisance (mosquito, odor), and can cause increase in water temperature.

**Applications:** Use for large drainage areas (≥ 1 acre), at storm sewer outfalls, and to collect overland flow.

**Maintenance:** Remove and dispose of sediment, trash and debris, and repair erosion.

**Design Life:** 50 years (3)

**Basis for Cost Estimate:** Wetland holds the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site.

**Cost:**
- Capital Cost: $26,000/acre of wetland excluding land purchase. (3)
- Maintenance Cost: 2% of capital cost/year. (3)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital costs annualized over design life at 4% interest rate.
Volume = (0.5 inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft
Assume wetland is 1 ft deep. Area = (1,089 sft) * (1 acre/43,560 sft) = 0.025 acres

Annual Capital Cost = ($26,000/acre) * (0.025 acres) = $650 * 0.04 = $26

Annual Maintenance Cost = 2% of capital cost = $650 * 2% = $13

**Pollutant Removal Efficiency:**
- TSS Load from 1 acre Site = 0.08 ton/year
  Reduction = 0.08 ton * 80% = 0.064 ton
- P Load from 1 Acre Site = 0.55 lb/year
  Reduction = 0.55 lb * 50% = 0.275 lb

**Pollutant Removal:**
- 80% of total suspended solids (5)
- 50% of total phosphorous (5)

**References:**
1. Rouge River National Wet Weather Demonstration Project, 2001
2. Costs of Urban Stormwater Control, 2002
Vegetated Swale

Type: Structural, Treatment Control BMP

Description: A broad, shallow channel consisting of dense vegetation and designed to accommodate concentrated flows without erosion.

Benefit: Achieves fine to coarse particulate pollutant removal by temporarily ponding water, removes nutrients, and minimal land requirement.

Limitations: Soils adequate for infiltration required to discourage ponding on slopes less than 2%, may require removal of trees and utility poles. If used at a storm sewer outfall (grass channel), phosphorous removal capabilities decrease approximately 20%. (5)

Applications: Use for drainage areas ≤ 5 acres (3), at storm sewer outfalls, and to collect overland flow.

Maintenance: Remove and dispose of sediment, trash and debris, and repair erosion.

Design Life: 50 years (3)

Basis for Cost Estimate: Vegetated swale holds the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site.

Cost: Capital Cost: $0.50/square foot of swale. (1)

Maintenance Cost: $0.03/square foot/year. (1)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital costs annualized over design life at 4% interest rate.
Volume = (0.5 inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft
Assume swale 1.5 ft deep.
Area of swale is 1,089 cft/ 1.5 ft = 726 sft.
Annual Capital Cost = (726 sft) * ($0.50/sft) = $363 * 0.04 = $15
Annual Maintenance Cost = ($0.03/sft) * (726 sft) = $22

Pollutant Removal Efficiencies:
80% of total suspended solids. (5)
50% of total phosphorous. (5)

Pollutant Removal: Calculate Annualized Pollutant Removal per Acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 80% = 0.064 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 35% = 0.193 lb

References:
1. Rouge River National Wet Weather Demonstration Project, 2001
2. Costs of Urban Stormwater Control, 2002
Catch Basin Inlet Devices

Type: Structural, Treatment Control BMP

Description: Devices that are inserted into the storm drain inlets to filter or absorb sediment, pollutants, and sometimes oil and grease. The capture of hydro carbons can be enhanced with the use of sorbents.

Benefit: Achieves fine to coarse particulate pollutant removal, traps trash and debris, minimal land requirements, and flexibility for retrofit of existing systems.

Limitations: Frequent maintenance required.

Applications: Use for catch basins with high pollutant loads.

Maintenance: Remove and dispose of sediment, trash and debris, and change filters as needed (approximately every 6 months).

Design Life: Assumed 5 years

Basis for Cost Estimate: Assume that catch basins placed at standard intervals (every 400 feet) are adequate to treat the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site. Catch basins are placed on each side of the road. In residential areas, 56% and 60% impervious, 2 catch basins service 1 acre. In areas with 100% impervious, 4 catch basins service 1 acre.

Cost:

Capital Cost = $1,500/catch basin (1)
Maintenance Cost = $300/catch basin/year (1)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital cost annualized over design life at 4% interest rate.
2 Catch Basins (1 each side of road) for 272 ft length of 160 ft wide contributing area (roadway, parkway, sidewalk, yard, and 0.5 of house - both sides of road).

Annual Capital Cost: ($1,500/catch basin) * (2 catch basins) = $3,000 * 0.2246 = $674

Annual Maintenance Cost: ($300/catch basin) * (2 catch basins) = $600

Pollutant Removal Efficiencies:
70% of total suspended solids. (1)
<20% of total phosphorous. Assume same as Hydrodynamic Separators.

Pollutant Removal:
Calculate Annualized Pollutant Removal per acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 25% = 0.02 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 20% = 0.11 lb

References:
1. Hydro-Compliance Management, Inc.
Hydrodynamic Separators

Type: Structural, Treatment Control BMP

Description: Precast, flow-through, underground units that capture sediments, debris, and oils (in some units). The capture of oils can be enhanced with the use of sorbents. (CDS, Vortechs, Downstream Defender, Stormceptor)

Benefit: Achieves medium to coarse particulate pollutant removal, traps trash and debris, prevents release of trapped pollutants, hidden from view, and suited for areas with limited land available.

Limitations: Frequent inspections and maintenance required, and expensive to install and maintain.

Applications: Use for small drainage areas (≤ 1 acre) with high pollutant loads, in-line with storm sewer system, and to collect overland flow.

Maintenance: Remove and dispose of sediment, trash and debris.

Design Life: 30 years (1)

Basis for Cost Estimate: Hydrodynamic separators treat the first 0.5 inch of runoff from the directly connected impervious area in a 1 acre test site. Assume a hydrodynamic separator is installed in lieu of a manhole. The cost of the separator is only the addition cost above the installation costs of a manhole applied after determining the total capital cost of the unit. Typical manhole costs = $2,000/each. Flow rates based on rational method assumptions.

Cost: Capital Cost: $6,000/cfs capacity (2)

Maintenance Cost: $1,000/year (2)

Calculate annualized cost per acre:
Assume 60% Impervious. Capital cost annualized over design life at 4% interest rate.
Volume = (0.5 inch runoff) * (1 acre) * (60%) * (1ft/12 in) * (43,560 sft/acre) = 1,089 cft
Calculate flow rate generated from 0.5 inch of runoff over 1 acre. Assume 15 minute time of concentration.
(1,089 cft/15 minute) * (1 min/60 sec) = 1.2 cfs
Annual Capital cost = ($6,000/cfs * 1.2 cfs) - $2,000 = $5,200 * 0.0578 = $301
Annual Maintenance Cost = $1,000

Pollutant Removal Efficiencies:
60% of total suspended solids. (1)
<20% of total phosphorous. (3)

Pollutant Removal: Calculate Annualized Pollutant Removal per Acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 25% = 0.02 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 20% = 0.11 lb

References:
Catch Basin Cleaning

Type: Managerial, Source Control BMP

Description: Catch basins are periodically inspected and cleaned out using a vacuum truck.

Benefit: Reduces pollutant slugs during the first flush, prevents downstream clogging, and restores sediment trapping capacity of the catch basin.

Limitations: Frequent inspection is important to identify areas with increased pollutant loads and the need for an accelerated cleaning program.

Applications: All catch basins.

Design Life: Assume 10 years for vactor truck.

Basis for Cost Estimate: A vactor truck will clean catch basins 6 months (26 weeks) per year, 5 days per week, and assumed 24 catch basins/day = 3120 catch basins/year. In residential areas, 56% and 60% impervious, 2 catch basins service 1 acre. In areas with 100% impervious, 4 catch basins service 1 acre. Assume each catch basin cleaned once per year. Maintenance of the vactor truck is included in the capital cost. Catch basin cleaning is a maintenance activity, so no additional maintenance costs are associated with this BMP.

Cost: Calculate annualized cost per acre:
Assume 60% Impervious.
Capital cost for vacuum truck (vactor truck) is $200,000. (3) The capital cost annualized over design life at 4% interest rate is $24,660.

Cost of vactor truck per catch basin: ($24,660/year) * (1 year/3120 catch basins) = $8 catch basin. Cost of cleaning is $40/catch basin (including contractor cost and disposal in an approved landfill) (5).

Total annual cost per catch basin = ($8/catch basin) + ($40/catch basin) = $48/catch basin.
Total annual cost per acre = ($48/catch basin) * (2 catch basin/1 acre) = $96/acre

Pollutant Removal Efficiencies: Assumed 25% of total suspended solids.
Assumed <20% of total phosphorous.

Pollutant Removal: Calculate Annualized Pollutant Removal per Acre:
TSS Load from 1 acre Site = 0.08 ton/year
Reduction = 0.08 ton * 25% = 0.02 ton

P Load from 1 Acre Site = 0.55 lb/year
Reduction = 0.55 lb * 20% = 0.11 lb

References:
Storm Sewer Inspection/Maintenance

Type: Managerial, Source Control BMP

Description: Storm sewers are periodically inspected and cleaned out using a vacuum truck.

Benefit: Reduces pollutant slugs during the first flush, improves capacity by removing sedimentation, and removes debris.

Limitations: Frequent inspection is important to identify areas with increased pollutant loads and the need for accelerated cleaning program.

Applications: All storm sewer.

Design Life: Assume 10 years for vactor truck.

Basis for Cost Estimate: Assume a vactor truck will clean storm sewer 6 months (26 weeks) per year, 5 days per week, and (3000 ft/day) / (8 hours/day) = 375 ft/hour = 390,000 ft of storm sewer/year.

Cost: Capital cost for vactor truck is $200,000. (5) The annualized cost over the design life at 4% interest is $24,660.

Cost of vactor truck per ft of storm sewer: ($24,660/year) * (1 year/390,000 ft storm sewer) = $0.06/ft storm sewer.

Labor and disposal cost = $0.28/lf
Total cost per ft of storm sewer = ($0.06/ft of storm sewer) + ($0.28/lf of storm sewer) = $0.34/lf of storm sewer.

Assume 60% Impervious.
Assume 272 lf of storm sewer services 1 acre.
(272 lf road runoff) * (160 ft wide streetscape) = 43,520 sft * (1 acre/43,560 sft) = 1 acre.

Total annual cost per acre = ($0.34/lf storm sewer) * (272 lf storm sewer/1 acres) = $92.48/acre

Pollutant Removal Efficiencies: 15% of total suspended solids (60% removal of grit (2), assume 25% of TSS is grit). Assume <20% of total phosphorous.

References:
4. Pollution Prevention/Good Housekeeping for Municipal Operations
Appendix 5
BMP Benefits Calculator

Low Impact Development Hydrologic Analysis (SCS-92 Method)

PROJECT: GVSU Stormwater management plan
FTC&H JOB #: G06834
DATE: 4/30/2007
PROJECT ENGR: SDT
LOCATION: Ottawa county, Michigan

Total Area of Development (ac) 4.83
Hydrologic Soils Group C
Time of Concentration (hr)
Predeveloped = 0.50
Developed = 0.25
Low Impact Development = 0.25

Predevelopment Summary

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<th>% Total Area</th>
<th>SCS CN</th>
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<td>Woods or forest land</td>
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Development Summary

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<th>% Total Area</th>
<th>SCS CN</th>
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<td>Impervious (paved, roof, concrete, etc.)</td>
<td>42</td>
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<tr>
<td>Open (lawns, parks, etc.) - good</td>
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Best Management Practice

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<th>Area (sf)</th>
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<tr>
<td>Porous Pavement</td>
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<td>Green Roofs</td>
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<tr>
<td>Rain Gardens</td>
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Results:

Storm Event

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<th>Rainfall (inches)</th>
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<th>2-yr</th>
<th>10-yr</th>
<th>25-yr</th>
<th>100-yr</th>
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</thead>
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Predeveloped

- Composite Curve Number: 73.0
- Average Runoff (inches): 0.30, 0.50, 1.19, 1.86, 3.21
- Discharge (cfs): 0.95, 1.59, 3.79, 5.91, 10.22
- Volume (ac-ft): 0.12, 0.20, 0.48, 0.75, 1.29

Developed

- Composite Curve Number: 84.1
- Average Runoff (inches): 0.71, 1.02, 1.96, 2.78, 4.35
- Discharge (cfs): 4.00, 5.73, 11.00, 15.60, 24.39
- Volume (ac-ft): 0.29, 0.41, 0.79, 1.12, 1.75

Low Impact Development

- Composite Curve Number: 79.3
- Average Runoff (inches): 0.50, 0.77, 1.60, 2.36, 3.84
- Discharge (cfs): 1.73, 2.64, 5.79, 9.06, 16.06
- Volume (ac-ft): 0.20, 0.31, 0.64, 0.95, 1.55
Appendix 6
## PRELIMINARY PROJECT COST ESTIMATE

### Radio Tower Wetland Complex

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip and Respread Topsoil</td>
<td>20,200 CY</td>
<td>$7.00</td>
<td>$141,400</td>
</tr>
<tr>
<td>Excavation (1),(2)</td>
<td>100,800 CY</td>
<td>$5.00</td>
<td>$504,000</td>
</tr>
<tr>
<td>Wetland Plantings (3)</td>
<td>25 AC</td>
<td>$3,500.00</td>
<td>$87,500</td>
</tr>
<tr>
<td>Storm Sewer (4)</td>
<td>1,000 LF</td>
<td>$120.00</td>
<td>$120,000</td>
</tr>
<tr>
<td>Wetland Overflow Control Structures</td>
<td>1 LS</td>
<td>$25,000.00</td>
<td>$25,000</td>
</tr>
<tr>
<td>Boardwalk</td>
<td>1,000 LF</td>
<td>$300.00</td>
<td>$300,000</td>
</tr>
</tbody>
</table>

**Construction Sub-Total** = $1,177,900

**Engineering & Contingencies** = $412,265

**Estimated Total Project Cost** (5) = $1,590,165

### Notes:

1. Excavation volume based on an average depth of 2.5' over 25 acres assuming 6" topsoil stripped and spoil graded onsite.
2. MDEQ estimated excavation costs range from $3 to $5 per cubic yard.
3. MDEQ estimated cost of wetland plantings range from $3,500 to $9,000 per acre.
4. Includes storm sewer pipe and manholes for diversion, restoration over pipe.
5. Does not include legal, administrative or financing costs.