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Implementation of Rain Gardens as Alternative Stormwater Management in the Saratoga Lake Watershed

Abstract

Rain gardens are modeled to reduce stormwater runoff or residential developments by 42-80%. Within Saratoga Lake Watershed, 88% of existing residences contain soils suitable for rain garden implementation and 91% of existing residences are located on such soils. Government regulation or economic benefit is necessary to incentivize developers. Successful implementation examples are required to convince engineers to implement rain gardens.

Introduction

Increasing urban populations and the spread of urban development in the United States is placing greater pressures on environments. Basic features of urban development include uniform slopes that replace varying landscapes, loss of vegetation, and impervious surfaces that replace permeable surfaces. These changes impact the way water moves in a watershed, as well as the presence of pollutants in the water (Department of Environmental Resources June 1999). Conventional methods of conveying and collecting stormwater are hydrologically and environmentally problematic and are costly to both developers and municipalities. Low Impact Design (LID) alternatives are low-cost, environmentally appropriate solutions.

Urbanization alters hydrology, the movement of water. Before urbanization, stormwater flows through ecosystems, including fields and forests, and drains into the underlying aquifer through infiltration, or into a surface water body through surface runoff. In Eastern hardwood forests, 40% of water exits the system through evapotranspiration, 50% through subsurface flows, and less than 10% as surface runoff volume (Department of Environmental Resources July 1999). Groundwater typically moves several orders of magnitude slower than surface runoff. Streams that receive their water primarily from groundwater have a relatively long lag time between precipitation event and peak flood, low intensity floods that are long in duration, and high base flow during times of little rain (Dunne and Leopold 1978).

These runoff patterns change with construction and development of typical urbanization projects, including roads and buildings. These impervious surfaces decrease groundwater infiltration and increase runoff, resulting in a shorter lag time between precipitation event and peak flood, high intensity floods that are short in duration, and low base flow during times of little rain. With 20% more impervious surface in an area, runoff amount, on average, doubles (Pers. Comm. Neils, Feb. 9, 2010). Altering sites with urban development projects changes runoff patterns that "can cause an increase in the volume and frequency of runoff flows (discharge) and velocities that cause flooding, accelerated erosion, and reduced groundwater recharge" (Department of Environmental Resources June 1999: 4). Along with altered hydrology, pollutants enter the water system. Sediments, nitrogen, phosphorus, gasoline, and heavy metals are pollutants that can be collected in stormwater runoff from cars, fertilized lawns, buildings and paved surfaces[1] (Dietz, 2005). More impervious surfaces results in increased surface runoff, along with accumulated pollutants in water bodies.

Current stormwater standards, as outlined in the New York State Stormwater Management Design Manual (2003), offer solutions for conveying and collecting runoff most commonly by means of catch basins, underground piping and retention ponds. These systems are commonly referred to as "end of pipe" treatment, where water is transported away from a site to a holding pond, then eventually released into the watershed. They allow for little on-site infiltration or localized groundwater recharge, and are increasingly becoming burdens for local governments who must inspect and maintain these systems (Department of Environmental Resources July 1999). According to the New York State Department of Environmental Conservation's (DEC) Stormwater Design Manual (2003), the authority on the matter for the State of New York, slow infiltration through the soil is essential for replenishing groundwater and groundwater is a "critical water resource across the State. Not only do many residents depend on groundwater for their drinking water, but the health of many aquatic systems is also dependent on its steady discharge" (2-7). Current standards do not encourage this infiltration at every part of the system.

[1] For more information on pollutants and water quality issues related to urbanization, refer to the University of Connecticut's study, (1994) "Impacts of Development on Waterways", www.mainenemo.org/publication/NEMOfact3.pdf and Lena et al. (2008), "Assessing Stormwater Runoff and Policy in the Kayderosseras Watershed, New York".

The United States Environmental Protection Agency (EPA) has issued a menu of LID options to address the issues of quantity and quality of stormwater runoff associated with urbanization and to encourage appropriate means of mitigating the negative effects of urban development on watersheds, including methods that allow on-site infiltration (US EPA 2009). According to the U.S. Department of Housing and Urban Development, LIDs "use various land planning and design practices and technologies to simultaneously conserve and protect natural resource systems and reduce infrastructure costs" (2003: ix). Post-construction LIDs include rain gardens, grassed waterways, porous pavement, and cisterns, among others (US EPA). We focus on rain gardens in this paper. Rain gardens allow for stormwater runoff to infiltrate into the soil, entering the groundwater rather than becoming surface runoff.

Saratoga Lake Watershed

Saratoga Lake covers 5.8 square miles and is located in Saratoga County, NY. It is an important water resource both for surrounding municipalities and biodiversity, making its water quality critical to local residents, summer tourists, and plant and animal populations. Its 244 square mile watershed encompasses 12 municipalities. For the past 20 years, Saratoga County has been the fastest growing county in the state, increasing in population over 30% annually (US Census Bureau 2000). This development growth results in more impermeable surfaces and associated runoff.

The most common forms of development in the watershed are new houses and subdivisions, and growing urban centers. The aforementioned growth rate continually transforms forest into urban land. Particularly considering the upcoming construction of the Advanced Micro Devices, Inc. computer chip manufacturing plant in Malta, urban area will continue to grow and negatively impact hydrology. Quentin and Siegwrath (2007) determined that 56% of the watershed has the potential to be developed. Rain gardens and other LIDs can be implemented to reduce the injurious effects of these developments.

The problem here is how to best implement these measures. In 2003, regulation of stormwater became required of small cities, including Saratoga Springs, through Phase II of the Municipal Separate Storm Sewer System

(MS4). Cities are required to review permits, monitor construction and discharges, and raise awareness. The County of Saratoga has a Stormwater Management office that oversees stormwater within the county, a significant part of the watershed. Saratoga Springs has no department of stormwater management to focus on implementation of these issues. Nor does it currently have the funding for this department, a cost estimated by the EPA to range from $125,000 - $500,000 annually (Ruschp et al. 2009). In other towns, success at establishing more proactive stormwater management programs based on LID was initially achieved by gaining funding, usually through a utility tax. Education programs also raised public understanding and support (Ruschp et al. 2009). Implementation of LID methods, including rain gardens, offers one potential solution to this problem.

Rain Gardens

Rain gardens are a stormwater management LID practice that more closely replicate pre-development hydrology than end of pipe systems. Rather than directing all the stormwater in a development to a single centralized retention basin, stormwater runoff from roofs and roads are directed to many decentralized rain gardens and other LID methods throughout the development. Rain gardens allow for stormwater to infiltrate into the ground rather than flow as surface runoff.

Rain gardens consist of water-intensive plants in a shallow depression that combine water infiltration and bio-geochemical processes to remove pollutants (New York State Stormwater Management Design Manual 2003). They are placed in areas conducive to water runoff, usually adjacent to a house or parking lot, and are sized based on the amount of water runoff available. Depending on the garden and water conditions, the runoff usually takes one or two days to completely infiltrate the soil or piping below (Southeastern Oakland County Water Authority 2006). The bottom layer is typically gravel to allow infiltration into the underlying soil, a layer of soil and mulch, and a vegetative top layer that range from wildflowers to shrubs. Geographic location is a large determinant for the type of plants appropriate for a rain garden. New York State estimates the cost to be $10 - $12 per square foot of garden (New York State DEC 2003).

Maintenance is similar to that of other landscaped areas, establishing plants and weeding and pruning when necessary. With the use of perennial trees and shrubs, maintenance can be less than the average garden bed of annuals.

The type of soil, e.g. clay or sandy, is an important factor in considering how the water will infiltrate, how the garden should be designed, and where it should be placed to maximize infiltration. Well-draining soils that infiltrate water quickly are important for attenuating large rainfalls. Geologists classify permeability of soils as Type A, B, C, or D. Type A soils, typically consisting of well sorted gravel or fractured rock, indicate very high permeability rates and Type D soils, typically consisting of unweathered clay or bedrock, indicate very low permeability rates (Dunne and Leopold 1978). Rain gardens are typically suitable on Type A or B soils that allow water to infiltrate relatively quickly.

Numerous public resources have become available regarding the effectiveness and construction techniques for rain gardens and there have been many efforts across the country to integrate rain gardens as a means of stormwater management. For example, in Burnsville, Minnesota, a paired watershed study was conducted to test the effectiveness of rain gardens. In 2004, a subdivision in the Crystal Lake watershed was divided in half – the control retained traditional stormwater management methods, while the experimental half was retrofitted with rain gardens. Costing only $12.50 per square foot, the 17 rain gardens constructed reduced stormwater runoff by 90% (Barr Engineering Group 2006). More locally, in 2009, Environmental Studies students at Skidmore College constructed a rain garden to capture run-off from the Tang Teaching Museum and Art Gallery. The site was chosen based on soil availability and proximity to a building. The Saratoga Lake watershed can use these sites as models for installing effective rain garden programs.

The aim of this study is to further the progress made in recent years by exploring implementation of rain gardens as an effective stormwater management technique in the Saratoga Lake watershed. Rain gardens are a less expensive[2], more aesthetically pleasing and more environmentally friendly method of stormwater management than

[2] For more information regarding the economics of LIDs, refer to Woosnik et al. (2003) The Economics of Structural Stormwater BMPs in North Carolina. North Carolina State University.

conventional methods. Rain gardens unite public space with municipal and private action in creating real alternatives for the negative effects of stormwater runoff. But it is a new and emerging technology that has not yet been embraced by the general public and private developers. This study will assess the local development of rain gardens through identifying specific potential rain garden locations and the potential hydrological impact rain gardens could have within the Saratoga Lake Watershed

Methods

Information about current stormwater management practices in the area was gathered from previous studies and personal interviews. Interviews qualitatively clarified the realities of implementing rain gardens in the Saratoga Lake watershed, and provided recent updates that postdate the literature. Interview subjects were:

- Mike McNamara, P.E., project engineer for Environmental Design Partnership, LLP (EDP)
- Travis Mitchell, P.E., project engineer for Environmental Design Partnership, LLP
- Blue Neils, Saratoga County Intermunicipal Stormwater Coordinator

The interviews provided expert knowledge of stormwater management in the watershed to determine feasibility of creating rain gardens at specific sites. Background literature of federal/state legislation, academic studies and case studies of similar-size cities with successful rain garden implementation, such as Lansing, Michigan, provided successful examples of methodologies and implementation of rain gardens in other watersheds.

The recently constructed Wiebicke housing development site located along Hoffman Road in Milton, New York was chosen for the study site. It consists of fourteen single-family houses, some of which have not been built as of May 2010. The eight lots west of Hoffman Road, the adjacent detention pond, and the 550 feet of new proposed roadway, were the focus area for the study. According to the Stormwater Management Narrative by EDP, the soils in this area are between Class A and B soils, with "moderately drained sands in the upper two feet [and] poorer drained silt below that depth" (EDP 2004). There are four catch basins which convey stormwater runoff through 560 feet of underground piping into the retention pond at the bottom of the site (see Appendix B).

This site was analyzed for rain garden potential to serve as a typical development in the Saratoga Lake watershed. On April 10, 2010, an infiltration test was conducted on this site to determine the infiltration capacity of the soils. We used a rainfall simulator to apply precipitation to a circular test area with a diameter of one meter. Water was sprayed evenly throughout the test area, as well as beyond to reduce capillary action. Three rain gauges recorded precipitation depth. Runoff was collected in a container and poured into a graduated cylinder to determine volume. We recorded measurements of precipitation and runoff every five minutes. We calculated infiltration capacity of the soil by subtracting depth of runoff - found by dividing volume of runoff by area of study - from depth of precipitation.

Computer modeling was used to compare hydrological runoff differences between rain gardens and traditional techniques in developed areas. HydroCAD was used to model the hydrology of the parcel, comparing current forms of stormwater management to the effect of rain gardens. This is a program that most all stormwater engineers use to determine sizing and appropriate technologies of stormwater systems. We used EDP's HydroCAD data to replicate their analysis and to compare rain garden hydrology. See Appendix B for a full description of the nodes.

The LID HydroCAD model consisted of the same subcatchment and detention pond assumptions used for the existing site conditions. Grassed channels were added to convey stormwater inflow into the "rain gardens" using a Manning's coefficient of 0.03 for grassed and winding earth,[3] and a slope of 0.01. The "rain garden" nodes had a ponding depth of 4 inches, with additional 4 feet of infiltrating soil beneath. The infiltration rate for the rain gardens was informed by the infiltration test performed on site. See Appendix B for a full description of the nodes.

[3] This is a coefficient that relates surface type (e.g. roads, grass and forest) to the resistance of flow over the surface.

Geographic Information Systems (GIS) was used to delineate subwatersheds in the Town of Milton and to analyze soil permeability types and current land use in the Saratoga Lake watershed. ArcHydro, a component of GIS, was used to delineate subwatersheds in Milton. A 10-meter raster DEM data set from the USGS was used for this purpose. Soil data from the USGS provided data about the surficial geology and soil permeability types of the region. Soil permeability types were compared to locations of residential lots less than two acres, defined as family residences in the parcel data of the 2000 Census.

Results

Infiltration Test

During the infiltration test, 2.53 in of precipitation was simulated over an 85-minute time period, producing 0.18 in of runoff. This data equates to an infiltration rate of 1.66 in/hour. Because this test was performed in April, this rate is likely an underestimate throughout much of the year when the ground is not saturated. However, data for April is good to use when planning stormwater management because that is when the majority of floods occur.

HydroCAD

The 5-year storm model hydrograph comparison shows the primary outflow from existing stormwater management conditions has a peak outflow rate of 0.05 cubic feet per second (cfs) at 20 hours, while the rain garden model has a peak outflow rate of 0.01 cfs at 24 hours (Figure 1, Appendix A). Wiebicke Existing conditions produce a total outflow volume of 54.3 meters^3 (m^3) and the rain garden model produces a runoff volume of 11.1 m^3, 80% less than Wiebicke Existing (Figure 5, Appendix A).

The 10-year storm model hydrograph comparison shows the primary outflow from existing stormwater management conditions has a peak outflow rate of 0.21 cfs at 14 hours, while the rain garden model has a peak outflow rate of 0.07 cfs at 16 hours (Figure 2, Appendix A). Wiebicke Existing conditions produce a total outflow volume of

185.02 m^3, while the rain garden model produces an outflow volume of 85.11 m^3, 54% less than Wiebicke Existing (Figure 5, Appendix A).

The 25-year storm model hydrograph comparison shows the primary outflow from existing stormwater management conditions has a peak outflow rate of 0.64 cfs at 13 hours, while the rain garden model has a peak outflow rate of 0.23 cfs at 14 hours (Figure 3, Appendix A). Wiebicke Existing condition produce an outflow volume of 339.2 m^3 and the rain garden model produces an outflow volume of 171.4 m^3, 49% less than Wiebicke Existing (Figure 5, Appendix A).

The 100-year storm model hydrograph comparison shows the primary outflow from existing stormwater management conditions has a peak outflow rate of 1.52 cfs at 13 hours, while the rain garden model has a peak outflow rate of 0.69 cfs at 13 hours (Figure 4, Appendix A). Wiebicke Existing condition produce an outflow volume of 514.4 m^3 and the rain garden model produces an outflow volume of 292.3 m^3, 43% less than Wiebicke Existing (Figure 5, Appendix A).

The Wiebicke Existing Conditions and the rain garden model generate between 43% and 80% difference between the volume outflows from the two site technologies with intensifying storm events (Figure 5, Appendix A).

Sub Watersheds

For the Town of Milton, we identified 66 sub watersheds, which have an average size of 300 acres, ranging from 30 to 1000 acres (Figure 6, Appendix A). For the northeast quarter of Milton, where Wiebicke is located, we identified 104 sub watersheds of a smaller scale (Figure 7, Appendix A). These catchments range in size from 2 – 380 acres, averaging 61 acres/sub watershed.

Regional Soils

Saratoga Lake Watershed is composed of 11 types of surficial geology, primarily glacial and periglacial sediment deposits, including lacustrine sand, glacial till, lacustrine delta, fluvial sand, outwash sand and kame deposits (Figure 8, Appendix A). These deposits were left by glaciers and associated forces 10,000 – 15,000 years ago. The lacustrine sand deposit that composes much of Milton's surficial geology is a result of sediment deposits in Glacial Lake Albany, which was formed 15,000 years ago when glacial debris dammed glacial meltwater. The sediments deposited by the glacial outwash are apparent as a north-south deposit of outwash sand which formerly flowed south into Glacial Lake Albany. Generally, soils with such glacial deposits are highly permeable.

Each surficial geology deposit is composed of multiple soil types. We identified 120 different soil types of varying permeability types in Saratoga Lake Watershed. Concerning rain garden implementation, the most important aspect of soil types is their permeability. Saratoga Lake Watershed is composed of 60 square miles, or 25%, of Type A soils and 69 square miles, or 28%, of Type B soils, totaling 129 square miles of highly permeable soils, or 53% of the watershed (Figure 9, Appendix A). There are 13.0 mi^2 of residential lots under two acres within the watershed. An impressive 11.5 mi^2 of these lots, or 88%, are located on highly permeable soils.

Milton's soils are composed of 14 square miles, or 39%, of Type A soils, and 11 mi^2, or 30%, of Type B soils, totaling 25 square miles, or 69% of the town (Figure 10, Appendix A). There are 3.2 mi^2 of residential lots under two acres within Milton. An impressive 2.9 mi^2 of these lots, or 91%, are located on highly permeable soils.

Interview

We interviewed Mike McNamara, P.E. and Travis Mitchell, P.E., stormwater project engineers at Environmental Design Partnership (EDP) in Clifton Park, NY. Mr. McNamara was part of the design team on the Wiebicke development. Mr. McNamara described the initial site design process:

> "Normally a developer will come to us and they purchase a piece of land, and obviously they are interested in what the zoning allows them to do and will develop a 2-D sketch of a lot layout and a road layout, see what they can get for it – and

> stormwater is usually fit in after that with the available space that's left over…They [the site developers] are not very interactive in it at all." (Pers. Comm. McNamara, April 2, 2010)

Mr. Mitchell continued, "Stormwater is low on their [developers'] priorities" (Mitchell, T. Pers. Comm. April 2, 2010). Developers invest in the property intending to maximize profits and, other than practices that may add to aesthetic value, are generally unreceptive to things that will add to cost. "If Low Impact Design is not a requirement…it's all going to come down to cost. If it's more cost effective to go with LID, they [developers] will go with it," Mr. Mitchell added (Pers. Comm. Mitchell, April 2, 2010).

The standard treatment for stormwater currently involves a series of catch basins piped underground to a retention facility, usually a pond, which releases the water gradually into the surrounding watershed. This is called "end of pipe "management (McNamara, M. Pers. Comm. April 2, 2010). Design guidelines are given by the New York State DEC's Stormwater Design Manual which the developers and engineers must adhere to. "That's the mandate," said Mr. McNamara. "HydroCAD drives everything" to draft the final site design (Pers. Comm. McNamara, April 2, 2010). The computer models can be manipulated based on different assumptions used. The manipulations, such as infiltration capabilities of a site, can lead to exaggerated results and very different models of the same site. During this process, "you have five different people yelling at you, and they all want different things, and I try to make them all happy, as best that I can", said Mr. McNamara. Designs are typically conservative to over-compensate for potential storm runoff and assuage any liability concerns. Models can double and double again in size by the time of construction. At the end of the day, "it's all about liability. That's what drives us. It will fail some day and, ultimately, if that stuff doesn't work the water is going to have to find a way out – through somebody's basement?" (Pers. Comm. McNamara, April 2, 2010).

Over time, the standards for stormwater management have evolved. In the 1970's, it was common practice to discharge directly into a water source. That would be highly scrutinized by today's standards. "Ultimately you want to protect the pond and the river," said Mr. McNamara (Pers. Comm. McNamara, April 2, 2010). Retention pond facilities, a practice that became commonplace in the 1990's, collect and slowly release collected stormwater into the watershed. Mr. McNamara sees this practice and other new standards as hydrologically beneficial:

> "Oh, there's no question there's a benefit. When you develop a site, you put a bunch of pavement in it, you're going to get more runoff, more volume, because what used to go into the ground is now on the surface, and it's going to get there faster because water runs along pavement much faster than if it's going through the woods. So those two combinations are bad impacts on everyone downstream. So if you were at the downstream end of a stream and everyone develops up, you're going to get flooding that you never used to get" (Pers. Comm. McNamara, April 2, 2010).

The political conditions give guidelines to how stormwater management is done. A site developer pays the construction costs for the system, and it is maintained by the municipality over the lifetime of the system. Town planning boards oversee the project designs. If a planning board is unfamiliar with LID practices, someone will have to familiarize and convince them to integrate these practices into the town standards. "A lot of the time, the developer doesn't want to go through the effort of convincing the town that they want it," said Mr. Mitchell (Pers. Comm. Mitchell, April 2, 2010). Also, town engineers are sometimes conservative and will enforce a certain size (usually larger) despite any modeling to try diminishing any stormwater problems:

> "[If the] town of Milton is pissed off because of flooding five years-ago, and they're going to make me use a 30" pipe anyway…it doesn't necessarily save money if one of the five people yelling at me says I got to use this [rain garden design]" (Pers. Comm. McNamara, April 2, 2010).

The EDP engineers described two ways in which LID's would become incorporated into development projects on a large scale: a legislative mandate from the New York State Department of Environmental Conservation or local authorities, or a developer who risks the financial uncertainty and shows the usefulness and cost-efficacy of LID initiatives.

Financial considerations are a major part of every project, "ultimately, the profit motive is the best way to motivate people…the bottom line is the dollar," said Mr. McNamara (Pers. Comm. McNamara, April 2, 2010). Any extra expense is eventually included in the price tag of the house. Homeowners will then assume the financial burden of costly practices. In this way, homeowners and the public must also want to pay for LID techniques used for their homes and community.

The engineers also raised concerns over hydrological conditions. Infiltration conditions change over the year, and may not attenuate the stormwater inflow, even if the computer models show that it does. Additionally, good land is harder to find. Developments are increasingly placed in “clay soils where you can’t get any infiltration in. If you want to call it a rain garden and get credit as a stormwater device, you’ve got to have the good soils for it, if not you can’t use it…Now a lot of sites have clay or silty soils” (Pers. Comm. McNamara, April 2, 2010).

Academic studies are important to the engineers but generally do not include the full context of the political, geological and financial conditions that make each development site and case study unique. Rain gardens (and other LIDs) do not apply everywhere. Mr. Mitchell stated, “You can’t just universally say, ‘I’m doing rain gardens and they work better across the board’” (Pers. Comm. Mitchell, April 2, 2010).

In addition to the financial and political hurdles, and concerns of surficial geology, the EDP engineers were skeptical of the usefulness of rain garden and other LID technologies. They claimed if a development site is small enough and infiltration takes place in one corner of the site where the retention pond is located, the water is infiltrating into the same aquifer it was pre-development. The engineers didn’t see a benefit of infiltrating at each lot individually. They anticipated increased burdens on the town and homeowners because, “Now, instead of three stormwater management basins that the town might own you’ve got eighty rain gardens that the homeowners own and maintain,” Mr. Mitchell added (Pers. Comm. Mitchell, April 2, 2010). The homeowner now has responsibility to maintain the rain garden, and the town has the responsibility to monitor them. If the homeowners fail to maintain the gardens, then the stormwater purposes are lost. It is the engineers’ responsibility to develop lasting management and if the rain gardens are not there in twenty years, they would be liable. Also, roads have to be considered into the equations. Roads are one of the major causes of runoff in a development and rain gardens might not totally capture and retain the road flow in all storm conditions.

The engineers viewed open ditches, also referred to as grassed waterways that serve to transport water while infiltrating, as problematic. Site layout and grading make ditches difficult to effectively implement and homeowners may fill in the ditch with leaves or earth, changing its usefulness. Winter snow build-up and spring rains may also hinder the effectiveness of open ditches.

The engineers see potential for LID techniques working complementary, through a "combination of a lot of different technologies" (Pers. Comm. Mitchell, April 2, 2010). These include structural things such as rain gardens and cisterns, and regulatory policies such as road width. There is "no one magic bullet" (Pers. Comm. McNamara, April 2, 2010).

Ultimately, "it's got to fit the site – whatever you want to use – it's got to fit the site", concluded Mr. McNamara (Pers. Comm. McNamara, April 2, 2010).

<u>Discussion</u>

We assessed the hydrological conditions of Wiebicke Court, a recent development in Milton, to serve as a typical development site in the Saratoga Lake Watershed. An infiltration test produced an infiltration rate of 1.7 in/hr. We used this rate to model the discharge from the site associated with 5-, 10-, 25-, and 100-year storm events for both the existing stormwater management conditions and a model that included rain gardens. The HydroCAD model predicted 43-80% less runoff associated with the model that includes rain gardens. Spatial distribution of permeable soils suitable for rain gardens and location of current residences were analyzed in GIS. In the Saratoga Lake Watershed, 53% of the soils are suitable for rain gardens and 88% of residential homes are located on these soils. In Milton, 69% of the soils are suitable for rain gardens and 91% of residential homes are located on these soils. We then talked to the site engineers, who shared concerns from their perspective regarding the practicality of rain garden implementation.

When used effectively, rain gardens have the potential to appreciably reduce stormwater runoff from developed residential areas.

Current stormwater management practices apply the same principles to every site, implementing catch basins, sewers, pipes, and retention ponds. While these components are applied differently to each site depending on topography and total area, the same general management practices are applicable in all instances, regardless of site specific factors, such as soil type or permeability.

Rain gardens, however, are not a blanket solution to stormwater management that can be applied on all developed sites across the board. They must be implemented on an individual basis to each site. Rain gardens are generally applicable to highly permeable Type A or B soils. An infiltration test must then be performed to determine actual rates of infiltration. In addition, topography must be suitable for rain gardens; they must be sited in a flat and shallow depression that is down gradient of the runoff source. Taking these factors into account, some locations will not be suitable for rain gardens and other LID approaches or current management practices will have to be used instead.

Different rain garden uses work best at different sites. On highly permeable soils, runoff from houses, which represent 45% of the impermeable surfaces in our study area, can be infiltrated into the lawn without the implementation of rain gardens. At these sites, rain gardens are better used to absorb runoff from the roads and driveways, which represent 55% of the impervious surfaces in our study area. Current practices channel runoff along impermeable roads into closed pipes, not taking advantage of any potential infiltration or evaporation until runoff is finally discharged into a retention pond. By diverting the runoff to rain gardens, open grass waterways, and rectangular weirs, the HydroCAD models show that stormwater runoff is reduced by 43-80%, depending on the magnitude of the storm event (Figure 5, Appendix 1).

On soils with low permeability rates, such as clay or silty soils, rain gardens may instead be used to address runoff from houses. While the infiltration rates do not allow for infiltration of street runoff, they may allow for infiltration from smaller individual sources, such as homes. Without the use of rain gardens, much of the runoff likely flows across the lawn into the street, where it is directed into the nearest retention pond. That said, most of the residences within Saratoga Lake Watershed are located on highly permeable soils, likely because nice soils are a desirable trait for construction of and living in a house. This result implies that most of the well drained soils may already be developed, while undeveloped areas are on poorly drained soils. This coincides with NYSDEC Stormwater Management Design Manual's recommendation for rain garden as redevelopment projects rather than initial development projects, due to the fact that the effectiveness of rain gardens has yet to be established (New York State DEC 2003). During redevelopment projects within the watershed, most existing residential areas contain soils suitable for rain garden implementation. Such implementation would decrease the amount of runoff from a storm into nearby streams, allowing precipitation to instead enter the groundwater.

While located on well draining soils, the HydroCAD models show that rain gardens and grassed waterways could not fully capture all of the stormwater runoff. There were significant losses in runoff recorded, but in no storm event was 100% of the runoff attenuated. For Wiebicke, rain gardens would not be a total replacement for the stormwater management system. However, the significant losses in runoff predict that the Wiebicke development and other similar housing developments could totally attenuate the stormwater runoff with a combination of LID technologies, including rain gardens. Changing from the catch basin and retention pond blanket solution to the myriad of LID possibilities may be met with initial hesitations and skepticisms, especially among new construction projects, but could be hydrologically appropriate solutions if accompanied with suitable siting and grading design layouts.

Allowing precipitation to enter the groundwater instead of surficial waters is beneficial from a large scale planning perspective and problematic from an onsite development perspective. When precipitation runs off directly into streams, downstream flooding is a major concern. A great volume of water enters streams simultaneously, creating artificially high flood levels that cause increased erosion and property damage. Additionally, water is kept out of the groundwater, which recharges stream levels in between periods of rain. Development thus causes high levels of flood and low levels during drought. By combating high runoff rates, rain gardens mitigate the effects of development. From a developer's perspective, however, infiltrating precipitation into groundwater onsite is risky. When a typical house in the watershed costs hundreds of thousands of dollars, the last thing a homeowner wants is a flooded basement. This outcome can occur when the water table breaches a basement's foundation, which can occur during times of heavy rain. Allowing the water table onsite to remain high can increase this risk. Developers and engineers are liable for such flooding, and prefer to keep precipitation off site.

Another liability issue raised by engineers is that rain gardens have not been adequately tested in the field. There is a distinction between academic studies and real world implementation. Academic studies do not always account for all variables or extended temporal scales. Engineers are often skeptical of a study, even if it produces extremely favorable results, because they cannot witness the effects themselves. For example, McNamara and Mitchell were impressed by the results of the Burnsville, MN study, but doubted its applicability to upstate New York. Because engineers are understandably wary of a stormwater management method they have not personally tested or witnessed, they are generally unwilling to use those methods and risk a faulty stormwater management system. Engineers could potentially save money by substituting rain gardens for traditional approaches. But if rain gardens fail due to poor design or lack of upkeep, the engineer is at fault. To be safe, the engineer could implement both rain gardens and traditional approaches, but the developer will not likely find the additional cost attractive.

Engineers are also concerned about upkeep of LID features. It is not clear whether the town or homeowners would be responsible for the upkeep of these features. The town may be wary of switching from maintaining several catch basins and one large retention pond to many separate and dispersed rain gardens. Homeowners, meanwhile, might also not care for the rain garden. Homeowners might also not be receptive to implementation of open grass waterways, and try to fill these features in. Porous pavement, meanwhile, may not have the structural integrity to serve as roads, especially in this region, which often requires snowplows, which would be particularly harsh on the road. Even if the porous pavement remains intact, it would require continual maintenance to remain effective and porous.

A research study in this region documenting the effects of rain gardens over a long period of time would be beneficial to evaluate the effectiveness of rain gardens. Such a study would likely include both rain gardens and traditional methods as a backup. The study site could be divided into a control, with no rain gardens, and the experiment, with rain gardens as the variable. Important aspects to address include effectiveness of infiltrating stormwater, longitudinal stability, homeowner receptiveness, responsibility for upkeep, and aesthetic value. If rain gardens in the study prove successful, engineers may feel comfortable enough to replace all or part of traditional approaches with LID in site development.

Such a replacement would save developers upfront capital in the construction phase, increasing the profit margin of the project. This economic benefit is the only way to convince a typical developer to willingly implement LID approaches. Rain gardens that are reliable for stormwater management and save money would be attractive to all developers. Rain gardens can be economically profitable in other ways as well. By using and advertising rain gardens as environmentally responsible, developers may market a green development for a higher price. This is a relatively small market and has limited reach. Rain gardens also make a development more aesthetically appealing, and increase the market value for a house. Indeed, homes have been built for years with features that can be considered rain gardens – but they were called landscaping. By grading the site differently and being careful with placement, this landscaping can be utilized to manage stormwater. The market for these aesthetics is also limited, and becomes even more so during tough economic times.

The other way to convince developers to implement rain gardens is through a legislative mandate. If the state or local government adopts LID approaches as the best management practices, developers will not have a choice but to comply, despite the possibility of any additional expense. Another impact that lies in the hands of local governments is the width of the road. By reducing the standard width of roads in Milton from 34 feet to 26 feet, Milton could eliminate 24% of the impervious road surfaces. This is a win-win for all parties involved; not only is there less stormwater runoff, but the developer saves money by not having to lay down that road.

Rain gardens are aesthetically pleasing, cost effective, hydrologically beneficial LID approaches to stormwater management that can be applied on an individual site basis. Upstate New York's geologic history and permeable soils makes the Saratoga Lake Watershed suitable for widespread implementation. Rain gardens have the potential to significantly reduce stormwater runoff associated with residential development.

The status quo is a powerful force. However, the multiple generations in stormwater engineering within the past few decades shows that even among the most resistant, change is possible.

Acknowledgements

We would like to thank Josh Ness for his guidance and support, Karen Kellogg for her insight, Blue Neils for his enthusiasm for better design practices, Mike McNamara and Travis Mitchell for their realism, Kyle Nichols for his hydrology knowledge, Alex Chaucer for his computer skills, and the 2010 ES Capstone family for all the love.

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Appendix A
Figures

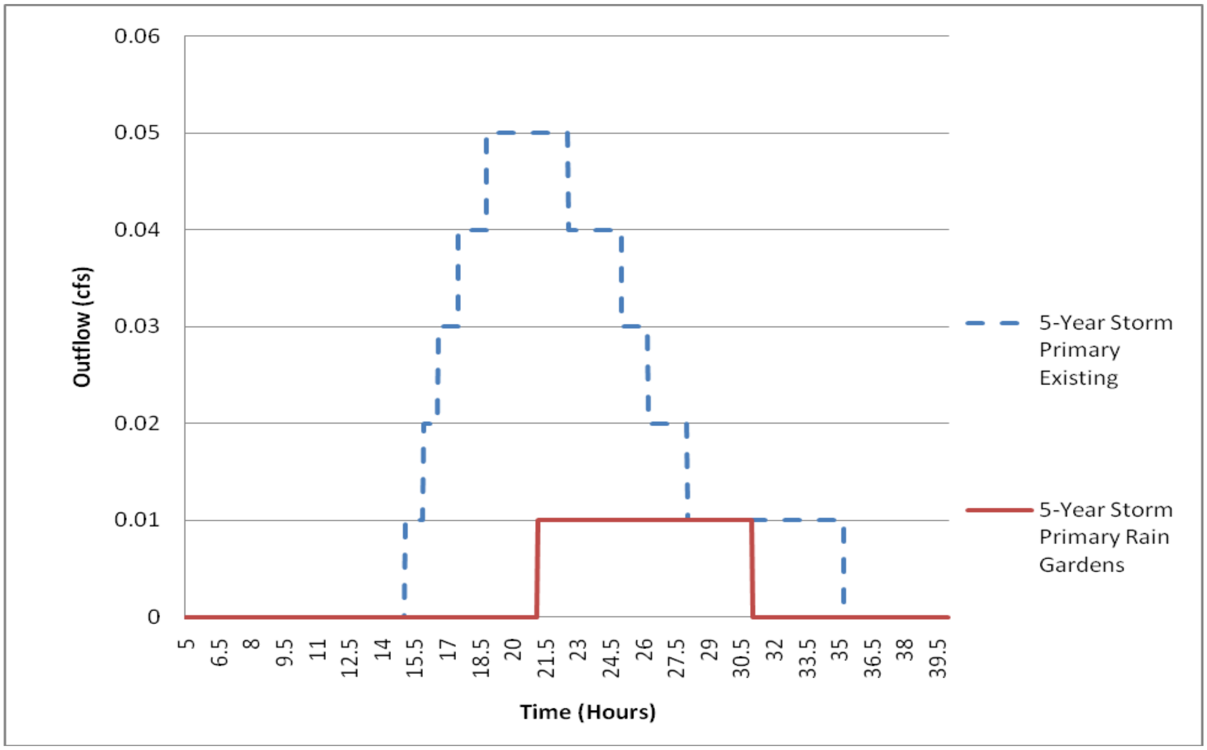

Figure 1: Model Hydrograph Comparison of Primary Outflow in 5-Year Storm

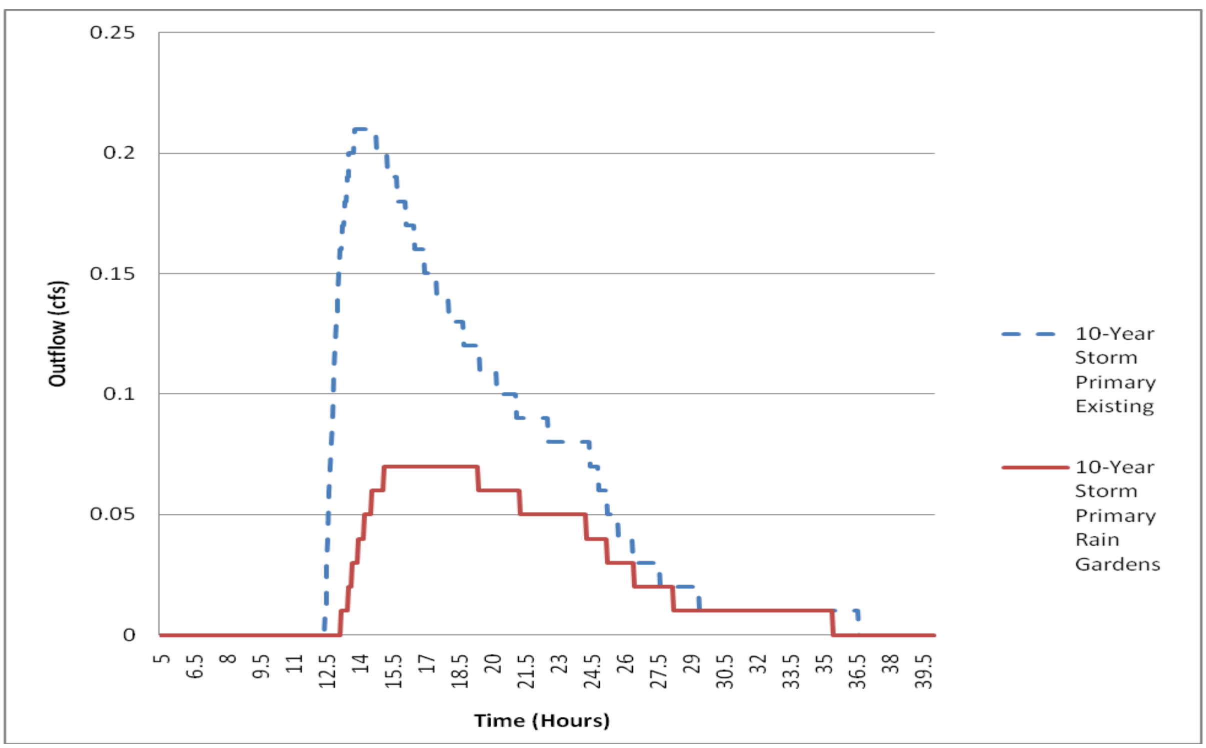

Figure 2: Model Hydrograph Comparison of Primary Outflow in 10-Year Storm

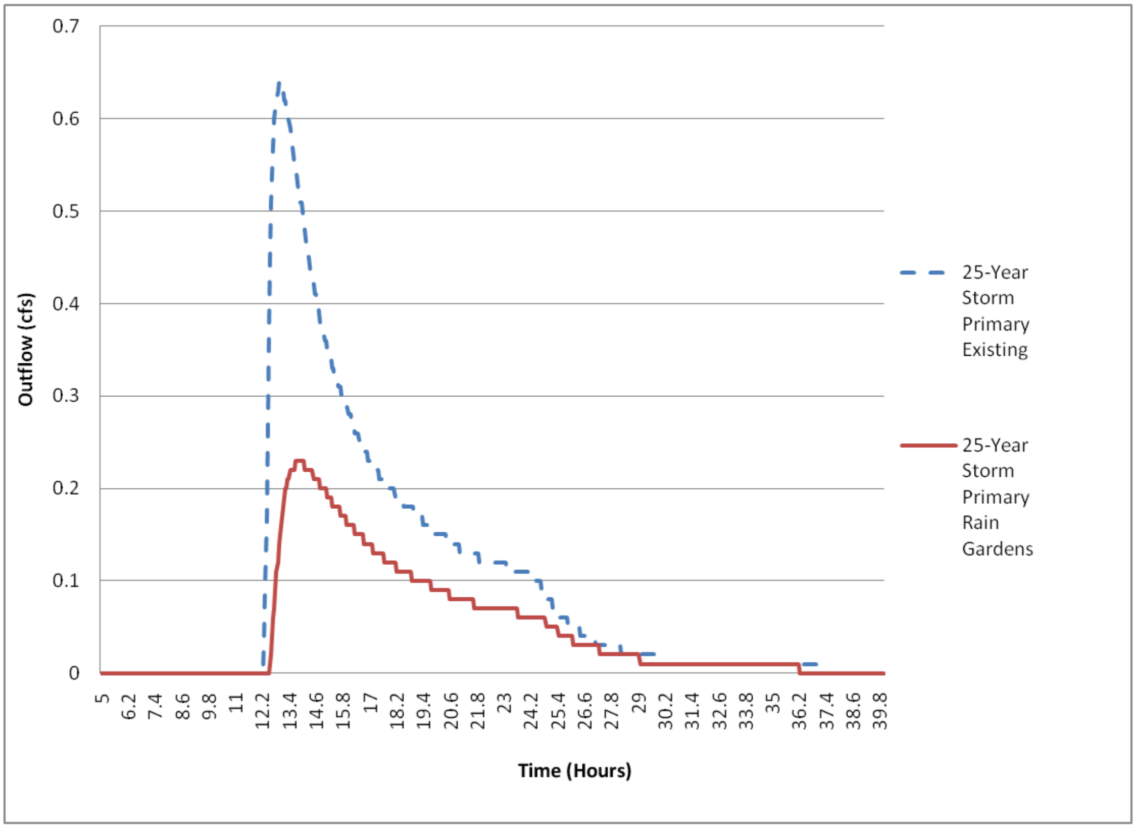

Figure 3: Model Hydrograph Comparison of Primary Outflow in 25-Year Storm

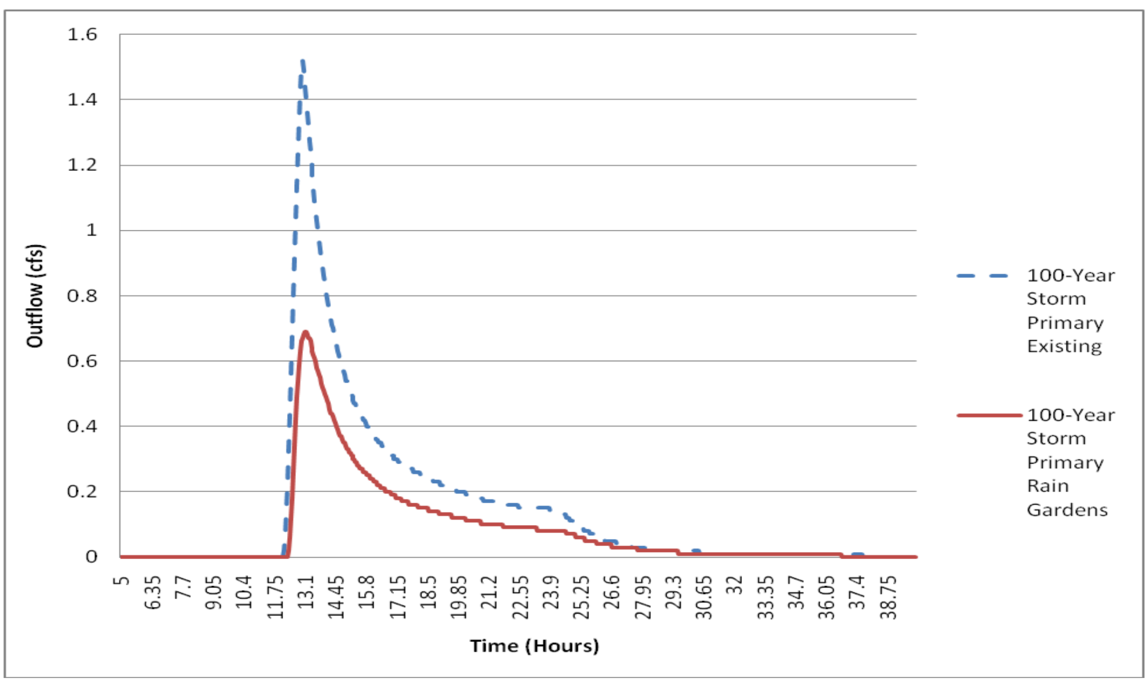

Figure 4: Model Hydrograph Comparison of Primary Outflow in 100-Year Storm

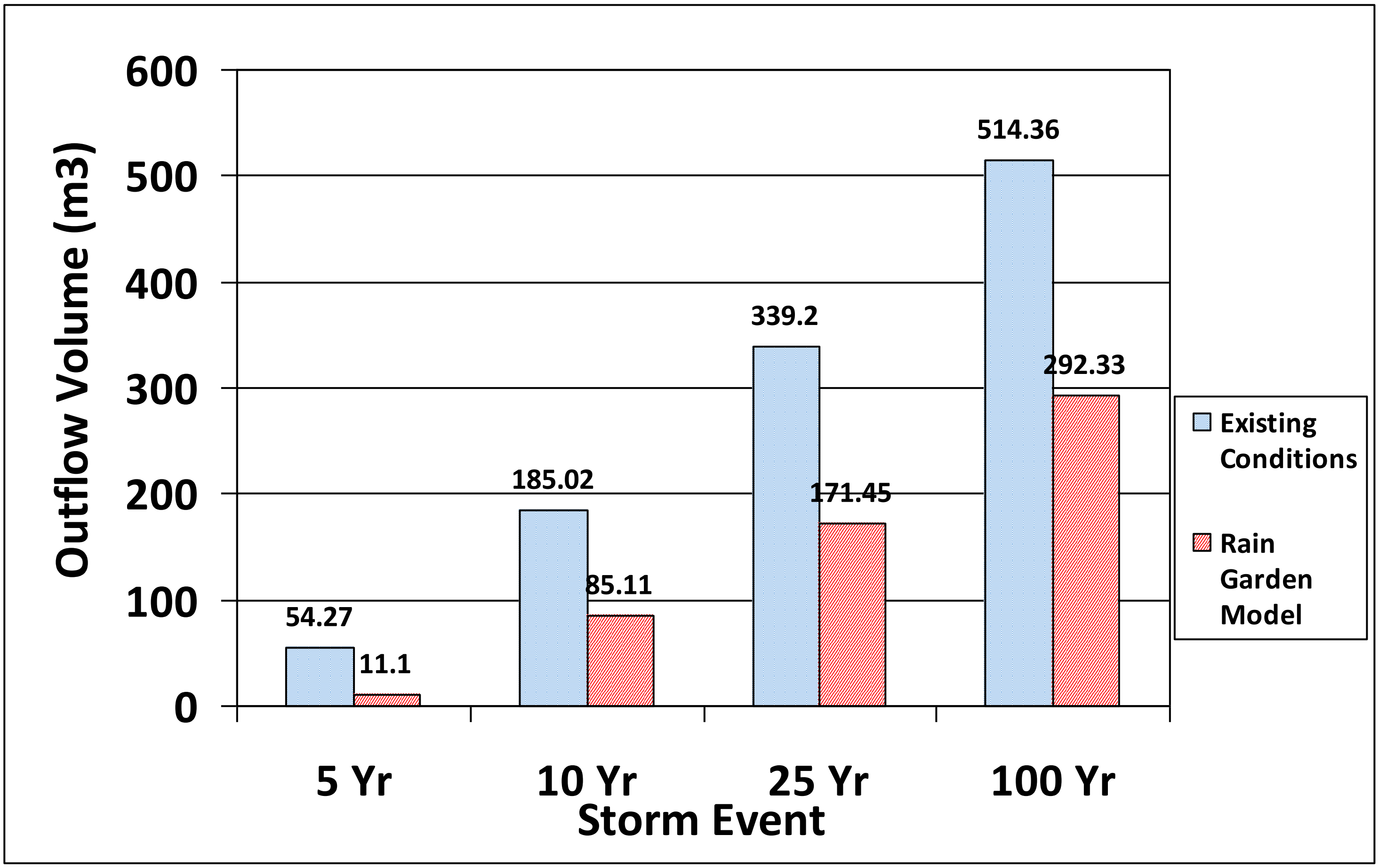

Figure 5: Outflow Difference of Existing and Rain Garden HydroCAD Models with Different Storm Events

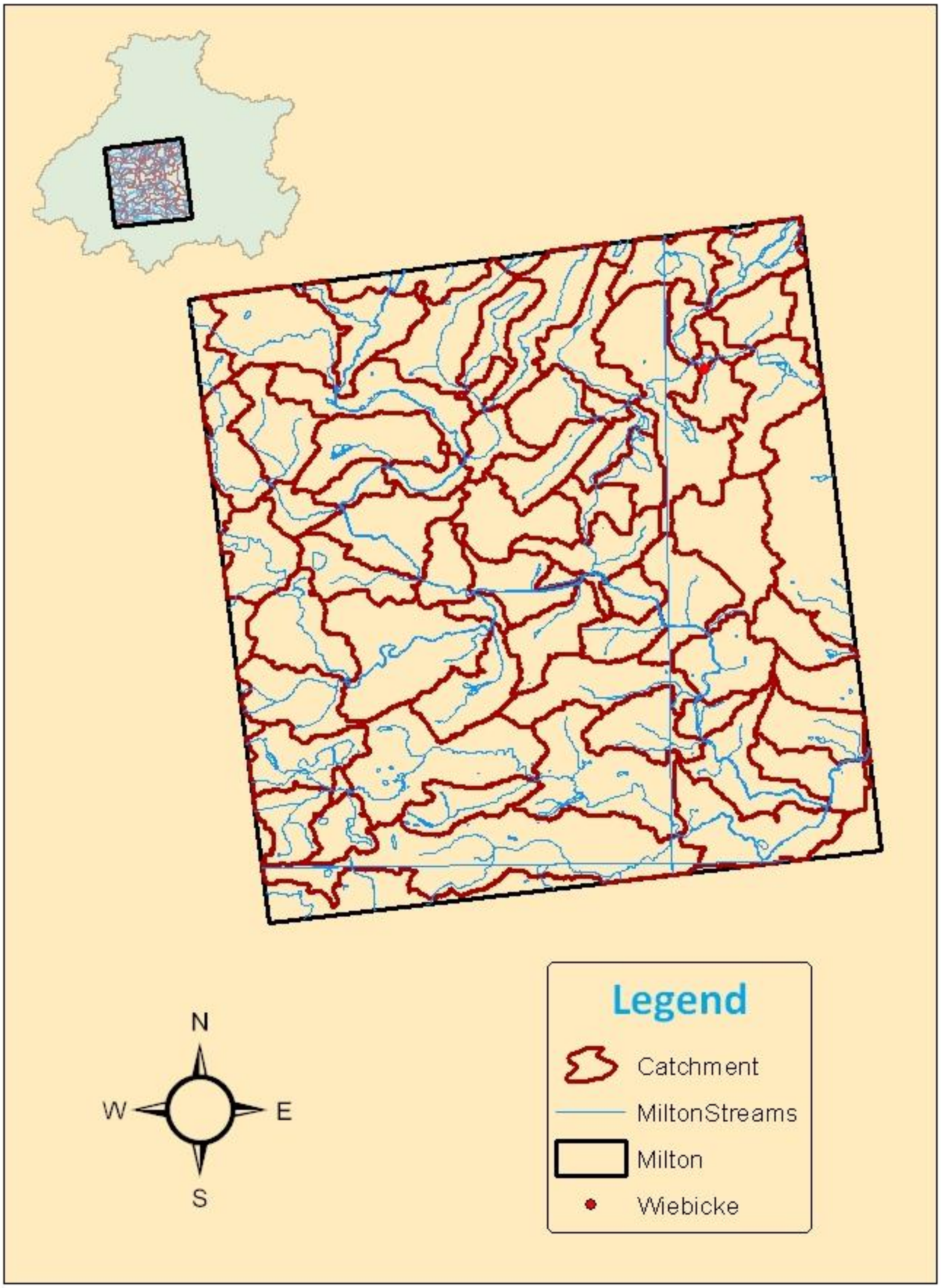

Figure 6: Subwatersheds in Milton, NY

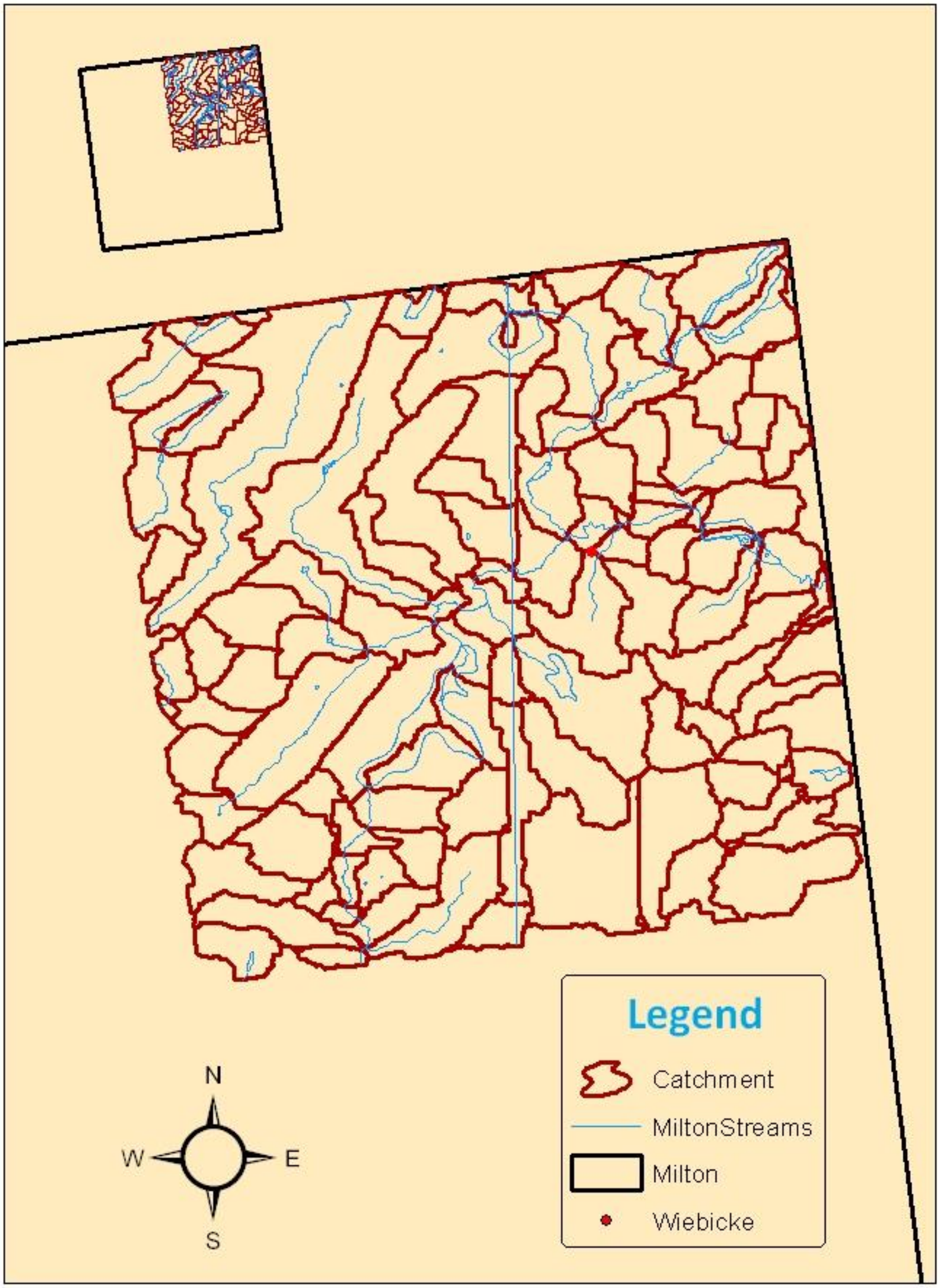

Figure 7: Small Scale Subwatersheds in Northeast Milton, NY

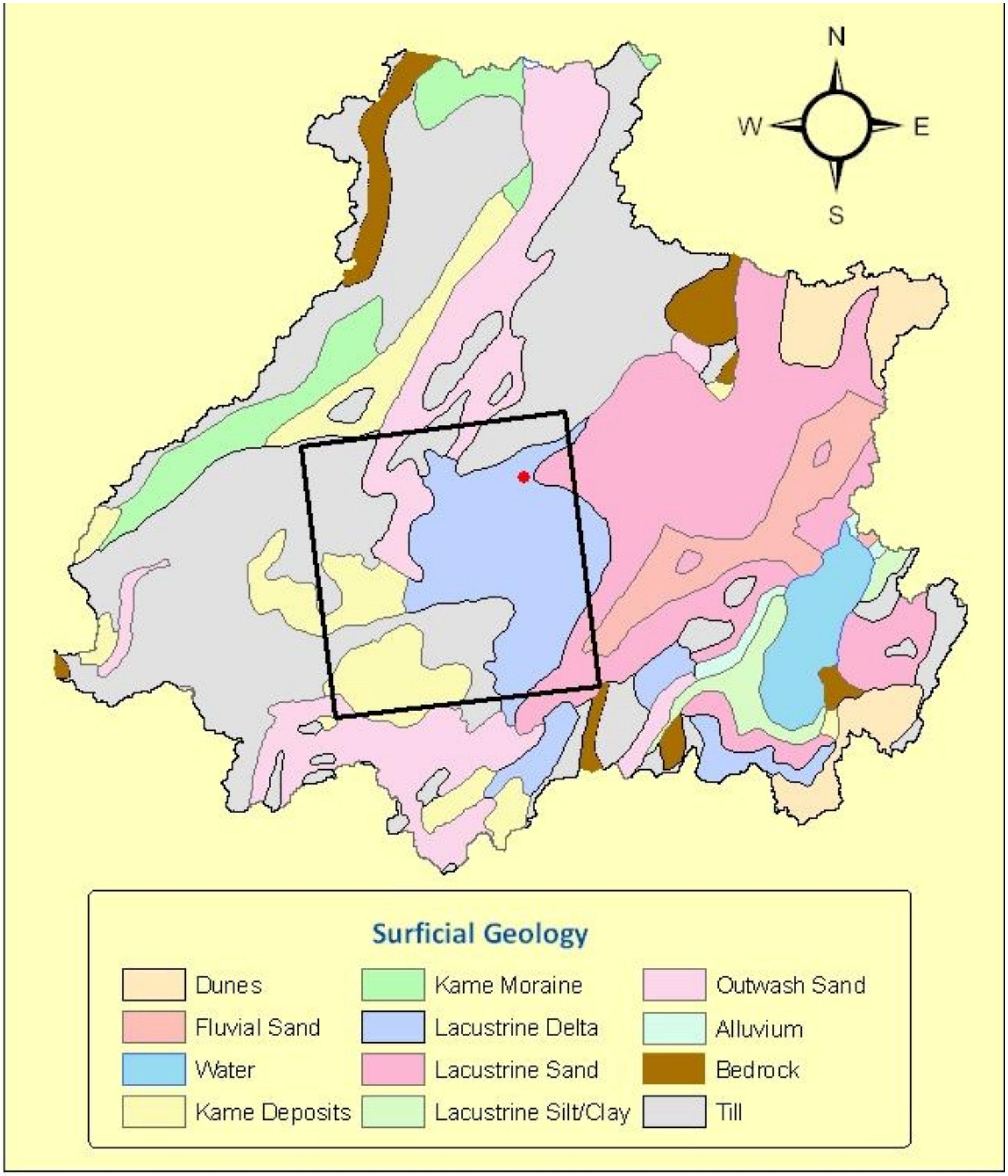

Figure 8: Surficial Geology in Saratoga Lake Watershed

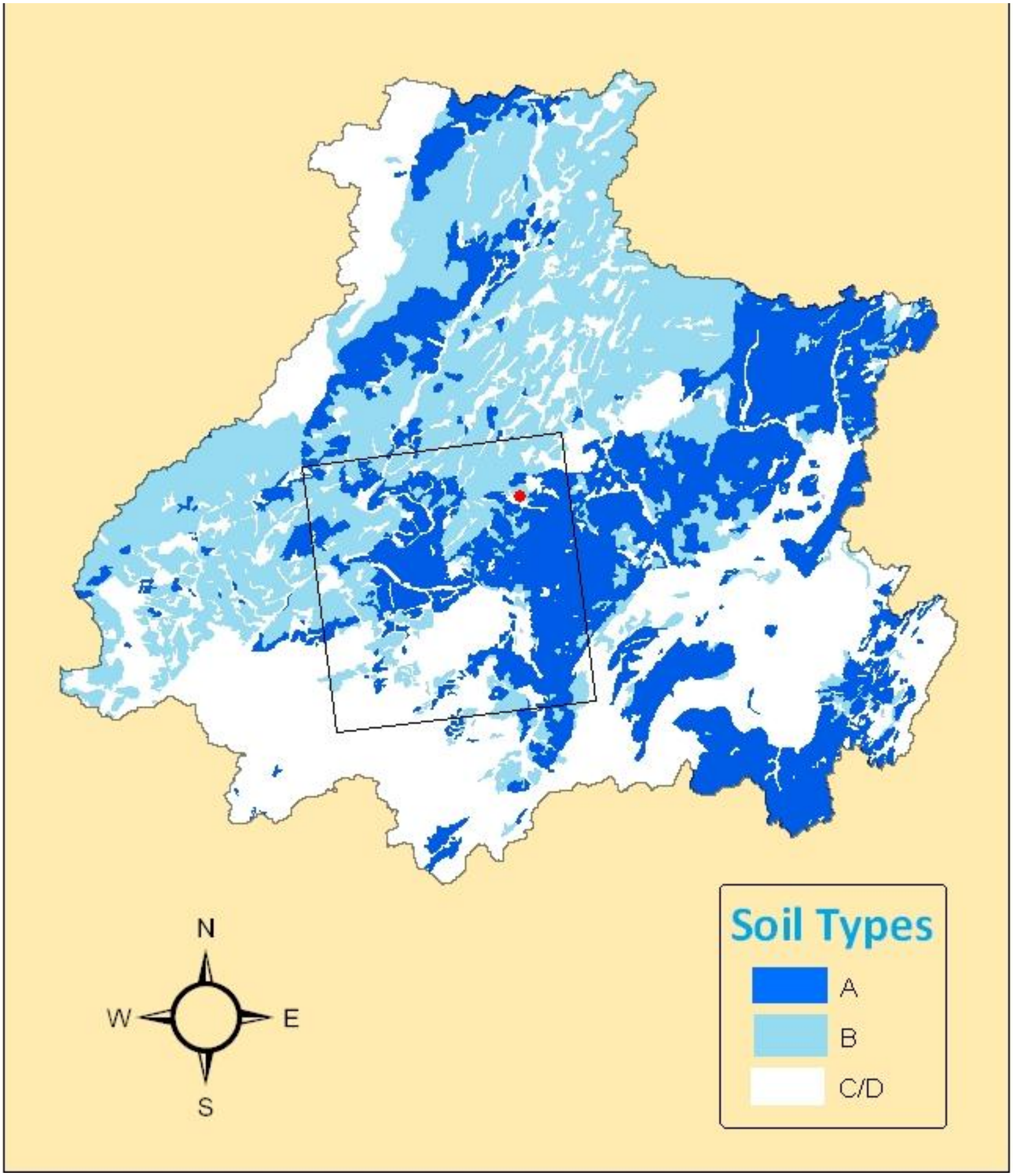

Figure 9: Soil Permeability Types in Saratoga Lake Watershed

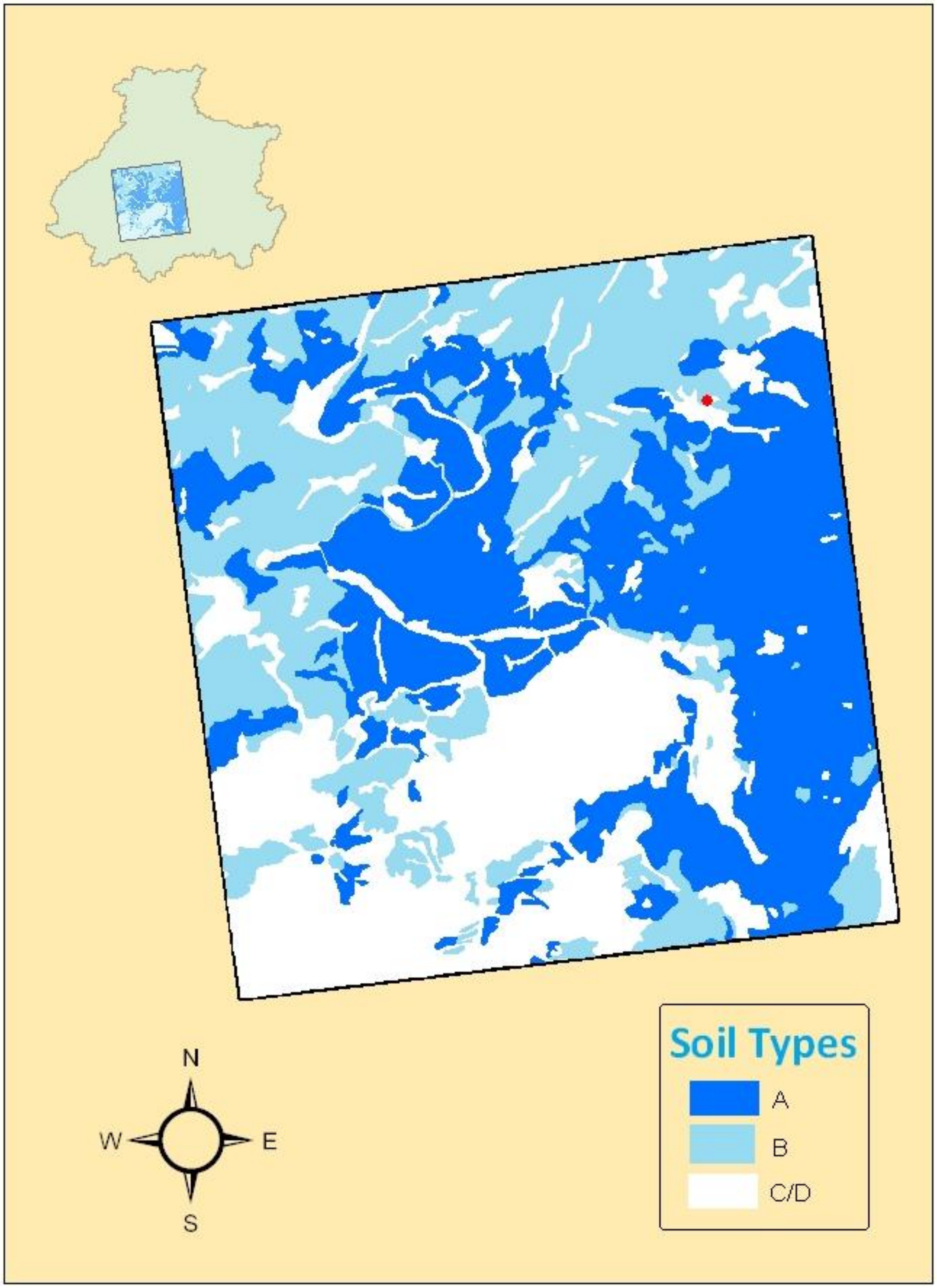

Figure 10: Soil Permeability Types in Milton, NY

Appendix B
HydroCAD Data

Predevelopment

Summary for Subcatchment 1S: PreDevelopment

Runoff = 0.01 cfs @ 18.39 hrs, Volume= 0.004 af, Depth> 0.01"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 2 Year Storm Rainfall=2.50"

	Area (sf)	CN	Description
*	148,300	50	Woods/Brush, Class A/B Soils
	148,300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
21.5	400	0.0250	0.31		**Lag/CN Method,**

Summary for Subcatchment 1S: PreDevelopment

Runoff = 0.41 cfs @ 12.26 hrs, Volume= 0.070 af, Depth> 0.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 10 Year Storm Rainfall=3.90"

	Area (sf)	CN	Description
*	148,300	50	Woods/Brush, Class A/B Soils
	148,300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
21.5	400	0.0250	0.31		**Lag/CN Method,**

Summary for Subcatchment 1S: PreDevelopment

Runoff = 1.23 cfs @ 12.21 hrs, Volume= 0.137 af, Depth> 0.48"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 Year Storm Rainfall=4.70"

	Area (sf)	CN	Description
*	148,300	50	Woods/Brush, Class A/B Soils
	148,300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
21.5	400	0.0250	0.31		**Lag/CN Method,**

Summary for Subcatchment 1S: PreDevelopment

Runoff = 2.56 cfs @ 12.19 hrs, Volume= 0.233 af, Depth> 0.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Year Storm Rainfall=5.60"

	Area (sf)	CN	Description
*	148,300	50	Woods/Brush, Class A/B Soils
	148,300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
21.5	400	0.0250	0.31		**Lag/CN Method,**

Existing Conditions

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Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,300 sf 23.28% Impervious Runoff Depth=0.25"
Flow Length=350' Slope=0.0100 '/' Tc=25.6 min CN=57 Runoff=0.15 cfs 0.032 af

Subcatchment 2S: Subcat 2S Runoff Area=79,900 sf 32.92% Impervious Runoff Depth=0.40"
Flow Length=300' Slope=0.0100 '/' Tc=20.0 min CN=62 Runoff=0.52 cfs 0.061 af

Reach 1R: Reach 1R Avg. Flow Depth=0.31' Max Vel=2.45 fps Inflow=0.52 cfs 0.061 af
12.0" Round Pipe n=0.012 L=360.0' S=0.0040 '/' Capacity=2.45 cfs Outflow=0.50 cfs 0.061 af

Reach 2R: Reach 2R Avg. Flow Depth=0.33' Max Vel=2.83 fps Inflow=0.64 cfs 0.093 af
12.0" Round Pipe n=0.012 L=200.0' S=0.0050 '/' Capacity=2.73 cfs Outflow=0.63 cfs 0.093 af

Pond 6P: Storm Basin Peak Elev=367.20' Storage=2,785 cf Inflow=0.63 cfs 0.093 af
Outflow=0.05 cfs 0.044 af

Total Runoff Area = 3.402 ac Runoff Volume = 0.093 af Average Runoff Depth = 0.33"
71.52% Pervious = 2.433 ac 28.48% Impervious = 0.969 ac

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 0.15 cfs @ 12.32 hrs, Volume= 0.032 af, Depth= 0.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 2 Year-Storm Rainfall=3.00"

	Area (sf)	CN	Description
*	52,400	45	>75% Grass cover, Good, HSG A/B
	15,900	98	Paved parking, HSG A
	68,300	57	Weighted Average
	52,400		76.72% Pervious Area
	15,900		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.6	350	0.0100	0.23		**Lag/CN Method,**

Summary for Subcatchment 2S: Subcat 2S

Runoff = 0.52 cfs @ 12.18 hrs, Volume= 0.061 af, Depth= 0.40"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 2 Year-Storm Rainfall=3.00"

	Area (sf)	CN	Description
*	53,600	45	>75% Grass cover, Good, HSG A/B
	26,300	98	Paved parking, HSG A
	79,900	62	Weighted Average
	53,600		67.08% Pervious Area
	26,300		32.92% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.0	300	0.0100	0.25		**Lag/CN Method,**

Summary for Reach 1R: Reach 1R

Inflow Area = 1.834 ac, 32.92% Impervious, Inflow Depth = 0.40" for 2 Year-Storm event
Inflow = 0.52 cfs @ 12.18 hrs, Volume= 0.061 af
Outflow = 0.50 cfs @ 12.26 hrs, Volume= 0.061 af, Atten= 3%, Lag= 4.6 min

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Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.45 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 1.11 fps, Avg. Travel Time= 5.4 min

Peak Storage= 74 cf @ 12.22 hrs
Average Depth at Peak Storage= 0.31'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.45 cfs

12.0" Round Pipe
n= 0.012
Length= 360.0' Slope= 0.0040 '/'
Inlet Invert= 368.45', Outlet Invert= 367.00'

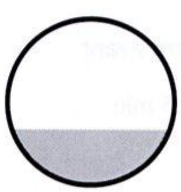
Summary for Reach 2R: Reach 2R

Inflow Area =	3.402 ac, 28.48% Impervious, Inflow Depth = 0.33"	for 2 Year-Storm event
Inflow =	0.64 cfs @ 12.27 hrs, Volume=	0.093 af
Outflow =	0.63 cfs @ 12.31 hrs, Volume=	0.093 af, Atten= 2%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.83 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 1.37 fps, Avg. Travel Time= 2.4 min

Peak Storage= 45 cf @ 12.28 hrs
Average Depth at Peak Storage= 0.33'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.73 cfs

12.0" Round Pipe
n= 0.012
Length= 200.0' Slope= 0.0050 '/'
Inlet Invert= 367.00', Outlet Invert= 366.00'



Summary for Pond 6P: Storm Basin

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 0.33" for 2 Year-Storm event
Inflow = 0.63 cfs @ 12.31 hrs, Volume= 0.093 af
Outflow = 0.05 cfs @ 20.04 hrs, Volume= 0.044 af, Atten= 92%, Lag= 464.1 min
Primary = 0.05 cfs @ 20.04 hrs, Volume= 0.044 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 367.20' @ 20.04 hrs Surf.Area= 8,362 sf Storage= 2,785 cf

Plug-Flow detention time= 614.9 min calculated for 0.044 af (47% of inflow)
Center-of-Mass det. time= 437.1 min (1,388.4 - 951.3)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.05 cfs @ 20.04 hrs HW=367.20' (Free Discharge)
1=Culvert (Inlet Controls 0.05 cfs @ 1.09 fps)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

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Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,300 sf 23.28% Impervious Runoff Depth=0.58"
Flow Length=350' Slope=0.0100 '/' Tc=25.6 min CN=57 Runoff=0.58 cfs 0.075 af

Subcatchment 2S: Subcat 2S Runoff Area=79,900 sf 32.92% Impervious Runoff Depth=0.81"
Flow Length=300' Slope=0.0100 '/' Tc=20.0 min CN=62 Runoff=1.37 cfs 0.124 af

Reach 1R: Reach 1R Avg. Flow Depth=0.53' Max Vel=3.19 fps Inflow=1.37 cfs 0.124 af
12.0" Round Pipe n=0.012 L=360.0' S=0.0040 '/' Capacity=2.45 cfs Outflow=1.33 cfs 0.124 af

Reach 2R: Reach 2R Avg. Flow Depth=0.61' Max Vel=3.75 fps Inflow=1.89 cfs 0.199 af
12.0" Round Pipe n=0.012 L=200.0' S=0.0050 '/' Capacity=2.73 cfs Outflow=1.87 cfs 0.199 af

Pond 6P: Storm Basin Peak Elev=367.32' Storage=3,812 cf Inflow=1.87 cfs 0.199 af
Outflow=0.21 cfs 0.150 af

Total Runoff Area = 3.402 ac Runoff Volume = 0.199 af Average Runoff Depth = 0.70"
71.52% Pervious = 2.433 ac 28.48% Impervious = 0.969 ac

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 0.58 cfs @ 12.26 hrs, Volume= 0.075 af, Depth= 0.58"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 10 Year-Storm Rainfall=3.90"

	Area (sf)	CN	Description
*	52,400	45	>75% Grass cover, Good, HSG A/B
	15,900	98	Paved parking, HSG A
	68,300	57	Weighted Average
	52,400		76.72% Pervious Area
	15,900		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.6	350	0.0100	0.23		**Lag/CN Method,**

Summary for Subcatchment 2S: Subcat 2S

Runoff = 1.37 cfs @ 12.16 hrs, Volume= 0.124 af, Depth= 0.81"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 10 Year-Storm Rainfall=3.90"

	Area (sf)	CN	Description
*	53,600	45	>75% Grass cover, Good, HSG A/B
	26,300	98	Paved parking, HSG A
	79,900	62	Weighted Average
	53,600		67.08% Pervious Area
	26,300		32.92% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.0	300	0.0100	0.25		**Lag/CN Method,**

Summary for Reach 1R: Reach 1R

Inflow Area = 1.834 ac, 32.92% Impervious, Inflow Depth = 0.81" for 10 Year-Storm event
Inflow = 1.37 cfs @ 12.16 hrs, Volume= 0.124 af
Outflow = 1.33 cfs @ 12.22 hrs, Volume= 0.124 af, Atten= 3%, Lag= 3.5 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.19 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 1.32 fps, Avg. Travel Time= 4.6 min

Peak Storage= 152 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.53'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.45 cfs

12.0" Round Pipe
n= 0.012
Length= 360.0' Slope= 0.0040 '/'
Inlet Invert= 368.45', Outlet Invert= 367.00'

Summary for Reach 2R: Reach 2R

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 0.70" for 10 Year-Storm event
Inflow = 1.89 cfs @ 12.23 hrs, Volume= 0.199 af
Outflow = 1.87 cfs @ 12.26 hrs, Volume= 0.199 af, Atten= 1%, Lag= 1.8 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.75 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 1.64 fps, Avg. Travel Time= 2.0 min

Peak Storage= 101 cf @ 12.24 hrs
Average Depth at Peak Storage= 0.61'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.73 cfs

12.0" Round Pipe
n= 0.012
Length= 200.0' Slope= 0.0050 '/'
Inlet Invert= 367.00', Outlet Invert= 366.00'

Summary for Pond 6P: Storm Basin

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 0.70" for 10 Year-Storm event
Inflow = 1.87 cfs @ 12.26 hrs, Volume= 0.199 af
Outflow = 0.21 cfs @ 14.18 hrs, Volume= 0.150 af, Atten= 89%, Lag= 115.6 min
Primary = 0.21 cfs @ 14.18 hrs, Volume= 0.150 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 367.32' @ 14.18 hrs Surf.Area= 8,626 sf Storage= 3,812 cf

Plug-Flow detention time= 330.7 min calculated for 0.150 af (75% of inflow)
Center-of-Mass det. time= 226.5 min (1,142.0 - 915.4)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.21 cfs @ 14.18 hrs HW=367.32' (Free Discharge)
↑—**1=Culvert** (Inlet Controls 0.21 cfs @ 1.61 fps)
└—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,300 sf 23.28% Impervious Runoff Depth=0.95"
Flow Length=350' Slope=0.0100 '/' Tc=25.6 min CN=57 Runoff=1.14 cfs 0.124 af

Subcatchment 2S: Subcat 2S Runoff Area=79,900 sf 32.92% Impervious Runoff Depth=1.26"
Flow Length=300' Slope=0.0100 '/' Tc=20.0 min CN=62 Runoff=2.31 cfs 0.192 af

Reach 1R: Reach 1R Avg. Flow Depth=0.76' Max Vel=3.54 fps Inflow=2.31 cfs 0.192 af
12.0" Round Pipe n=0.012 L=360.0' S=0.0040 '/' Capacity=2.45 cfs Outflow=2.24 cfs 0.192 af

Reach 2R: Reach 2R Avg. Flow Depth=1.00' Max Vel=3.96 fps Inflow=3.37 cfs 0.316 af
12.0" Round Pipe n=0.012 L=200.0' S=0.0050 '/' Capacity=2.73 cfs Outflow=2.79 cfs 0.316 af

Pond 6P: Storm Basin Peak Elev=367.49' Storage=5,263 cf Inflow=2.79 cfs 0.316 af
Outflow=0.60 cfs 0.267 af

Total Runoff Area = 3.402 ac Runoff Volume = 0.316 af Average Runoff Depth = 1.11"
71.52% Pervious = 2.433 ac 28.48% Impervious = 0.969 ac

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 1.14 cfs @ 12.23 hrs, Volume= 0.124 af, Depth= 0.95"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 Year-Storm Rainfall=4.70"

	Area (sf)	CN	Description
*	52,400	45	>75% Grass cover, Good, HSG A/B
	15,900	98	Paved parking, HSG A
	68,300	57	Weighted Average
	52,400		76.72% Pervious Area
	15,900		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.6	350	0.0100	0.23		**Lag/CN Method,**

Summary for Subcatchment 2S: Subcat 2S

Runoff = 2.31 cfs @ 12.15 hrs, Volume= 0.192 af, Depth= 1.26"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 25 Year-Storm Rainfall=4.70"

	Area (sf)	CN	Description
*	53,600	45	>75% Grass cover, Good, HSG A/B
	26,300	98	Paved parking, HSG A
	79,900	62	Weighted Average
	53,600		67.08% Pervious Area
	26,300		32.92% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.0	300	0.0100	0.25		**Lag/CN Method,**

Summary for Reach 1R: Reach 1R

Inflow Area = 1.834 ac, 32.92% Impervious, Inflow Depth = 1.26" for 25 Year-Storm event
Inflow = 2.31 cfs @ 12.15 hrs, Volume= 0.192 af
Outflow = 2.24 cfs @ 12.20 hrs, Volume= 0.192 af, Atten= 3%, Lag= 3.3 min

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Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.54 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.46 fps, Avg. Travel Time= 4.1 min

Peak Storage= 231 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.76'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.45 cfs

12.0" Round Pipe
n= 0.012
Length= 360.0' Slope= 0.0040 '/'
Inlet Invert= 368.45', Outlet Invert= 367.00'

Summary for Reach 2R: Reach 2R

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 1.11" for 25 Year-Storm event
Inflow = 3.37 cfs @ 12.21 hrs, Volume= 0.316 af
Outflow = 2.79 cfs @ 12.19 hrs, Volume= 0.316 af, Atten= 17%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.96 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.81 fps, Avg. Travel Time= 1.8 min

Peak Storage= 157 cf @ 12.20 hrs
Average Depth at Peak Storage= 1.00'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.73 cfs

12.0" Round Pipe
n= 0.012
Length= 200.0' Slope= 0.0050 '/'
Inlet Invert= 367.00', Outlet Invert= 366.00'

Summary for Pond 6P: Storm Basin

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 1.11" for 25 Year-Storm event
Inflow = 2.79 cfs @ 12.19 hrs, Volume= 0.316 af
Outflow = 0.60 cfs @ 13.04 hrs, Volume= 0.267 af, Atten= 78%, Lag= 50.7 min
Primary = 0.60 cfs @ 13.04 hrs, Volume= 0.267 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 367.49' @ 13.04 hrs Surf.Area= 8,985 sf Storage= 5,263 cf

Plug-Flow detention time= 234.8 min calculated for 0.267 af (84% of inflow)
Center-of-Mass det. time= 161.0 min (1,058.7 - 897.7)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.60 cfs @ 13.04 hrs HW=367.49' (Free Discharge)
1=Culvert (Inlet Controls 0.60 cfs @ 2.12 fps)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,300 sf 23.28% Impervious Runoff Depth=1.44"
Flow Length=350' Slope=0.0100 '/' Tc=25.6 min CN=57 Runoff=1.90 cfs 0.188 af

Subcatchment 2S: Subcat 2S Runoff Area=79,900 sf 32.92% Impervious Runoff Depth=1.82"
Flow Length=300' Slope=0.0100 '/' Tc=20.0 min CN=62 Runoff=3.51 cfs 0.278 af

Reach 1R: Reach 1R Avg. Flow Depth=1.00' Max Vel=3.56 fps Inflow=3.51 cfs 0.278 af
12.0" Round Pipe n=0.012 L=360.0' S=0.0040 '/' Capacity=2.45 cfs Outflow=2.45 cfs 0.278 af

Reach 2R: Reach 2R Avg. Flow Depth=1.00' Max Vel=3.95 fps Inflow=4.35 cfs 0.466 af
12.0" Round Pipe n=0.012 L=200.0' S=0.0050 '/' Capacity=2.73 cfs Outflow=2.75 cfs 0.466 af

Pond 6P: Storm Basin Peak Elev=367.77' Storage=7,840 cf Inflow=2.75 cfs 0.466 af
Outflow=1.52 cfs 0.417 af

Total Runoff Area = 3.402 ac Runoff Volume = 0.466 af Average Runoff Depth = 1.65"
71.52% Pervious = 2.433 ac 28.48% Impervious = 0.969 ac

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 1.90 cfs @ 12.22 hrs, Volume= 0.188 af, Depth= 1.44"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 Year-Storm Rainfall=5.60"

	Area (sf)	CN	Description
*	52,400	45	>75% Grass cover, Good, HSG A/B
	15,900	98	Paved parking, HSG A
	68,300	57	Weighted Average
	52,400		76.72% Pervious Area
	15,900		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.6	350	0.0100	0.23		**Lag/CN Method,**

Summary for Subcatchment 2S: Subcat 2S

Runoff = 3.51 cfs @ 12.14 hrs, Volume= 0.278 af, Depth= 1.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 Year-Storm Rainfall=5.60"

	Area (sf)	CN	Description
*	53,600	45	>75% Grass cover, Good, HSG A/B
	26,300	98	Paved parking, HSG A
	79,900	62	Weighted Average
	53,600		67.08% Pervious Area
	26,300		32.92% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.0	300	0.0100	0.25		**Lag/CN Method,**

Summary for Reach 1R: Reach 1R

Inflow Area = 1.834 ac, 32.92% Impervious, Inflow Depth = 1.82" for 100 Year-Storm event
Inflow = 3.51 cfs @ 12.14 hrs, Volume= 0.278 af
Outflow = 2.45 cfs @ 12.15 hrs, Volume= 0.278 af, Atten= 30%, Lag= 0.5 min

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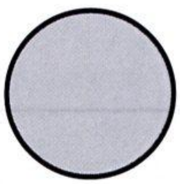
Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.56 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.56 fps, Avg. Travel Time= 3.8 min

Peak Storage= 283 cf @ 12.10 hrs
Average Depth at Peak Storage= 1.00'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.45 cfs

12.0" Round Pipe
n= 0.012
Length= 360.0' Slope= 0.0040 '/'
Inlet Invert= 368.45', Outlet Invert= 367.00'



Summary for Reach 2R: Reach 2R

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 1.65" for 100 Year-Storm event
Inflow = 4.35 cfs @ 12.22 hrs, Volume= 0.466 af
Outflow = 2.75 cfs @ 12.10 hrs, Volume= 0.466 af, Atten= 37%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.95 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.94 fps, Avg. Travel Time= 1.7 min

Peak Storage= 157 cf @ 12.10 hrs
Average Depth at Peak Storage= 1.00'
Bank-Full Depth= 1.00', Capacity at Bank-Full= 2.73 cfs

12.0" Round Pipe
n= 0.012
Length= 200.0' Slope= 0.0050 '/'
Inlet Invert= 367.00', Outlet Invert= 366.00'

Summary for Pond 6P: Storm Basin

Inflow Area = 3.402 ac, 28.48% Impervious, Inflow Depth = 1.65" for 100 Year-Storm event
Inflow = 2.75 cfs @ 12.10 hrs, Volume= 0.466 af
Outflow = 1.52 cfs @ 12.99 hrs, Volume= 0.417 af, Atten= 45%, Lag= 53.7 min
Primary = 1.52 cfs @ 12.99 hrs, Volume= 0.417 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 367.77' @ 12.99 hrs Surf.Area= 9,590 sf Storage= 7,840 cf

Plug-Flow detention time= 178.2 min calculated for 0.417 af (89% of inflow)
Center-of-Mass det. time= 124.8 min (1,012.3 - 887.5)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=1.51 cfs @ 12.99 hrs HW=367.77' (Free Discharge)
1=Culvert (Barrel Controls 1.51 cfs @ 3.87 fps)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Rain Garden Model

Rain Gardens
Prepared by HydroCAD SAMPLER 1-800-927-7246 www.hydrocad.net Printed 5/3/2010
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Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
1.203	45	>75% Grass cover, Good, HSG A/B (1S)
0.365	98	Paved parking, HSG A (1S)

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Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,302 sf 23.28% Impervious Runoff Depth=0.25"
Flow Length=230' Slope=0.0010 '/' Tc=36.0 min CN=57 Runoff=0.12 cfs 0.032 af

Reach 3R: Reach 1A Avg. Flow Depth=0.14' Max Vel=1.00 fps Inflow=0.12 cfs 0.032 af
n=0.030 L=25.0' S=0.0100 '/' Capacity=33.02 cfs Outflow=0.12 cfs 0.032 af

Reach 5R: Reach 2A Avg. Flow Depth=0.00' Max Vel=0.00 fps Inflow=0.00 cfs 0.000 af
n=0.030 L=375.0' S=0.0020 '/' Capacity=14.77 cfs Outflow=0.00 cfs 0.000 af

Pond 1P: Rain Garden 2 Peak Elev=370.02' Storage=484 cf Inflow=0.12 cfs 0.032 af
Discarded=0.02 cfs 0.032 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.032 af

Pond 6P: Storm Basin Peak Elev=366.00' Storage=0 cf Inflow=0.00 cfs 0.000 af
Outflow=0.00 cfs 0.000 af

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 0.12 cfs @ 12.50 hrs, Volume= 0.032 af, Depth= 0.25"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-Year Storm Rainfall=3.00"

	Area (sf)	CN	Description
*	52,403	45	>75% Grass cover, Good, HSG A/B
	15,899	98	Paved parking, HSG A
	68,302	57	Weighted Average
	52,403		76.72% Pervious Area
	15,899		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
28.5	50	0.0010	0.03		**Sheet Flow, Turf Grass** Grass: Dense n= 0.240 P2= 2.90"
2.1	80	0.0010	0.64		**Shallow Concentrated Flow, Roadway** Paved Kv= 20.3 fps
5.4	100	0.0010	0.31	5.30	**Channel Flow, Grass Channel** Area= 17.3 sf Perim= 200.0' r= 0.09' n= 0.030 Earth, grassed & winding
36.0	230	Total			

Summary for Reach 3R: Reach 1A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.25" for 2-Year Storm event
Inflow = 0.12 cfs @ 12.50 hrs, Volume= 0.032 af
Outflow = 0.12 cfs @ 12.51 hrs, Volume= 0.032 af, Atten= 0%, Lag= 0.7 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.00 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 0.60 fps, Avg. Travel Time= 0.7 min

Peak Storage= 3 cf @ 12.50 hrs
Average Depth at Peak Storage= 0.14'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.02 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 25.0' Slope= 0.0100 '/'
Inlet Invert= 373.25', Outlet Invert= 373.00'

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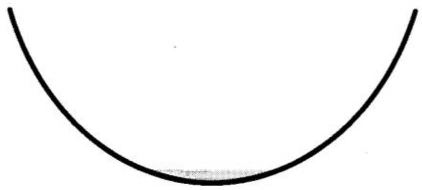


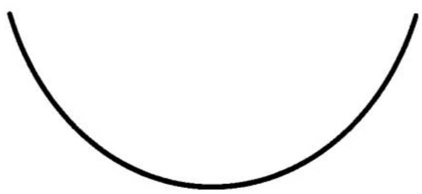
Summary for Reach 5R: Reach 2A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.00" for 2-Year Storm event
Inflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.00 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.00 fps, Avg. Travel Time= 0.0 min

Peak Storage= 0 cf @ 5.00 hrs
Average Depth at Peak Storage= 0.00'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 14.77 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030
Length= 375.0' Slope= 0.0020 '/'
Inlet Invert= 367.75', Outlet Invert= 367.00'



Summary for Pond 1P: Rain Garden 2

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.25" for 2-Year Storm event
Inflow = 0.12 cfs @ 12.51 hrs, Volume= 0.032 af
Outflow = 0.02 cfs @ 12.25 hrs, Volume= 0.032 af, Atten= 81%, Lag= 0.0 min
Discarded = 0.02 cfs @ 12.25 hrs, Volume= 0.032 af
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 370.02' @ 18.37 hrs Surf.Area= 600 sf Storage= 484 cf

Plug-Flow detention time= 253.6 min calculated for 0.032 af (100% of inflow)

Center-of-Mass det. time= 253.6 min (1,235.2 - 981.7)

Volume	Invert	Avail.Storage	Storage Description
#1	368.00'	1,290 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
368.00	600	0.0	0	0	600
368.75	600	40.0	180	180	665
369.75	600	40.0	240	420	752
371.75	600	40.0	480	900	926
372.75	600	40.0	240	1,140	1,012
373.00	600	100.0	150	1,290	1,034

Device	Routing	Invert	Outlet Devices
#1	Discarded	368.00'	**1.660 in/hr Exfiltration over Surface area**
#2	Primary	373.00'	**50.0' long x 0.25' rise Sharp-Crested Rectangular Weir** 2 End Contraction(s) 0.5' Crest Height

Discarded OutFlow Max=0.02 cfs @ 12.25 hrs HW=368.07' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=368.00' (Free Discharge)
↑—**2=Sharp-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Pond 6P: Storm Basin

Inflow Area =	1.568 ac,	23.28% Impervious,	Inflow Depth = 0.00"	for 2-Year Storm event
Inflow =	0.00 cfs @	5.00 hrs, Volume=	0.000 af	
Outflow =	0.00 cfs @	5.00 hrs, Volume=	0.000 af,	Atten= 0%, Lag= 0.0 min
Primary =	0.00 cfs @	5.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 366.00' @ 5.00 hrs Surf.Area= 1,100 sf Storage= 0 cf

Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= (not calculated: no inflow)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=366.00' (Free Discharge)
↑—**1=Culvert** (Controls 0.00 cfs)
└—**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,302 sf 23.28% Impervious Runoff Depth=0.58"
Flow Length=230' Slope=0.0010 '/' Tc=36.0 min CN=57 Runoff=0.45 cfs 0.075 af

Reach 3R: Reach 1A Avg. Flow Depth=0.26' Max Vel=1.48 fps Inflow=0.45 cfs 0.075 af
n=0.030 L=25.0' S=0.0100 '/' Capacity=33.02 cfs Outflow=0.45 cfs 0.075 af

Reach 5R: Reach 2A Avg. Flow Depth=0.00' Max Vel=0.12 fps Inflow=0.00 cfs 0.000 af
n=0.030 L=375.0' S=0.0020 '/' Capacity=14.77 cfs Outflow=0.00 cfs 0.000 af

Pond 1P: Rain Garden 2 Peak Elev=373.00' Storage=1,290 cf Inflow=0.45 cfs 0.075 af
Discarded=0.02 cfs 0.053 af Primary=0.00 cfs 0.000 af Outflow=0.02 cfs 0.053 af

Pond 6P: Storm Basin Peak Elev=366.00' Storage=0 cf Inflow=0.00 cfs 0.000 af
Outflow=0.00 cfs 0.000 af

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 0.45 cfs @ 12.41 hrs, Volume= 0.075 af, Depth= 0.58"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 10-Year Storm Rainfall=3.90"

	Area (sf)	CN	Description
*	52,403	45	>75% Grass cover, Good, HSG A/B
	15,899	98	Paved parking, HSG A
	68,302	57	Weighted Average
	52,403		76.72% Pervious Area
	15,899		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
28.5	50	0.0010	0.03		**Sheet Flow, Turf Grass** Grass: Dense n= 0.240 P2= 2.90"
2.1	80	0.0010	0.64		**Shallow Concentrated Flow, Roadway** Paved Kv= 20.3 fps
5.4	100	0.0010	0.31	5.30	**Channel Flow, Grass Channel** Area= 17.3 sf Perim= 200.0' r= 0.09' n= 0.030 Earth, grassed & winding
36.0	230	Total			

Summary for Reach 3R: Reach 1A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.58" for 10-Year Storm event
Inflow = 0.45 cfs @ 12.41 hrs, Volume= 0.075 af
Outflow = 0.45 cfs @ 12.42 hrs, Volume= 0.075 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.48 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 0.74 fps, Avg. Travel Time= 0.6 min

Peak Storage= 8 cf @ 12.41 hrs
Average Depth at Peak Storage= 0.26'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.02 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 25.0' Slope= 0.0100 '/'
Inlet Invert= 373.25', Outlet Invert= 373.00'

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Summary for Reach 5R: Reach 2A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.00" for 10-Year Storm event
Inflow = 0.00 cfs @ 14.45 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 15.66 hrs, Volume= 0.000 af, Atten= 90%, Lag= 72.6 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.12 fps, Min. Travel Time= 50.3 min
Avg. Velocity = 0.12 fps, Avg. Travel Time= 50.3 min

Peak Storage= 0 cf @ 14.81 hrs
Average Depth at Peak Storage= 0.00'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 14.77 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030
Length= 375.0' Slope= 0.0020 '/'
Inlet Invert= 367.75', Outlet Invert= 367.00'

Summary for Pond 1P: Rain Garden 2

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.58" for 10-Year Storm event
Inflow = 0.45 cfs @ 12.42 hrs, Volume= 0.075 af
Outflow = 0.02 cfs @ 14.45 hrs, Volume= 0.053 af, Atten= 95%, Lag= 121.9 min
Discarded = 0.02 cfs @ 12.10 hrs, Volume= 0.053 af
Primary = 0.00 cfs @ 14.45 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 373.00' @ 14.45 hrs Surf.Area= 600 sf Storage= 1,290 cf

Plug-Flow detention time= 743.0 min calculated for 0.053 af (71% of inflow)

Center-of-Mass det. time= 623.6 min (1,561.2 - 937.6)

Volume	Invert	Avail.Storage	Storage Description
#1	368.00'	1,290 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
368.00	600	0.0	0	0	600
368.75	600	40.0	180	180	665
369.75	600	40.0	240	420	752
371.75	600	40.0	480	900	926
372.75	600	40.0	240	1,140	1,012
373.00	600	100.0	150	1,290	1,034

Device	Routing	Invert	Outlet Devices
#1	Discarded	368.00'	**1.660 in/hr Exfiltration over Surface area**
#2	Primary	373.00'	**50.0' long x 0.25' rise Sharp-Crested Rectangular Weir** 2 End Contraction(s) 0.5' Crest Height

Discarded OutFlow Max=0.02 cfs @ 12.10 hrs HW=368.10' (Free Discharge)
↑**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.00 cfs @ 14.45 hrs HW=373.00' (Free Discharge)
↑**2=Sharp-Crested Rectangular Weir** (Weir Controls 0.00 cfs @ 0.01 fps)

Summary for Pond 6P: Storm Basin

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.00" for 10-Year Storm event
Inflow = 0.00 cfs @ 15.66 hrs, Volume= 0.000 af
Outflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 366.00' @ 37.35 hrs Surf.Area= 1,100 sf Storage= 0 cf

Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= (not calculated: no outflow)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=366.00' (Free Discharge)
├─**1=Culvert** (Controls 0.00 cfs)
└─**2=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,302 sf 23.28% Impervious Runoff Depth=0.95"
Flow Length=230' Slope=0.0010 '/' Tc=36.0 min CN=57 Runoff=0.89 cfs 0.124 af

Reach 3R: Reach 1A Avg. Flow Depth=0.35' Max Vel=1.80 fps Inflow=0.89 cfs 0.124 af
n=0.030 L=25.0' S=0.0100 '/' Capacity=33.02 cfs Outflow=0.89 cfs 0.124 af

Reach 5R: Reach 2A Avg. Flow Depth=0.49' Max Vel=0.98 fps Inflow=1.10 cfs 0.135 af
n=0.030 L=375.0' S=0.0020 '/' Capacity=14.77 cfs Outflow=0.78 cfs 0.135 af

Pond 1P: Rain Garden 2 Peak Elev=373.03' Storage=1,290 cf Inflow=0.89 cfs 0.124 af
Discarded=0.02 cfs 0.054 af Primary=1.10 cfs 0.135 af Outflow=1.13 cfs 0.188 af

Pond 6P: Storm Basin Peak Elev=367.26' Storage=3,286 cf Inflow=0.78 cfs 0.135 af
Outflow=0.11 cfs 0.086 af

Summary for Subcatchment 1S: Subcat 1S

Runoff = 0.89 cfs @ 12.38 hrs, Volume= 0.124 af, Depth= 0.95"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Year Storm Rainfall=4.70"

	Area (sf)	CN	Description
*	52,403	45	>75% Grass cover, Good, HSG A/B
	15,899	98	Paved parking, HSG A
	68,302	57	Weighted Average
	52,403		76.72% Pervious Area
	15,899		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
28.5	50	0.0010	0.03		**Sheet Flow, Turf Grass** Grass: Dense n= 0.240 P2= 2.90"
2.1	80	0.0010	0.64		**Shallow Concentrated Flow, Roadway** Paved Kv= 20.3 fps
5.4	100	0.0010	0.31	5.30	**Channel Flow, Grass Channel** Area= 17.3 sf Perim= 200.0' r= 0.09' n= 0.030 Earth, grassed & winding
36.0	230	Total			

Summary for Reach 3R: Reach 1A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.95" for 25-Year Storm event
Inflow = 0.89 cfs @ 12.38 hrs, Volume= 0.124 af
Outflow = 0.89 cfs @ 12.38 hrs, Volume= 0.124 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.80 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 0.84 fps, Avg. Travel Time= 0.5 min

Peak Storage= 12 cf @ 12.38 hrs
Average Depth at Peak Storage= 0.35'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.02 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 25.0' Slope= 0.0100 '/'
Inlet Invert= 373.25', Outlet Invert= 373.00'

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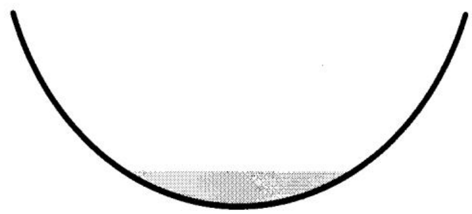


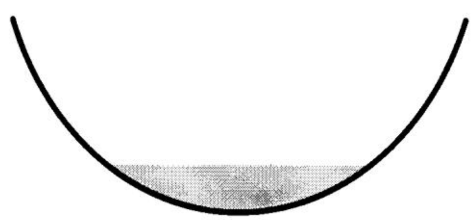
Summary for Reach 5R: Reach 2A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 1.03" for 25-Year Storm event
Inflow = 1.10 cfs @ 12.62 hrs, Volume= 0.135 af
Outflow = 0.78 cfs @ 12.92 hrs, Volume= 0.135 af, Atten= 29%, Lag= 18.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.98 fps, Min. Travel Time= 6.4 min
Avg. Velocity = 0.43 fps, Avg. Travel Time= 14.6 min

Peak Storage= 299 cf @ 12.81 hrs
Average Depth at Peak Storage= 0.49'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 14.77 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030
Length= 375.0' Slope= 0.0020 '/'
Inlet Invert= 367.75', Outlet Invert= 367.00'



Summary for Pond 1P: Rain Garden 2

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.95" for 25-Year Storm event
Inflow = 0.89 cfs @ 12.38 hrs, Volume= 0.124 af
Outflow = 1.13 cfs @ 12.62 hrs, Volume= 0.188 af, Atten= 0%, Lag= 14.3 min
Discarded = 0.02 cfs @ 12.00 hrs, Volume= 0.054 af
Primary = 1.10 cfs @ 12.62 hrs, Volume= 0.135 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 373.03' @ 12.60 hrs Surf.Area= 600 sf Storage= 1,290 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)

Center-of-Mass det. time= 195.1 min (1,111.8 - 916.7)

Volume	Invert	Avail.Storage	Storage Description
#1	368.00'	1,290 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
368.00	600	0.0	0	0	600
368.75	600	40.0	180	180	665
369.75	600	40.0	240	420	752
371.75	600	40.0	480	900	926
372.75	600	40.0	240	1,140	1,012
373.00	600	100.0	150	1,290	1,034

Device	Routing	Invert	Outlet Devices
#1	Discarded	368.00'	**1.660 in/hr Exfiltration over Surface area**
#2	Primary	373.00'	**50.0' long x 0.25' rise Sharp-Crested Rectangular Weir** 2 End Contraction(s) 0.5' Crest Height

Discarded OutFlow Max=0.02 cfs @ 12.00 hrs HW=368.07' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.83 cfs @ 12.62 hrs HW=373.03' (Free Discharge)
↑—**2=Sharp-Crested Rectangular Weir** (Weir Controls 0.83 cfs @ 0.56 fps)

Summary for Pond 6P: Storm Basin

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 1.03" for 25-Year Storm event
Inflow = 0.78 cfs @ 12.92 hrs, Volume= 0.135 af
Outflow = 0.11 cfs @ 16.71 hrs, Volume= 0.086 af, Atten= 85%, Lag= 227.2 min
Primary = 0.11 cfs @ 16.71 hrs, Volume= 0.086 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 367.26' @ 16.71 hrs Surf.Area= 8,491 sf Storage= 3,286 cf

Plug-Flow detention time= 411.7 min calculated for 0.085 af (64% of inflow)
Center-of-Mass det. time= 293.5 min (1,243.7 - 950.1)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

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Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.11 cfs @ 16.71 hrs HW=367.26' (Free Discharge)
1=Culvert (Inlet Controls 0.11 cfs @ 1.37 fps)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)

Time span=5.00-40.00 hrs, dt=0.05 hrs, 701 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Subcat 1S Runoff Area=68,302 sf 23.28% Impervious Runoff Depth=1.44"
Flow Length=230' Slope=0.0010 '/' Tc=36.0 min CN=57 Runoff=1.49 cfs 0.188 af

Reach 3R: Reach 1A Avg. Flow Depth=0.45' Max Vel=2.10 fps Inflow=1.49 cfs 0.188 af
n=0.030 L=25.0' S=0.0100 '/' Capacity=33.02 cfs Outflow=1.49 cfs 0.188 af

Reach 5R: Reach 2A Avg. Flow Depth=0.43' Max Vel=0.92 fps Inflow=0.98 cfs 0.019 af
n=0.030 L=375.0' S=0.0020 '/' Capacity=14.77 cfs Outflow=0.61 cfs 0.019 af

Pond 1P: Rain Garden 2 Peak Elev=373.03' Storage=1,290 cf Inflow=1.49 cfs 0.188 af
Discarded=0.02 cfs 0.054 af Primary=0.98 cfs 0.019 af Outflow=1.00 cfs 0.073 af

Pond 6P: Storm Basin Peak Elev=366.76' Storage=841 cf Inflow=0.61 cfs 0.019 af
Outflow=0.00 cfs 0.000 af

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Summary for Subcatchment 1S: Subcat 1S

Runoff = 1.49 cfs @ 12.36 hrs, Volume= 0.188 af, Depth= 1.44"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Year Storm Rainfall=5.60"

	Area (sf)	CN	Description
*	52,403	45	>75% Grass cover, Good, HSG A/B
	15,899	98	Paved parking, HSG A
	68,302	57	Weighted Average
	52,403		76.72% Pervious Area
	15,899		23.28% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
28.5	50	0.0010	0.03		**Sheet Flow, Turf Grass** Grass: Dense n= 0.240 P2= 2.90"
2.1	80	0.0010	0.64		**Shallow Concentrated Flow, Roadway** Paved Kv= 20.3 fps
5.4	100	0.0010	0.31	5.30	**Channel Flow, Grass Channel** Area= 17.3 sf Perim= 200.0' r= 0.09' n= 0.030 Earth, grassed & winding
36.0	230	Total			

Summary for Reach 3R: Reach 1A

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 1.44" for 100-Year Storm event
Inflow = 1.49 cfs @ 12.36 hrs, Volume= 0.188 af
Outflow = 1.49 cfs @ 12.36 hrs, Volume= 0.188 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.10 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 0.93 fps, Avg. Travel Time= 0.4 min

Peak Storage= 18 cf @ 12.36 hrs
Average Depth at Peak Storage= 0.45'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 33.02 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030 Earth, grassed & winding
Length= 25.0' Slope= 0.0100 '/'
Inlet Invert= 373.25', Outlet Invert= 373.00'

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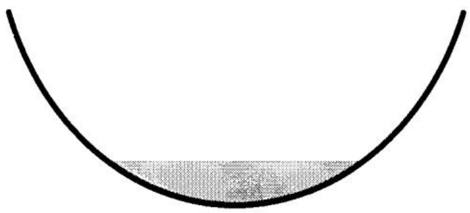

Summary for Reach 5R: Reach 2A

Inflow Area =	1.568 ac, 23.28% Impervious, Inflow Depth = 0.15"	for 100-Year Storm event	
Inflow =	0.98 cfs @ 12.42 hrs, Volume=	0.019 af	
Outflow =	0.61 cfs @ 12.67 hrs, Volume=	0.019 af,	Atten= 38%, Lag= 15.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.92 fps, Min. Travel Time= 6.8 min
Avg. Velocity = 0.22 fps, Avg. Travel Time= 28.5 min

Peak Storage= 253 cf @ 12.56 hrs
Average Depth at Peak Storage= 0.43'
Bank-Full Depth= 2.00', Capacity at Bank-Full= 14.77 cfs

5.00' x 2.00' deep Parabolic Channel, n= 0.030
Length= 375.0' Slope= 0.0020 '/'
Inlet Invert= 367.75', Outlet Invert= 367.00'

Summary for Pond 1P: Rain Garden 2

Inflow Area =	1.568 ac, 23.28% Impervious, Inflow Depth = 1.44"	for 100-Year Storm event	
Inflow =	1.49 cfs @ 12.36 hrs, Volume=	0.188 af	
Outflow =	1.00 cfs @ 12.42 hrs, Volume=	0.073 af,	Atten= 33%, Lag= 3.5 min
Discarded =	0.02 cfs @ 11.90 hrs, Volume=	0.054 af	
Primary =	0.98 cfs @ 12.42 hrs, Volume=	0.019 af	

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs / 2
Peak Elev= 373.03' @ 12.40 hrs Surf.Area= 600 sf Storage= 1,290 cf

Plug-Flow detention time= 598.7 min calculated for 0.073 af (39% of inflow)

Center-of-Mass det. time= 441.9 min (1,343.3 - 901.4)

Volume	Invert	Avail.Storage	Storage Description
#1	368.00'	1,290 cf	**Custom Stage Data (Conic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Voids (%)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
368.00	600	0.0	0	0	600
368.75	600	40.0	180	180	665
369.75	600	40.0	240	420	752
371.75	600	40.0	480	900	926
372.75	600	40.0	240	1,140	1,012
373.00	600	100.0	150	1,290	1,034

Device	Routing	Invert	Outlet Devices
#1	Discarded	368.00'	**1.660 in/hr Exfiltration over Surface area**
#2	Primary	373.00'	**50.0' long x 0.25' rise Sharp-Crested Rectangular Weir** 2 End Contraction(s) 0.5' Crest Height

Discarded OutFlow Max=0.02 cfs @ 11.90 hrs HW=368.06' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.02 cfs)

Primary OutFlow Max=0.70 cfs @ 12.42 hrs HW=373.03' (Free Discharge)
↑—**2=Sharp-Crested Rectangular Weir** (Weir Controls 0.70 cfs @ 0.53 fps)

Summary for Pond 6P: Storm Basin

Inflow Area = 1.568 ac, 23.28% Impervious, Inflow Depth = 0.15" for 100-Year Storm event
Inflow = 0.61 cfs @ 12.67 hrs, Volume= 0.019 af
Outflow = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min
Primary = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af

Routing by Stor-Ind method, Time Span= 5.00-40.00 hrs, dt= 0.05 hrs
Peak Elev= 366.76' @ 39.60 hrs Surf.Area= 1,101 sf Storage= 841 cf

Plug-Flow detention time= (not calculated: initial storage excedes outflow)
Center-of-Mass det. time= (not calculated: no outflow)

Volume	Invert	Avail.Storage	Storage Description
#1	366.00'	29,337 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
366.00	1,100	0	0
366.99	1,101	1,089	1,089
367.00	7,920	45	1,135
368.00	10,100	9,010	10,145
369.50	15,490	19,193	29,337

Device	Routing	Invert	Outlet Devices
#1	Primary	367.10'	**12.0" Round Culvert** L= 35.0' Ke= 0.500 Inlet / Outlet Invert= 367.10' / 366.70' S= 0.0114 '/' Cc= 0.900 n= 0.012
#2	Primary	368.00'	**10.0' long x 2.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00 2.50 3.00 3.50 Coef. (English) 2.54 2.61 2.61 2.60 2.66 2.70 2.77 2.89 2.88 2.85 3.07 3.20 3.32

Primary OutFlow Max=0.00 cfs @ 5.00 hrs HW=366.00' (Free Discharge)
1=Culvert (Controls 0.00 cfs)
2=Broad-Crested Rectangular Weir (Controls 0.00 cfs)