METHODOLOGIES TO EVALUATE DECENTRALIZED STORMWATER BEST MANAGEMENT PRACTICES IN GAINESVILLE, FL

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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This document is dedicated to all those who helped foster my interest in the beyond all around us. I would especially like to thank my parents for encouraging me to try new things…and to never stop trying.

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TABLE OF CONTENTS

page

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
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METHODOLOGIES TO EVALUATE DECENTRALIZED
STORMWATER BEST MANAGEMENT PRACTICES IN GAINESVILLE, FLORIDA.

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A wide variety of best management practices (BMPs) are available for controlling urban stormwater quantity and quality. Best management practices are tailored for many applications, from particle size alteration to sorption or flow attenuation. Low impact development (LID) methods are often classified as BMPs tailored for use in urban environments. From a functional perspective, LID can be thought of as onsite stormwater control, controlling runoff close to the source in a disaggregated and distributed network.

Two issues arise when trying to implement LID controls in an urban environment. The first issue is the need to control runoff volume within tight spatial constraints. The second issue is closely related. It is difficult to determine the net utility of decentralized BMPs within a watershed or even one parcel. My study documents cases in which one or more BMPs are implemented within parcels ranging from 1 to 1000 acres. My study addresses how to assess the net effect of these onsite control methods by presenting a methodology which steps the reader through the process of determining watershed goals, obtaining data, building a geographic database, moving the spatial and physical information from the geodatabase to a hydraulic/hydrologic modeling program, and evaluating BMPs by manipulating functional unit parameters.

Results indicate that BMPs are ubiquitous and that they function as control areas as well as sources of runoff in what can be a long chain of storage-infiltration-runoff steps. These BMPs can be represented explicitly by simulating a parcel or watershed at the functional unit scale. An efficient method for building a strong stormwater model is to perform analyses at a focused scale. Scales of site redevelopment seen in urban watersheds such as the Tumblin Creek Watershed in Gainesville, FL, are desirable.

Simulations were created for the adjacent Lake Alice Watershed, on the University of Florida campus, at three scales: 1,000 acres, 300 acres, and 7 acres. Modeling at the micro-scale level both captures the spatial reality of the site of interest and promotes a modular approach to modeling the larger watershed by aggregating those spatial data and combining the associated analysis with other micro-scale models to form a larger macro model that is still true to the spatial reality of the watershed. Results indicate that even a small increase in the depression storage of a functional land unit can reduce annual runoff volume measurably if placed in a strategic location.

Results also demonstrate the need to organize data and reference publications in a centralized, secure, and accessible manner. Future research opportunities include the production of a rapid simulation tool to select an optimal onsite control method using multiple criteria such as cost, social benefit, and longevity, simulating water quality benefits by changing functional land uses, and implementing an ontology to increase the value of current stormwater information.

CHAPTER 1
INTRODUCTION

Two conflicting issues arise in trying to implement and determine the performance of low impact development (LID) controls in urban watersheds. The first conflict exists between spatial constraints in urban environments and water quantity/quality control needs as described by Lewis (University of Florida 2006a, p 9-8):

> In general, the most effective stormwater treatment techniques come from traditional stormwater systems that retain as much water as is being displaced by new impervious surface. Therefore, these systems are large in area and require a great deal of additional land to treat runoff. This factor contrasts with the documented benefits of compact urban development (shorter distances for utilities, mass transit, walk-ability, fire and police protection, school busing – neighborhood schools and other energy-related sustainability factors). Thus, redevelopment and infill projects face a difficult task meeting today's stormwater requirements.

The second issue is that of managing or assessing the performance of disconnected controls. A major management concern is that while regional solutions for a watershed range from 1 to about 5 BMPs per 1,000 acres, as supported by the Lake Alice (University of Florida 2006a) and Tumblin Creek (Jones Edmunds & Associates 2006) watersheds, a network of thousands of LID controls within the same watershed can perform similar water quantity and quality control functions. Historically, it has been relatively easy to evaluate the net performance of centralized best management practices (BMPs), but it is much more challenging to evaluate numerous disconnected BMPs in a manner that allows locales to compare their effectiveness alongside centralized solutions. My study describes a methodology to evaluate decentralized LID controls in watersheds with largely centralized quantity controls.

Chapter 2 begins with a literature review of methods used to select BMPs in context of urban runoff management goals, followed by a second section summarizing how onsite control BMPs are integrated into the urban landscape today in part of the Tumblin Creek Watershed in Gainesville, Florida, known as the University Heights Redevelopment District. This section shows redeveloped/redeveloping properties and opportunity properties as identified in the City of Gainesville's University Heights Redevelopment Master Plan. Each redeveloped property is presented in four parts: pre-redevelopment site condition, current site condition, stormwater control calculations, and onsite BMP alternatives.

Chapter 3 discusses how to leverage data, models, and tools to make better decisions by developing a “cyberinfrastructure” as coined by the National Science Foundation (National Academy of Sciences 2001). The chapter is divided into three sections: computation services, information management, and collaboration services. It concludes with a demonstration of how an information management and collaboration system called Drupal® can be used to share lot-level site data described in Chapter 2 in a collaborative environment.

Chapters 4, 5, and 6 focus on the Lake Alice Watershed, directly west of the Tumblin Creek Watershed. Each chapter contains one of three case studies, progressing from a large watershed (1000 acres) in chapter 4, to a medium scale (300 acres) in Chapter 5 to a fine scale watershed analysis and simulation study (7 acres) in Chapter 6, as shown in Figure 1-1. The goal of each case study is to simulate stormwater flow within the watershed and select a cost-effective BMP solution to increase onsite stormwater volume control.

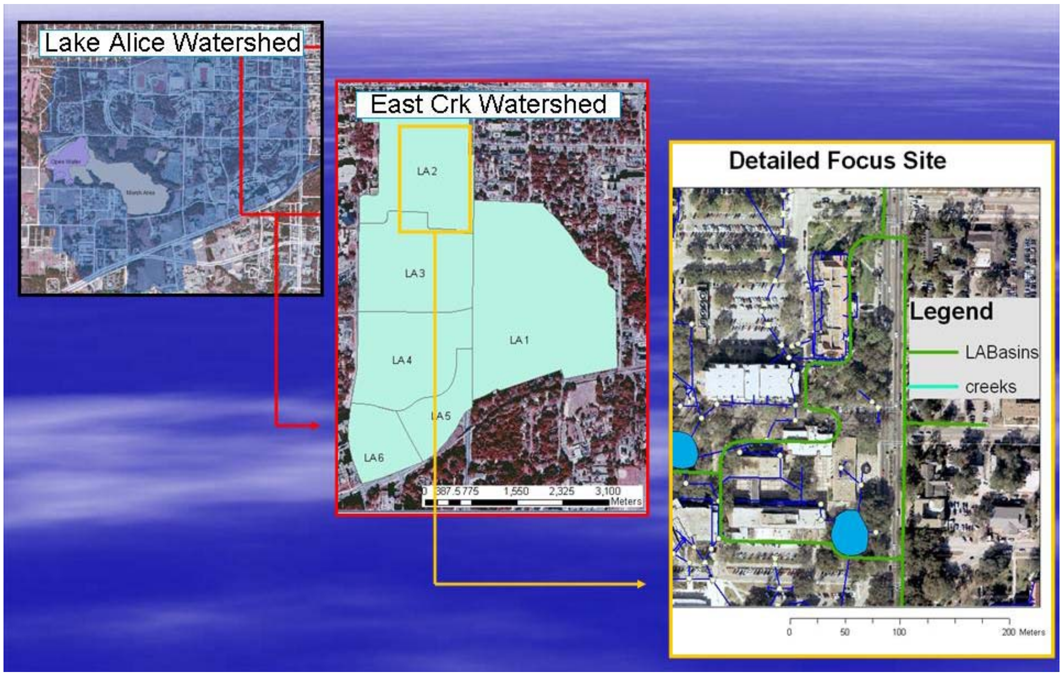

Figure 1-1: Three Scales Studied in Lake Alice Watershed

The hypotheses considered in these chapters are:

1. Watershed runoff can be simulated quickly and easily, provided that the site is well characterized and the data are organized in a minable cyberinfrastructure.

2. It is possible to select BMPs that increase onsite stormwater control by mining site data for critical flowpaths and using simulation tools to augment strategic functional land units within the watershed

The gradual progression towards increasingly focused case studies shows what difficulties are raised in simulating the behavior of the watersheds at each scale. The optimal simulation scenario involves creating a number of small, manageable simulations for subwatersheds (e.g., 7 acres) within a larger watershed (e.g., 300 acres). Components of each simulations can be aggregated into a simplifiied model (ideal for creating a larger aggregate model) and disaggregated to simulate the local influence of BMPs on a given site. Best management practices can be chosen based on desired goals and first principles. Chapter 7 summarizes my study and discusses research findings as well as future research needs.

CHAPTER 2
BEST MANAGEMENT PRACTICES IN TODAY'S URBAN ENVIRONMENT

Literature Review: Low Impact Development Practices Used for Urban Stormwater Management

A wide variety of best management practices (BMPs) are available for controlling urban stormwater quantity and quality. Low impact development (LID) options are now considered valid BMPs along with more traditional ponds, pits, and wetlands. Researchers from Oregon State University, the University of Florida, Geosyntec, and the Low Impact Development Center have created a guidebook on the effectiveness of stormwater BMPs (including LID) in the context of management objectives and fundamental processes (Geosyntec Consultants et al. 2006; Low Impact Development Center et al. 2006; Oregon State University et al. 2006; Strecker et al. 2005). Low impact development is a method of managing urban stormwater management close to the source of runoff. Stormwater management systems traditionally direct stormwater away from the site via a conveyance system to a centralized storage/treatment system or directly to a receiving water without any treatment. Detention has been a popular storage/treatment system since the 1970's. One example of a detention system in Gainesville is Lake Alice, on the University of Florida campus. Detention systems accumulate pollutants from stormwater runoff which need to be removed periodically and sometimes become unattractive or serve as mosquito breeding areas. Dissatisfaction with detention systems led to the idea of LID, beginning in Prince Georges County Maryland. Detailed information can be found at the website of The Low Impact Development Center (www.lowimpactdevelopment.org).

Urban stormwater management has three primary and numerous ancillary purposes. The three primary purposes are

- Flood control
- Drainage control
- Water quality control

Ancillary purposes include aesthetics, public greenspace, and other social or ecological elements which are often considered when siting BMPs.

Stormwater control has traditionally meant moving the excess water offsite as fast as possible so as to prevent onsite flooding and associated damages. A large scale example of this phenomenon is the Southeast Florida canal system that links multiple fields, farms, and storage reservoirs. It is only in the last 30 years that stormwater quality control has become a recognized issue in the United States. Urban runoff management needs to address the combination of objectives shown in Table 2-1.

There are some technical conflicts between the objectives of flood control and water quality control. Detention systems are traditionally designed for flood control, and so drain quickly in order to be available for the next storm. From a water quality perspective, it is desirable to hold water in these detention systems for a longer period of time to better reduce pollutant load through primary or secondary removal. It is possible to achieve both water quantity and quality requirements by focusing on the fundamental processes a given BMP performs and placing two or more in series if necessary. Table 2-

2 organizes BMPs according to their fundamental processes and Table 2-3 organizes BMPs according to pollutant control objectives.

Table 2-1: Urban Runoff Management Objectives Checklist

Category	Typical Objectives of Urban Runoff Management Projects
Hydraulics	Manage flow characteristics upstream, within, and/or downstream of treatment system components
Hydrology	Mitigate floods; improve runoff characteristics (peak shaving)
Water Quality	Reduce downstream pollutant loads and concentrations of pollutants Improve/minimize downstream temperature impact Achieve desired pollutant concentration in outflow Remove litter and debris
Toxicity	Reduce acute toxicity of runoff Reduce chronic toxicity of runoff
Regulatory	Comply with NPDES permit Meet local, state, or federal water quality criteria
Implementation	Function within management and oversight structure
Cost	Minimize capital, operation, and maintenance costs
Aesthetic	Improve appearance of site and avoid odor or nuisance
Maintenance	Operate within maintenance, and repair schedule and requirements Design system to allow for retrofit, modification, or expansion
Longevity	Achieve long-term functionality
Resources	Improve downstream aquatic environment/erosion control Improve wildlife habitat Achieve multiple use functionality
Safety, Risk and Liability	Function without significant risk or liability Function with minimal environmental risk downstream Contain spills
Public Perception	Clarify public understanding of runoff quality, quantity and impacts on receiving waters

Source: Oregon State University et al. 2006

Table 2-2: Structural Stormwater Controls and Associated Fundamental Process Categories

FPC**	UOP+	TSCs* Chosen to Provide UOP+
Hydrologic Operations	Flow Attenuation	Extended detention basins Retention/detention ponds Wetlands Tanks/Vaults
	Volume Reduction	Infiltration/exfiltration trenches and basins Porous pavement Bioretention cells Dry swales Dry well Extended detention basins
Physical Treatment Operations	Particle Size Alteration	Comminutors (not common for stormwater) Mixers (not common for stormwater)
	Size Separation and Exclusion (screening and filtration)	Screens/bars/trash racks Biofilters Porous pavement Infiltration/exfiltration trenches and basins Manufactured bioretention systems Media/sand/compost filters Hydrodynamic separators Catch basin inserts
	Density Separation (grit separation, sedimentation , flotation and skimming, and clarification)	Extended detention basins Retention/detention ponds Wetlands Settling basins Tanks/vaults Swales with check dams Oil-water separators Hydro-dynamic separators
	Aeration and Volatilization	Sprinklers Aerators Mixers
	Physical Agent Disinfection	Shallow detention ponds Ultra-violet systems

Table 2-2 continued.

FPC**	UOP+	TSCs* Chosen to Provide UOP+
Biological Processes	Microbially Mediated Transformation	Wetlands Bioretention systems Biofilters Retention ponds Media/sand/compost filters
	Uptake and Storage	Wetlands/Wetland Channels Bioretention systems Biofilters Retention ponds
Chemical Processes	Sorption Processes	Subsurface wetlands Media/sand/compost filters Infiltration/exfiltration trenches and basins
	Coagulation/Flocculation	Detention/retention Ponds Coagulant/flocculant Injection Systems
	Chemical Disinfection	Custom devices for mixing chlorine or aerating with ozone Advanced treatment systems

**FPC- Fundamental Process Category
*TSC-Treatment System Components
+UOP-Unit Operation and Processes
Source: Geosyntec et al., 2006

Table 2-3: Summary of Groups of Pollutants and Relevant BMPs Listed Based on Fundamental Process Categories

		BMPs					
Pollutant Class	Constituents	Gravity Settling	Filtration/ Adsorption	Infiltration	Biological	Chemical	Others/ Proprietary BMPs
Particulates	Sediments Solids Heavy metals Organics Nutrients	Retention ponds Detention basins Wetlands Tanks/vaults	Biofilters Media filters Compost filters Wetlands	Inf. trenches Inf. basins Porous pavement Swales Biofilters/ Bioretention	Biofilters/Compost filters Wetlands/Wetland channels		Wet vaults Vortex-Separators Constructedw etlands
Solubles	Heavy metals Organics/ BOD Nutrients		Media filters Compost filters Wetlands/ Wetland channels Retention ponds	Inf. trenches Inf. basins Porous pavement	Biofilters/compost filters Wetlands/wetland channels	Precipitation/ flocculation Activated carbon	Inert/media filters
Trash/ Debris	Trash/ Debris		Screening Continuous deflective separation				
Floatables	Oil and Grease	Retention ponds Wetlands Hooded catchbasins	Catch basin inserts Vault filters Compost filters		Biofilters/compost filters Wetlands		Oil/water separators

Source: Geosyntec et al. 2006

When a fundamental process category (FPC) view is taken, MPs/LID principles are everywhere. Indeed, most existing urban developments include some form of on-site control, whether proprietary, as shown in Table 2-4, or otherwise. A survey of the Tumblin Creek Watershed in Gainesville, FL (described in the next section) shows that a wide range of control methods are being utilized at various scales of urban redevelopment.

Table 2-4: Proprietary BMPs in Current Use by Treatment Type

Proprietary BMP	Trade Names
Wet vaults	Stormceptor BaySaver StormVault Continuous Deflective Separation (CDS) Unit ADS Retention/Detention System
Constructed wetlands	StormTreat
Vortex separators	Vortechs Aquafilter V2B1 Downstream Defender
Inert/sorptive media filters	StormFilter
High-flow bypass	StormGate
Modular pavement	Various

Source: Oregon State University et al. 2006

Low Impact Development Inventory of an Urban Watershed in Gainesville, Florida

University Heights is a redevelopment district within the Tumblin Creek Watershed (TCW). The redevelopment district has its boundaries defined and is managed by the Community Redevelopment Agency (CRA), part of the City of Gainesville. The CRA lays out a master plan for the site and provides funding for redevelopment within that area. University Heights is pictured in the 1,400 acre TCW (Figure 2-1).

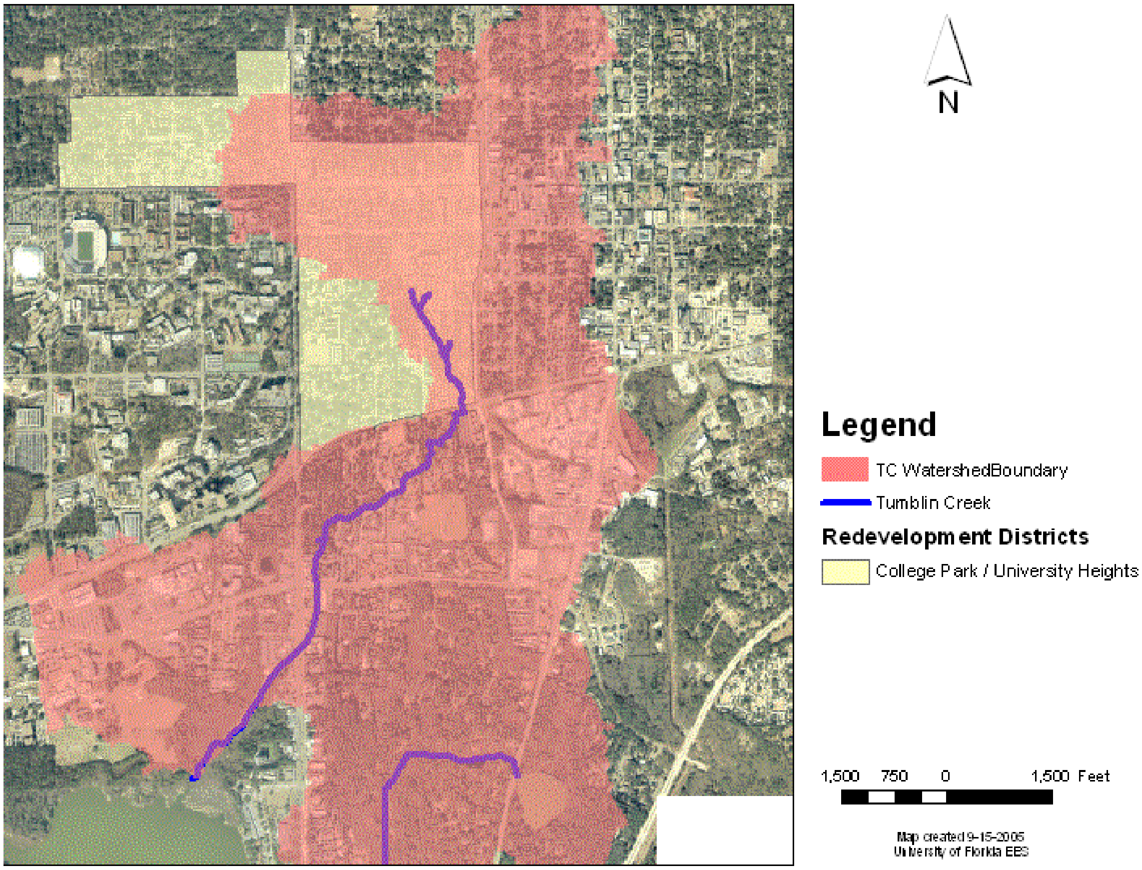

Figure 2-1: Map of Tumblin Creek Watershed and University Heights

The author performed an inventory of LID currently used in this redevelopment district under contract with Jones Edmunds & Associates for the City of Gainesville. A report that includes much of the following data is scheduled to be released within the year. Extensive portions of the upper TCW are undergoing redevelopment that will significantly intensify land use. From a stormwater management perspective, questions have arisen as to the extent to which this redevelopment will change the quantity and quality of runoff from these areas. There is interest in applying LID-type controls as part of the management strategy.

The following sections within this chapter describe existing and planned stormwater controls and the extent to which LID practices have been applied. This is an important step in identifying the ease of integrating LID practices into the urban landscape, and it provides an indication of what is already carried out onsite. Some of the redevelopment projects are shown in Figure 2-2. Please refer to Table 2-18 for addresses and parcel information associated with each development.

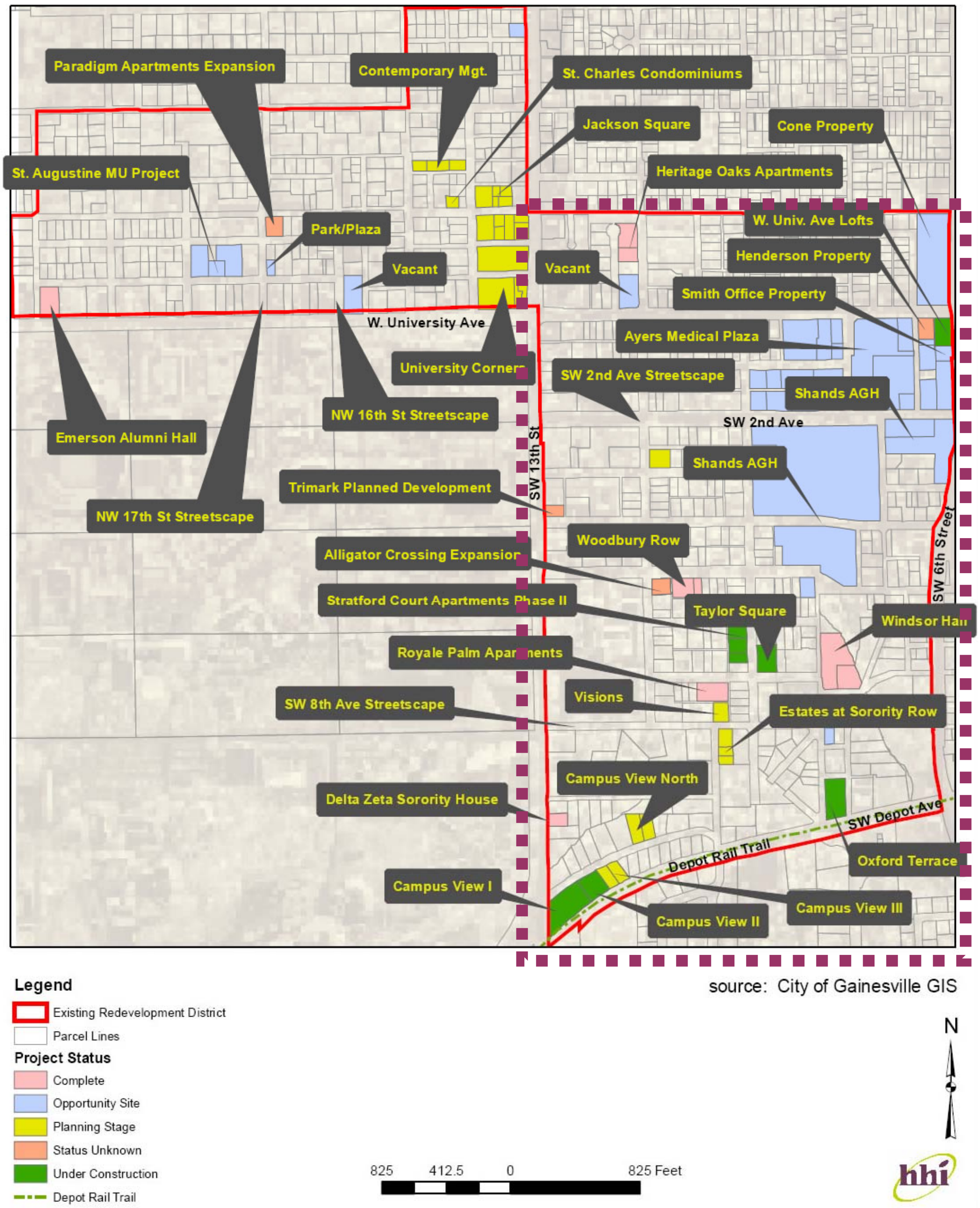

Figure 2-2: Selected Redevelopment Projects In or Near the Tumblin Creek Watershed (Community Redevelopment Association, 2005)

In an effort to condense this chapter while still providing useful BMP information, the next section entitled "Redeveloped/Redeveloping Properties" will focus on each of the redeveloped properties separately, discussing pre-existing site conditions, current site conditions, stormwater calculation information, and alternative stormwater control measures. Next, "Opportunity Sites" will focus on current site conditions only, followed by a brief summary and conclusion section.

Redeveloped/Redeveloping Properties

Heritage Oaks

Preexisting site conditions. Prior to 2002, this 0.89 acre site contained five two-story residential structures, a storage shed, concrete sidewalks, and brick paved driveways. Stormwater drained from the site to the City of Gainesville storm sewer system via curb and gutter drainage at NW 12th Terrace and NW 12th Street. A large grassy area around the houses infiltrated runoff from most roofs, sidewalks, and a patio. Driveways were generally directly connected impervious areas (DCIA), draining to the city streets as were a portion of some roofs.

Current site conditions. The re-development of Heritage Oaks integrates both new construction and historic buildings into an apartment complex with many low cost stormwater control BMPs. Existing impervious surfaces on the site (such as sidewalks and driveways) were razed prior to constructing three 2-story multi family homes, totaling 16 units. New concrete sidewalks and asphalt parking accompany the new buildings. All five existing residential structures were refurbished. Water quality treatment for the three new buildings and the parking lot is now provided by an infiltration trench beneath the parking lot while runoff from the older buildings drains onto the landscaped area surrounding each.

The old brick houses shown in Figure 2-3 represent houses that existed prior to reconstruction. The buildings with colored side paneling (back of photo) are newer construction. A majority of the stormwater draining from the roofs of older buildings continues to drain to the landscaped area around them as pictured in Figure 2-4. The concrete sidewalk around the perimeter of the property has been narrowed by one half of its width. A streetside bioretention strip infiltrates runoff generated from the sidewalk hardscape, and provides an aesthetically pleasing separation between sidewalk and roadway. The bioretention area pictured in Figure 2-5 is designed to treat runoff from a no mortar brick sidewalk and from the disconnected roof. The complex incorporates pervious parking next to the older buildings (see Figure 2-6) with asphalt parking at the new buildings. Flow from the roof travels to a pervious (no mortar) brick patio and parking lot as pictured in Figure 2-7. Runoff from the newer buildings drains into a centralized infiltration trench system located under the hardscape parking lot. The downspouts from the roof drains “disappear” underground. The landscaping around the buildings is watered by sprinkler, not roof runoff, as shown in Figure 2-8.

Figure 2-3: Heritage Oaks View From East

Figure 2-4: Heritage Oaks Refurbished Building, Facing West

Figure 2-5: Heritage Oaks Bioretention Area

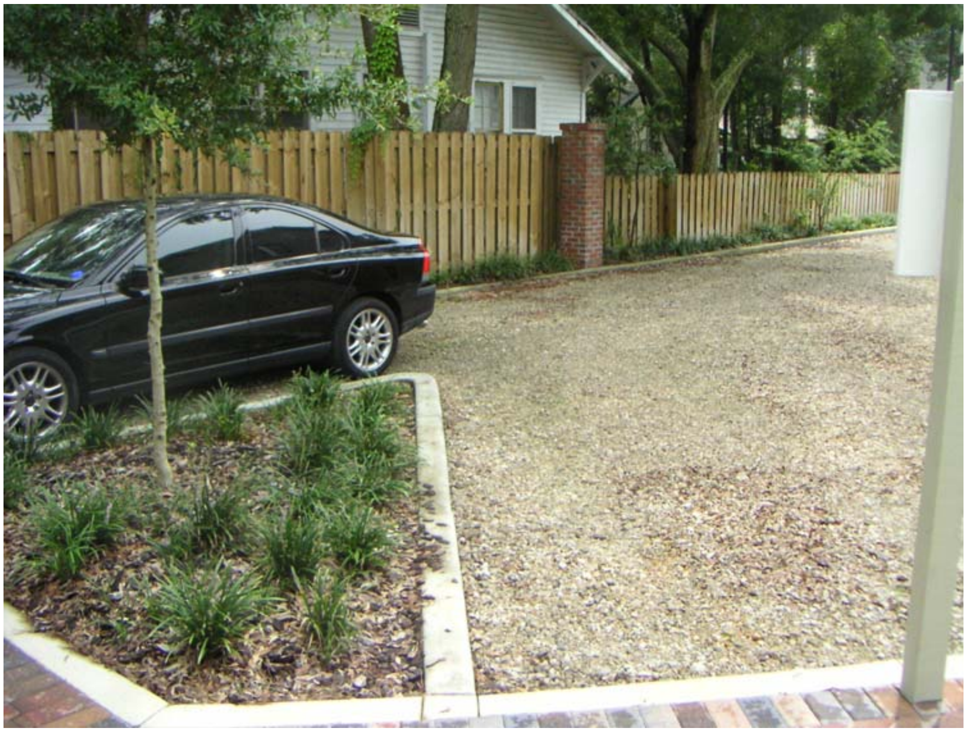

Figure 2-6: Heritage Oaks Pervious Parking Lot

Figure 2-7: Heritage Oaks Roof Draining to Pervious Parking via No-Mortar Patio.

Figure 2-8: Heritage Oaks—New Building Downspout

The largest single BMP onsite is the dual module infiltration system shown in Figure 2-9. The medium-gray area at the bottom of the image is the infiltration system (divided into two trenches). The trench system, called the Atlantis Water Management System (AWMS) and designed by the Atlantis Corporation® (http://www.atlantiscorp.com.au/) is located beneath the parking lot. This system is described in greater detail in the Oxford Terrace site review. This underground pit temporarily stores and treats rooftop and pavement runoff before infiltrating into the subsurface.

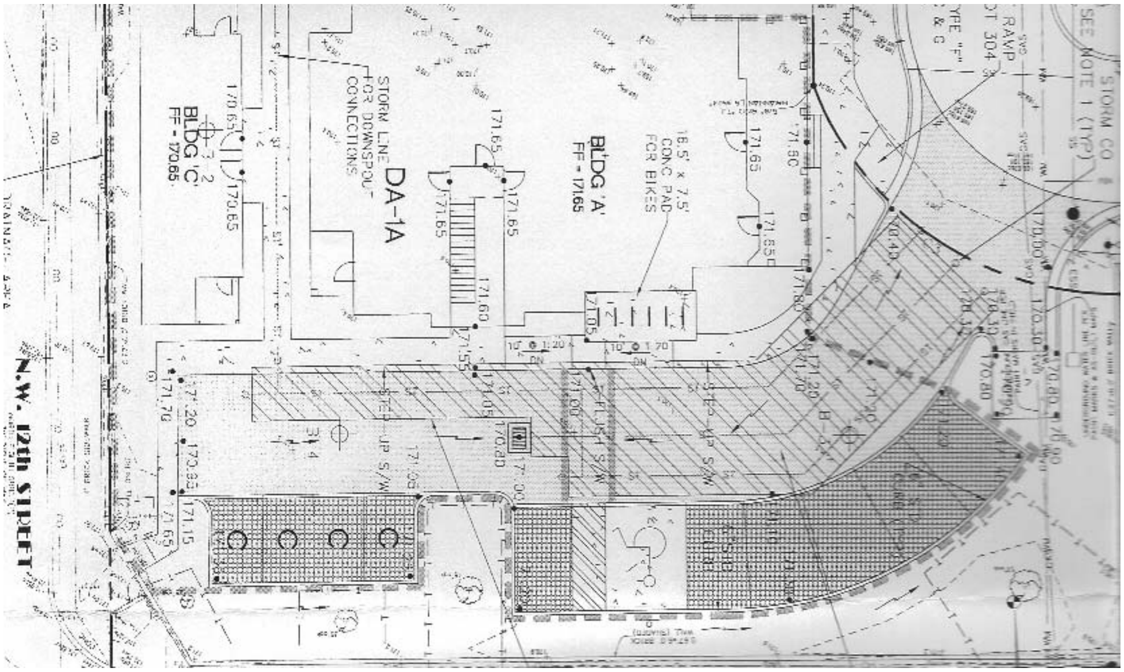

Figure 2-9: Heritage Oaks Infiltration Pits (Brown & Cullen Inc. 2002)

Stormwater calculation information. Water quality treatment for the new buildings and parking lot is provided by an infiltration pit beneath the parking lot. Runoff from two of the proposed buildings and the majority of the parking area will drain to the infiltration trench system by sheet flow and roof drains. Runoff from a building denoted “Building B” by the design engineers cannot feasibly be routed to the treatment system due to its location on the site; however the building area was used as part of the infiltration trench design calculations. Therefore, water quality treatment compensation via "over-treatment" is provided for the proposed impervious surface from “Building B” that cannot be routed to the proposed treatment system (SJRWMD 2002a). The remainder of the site follows pre-development drainage patterns with some notable changes such as reduced sidewalk hardscape area.

The SCS CN method was used to estimate runoff. Open area was estimated to have a coefficient of runoff (C) value of 0.15 while impervious area had a C value of .95 and semi-impervious area was given a C value of 0.75. Using these estimates, 1,878 cu. ft was determined as the water quality treatment volume (WQTV), defined as the first 1.25 inches of impervious runoff plus an additional 0.5 inches of overall runoff by the SJRWMD. Using the FDOT/SJRWMD Modified Rational Method, a peak stage of 169.9 ft MSL (of a max 170 ft MSL) was estimated.

A stormwater analysis was performed using PONDS software. The PONDS software automates the process of developing a hydrograph and routes the runoff to a pond, infiltration pit, or other retention facility (Seereeram, 2003). It can iteratively solve intra-storm drawdown during each time step under both unsaturated, transitory, and saturated conditions and will measure drawdown after the storm event. Transient vertical unsaturated flow is modeled using an algorithm developed by Seereeram, the software developer. The details of this algorithm are described in help documentation accompanying the latest version of PONDS (Seereeram, 2003). Transient, lateral saturated-flow ground water discharge is modeled using a modified version of the USGS MODFLOW numerical technique. The following parameters are necessary for the program.

1. Base of aquifer
2. Seasonal high water table elevation
3. Horizontal saturated hydraulic conductivity (safety factor of 2)
4. Fillable porosity [n]
5. Safety factor for vertical infiltration rate (unsaturated)
6. Maximum area for unsaturated infiltration
7. Equivalent pond length & equivalent pond width
8. Stage – area relationship

Calculations show a full recovery of the WQTV within 2 hours, calculated using PONDS. The geotechnical report estimates the SHWT at 7 feet below land surface, leaving enough space to install an infiltration trench without extensive backfill and/or lowering the local water table. Site soil analysis measured permeability between 17 and

18 ft/day, with one boring (B-5) at 11.6 ft/day. The infiltration system is considered online, and as such, satisfied SJRWMD criteria to treat the first 1.25 inches of impervious runoff plus an additional 0.5 inches of overall runoff, which produced a higher runoff volume than the first 1 inch from the site. The cost to install the infiltration system at Heritage Oaks was $45,066. This equates to $2,146 per dwelling unit for the 21 dwelling units.

Alternative stormwater control measures. Heritage Oaks integrates both old and new houses in a way that is both environmentally conscious and aesthetically pleasing. Many on-site BMPs were put in place at this complex. However, this is a medium intensity development and probably will not be used in the core of new development in University Heights. Although not technically owned by Heritage Oaks, the tree island in the cul-de-sac (Figure 2-10) can be converted to a notched and recessed design when the road is repaved to further reduce runoff adjacent to the lot.

Figure 2-10: Heritage Oaks Cul-de-sac

Campus View I, II, III, & North

Preexisting site conditions. No photographs are currently available for preexisting site conditions; however, the lot now known as Campus View I used to contain a one-story stucco house with disconnected roof drainage, a DCIA driveway that drained to the sidewalk and city stormwater system, a shed area, and a grassy treed area surrounding the house. Figure 2-11 shows the drainage path from the 0.5 acre property NW towards the city stormwater system. There is a significant elevation change from 122 ft to 117 ft.

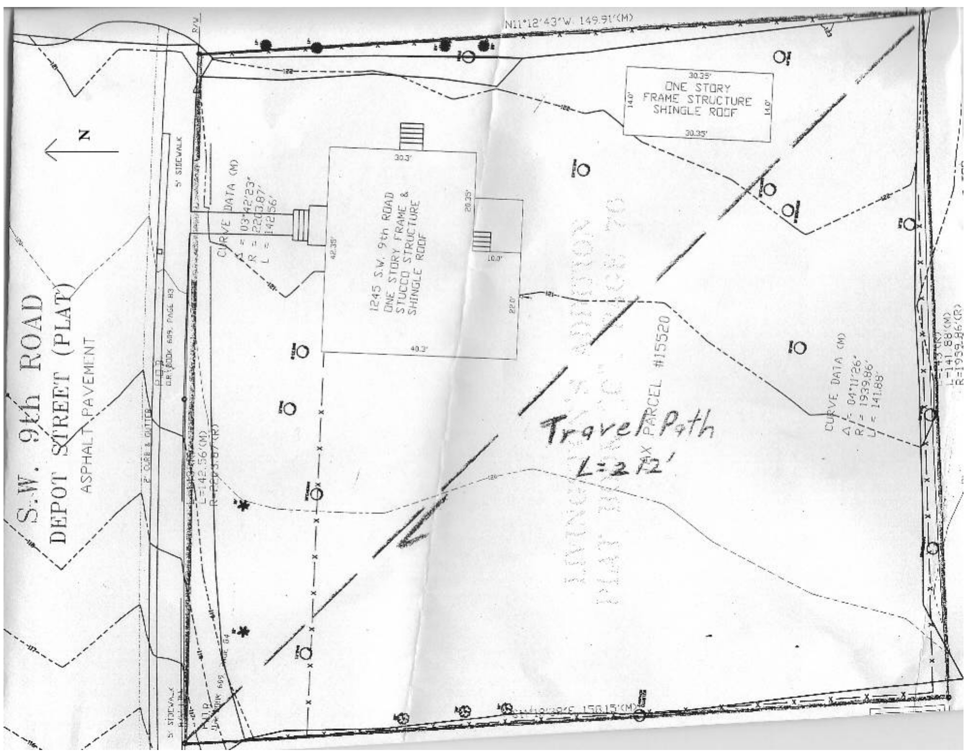

Figure 2-11: Campus View I—Pre Redevelopment (North is left) (Causseaux & Ellington 2004a)

While no explicit on-site controls have been in place, the pervious area on the property was large enough to infiltrate impervious area runoff from the shed and house with a greater than 2:1 pervious to impervious area relationship. Runoff to the city stormwater system was likely close to predevelopment conditions, with the exception of added peak flow from the driveway. At the time of writing, preexisting condition information is unavailable for Campus View II, III, and North which neighbor Campus View I to the East, far East, and North, respectively. However, based upon neighboring properties, lot conditions are likely similar, with a single family home on a pervious lot.

Current site conditions. Campus View II, III, and N are currently under planning and development. The redeveloped site layout for Campus View I is shown in Figure 2-12. Drainage area two covers most of the property, while drainage area one covers the northwest corner of the site. Figure 2-13 is a photograph of Campus View I to the right and Campus View II to the left; Figure 2-14 is a photograph of Campus View II. The facades of these buildings look very similar to the Oxford Terrace apartment complex. These buildings are three stories tall with no parking underneath. The land was converted from dense trees, ivy, underbrush, and grass that sloped to the northwest to a more impervious area with higher land use intensity and flow away from the property in both northern and southern directions

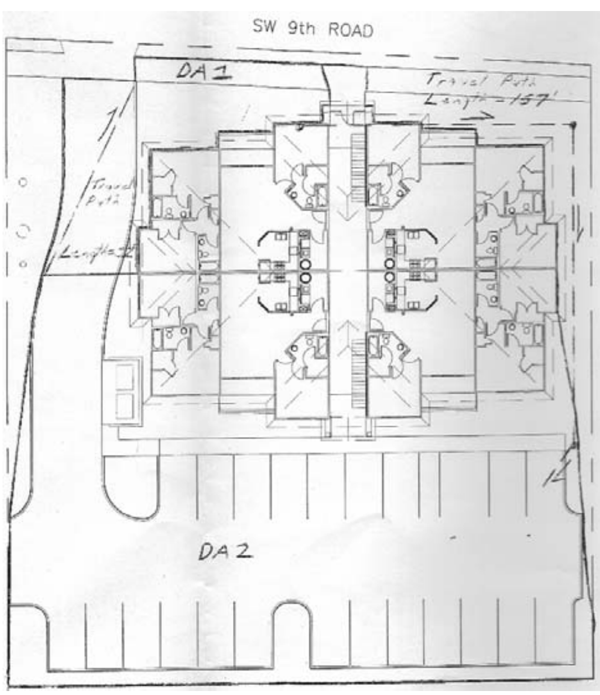

Figure 2-12: Campus View I—Redeveloped Site Map (North is up) (Causseaux & Ellington 2004a)

Figure 2-13: Campus View I and II (Under Development)

Figure 2-14: Campus View II (Under Development)

Stormwater calculation information. At Campus View I, two stormwater control facilities are used on site, one for each of two drainage areas. Drainage area one (DA-1) is serviced by a dry retention basin. Drainage area two (DA-2) is serviced by an infiltration pit beneath the parking lot called the Atlantis Water Management System (AWMS); this system is described in greater detail in the Oxford Terrace site review. According to Causseaux and Ellington (2004), the retention basin receives and infiltrates 100% of the DA-1 runoff volume. They also state that the AWMS system infiltrates 1005 of the runoff from DA-2. Therefore, Causseaux & Ellington considered both retention systems as offline. However, SJRWMD said that the systems must be analyzed as an online system because there is no bypass opportunity and a second analysis for DA-1 and DA-2 was submitted to SJRWMD in response to an RAI.

Causseaux & Ellington used a stormwater program called PONDS to assess WQTV recovery time and intra-storm water table mounding. Programmatic methods are as described in the Heritage Oaks calculation summary. The general analytical process used by Causseaux & Ellington can be summarized as follows: Predevelopment runoff calculations were performed. A weighted pre-redevelopment curve number (CN) of 46 was used; post-redevelopment CNs of 76 and 89 were used for DA-1 and DA-2, respectively. The post-redevelopment time of concentration was stated as less than 10 min but the engineers assumed it to be ten minutes in the PONDS simulations. Upon contacting the PONDS developer, the developer made it clear that PONDS can perform analyses with <10 min timesteps.

Soils information was gathered by SDII, a geotechnical consulting firm in Gainesville. The average depth to the seasonal high water table (SHWT) was determined to be 3.5 feet below land surface at the site of the infiltration BMPs. This caused problems in installation of the AWMS, as many feet of cut and backfill were necessary to provide enough water volume treatment.

A discussion surrounding the placement of an infiltration system above such a high water table can be found in SJRWMD RAI 92642-2-987426 (2004a) and the reply can be found in SJRWMD RAI Response 92642-2-154598 (2004a), wherein SJRWMD stated that “It [was] unclear how the seasonal high groundwater table elevation was determined” (SJRWMD 2004a). Causseaux & Ellington was asked to demonstrate how undercutting would lower the groundwater table to the needed 115.02 ft. A series of assumptions and conservative estimates were made to prove that the system would function as performed. A sediment sump was included in the design for both East and West ends of SMF-2 to assist in removing particulates and their associated metals and pathogens.

Alternative onsite control measures. Figures 2-13 and 2-14 show construction materials and mounds of overburden covering and possibly compacting the ground surface. During construction, the contractors could avoid putting heavy items on pervious surfaces that do not need soil augmentation. If this is not possible, then grading could be used to minimize the time of concentration (Tc). This could increase soil water capacity and decrease the need to irrigate. Currently, Campus View I, after being completely redeveloped, produces overland flow to the northwest corner of the property and onto the sidewalk during sprinkling.

Oxford Terrace

Preexisting site conditions. Oxford Terrace formerly consisted of a 1-story office building and asphalt parking lot with forested land area covering rest of the property. This is represented in the GIS image in Figure 2-15.

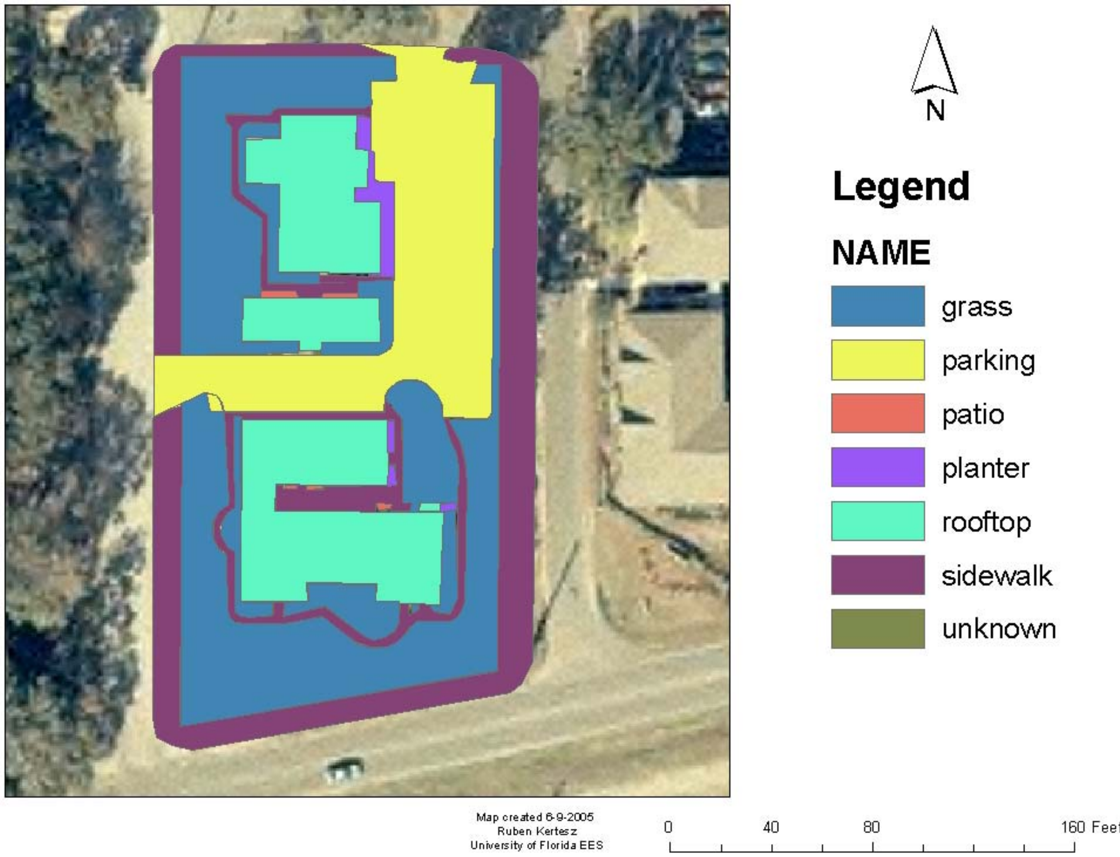

Figure 2-15: Oxford Terrace—GIS Representation of Pre-redevelopment Lot

Current site conditions. The 0.72 acre site is located at 847 Depot Avenue. The redevelopment plan involved demolishing all existing structures, including a 1-story office building with surface parking, and constructing a 3-story, 36 unit multifamily residential complex with parking underneath, two sidewalks, and two new paved drives (Causseaux & Ellington 2004b). This resulted in an impervious area of 0.54 acres, as calculated by Causseaux & Ellington.

The site can be divided into three drainage areas. Two of the drainage areas drain to infiltration pits beneath the parking lot while the southernmost drainage area drains to a surface dry retention basin at the southern end of the property. Post redevelopment conditions are represented in Figure 2-16.

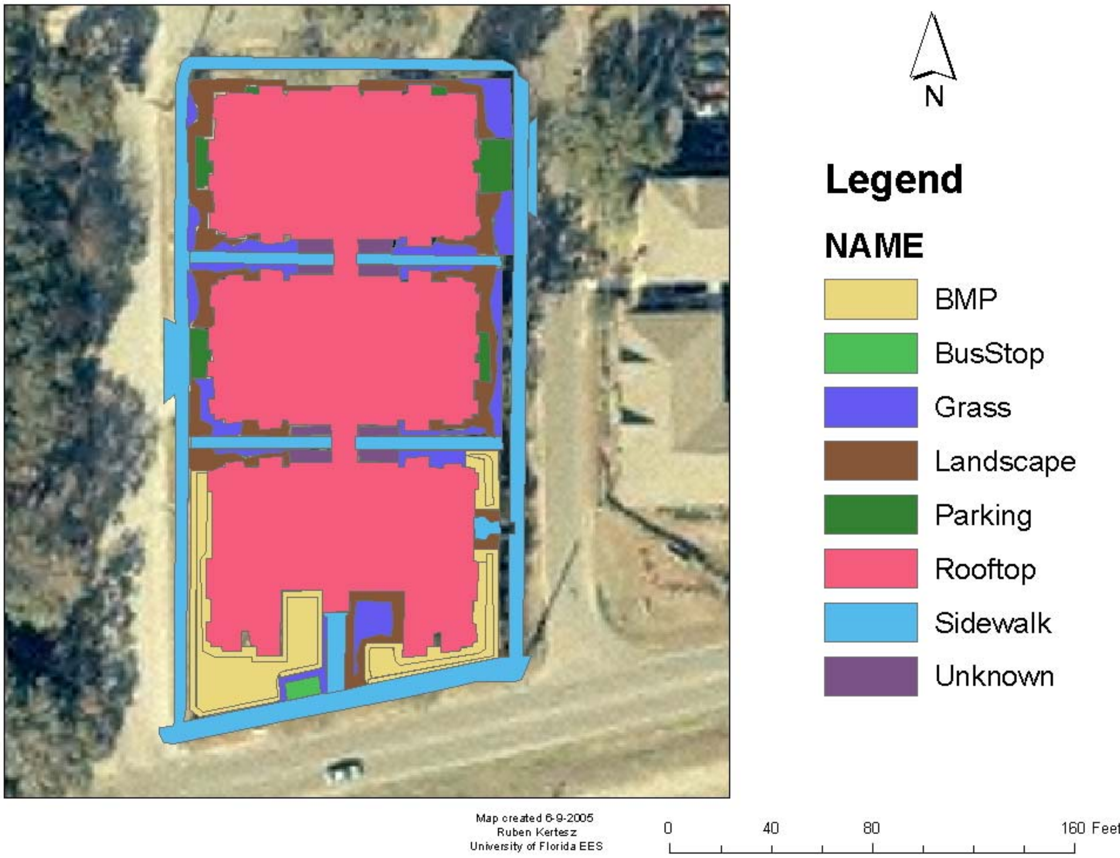

Figure 2-16: Oxford Terrace After Redevelopment

Stormwater calculation information. Drainage area characteristics such as size, infiltration BMP size, and curve number are summarized in Table 2-5. A CN of 32 was chosen for pervious area in DA-3 that characterizes a wooded or grassy area type A soil group. (CH2MHill, 1987) The post redevelopment CN calculation methodology is shown in Table 2-6. Soil boring and auger information is shown on a map of the site in Figure 2-17.

Table 2-5: Oxford Terrace Drainage Area Characteristics

Drainage Area	DA-1	DA-2	DA-3
Location on Property	North	Central	South
Acres	.281	.216	.217
Stormwater Management Facility	SMF-1 Online, closed, dry pond	SMF-2 Infiltration basin	SMF-3 Infiltration basin
Cubic feet of SMF	2,908	2,343	2,435
Predevelopment CN	77	77	32
Postdevelopment CN	89	93	80

Table 2-6: Oxford Terrace—Calculation of Post Development CN Values

Drainage Area	CN Soil	Area Soil (acres)	CN Impervious Area	Area Impervious (acres)	Runoff CN =(Col2*Col3+Col4*Col5)/(Col3+Col5)
SMF-1	77	.11	98	.17	89
SMF-2	77	.05	98	.16	93
SMF-3	32	.06	98	.16	80

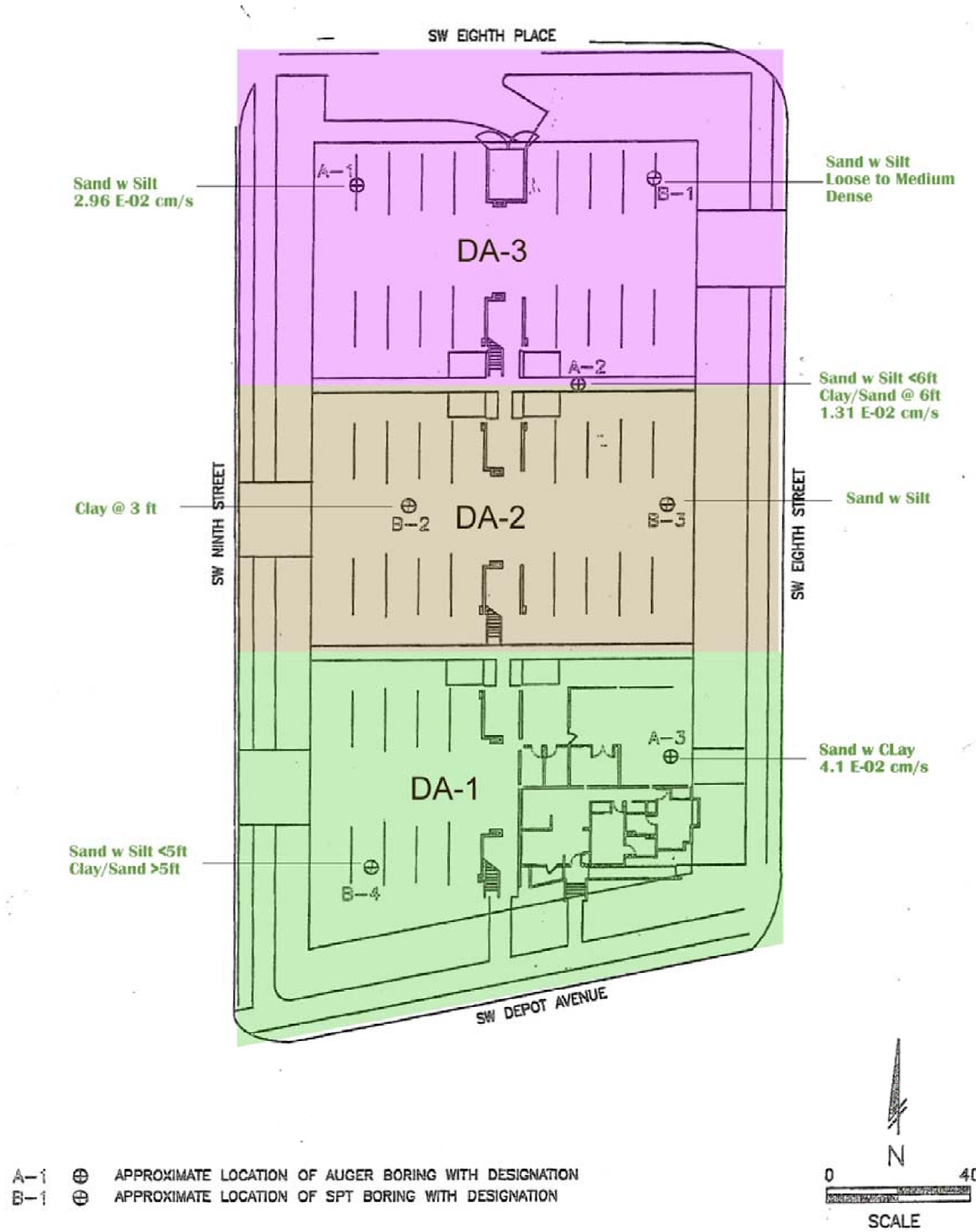

Figure 2-17: Oxford Terrace Auger Map / SDII Land Use Characteristics (SDII 2004a)

Causseaux & Ellington determined the stormwater management facility (SMF) dimensions shown in Figure 2-17 by sizing them to capture the 100 year critical storm as well as the 25-year 24-hour storm and the mean annual storm event, or the annual rainfall divided by the number of storm events in the year (EPA 1986). Then they checked to ensure that the SMFs also provided the proper WQTV. The method used to size the SMF to retain the 100 year critical storm (that storm which produces the greatest runoff) as well as the 25 year -24 hour storm and the mean annual storm event was as follows. The engineer first generated rainfall hyetographs using Florida Department of Transportation distributions for all the 100-year frequency storms and the 25 year -24 hour storm. - The mean annual storm event hyetograph was created by multiplying the NRCS Type II modified dimensionless rainfall distribution by the total rainfall depth of the mean annual storm event (MASE). The MASE rainfall distribution is shown in Table 2-7. Runoff hydrographs were then generated following the NRCS method (NRCS 1986). The hydrographs were routed through the modeled stormwater system.

Traditionally, predevelopment runoff is performed first, and then compared to post development runoff, but in this case, where all the systems are closed basins, pre-development calculations were not performed for SMF-2 or SMF-3 because they were sized to produce no post-development overflow for the aforementioned design storms. Parameters needed to create the runoff hydrograph for each drainage area are the watershed area, CN, and time of concentration (Tc) values for each drainage area, as shown in Table 2-8. The time of concentration used for all drainage areas was 10 minutes, which is a common practice for small basin sites. Tc is a function of overland flow length, slope, and roughness.

Table 2-7: Mean Annual Storm Event (MASE) Rainfall Distribution

Duration Hours	MASE P (in)	Duration hours	MASE P (in)	Duration hours	MASE P (in)	Duration hours	MASE P (in)
0	0	6	0.0123	12	1.107	18	0.0123
0.25	0.0082	6.25	0.0164	12.25	0.2624	18.25	0.0123
0.5	0.0082	6.5	0.0123	12.5	0.2091	18.5	0.0123
0.75	0.0041	6.75	0.0123	12.75	0.1189	18.75	0.0123
1	0.0082	7	0.0164	13	0.0943	19	0.0123
1.25	0.0082	7.25	0.0164	13.25	0.082	19.25	0.0123
1.5	0.0082	7.5	0.0164	13.5	0.0697	19.5	0.0082
1.75	0.0082	7.75	0.0164	13.75	0.0451	19.75	0.0123
2	0.0082	8	0.0164	14	0.041	20	0.0082
2.25	0.0082	8.25	0.0205	14.25	0.0369	20.25	0.0123
2.5	0.0082	8.5	0.0205	14.5	0.0369	20.5	0.0082
2.75	0.0123	8.75	0.0205	14.75	0.0328	20.75	0.0082
3	0.0082	9	0.0205	15	0.0287	21	0.0082
3.25	0.0082	9.25	0.0328	15.25	0.0205	21.25	0.0123
3.5	0.0082	9.5	0.0328	15.5	0.0205	21.5	0.0082
3.75	0.0123	9.75	0.0328	15.75	0.0205	21.75	0.0082
4	0.0082	10	0.041	16	0.0164	22	0.0082
4.25	0.0123	10.25	0.0451	16.25	0.0164	22.25	0.0082
4.5	0.0082	10.5	0.0492	16.5	0.0164	22.5	0.0082
4.75	0.0123	10.75	0.0738	16.75	0.0164	22.75	0.0082
5	0.0123	11	0.0861	17	0.0164	23	0.0082
5.25	0.0082	11.25	0.1066	17.25	0.0123	23.25	0.0082
5.5	0.0123	11.5	0.1353	17.5	0.0164	23.5	0.0082
5.75	0.0123	11.75	0.4469	17.75	0.0123	23.75	0.0082
						24	0.0041

Table 2-8: Oxford Terrace—Parameters Used to Create a Runoff Hydrograph

	Area	Predev. CN	Postdev. CN	Tc (min)
SMF 1	.281	77	89	10
SMF 2	.216	77	93	10
SMF 3	.217	32	80	10

PONDS software was used to route the runoff hydrograph through each of the three SMFs in separate discrete analyses. As a safety factor, Causseaux & Ellington chose to design using infiltration values reduced by one half from those measured by SDII. The saturated flow conductivity was reduced by an additional one half, resulting in a safety factor of 4. In SMF-1, it appears that a K of 7.5 was used instead of 22.5, resulting in an even higher safety factor. Maximum area is the area at the widest dimension of the pond. Equivalent pond length and width are determined by measuring the effective perimeter of the pond and ensuring that 2 * (width + length) is approximately equal to the perimeter while the volume is equal to the maximum volume of the SMF. It is used to approximate the pond as a rectangular prism to simplify calculations. General soil characteristics for the entire site are shown in Table 2-9. Detailed dimensions for each SMF are shown in Table 2-10.

Table 2-9: Oxford Terrace—Soil Characteristics Used for Storm Event Simulation

	Measured Value	Safety Factor of 2	Value used for SMF-1
Base of Aquifer	115 ft NGVD	--	--
SHWT	115.5 ft	--	--
Vertical Infiltration	37 ft/day	18.5 ft/day	--
Horizontal Conductivity	45 ft/day	22.5 ft/day	7.5 ft/day
Fillable Porosity	25 %	--	--

Table 2-10: Oxford Terrace—Stormwater Management Facility (SMF) Dimensions Used for Storm Event Simulation

SMF	Invert (ft)	Area at invert (ft^2)	Max. elev. (ft)	Area at max depth (ft^2)	Storage Volume (ft^3)
SMF-1	121	1689	122	2907	2309
SMF-2	118	2183	119.48	2183	3460
SMF-3	118	2435	119.48	2435	3615

Soil auger tests performed by SDII in drainage areas 1, 2, and 3 suggest all three areas consist mainly of a Millhopper/Urban land mix that is moderately well drained, with some Kanapaha sand interspersed throughout. The permeabilities of augers A-1, A-2, and A-3 with locations shown on Figure 2-17 are tabulated in Table 2-11.

Table 2-11: Oxford Terrace—SDII Soil Testing Infiltration Results

Auger	Permeability (cm/s)
A-1 (DA-3)	1.96 E-02
A-2 (DA-2)	1.31 E-02
A-3 (DA-1)	4.09 E-02

Soil boring tests were also performed by SDII, and while most of the borings indicated clayey sand soils, one boring, located in DA-2 indicated an expansive clay soil only 3 ft below the surface. Their recommendations were to undercut the soil in that location and backfill it in order to reduce the possibility of swelling of the partially clay substrate and therefore heaving of the foundation. They also indicated that removal of tree stumps will likely cause consolidation in the clay soils underneath the foundation but that it couldn’t be avoided.

SMF-1 is optimized to rise to 121.90 ft for the 100 year -1 hr storm (using a value of 7.5 ft/day saturated infiltration). It would overflow at >122 ft. SMF-2 and SMF-3 are sized to attenuate the peak for the 100 year -24 hour storms (using 22.5 ft/day saturated infiltration). SMF-2 rises to 119.45 ft and SMF-3 rises to 119.06 ft out of a possible 119.48 ft. All facilities provide post-development peak discharge rates that do not exceed pre-development rates for both the 100 year critical storm event, the 25 year -24 hour storm event, and for the mean annual storm event (1 day, 24 hours) (Causseaux & Ellington 2004b).

After sizing the SMFs to hold and infiltrate the 100 year critical and 25 year 24-hour storms, Causseaux & Ellington checked that water quality volume regulations were satisfied. In sizing the retention pond to capture and treat the WQTV, one must calculate the runoff from applying an instantaneous rainfall depth according to the aforementioned SJRWMD guidelines. Calculations of the necessary water quality treatment volume for each drainage area are shown below. Note that SJRWMD (2005) states that an online infiltration trench (called exfiltration trench in publication) discharging into a Class III receiving water bodies, should store the first one-half inch of runoff or 1.25 inches of runoff from the impervious area, whichever is greater, and an additional storage of one-half inch of runoff from the total area. Sample calculations are as follows.

SMF-1

WQTV = 0.5” * Drainage Area + 0.5” * Drainage Area
= .5/12 * .281 acres + .5/12 * .281 acres
= 0.023 ac-ft = 1020 ft^3
OR
WQTV = 1.25” * Imp Area + 0.5” * Drainage Area
= 1.25/12 * .17 acres + .5/12 * .281 acres
= 0.029 ac-ft = 1269 ft^3
This is the higher of the two methods (vs 0.5*D.A.)

SMF-2

WQTV = 0.5” * Drainage Area + 0.5” * Drainage Area
= .5/12 * .216 acres + .5/12 * .216 acres
= .018 ac-ft = 783 ft^3
OR
WQTV = 1.25” * Imp Area + 0.5” * Drainage Area
= 1.25/12 * .16 acres + .5/12 * .216 acres
= 0.026 ac-ft = 1124 ft^3
This is the higher of the two methods (vs 0.5*D.A.)

SMF-3

WQTV = 0.5” * Drainage Area + 0.5” * Drainage Area
= .5/12 * .217 acres + .5/12 * .217 acres
= .018 ac-ft = 789 ft^3
OR
WQTV = 1.25” * Imp Area + 0.5” * Drainage Area
= 1.25/12 * .16 acres + .5/12 * .217 acres
= 0.026 ac-ft = 1117 ft^3
This is the higher of the two methods (vs 0.5*D.A.)

The WQTV calculation method does not use the maximum possible retention of the soil (S), or initial abstractions. The method of determining WQTV drawdown is to apply a slug load of the WQTV to the basin at time zero and use PONDS to iteratively solve for drawdown over time. Because the SMFs are sized to capture and infiltrate a large volume storm, they can hold the entire WQTV slug and thus provide the necessary WQTV treatment. WQTV drawdown results are shown in Table 2-12. All three SMFs recover the WQTV within 3 days.

Results from running complete basin recovery analyses (not shown) indicate that each SMF, when filled to capacity, will recover its total volume well within 14 days. SMF-3, which is almost identical in size and shape to SMF-2 has a total recovery time that is 25% shorter than SMF-2 (not shown) probably because of the clay layer that is encountered only 3 feet below the surface on the west side of DA-2. A-2 was reported by SDII to have a permeability of 1.31E-02 cm/s while A-1 had 2.96E-02 cm/s.

Table 2-12: Oxford Terrace—Water Quality Treatment Volume Recovery

SMF*	WQTV+ volume (ft^3)	Recovery time (days)
SMF-1	1269	<= .10
SMF-2	1124	<= .10
SMF-3	1117	<= .10

* SMF - Stormwater Management Facility
+ WQTV - Water Quality Treatment Volume

Alternative onsite control measures. Oxford Terrace is very innovative in the placement of parking underneath the building and use of some strategic landscaping as a retention pond. Other options available at the site are somewhat limited by site conditions. Bioretention cells along the right of way could be used to capture relatively clean sidewalk runoff. Green roofs are another option. Due to the buildout of the site, no other form of retention is possible without installing cisterns or other above surface retention devices. An alternative to controlling runoff directly onsite is for the developer to buy into the swale directly south of the site, across Depot Ave. This swale drains road runoff and may have extra capacity to accommodate runoff that would exceed storage capacity onsite. The soil in the swale could be engineered to increase treatment capacity. Another alternative is connecting to a centralized treatment system while storing and infiltrating smaller daily storm events onsite. A regional solution would allow for storage within the system, increasing the time of concentration.

Delta Zeta sorority house

Preexisting site conditions. The 70-acre project site located on the southeast intersection of SW 13th Street and SW 9th Avenue used to consist of one story houses, a carport, and dirt driveways. Cars could drive over the curb to get on the property. Although no images are available for the property prior to redevelopment, neighboring houses provide good examples. Most of them have severely compacted pervious area and one to two story structures on the majority of the property

Current site conditions. The Delta Zeta sorority site drains from the northwest to the southeast, and was mistakenly stated by the SJRWMD as being inside the Tumblin Creek Watershed, discharging to Biven's Arm (SJRWMD 2003). It actually drains into Campus Creek (also known as Hawthorn Creek or East Creek) which flows west, through the University of Florida campus to Lake Alice as discussed in Korhnak (1996).

The site contains a 9,280 square foot three story apartment complex, a parking lot, sidewalks, and a driveway. The three story building uses the area efficiently compared to its neighbors, providing many bedrooms in a compact footprint; this allowed the developers to provide a large landscaped area that makes it look more like an estate (Figure 2-18). The wide landscaped area provides a large infiltration capacity that treats the runoff from the sidewalk inside the property, but not the sidewalk along the street due to the slope of that sidewalk towards the road (Figure 2-19).

Runoff from the roof and parking lot is conveyed via stormwater surface inlets and roof drains to a retention area on the S.E. side of the building. The rain garden provides enough vertical storage capacity to temporarily store very large storms, infiltrating it into the soil gradually. Excess volume generated during the peak of large events flows over a weir into Campus Creek. The retention/detention area appears to infiltrate fast enough to keep from ponding as evidenced by the separation of bark chips and grass implying no floatation (Figure 2-20). Water drains from the parking lot into this dry retention basin as well (Figure 2-21).

Figure 2-18: Delta Zeta Sorority House Landscaped Area

Figure 2-19: Delta Zeta Sorority House Sidewalk

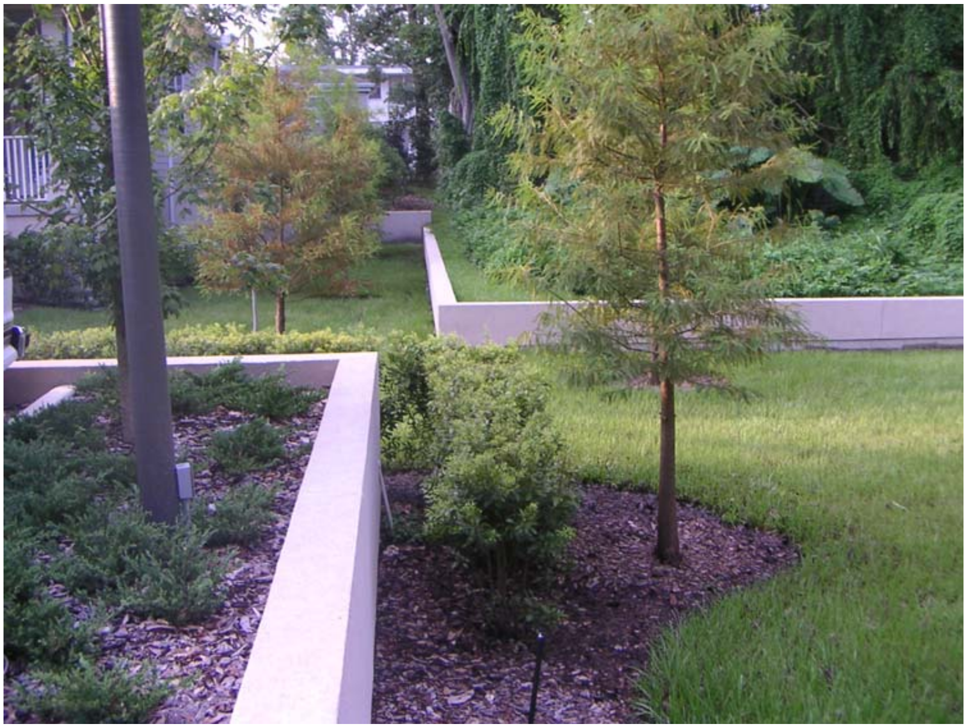

Figure 2-20: Delta Zeta Sorority House Rain Garden

Figure 2-21: Delta Zeta Sorority House Parking Lot Drain

Stormwater calculation information. The engineers developed a retention area with a stem wall to hold water onsite, slowly infiltrating and discharging over a weir.

Drawdown was modeled without infiltration for post re-developed conditions. Using PONDS software, they found that the WQTV recovers in 48 hours (<72 hours), using a horizontal conductivity rate of 3.6 ft/day; this value is 10% of the value measured by the geotechnical firm. The reason for doing this was because the stem wall is 2 ft below the ground surface and PONDS initially was modeled using a horizontal flow lens that could rise all the way to the ground surface. This technique seems to work well creek side, just as it did at Windsor Hall. It may be more beneficial than an infiltration trench because there is more material for the pollutants to flow through, adsorb to, and for some species degrade in than for an infiltration trench.

Alternative stormwater control measures. The location of the DZ house lends itself to using the detention/infiltration system adjacent to the creek because the water table flows directly into the stream, allowing quick drainage of the rain garden. The system is easy to maintain but infiltration may decrease because foot traffic is allowed in the area, possibly causing compaction.

The sidewalk adjacent to the street could be either removed while creating a swale or turned into a pervious pavement material. The meandering sidewalk in front of the house could serve as the main sidewalk, with the grassy area as a buffer between the people and the road, moving the setback away from the road and extending the DOT ROW to cover the grassy area. The grass could provide great treatment capacity for a portion of the road runoff if it were not curbed. Unfortunately, currently, the road runoff travels directly into the East Creek portion of UF's Lake Alice feeder system, untreated.

Estates at sorority row

Preexisting site conditions. No information is available as to site conditions prior to the current state. This site is scheduled for redevelopment.

Current site conditions. The site currently has no sophisticated stormwater control. All the properties purchased for the Estates, including the building shown in Figure 2-22, have roofs that drain directly onto the ground a few feet away from of the foundation. The parking lot for this building is a small four car lot of gravel and a concrete slab (Figure 2-23). The driveways for the single family homes on the properties to the South are also a dirt/gravel mix. The only hardscape present on any of the properties is the parking lot concrete slab and the sidewalk.

Stormwater calculation information. No information is currently available.

Alternative stormwater control measures. There currently is no DCIA on the property. Drainage is in a mostly southerly direction, towards a large pond connected to Campus Creek (Korhnak 1996). Future properties could take advantage of the pond/stream and drain large volume storm events into it, while smaller ones could be treated onsite.

Figure 2-22: Estates at Sorority Row—Current Building

Figure 2-23: Estates at Sorority Row—Current Building Parking Lot

Visions

Preexisting site conditions. No information of site conditions prior to the current state is available. This site is scheduled for redevelopment.

Current site conditions. This property, called Visions, currently has single story buildings with roofs that drain onto packed sandy soil (Figure 2-24). The soil has been compacted by vehicles and is very firm to walk on; however there are 3-5 inch deep channels that range from 3-10 inches wide which may indicate erosion (Figure 2-25). The buildings have no roof drains but the land around them has little vegetation.

Stormwater calculation information. No information is currently available.

Alternative stormwater control measures. While disconnected roof drains are often considered a cost effective onsite stormwater control method, in this case it doesn't work well due to lack of vegetation in the pervious area. If the site were not to be redeveloped, then the sandy soil could be stabilized using hardy grasses or other groundcover. Furthermore, automobile traffic could be confined to a smaller zone to prevent further soil compaction and erosion. Even a low cost permeable paving solution would help in curbing erosion and promoting infiltration. This site could be improved by redevelopment. Parking for the new development could be underneath the building or, due to the small area of the parcel, located elsewhere in a central lot.

Figure 2-24: Visions—Disconnected Roof and Dirt Alleyway

Figure 2-25: Visions—Channelization of the Parking Lot

Royale Palm apartments

Preexisting site conditions. No information is currently available.

Current site conditions. The Royale Palm apartments are one of a cluster of four completed new developments on SW 7th Ave and SW 9th Street. The project is located in the Alachua County Sensitive Karst Area (SJRWMD 2002b). Some parking for this three story development is on the road (Figure 2-26), with most of the parking in a hardscape lot behind the building. There are numerous hardscape sidewalks throughout the complex . The sidewalks along the road are not sloped into the landscaped areas. Landscaped areas are sprinklered. The landscaped areas use native vegetation. As shown in Figure 2-28, broad-leafed trees dot the site but are not dense enough to provide considerable interception before rain hits the pavement. The piping from the rooftop appears to be directly connected. In some cases it appears to drain into concrete planters at the surface as pictured in Figure 2-27. However, this was not permitted as a BMP in SJRWMD (2002b) possibly because runoff bypasses the planter.

Figure 2-26: Royale Palm Apartments Onstreet Parking

Figure 2-27: Royale Palm Apartments—Roof Drain Entering Planter

Figure 2-28: Royale Palm Apartments—Vegetative Site Cover

Stormwater calculation information. Stormwater control techniques used at this property consist of an infiltration trench that was installed at the cost of $102,350. In this case, roof runoff and parking lot runoff are mixed. Stormwater routing calculations were not available at the time of this report, however SJRWMD (2002b) states that runoff from preexisting impervious areas and the newly constructed parallel parking area along SW 7th Avenue is collected by roadside gutter improvements and conveyed to the City of Gainesville storm sewer network. The infiltration trench has capacity to compensate by overtreatment of the areas connected to the trench.

Alternative stormwater control measures. It could be cost effective to exfiltrate roof runoff into the planters if this is not being done at present if it would not compromise the foundation.

Windsor Hall

Preexisting site conditions. The 1.2 acre lot where Windsor Hall is now located used to contain small one story single family homes like those below. These lots, located close to the creek, had grass/forested areas that buffered the flow rate and time of concentration from the site, with the exception of a one story concrete complex that was located on the south side of the property.

Current site conditions. Windsor Hall, located just west of Lake Alice's Campus Creek, is a 3-story complex, with connected buildings that create the atmosphere of a small community. Stormwater from the impervious surfaces is piped to the east side of the property, where a walled in dry retention system is being used to store the peak of major storm events, not unlike at the Delta Zeta house. The image below (Figure 2-29) shows the roof draining into the underground drainage network that empties into the retention basin.

There are approximately 2 feet of freeboard at the retention area, which discharges into Tumblin Creek during high flow and infiltrating into Tumblin Creek during low flows. The entire treatment area drains to the basin via an 8 inch pipe, shown in Figure 2-30. Water flows out of the basin either by infiltration or, during high flows, by flowing over a weir and into a distributor pipe that carries flow down towards Tumblin Creek. This pipe is shown below in Figure 2-31.

Figure 2-29: Windsor Hall—DCIA Rooftop Drain

Figure 2-30: Windsor Hall—Rain Garden

Figure 2-31: Windsor Hall—Flow Distribution Pipe

Stormwater calculation information. Windsor Hall currently has two large detention basins that treat both roof and road runoff. A permit was previously issued by SJRWMD in 1997 for two retention areas and 3 buildings with 21 units; however in

January 2000, a permit was issued to modify the previous permit by constructing only one building of connected row houses, moving the retention areas, and adding a pool. The modification increased the project area from 0.98 acres to 1.14 acres. The half-acre project called Phase II added a detention area and an additional 7,800 sq ft building with associated paving and parking. Roof runoff flows to the retention area from roof drains and the parking lot via an underground piping network. The two 3-story buildings and their retention areas drain directly into Tumblin Creek.

The building area and pavement area for the 0.49 acre site (7802 and 4070 sf, respectively) are given C values of 0.9, while a smaller greenspace (755 sf) is given a C value of 0.15. The dry storage pond drains over a weir. The stage discharge curve shows that most of the storage is available from a stage of 128 to 130 ft. Infiltration capacity was not assessed.

Alternative stormwater control measures. This stormwater design appears to be a cost-effective small surface area solution. Additional improvements could have been made when developing this site, namely in creating more parking spaces in the lot and reducing the amount of hardscape, as with the bike racks. This walled basin solution cannot be used to collect water from parking lots at many properties because they do not provide enough driving head to fill the basin. However, it could be used to drain roofs.

The parking lot could be designed to have a porous paving turnaround or use a design that requires less impervious area per space. No car can park in the driveway of the current lot, which as represented in the photograph below (Figure 2-32) is a significant portion of the parking lot. It may be be cost effective to provide porous concrete or no-mortar brick bike parking (Figure 2-29) as this is a low load-bearing area and not likely to degrade as quickly as a high traffic area would.

Figure 2-32: Windsor Hall Parking Lot

Water quantity control is very important when contributing directly to a stream riparian habitat. The weir design serves well to distribute the water slowly, but the pipe does not appear to have holes drilled into it and thus only provides two drainage points rather than an even distributor.

Taylor Square apartments

Preexisting site conditions. The 0.48-acre site developed in Phase II formerly contained a parking lot and a single building surrounded by a grass and forested area. The runoff from this site flowed to a retention area, and then to the S.W. 7th Avenue storm sewer system. No further information could be obtained of preexisting site conditions at the time of this report.

Current site conditions. The Taylor Square apartment complex is located on the east side of SW 9th St., across the street from the Stratford Court Apartments. Taylor Square uses two infiltration trenches to infiltrate parking lot and roof runoff into the soil and eventually the surficial aquifer. The trenches used are the same Atlantis Water Management Rain Tank systems discussed in other properties. The turnkey system has a sump to capture sediment entering the system, which will help increase the lifespan of the system and prevent the introduction of pollutants associated with the sediment. The complex is designed such that the courtyard surrounds a large oak tree in the center. While the tree has a large potential to transpire water, the infiltration area is not very large, nor are the sidewalks designed to drain towards it. The tree can be seen in the center of Figure 2-33.

Figure 2-33: Taylor Square Courtyard with Oak Tree

The infiltration system used at this site was placed underneath a broad driveway shown in Figure 2-34, presumably to increase accessibility to the pit in addition to allowing two way traffic.

Figure 2-34: Taylor Square Asphalt Driveway with Infiltration Pit Beneath

Stormwater calculation information. The Atlantis Water Management System Rain Tank is marketed as part of a treatment solution for PAHs and various metals, but literature regarding its treatment mechanism could not be found at the time of this report. Product information for the AWMS can be found in SJRWMD (2004a).

The results of 4 soil borings that penetrated to a depth of 15 feet below ground surface show mainly clean sands with a layer of higher fines content at depths of 7.5, 9.5, 15 and 12.5 feet. (Brown & Cullen Inc. 2004) These have been reported as possible confining layers by Universal Engineering Services (UES). The following design parameters are recommended by the geotechnical report provided by UES:

1. Average depth to confining layer 11 ft
2. Average Vertical Infiltration Rate 14 ft per day
3. Average Horizontal Hydraulic Conductivity 21 ft per day
4. Drainable Porosity 30%
5. Average Depth to SHWT (perched) 6.0 ft

The SHWT is perched at 133.3 ft.-MSL. The Green & Ampt equation was used to model infiltration. The drainage area for the proposed basin is composed of 8,572 ft^2 of roof and carport area, 6,275 ft^2 of parking lot, 1,600 ft^2 of sidewalks and 457 ft^2 of open area as shown in Table 2-6. The hatched areas in Figure 2-35 are the infiltration trenches. A “C” value of 0.93 was calculated for the drainage area as shown in Table 2-13 and the Modified Rational Method was used to generate and route a hydrograph to the infiltration basins.

Table 2-13: Taylor Square—Stormwater Site Conditions Pre/Post Development

Pre-Development Areas and Rational Coefficients

Area Type	Area (SF)	Area (Acres)	C
Impervious Area	7,580	0.17	0.95
Open Area (Grass)	9,324	0.21	0.30
Total Drainage Area	**16,904**	**0.39**	**0.59**

Post-Development Areas and Rational Coefficients

Area Type	Area (SF)	Area (Acres)	CN
Impervious Area	16,447	0.38	0.95
Open Area	457	0.01	0.30
Total Drainage Area	**16,904**	**0.39**	**0.93**

Watet Quality Criteria

First 1.0 inch of runoff from site	(16,904 Ft^2 * 1" * (1' / 12"))	**1,409 Ft^3**
First 1.25" of Impervious runoff plus 0.5" of site runoff	(16,904 Ft^2 * 0.5" * (1' / 12") + 16,447 Ft2 * 1.25" * (1'/12"))	**2,418 Ft^3**

Originally produced in SJRWMD 2004b, pg 31

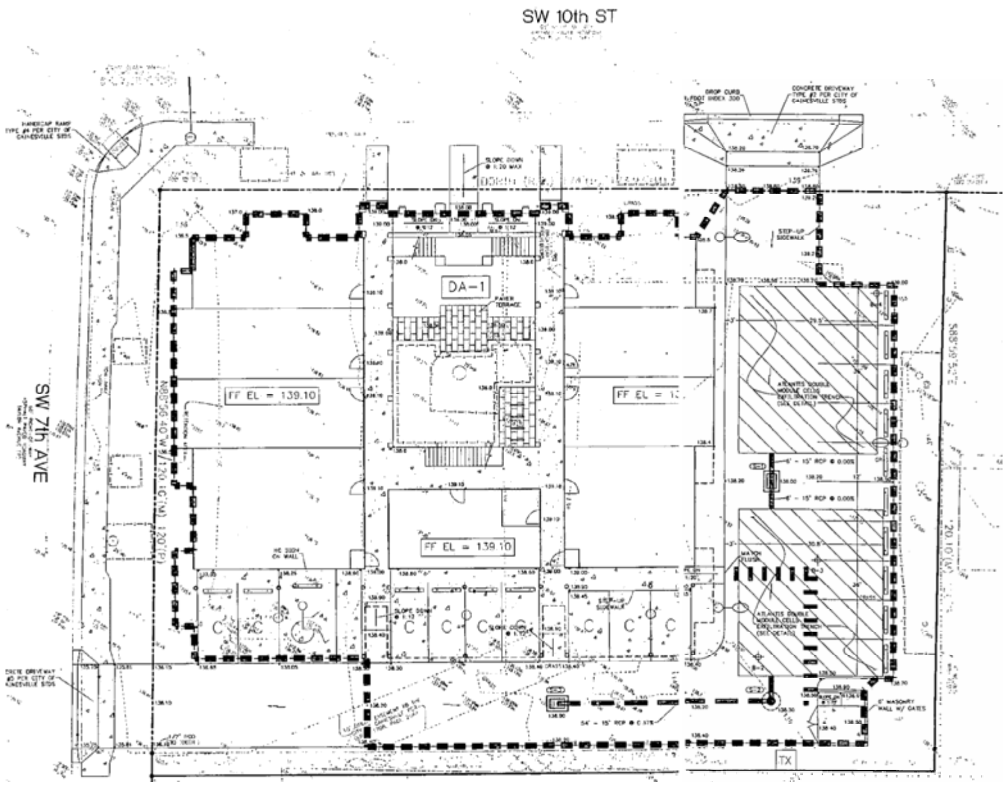

Figure 2-35: Taylor Square Drainage Area and Infiltration Trenches (Brown & Cullen Inc. 2004)

The FDOT rainfall distribution was used to analyze the 100-year critical storm. With an impervious area greater than 50%, the criteria for water quality treatment for the site is 1.25" across the impervious area plus 0.5" across the entire drainage area, generating a grand total of 2,418 ft^2 of runoff as shown in Table 2-13 above. The area between the basin bottoms and the SHWT is shown to be 3.75 ft, or a volume of 2,430 ft^3 assuming a 30% porosity. Recovery time is estimated to be 4 hours.

The bottoms of the infiltration trenches are at 133.5 ft and the tops are 136.4 ft MSL providing a volume of 5,940 ft^3 as calculated in Table 2-13. Design calculations show the system as retaining the 100 year critical storm event as modeled using a 14.0 ft/day infiltration rate. (Brown & Cullen Inc. 2004)

Table 2-14: Taylor Square Infiltration Trench Volume Calculations

Top of Trench =	136.40		
Bottom of Trench =	133.50		
No. of Atlantic Boxes =	720 Ea		(45 Rows of 16 Columns)
Type of Atlantis Box =	Double	=	8.25 Ft^3 / Box
Total Volume of Trench =	5,940 Ft^3		
Percolation Rate =	7.5 ft/day		

Stage/Storage:

Stage	Storage (cf)	Storage (ac-ft)
133.50	0	0
134.00	1,024	0.024
135.00	3,072	0.071
136.00	5,121	0.118
136.40	5,940	0.136

Originally produced in Brown & Cullen Inc. 2004, pg 12

Alternative stormwater control measures. One way to decrease the volume of runoff and volume of infiltration is to create a larger area around the large oak tree. A common method is to leave an undeveloped area as broad as the crown of the tree. While this is not possible with the design of the building, some more room can be created by thinning walkways and/or providing partially pervious or tiled walkways. Such a decision would also help prevent cracking and buckling in the pavement. Another option would be to create a curbside biofiltration planter system that would nourish the roots during small storm flow events and blowoff into the infiltration basin or another treatment system during more significant flows.

Washoff from building construction (Figure 2-36) indicates that the ground is being disturbed and topsoil is likely being washed away. This can lead to reduced performance for surface water retention than that suggested by the engineers. An important BMP to incorporate is to provide better construction sediment capture and to keep from disturbing topsoil wherever possible. If it has not already been done, it may be beneficial to develop a maintenance schedule to remove leaves from the property and sidewalks, to reduce the entrance of organic material into the street's stormwater system.

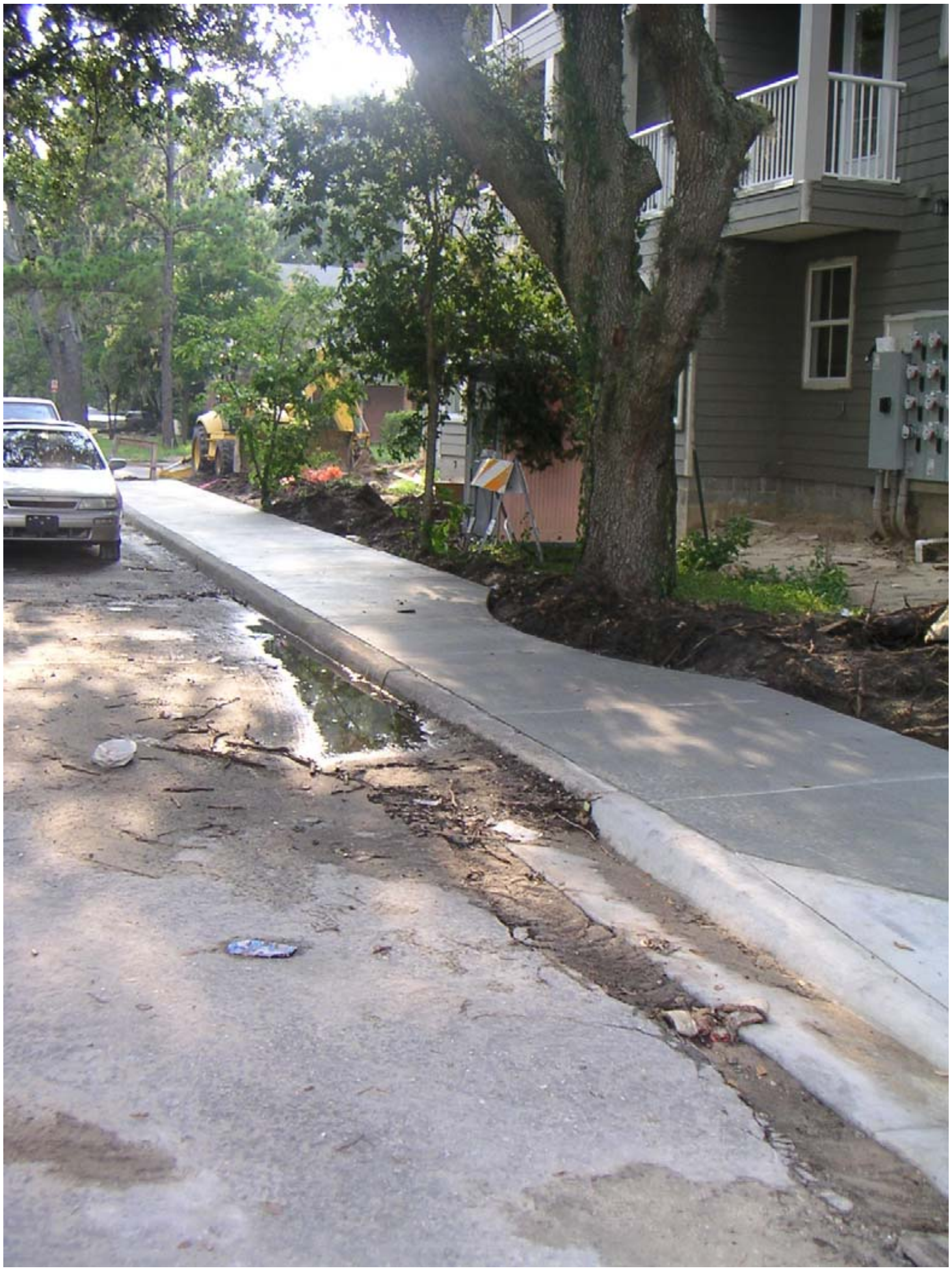

Figure 2-36: Taylor Square Construction Debris and Sediment Washoff

Stratford Court apartments

Preexisting site conditions. No information is currently available on preexisting site conditions for the Stratford Court Apartments; however the houses that surround the development are largely one story with disconnected roof drains, concrete/grass strip driveways and large pervious grassy areas.

Current site conditions. The Stratford Court apartments have just recently been completed. The three story apartment building was developed among restored historic buildings.

Stormwater calculation information. The Stratford Court apartments use an infiltration trench underneath the parking lot on the west side of the new building. Unlike at the Heritage Oaks apartments, the older historic buildings do not drain directly onto the ground and parking is not pervious. The infiltration trench was installed at the cost of $74,000. Soils information can be found in SDII (2004b).

Alternative stormwater control measures. The wide landscaped area on both sides of a narrow concrete sidewalk can be used to infiltrate runoff from the sidewalk (Figure 2-37). However, the curb prevents this area from infiltrating runoff from the road. In order to keep the landscape green, sprinklers have been installed. If runoff from the road is infiltrated by the landscaped sidewalk area, it may reduce the demand for irrigation water but it will not eliminate the need for sprinkling systems.

The use of brick paving may help infiltrate some water from the sidewalk. The few parking spaces alongside the road could be made of brick or a porous concrete material, possibly a sorptive concrete media (Figure 2-38). A number of other onsite infiltration techniques could also be applied at the property such as xeriscaping, using a rainwater cistern combined with an evaporative cooling system or irrigation system, etc.

Figure 2-37: Stratford Court Apartments Sidewalk and Grass Strip

Figure 2-38: Stratford Court Apartments Streetside Parking

Alligator Crossing

Preexisting site conditions. The Alligator Crossing apartments formerly consisted of two 2-story buildings with a total of five dwelling units on the corner of SW 10th Street and SW 2nd Avenue as shown in Figure 2-39.

Figure 2-39: Alligator Crossing—Preexisting Site Conditions

Current site conditions. A permit was recently granted to expand Alligator Crossing. The petitioners kept the old two story apartment buildings and expanded by adding a 3-story apartment building with six 1-bedroom apartments, resulting in a grand total of 11 dwelling units on the entire property. A very wide strip of landscaping surrounds the building. While the site is parking exempt, there are 7-8 gravel parking spaces on site. The total impervious area is 1,695 ft^2. The stormwater management summary sheet shows two retention basins on the property, one North, and one South, each with 70 c.f. of retention volume (City of Gainesville 2002).

Figure 2-40 is an image of the new addition to the east side of Alligator Crossing. Drainage from the roof flows off the edges, onto the landscape surrounding the building, just as all the other buildings do. There is no directly connected impervious area, and a strip of forested area approximately 20 feet wide is used to infiltrate water between this property and a property to the South during and subsequent to storm events. The vegetative buffer between the road and sidewalk shown in Figure 2-41 is functioning as a passive infiltration system for both. It is likely, however, that a curb will be placed on the road edge. The central picnic area in Figure 2-42 receives a majority of the runoff from the back of the older buildings. . Figure 2-43 shows the bioretention area just south of the new 3-story building. It is narrow but very dense and that it is quite close to the building. The thick biostrip is also shown in Figure 2-44 at the right of the photograph, while a house sits on a property directly downhill from Alligator Crossing.

Figure 2-40: Alligator Crossing—New Addition

Figure 2-41: Alligator Crossing—Grass Strip and Sidewalk

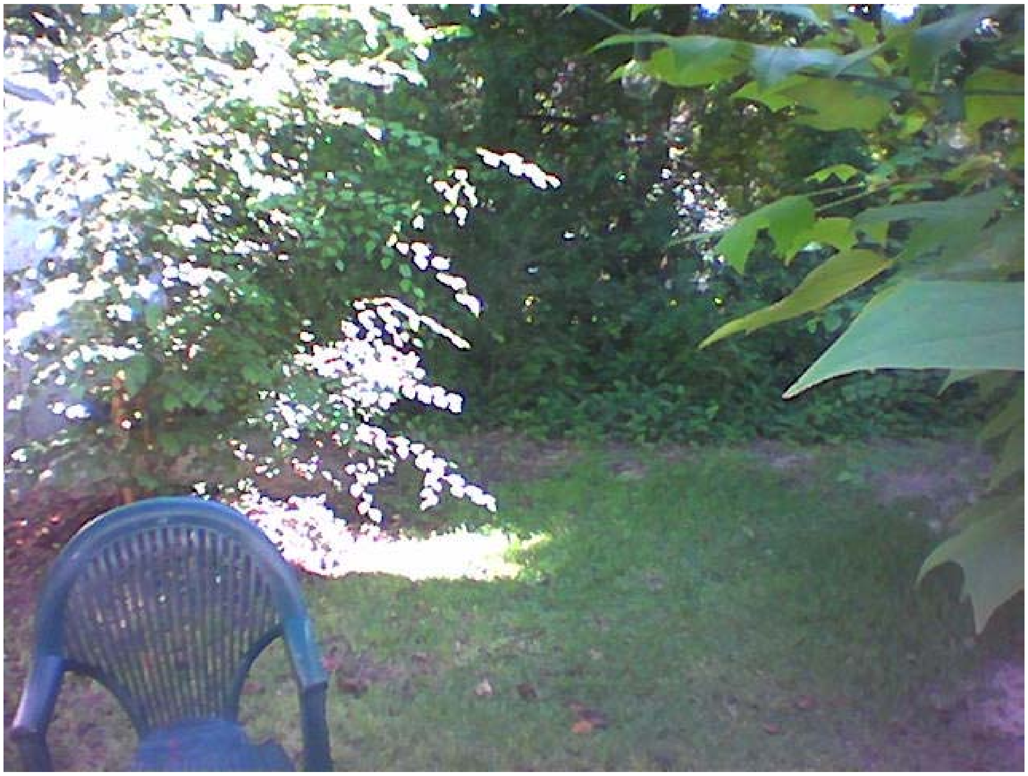

Figure 2-42: Alligator Crossing—Backyard

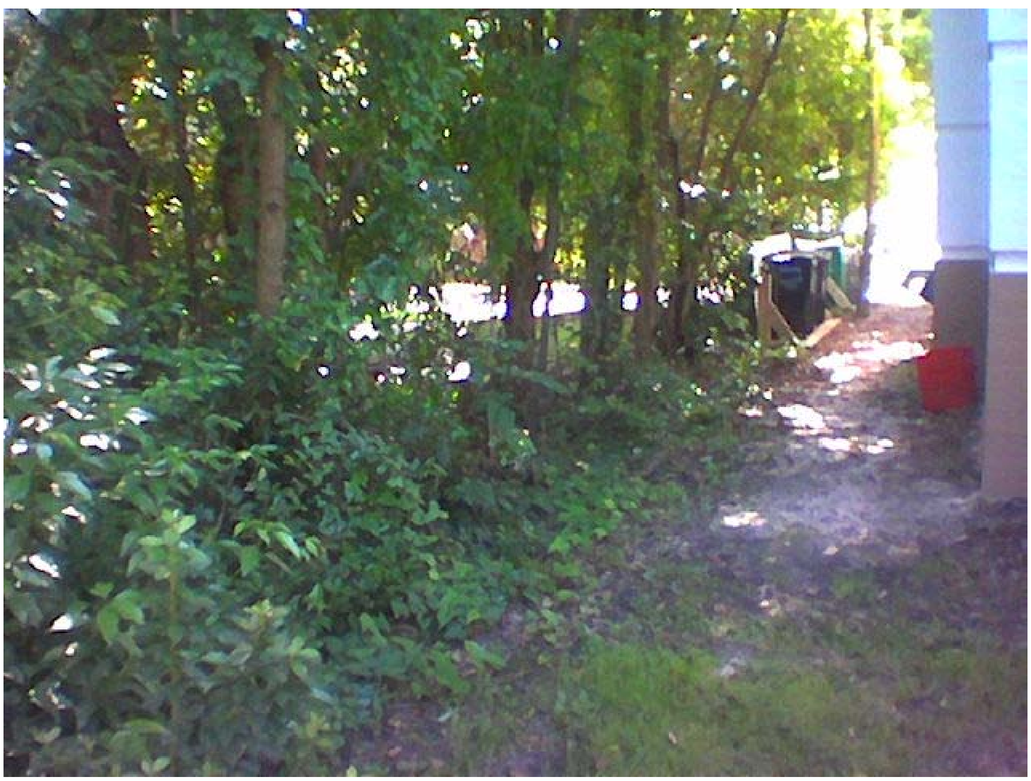

Figure 2-43: Alligator Crossing—Forested Strip

Figure 2-44: Alligator Crossing—Southern Side of Grass Swale

Stormwater calculation information. While it was not possible to locate the stormwater calculations submitted to the City of Gainesville or SJRWMD, a stormwater summary indicates that the post development impervious area is 1,695 sq ft and the northern and southern "basins" are 70 ft^3 each. The total area of the parcel is not stated, and thus stormwater runoff calculations cannot be reproduced. Residents living in this complex and in the complex directly south (downstream) did not identify ponding issues, with the exception of some minor ponding during the 2005 hurricane season. The owner of the Woodbury Row apartments stated that a large quantity of runoff from Alligator Crossing is captured by the retention pit on the Woodbury Row property, specifically making note of the parking spaces.

Alternative stormwater control measures. With only 7 parking spaces on the property, and 11 dwelling units, some individuals must park on the road. The reduced provision of parking per dwelling unit greatly reduces stormwater impacts per dwelling unit. However, off-site availability of parking will be important.

Woodbury Row

Preexisting site conditions. Until February of 2003, Woodbury Row was a paved and limerock parking site on SW 5th Avenue with one two-story house and a covered garage. The large two-story, eight bedroom house with a large grassy area shown in Figure 2-45 was part of the 0.27 acre site before redevelopment. Figure 2-46 shows the garage (right) and a grass parking lot adjacent to the house.

Figure 2-45: Woodbury Row—Preexisting Site Condition

Figure 2-46: Woodbury Row—Preexisting Garage

Current site conditions. The Woodbury Row apartment complex retains the old 2-story house with 8 bedrooms and adds seven 3-story single family attached units (4 bedrooms each) for a grand total of 36 bedrooms. Strategic landscaping and one small pond are used to drain the site. The roof drains onto a sidewalk and runs off into the landscaped area (one foot wide) on both sides of the sidewalk as shown in Figure 2-47. The landscaped areas then drain to a pond located behind the covered bike parking (Figure 2-48). This may introduce fines, sediments, and eventually clog the conduit (blue pipe) leading to the pit; however the pond is resourcefully constructed to treat runoff from the alleyway. The covered bike area shown in Figure 2-49 drains directly into the infiltration basin. The parking lot slopes towards the basin.

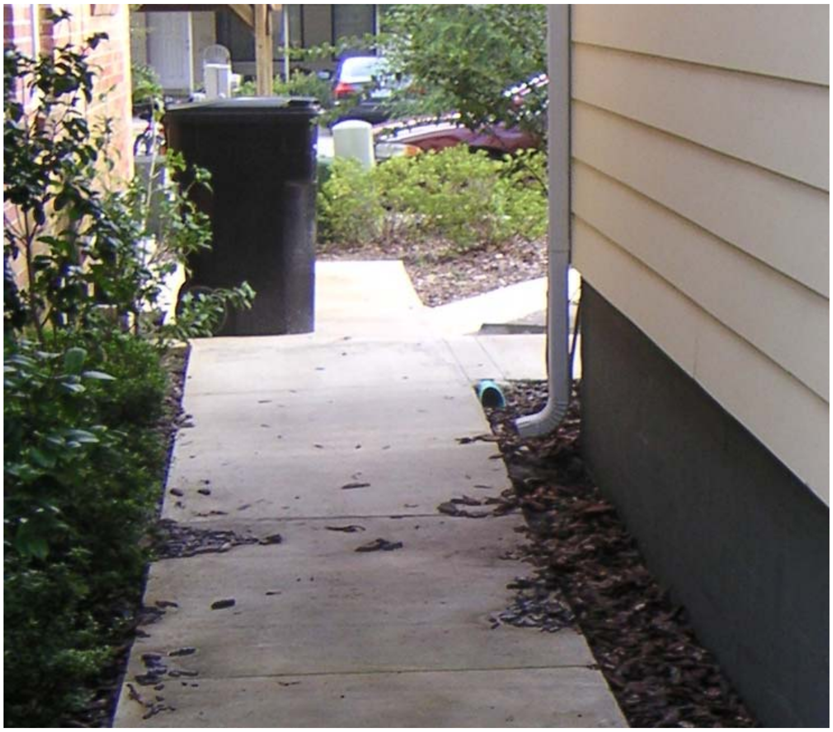

Figure 2-47: Woodbury Row—Landscaped Sidewalk Strips

Figure 2-48: Woodbury Row—Retention Pond

Figure 2-49: Woodbury Row—Bike Rack and Retention Pond

Stormwater calculation information. The geotechnical report states that soil borings shown predominantly silty sands. (Fetner 2003) Thus, one would assume that the pond has a high infiltration capacity and a relatively short retention time. The seasonal high water table is eight feet below grade. However, the pond is three feet deep, so the SHWT is about five feet below the bottom of the pond. The geotechnical engineers estimated a conservative infiltration rate of 3.1 feet per day. Using that infiltration rate, a square pond would be estimated to drain entirely within 24 hours; however calculations made by Fetner found the recovery time to be about 55 hours. The entire volume of the pond is calculated to be 1,016 cf with an area of 573 ft^2 at an elevation of 97.7 feet.

Recovery calculations were performed using infiltration only through the bottom of the pond, not taking into account saturated flow or flow through the side slopes of the basin. The required treatment volume is 1 inch over the total area or 1.25 inches over the impervious area, according to SJRWMD. One inch over the entire site (11,993 sq ft) is the larger volume of the two methods: 980.3 ft^3. Therefore, the volume provided by the pond (1,016 cu ft) is sufficient.

Alternative stormwater control measures. The pond used is narrow but deep. It may easily fill with organic matter as shown in Figure 2-48. A good maintenance schedule is needed to prevent it from filling in. Some steps could also be taken to make it more aesthetically pleasing. However, from a functional standpoint, it is well designed to treat alleyway runoff as well as runoff from the Woodbury Row property.

The tree island shown in the bottom left of Figure 2-50 is not notched and therefore must be irrigated using a sprinkler system. It could be designed to function as a small depression, providing some treatment volume and reducing the need for irrigation.

Similarly, the ditch at the Southern-most location of the site (not pictured) is cut off from the property by a curb. This may be available for infiltration during and after storm events but it is not known whether alleyway runoff already exhausts all the capacity.

Figure 2-50: Woodbury Row—Parking lot and Tree Island

West University Avenue Lofts

Preexisting site conditions. The West University Avenue Lofts used to contain a single story storefront building with asphalt parking on the South side and an old building that was destroyed by fire.

Current site conditions. The West University Avenue Lofts are located on the Southwest corner of SW 6th St and University Avenue. Construction is underway at the 0.67 acre site to produce a 3-story apartment building with 31 units and a total of 37 bedrooms on the top two floors. The bottom floor will contain four commercial units with over 3,114 sf of commercial space. From the street, the building appears to cover nearly the entire site, but there is a large parking lot behind it covering over 50% of the property as shown in Figure 2-51 and Figure 2-52. Stormwater from the roof and the parking lot drains away from the property to a centralized detention pond (SW 5th Ave. Pond). A schematic of the drainage network is shown in Figure 2-53. This site is a prime example of a ~100% DCIA buildout with no treatment onsite.

Stormwater calculation information. The Lofts drain into the three acre SW 5th Avenue Stormwater Pond. The pond was developed by the city and it drains various properties such as a downtown parking garage, Alachua County Criminal Courthouse, Alachua County Courthouse South lots, and West University Avenue Lofts. It has the capacity to receive stormwater runoff from an entire 50.6-acre urban drainage area in southwest downtown Gainesville. More information on the stormwater basin can be found at SJRWMD (2002c, 2004b). This large wet pond has the capacity to treat runoff from this site, which is not much more impervious than pre-redevelopment conditions. Each user of this pond contributes a prorated share of its cost.

Figure 2-51: West University Ave. Lofts Building Façade as photographed on 10/25/2005

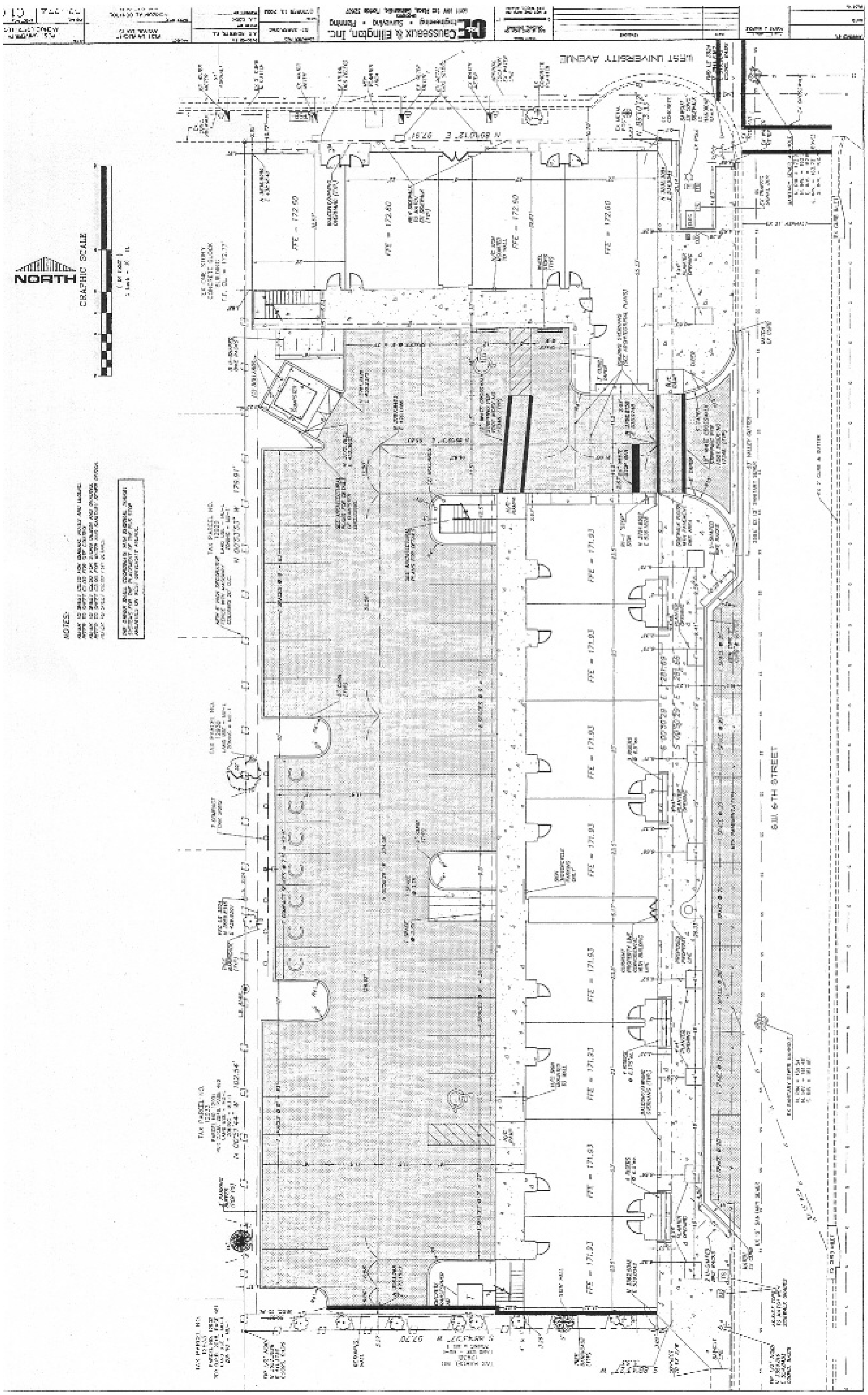

Figure 2-52: West University Ave. Lofts Building Plan (Causseaux & Ellington 2003)

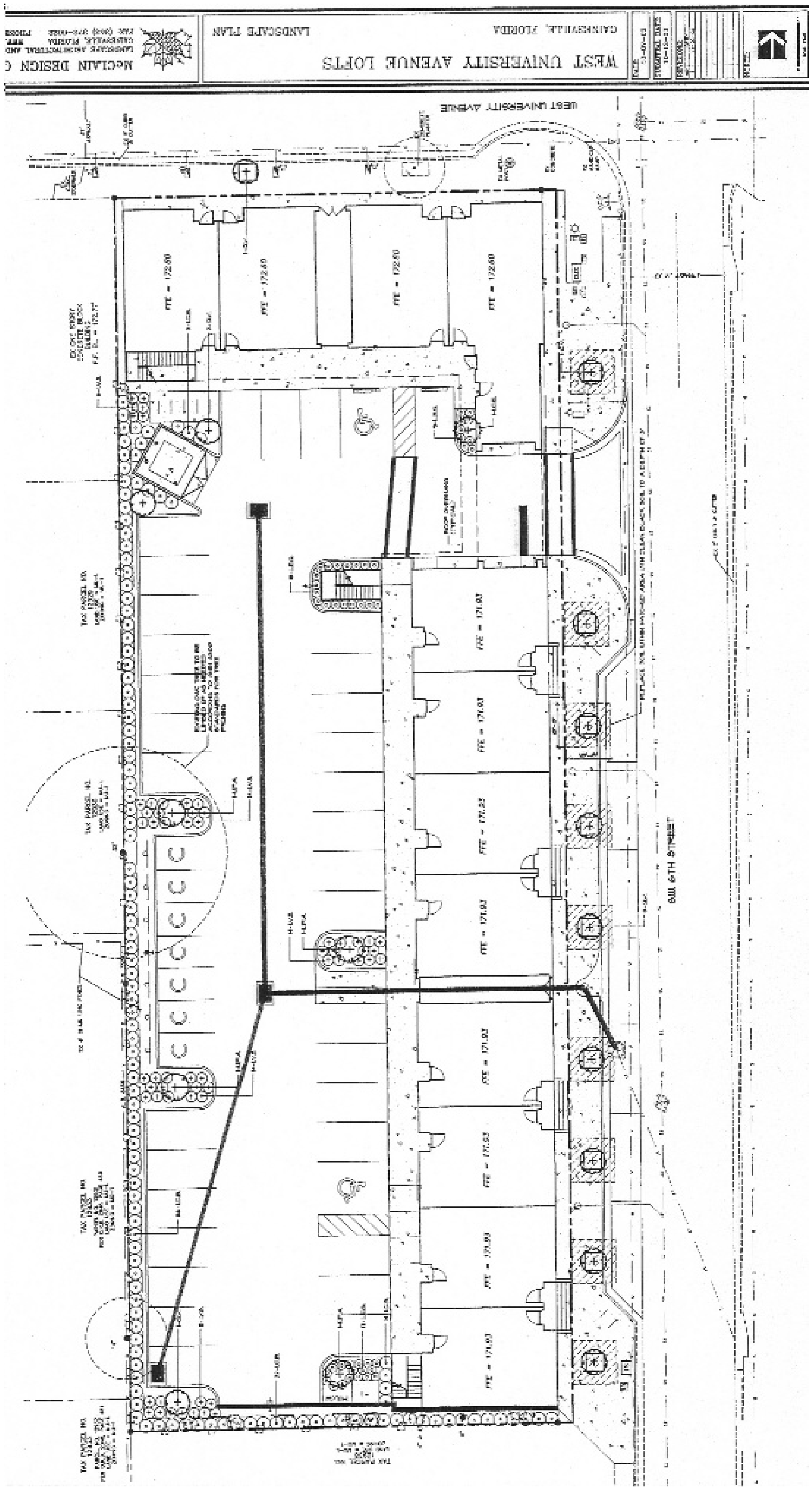

Figure 2-53: West University Ave. Lofts—Stormwater Drainage Network (Causseaux & Ellington 2003)

Alternative stormwater control measures. Many onsite control possibilities could be performed. These possibilities include the use of partially pervious brick paving or permeable paving, the use of a small bioretention strip surrounding the buildings, the use of an exfiltration pipe draining and connecting surface planters, or planning changes such as siting parking centrally and using the onsite space for other purposes.

As of the time of writing, while buying into the pond provides some or all runoff peak and/or quality control, a redeveloped property that does not provide stormwater retention onsite before leaving the lot lines will continue to be charged a stormwater utility fee per volume of runoff, even after having “bought into” the regional detention pond. This provides added incentive to control stormwater runoff onsite within the Tumblin Creek Watershed.

Opportunity Sites

Each of the opportunity sites could incur many onsite stormwater control strategies if redeveloped, limited by site conditions such as soil type, Karst conditions, seasonal high water table, topography, vegetation, and land use. For the following opportunity sites, current site conditions will be discussed. For some sites, notable alternative BMPs are mentioned.

Shands Alachua General Hospital

Current site conditions. Shands AGH is a large, sprawling, multi-story complex with a very large parking lot. Fully grown trees have cracked hardscape surfaces surrounding the lot (Figure 2-54). Parking lot runoff drains directly into the stormwater system without being treated. Nicely trimmed grassy areas (Figure 2-55) are sprinklered with fresh water and are curbed off from parking lot runoff but still provide infiltration capacity for sidewalks.

Figure 2-54: Shands AGH Parking Lot Catchbasin

Figure 2-55: Shands AGH Curbed Landscape Area

Alternative stormwater control measures. Many alternative stormwater control measures could be retrofitted on the current development. One of the easiest solutions is to channel runoff into grassy areas to infiltrate. A curbside planter system could be installed along the street corridor (Figure 2-56); one that is designed to treat runoff before it enters the stormwater system. In fact, if the curb was notched and the road was sloped toward the grass and less pitched towards the inlet, then a significant amount of the MASE could be treated. The mature trees that dot street sides and the AGH campus such as those shown in Figure 2-56 could be integrated into the redevelopment plan. If a treatment pond or stormwater park is built across the street, then the parking lot water could be piped there to be treated. One of the most advanced solutions, but one that would require mandatory periodic maintenance would be to indeed pipe parking lot runoff to the green spaces on site but also to amend their soils to capture metals, organics, and nutrients.

Figure 2-56: Shands AGH Sidewalk and Vegetation Strips

South parking lot, Shands AGH

Current site conditions. This parking lot, just South of Shands AGH (Figure 2-57) drains into a large gully which provides treatment and storage of the runoff. There are over 200 parking spaces on this lot. The drainage channel for the parking lot is shown in Figure 2-58. There is no treatment of parking lot runoff before it reaches the headwaters of Tumblin Creek. There are signs of sediment deposition at the end of the lot and some signs of erosion cutting into the vegetated slope. Figure 2-59 shows how a major portion of the city's stormsewer network confluences here and east of 909 SW 5th Avenue.

There are two buildings on the property, shown in Figure 2-60 and Figure 2-61. One is an office building (Figure 2-60) and the other a child daycare center (Figure 2-61). The grassy play area at the child care center is not affected by the water quality from the parking lot to the North or South because it is raised and curbed.

Figure 2-57: Shands AGH South Parking Lot—Looking West

Figure 2-58: Shands AGH South Parking Lot—Draining to Tumblin Creek

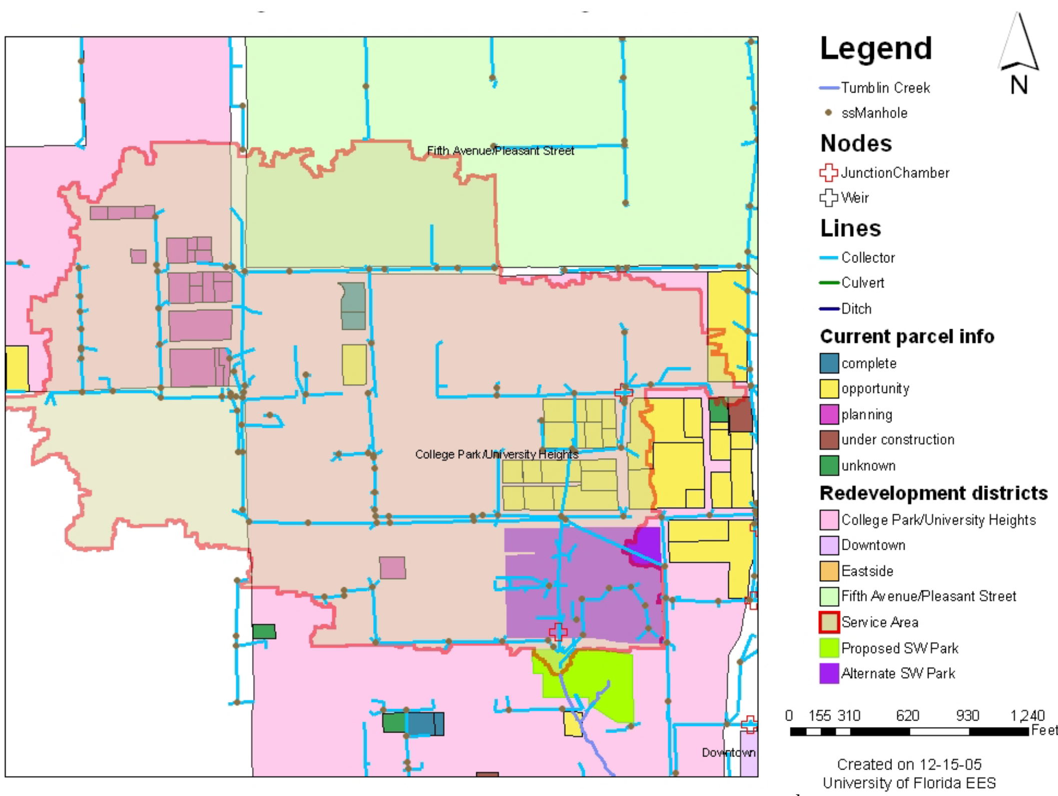

Figure 2-59 Drainage to South Shands Parking Lot and 909 SW 5th Ave. House

Figure 2-60: Shands AGH South Parking Lot—Southeast

Figure 2-61: Shands AGH South Parking Lot—Children’s Play Center

Alternative stormwater control measures. If this site is redeveloped, city planners or others involved in regional stormwater control may want to note its location as a confluence of a 160 acre drainage system (see Figure 2-59).

East Shands parking lot

Current site conditions. This parking lot located just east of Shands is large, with over 200 spaces (Figure 2-62). One feasible onsite BMP is shown in Figure 2-63. The parking area is asphalt with tree islands between each facing row of cars. The tree islands have small notches cut into them, presumably to allow the transfer of stormwater between the islands and the asphalt. However, because the islands are elevated, runoff travels to the hardscape surface rather than towards the greenspace.

Figure 2-62: Shands East Parking Lot

Alternative stormwater control measures. The parking lot has wide roads and straight spaces. One way to reduce the impervious area per space is to reduce the width of the lanes. The notched parking spaces at the tree island potentially allow flow into and out of the grassy islands. However, this could be improved if the islands were depressed. Currently, the notches serve little beneficial function. The BMP area currently in service is silted in from all the parking lot runoff. This is an example of the need for continuous BMP maintenance.

Figure 2-63: Shands East Parking Lot BMP

909 SW 5th Avenue

Current site conditions. The 909 house (Figure 2-64) is located directly next to a steeply sloped hillside of native vegetation that drains down to the headwaters of Tumblin Creek. There is no treatment of runoff from the East side of the house before it enters the drainage area. The parking lot on the West side is dirt and there currently is no DCIA on the property.

Figure 2-64: 909 SW 5th Ave—Front Lot

Ayers complex

Current site conditions. The building, as it currently exists, is three stories. Figure 2-65 is a photograph taken on the west side of the property which shows a large grate and wall to channel storm events away from the property. However, the gradually sloped landscape is shallow enough to allow most rain events to infiltrate before going into the city stormwater system. The well manicured grassy areas (Figure 2-66) do not appear to receive stormwater runoff from adjacent areas. The storm drain pictured in Figure 2-67 accepts stormwater runoff from a heavily treed parking lot on the Ayers property. The planters shown in the photograph currently serve aesthetic and safety purposes; they are curbed off from the asphalt lot. This is in sharp contrast to a large depression shown in Figure 2-68. The depression leaves a large area for infiltration and root nourishment but still provides a conduit to convey large flows away from the property.

Figure 2-65: Ayers Complex—Stormwater Conduit

Figure 2-66: Ayers Complex—Landscaping


Figure 2-67: Ayers Complex—Parking Lot

Figure 2-68: Ayers Complex—Depression Area

Ayers parking lot

Current site conditions. The parking lot shown in Figure 2-69 is used for the Ayer's medical plaza. It has over 200 spaces. The parking lot is fully asphalted with no stormwater retention in tree islands. The stormwater swale shown in Figure 2-70 was ponded 3 hours after a typical afternoon storm on August 10th. It was recently mowed with heavy mowing equipment.

Figure 2-69: Ayers Parking Lot—Tree Island

Figure 2-70: Ayers Parking Lot—Infiltration Swale

809 SW 9th St. parking lot

Current site conditions. This small 20 space lot is bordered by a single family home with dense vegetation to the east. Water drains from the lot into the landscaping between it and the house. The grass strip to the west (Figure 2-71) receives very little water because the slope of the lot is away from it and the road is curbed off from it.

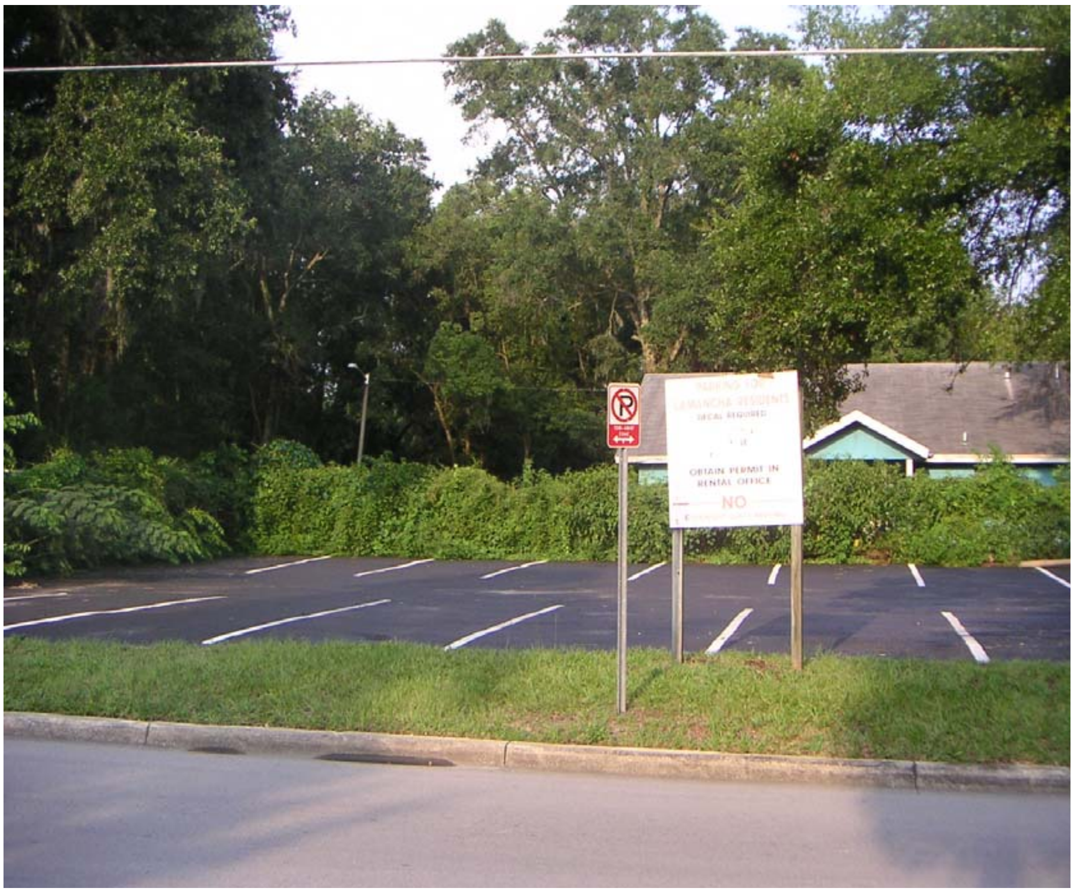

Figure 2-71: Parking Lot East of the Estates

1122 SW 3rd Ave

Current site conditions. This house, located on the corner of SW 12th Street and SW 3rd Avenue, is of unknown planning status. The property is currently in very good condition with a maintained garden (Figure 2-72). This home is hidden by large hedges and trees. There appears to be no directly connected surface on this property.

Figure 2-72: 1122 SW 3rd Ave—House and Perimeter Vegetation

SW 10th St. and SW 1st & SW 2nd Avenues

Current site conditions. This property forms a contiguous grassy parking lot that extends southbound from SW 1st to SW 2nd Ave along SW 9th street as shown in Figure 2-73. The lot is highly vegetated with a variety of large trees. The spaces between them are just wide enough for small cars to pass through. The main driveways have been worn and are sandy.

Figure 2-73: SW 10th St. & SW 1st/2nd Ave—Parking Lot

SW 1st Ave house

Current site conditions. The third of four parcels marked for redevelopment along the south side of SW 1st Ave. appears to have no DCIA (Figure 2-74). The driveway is composed of two concrete strips with a center grass path to infiltrate some storm volume (Figure 2-75).

Figure 2-74: SW 1st Ave House—Driveway

Figure 2-75: SW 1st Ave House—Lawn

923 SW 1st Ave

Current site conditions. West on the 1st Avenue streetscape, this property has manicured ground cover and trees which have presumably been left from pre-initial development conditions (see Figure 2-76). Redeveloping around the natural area seems a good choice as there is likely high infiltration, storage, and evapotranspiration potential.

Figure 2-76: 1st Ave House—Forested Landscape

926 SW 2nd Avenue

Current site conditions. This is a continuation of the previous property but on the south side, along SW 2nd Avenue. This lot is home to a doctor's office (Figure 2-77). Roof runoff drains into a small landscaped area and overflows onto an asphalt parking lot. The parking lot drains to both a shallow gulch to the east and a treatment pond to the north (Figure 2-78). The parking lot is otherwise curbed off.

Figure 2-77: Second Avenue House—Building

At the north side of the lot, which actually faces SW 1st Avenue, there are two parking spots that are pervious (Figure 2-79). Regular maintenance is necessary to keep these spots from collecting sediment. No information is currently available as to a maintenance schedule for these spaces.

The area shown in Figure 2-80 drains many buildings and parking lots from parcel 13274 and its associated subparcels as well as many portions of parcel 12893 and its associated subparcels. The developers left a treed area separating this part of the property from SW 1st Avenue. The drainage systems (both the gulch and the pond) may have enough freeboard to treat and infiltrate runoff from most major storm events.

Figure 2-78: SW 2nd Avenue House—Shallow Gulch

Figure 2-79: SW 2nd Avenue House—Pervious Paving

Figure 2-80: SW 2nd Avenue House—Rain Garden / Retention Pond

104 SW 8th St

Current site conditions. This house, located on the south side of SW 1st Ave., is a simple design with no sophisticated stormwater treatment. Like many of the other houses on this block, there is no DCIA present. Figure 2-81 shows that the ground is relatively flat, with a slight slope to the west (right). The streetscape along SW 1st avenue is curbed with 3 ft sidewalks and a high pitched crown road with onstreet parking as pictured in Figure 2-82.

Figure 2-81: 104 SW 8th St—House and Shed

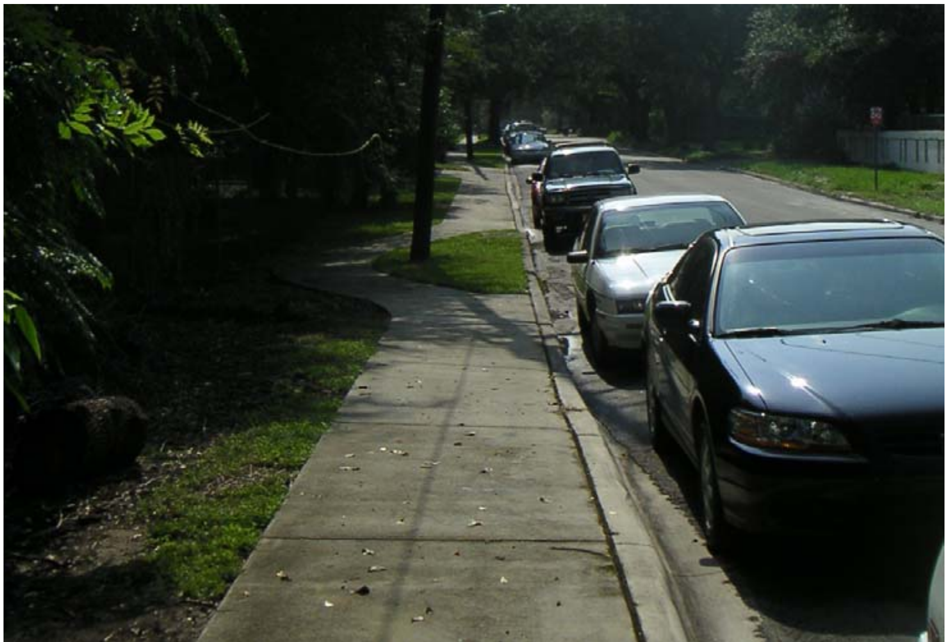

Figure 2-82: 104 SW 8th St—1st Ave. Streetscape

2nd Ave & 7th St parking lot

Current site conditions. The parking lot located on SW 2nd Avenue and SW 7th Street is surrounded by a two-lane road, a commercial building, and an historic home. Water drains from the parking lot to two swales, one adjacent to the road and the other between it and a neighboring building as shown in Figure 2-83 and Figure 2-84. The swale on the East side of the parking lot is 15-20 ft wide.

Figure 2-83: SW 2nd Ave & SW 7th St. Parking Lot

Figure 2-84: SW 2nd Ave & SW 7th St. Parking Lot—depression

112 SW 6th St.

Current site conditions. This parcel located on the corner of 6th St and SW 2nd Avenue, South of the Smith office property, contains a 1-story office space (Figure 2-85) with a grassy swale to infiltrate parking lot, rooftop, and road runoff. The building shows no external DCIA drainage and likely only drains into the swale.

Figure 2-85: 112 SW 6th St.—Office Space

The swale is largely disconnected from the road except for some breaks in the curb. The top of Figure 2-86 shows the large drain that empties into the city stormwater system during heavy storm events. This swale shows good infiltration capacity as it is completely dry after a typical summer rainfall earlier in the day (August 10th 2005).

Figure 2-86: 112 SW 6th St.—Swale

117 SW 7th St.

Current site conditions. This house is nestled between the Smith office property, the Henderson property, and Ayers medical plaza, just north of a parking lot (Figure 2-87). There is no directly connected impervious area. Instead, rainfall runs off of the roof to the landscaped area surrounding it, with no noticeable foundation settling or other signs of water logging.

Figure 2-87: 117 SW 7th St

20 SW 8th St.

Current site conditions. This large open corner lot has bare ground adjacent to the building. It appears compressed as can be shown by the ponding in the lower photographs (Figure 2-88, Figure 2-89).

Figure 2-88: 20 SW 8th St.—Unpaved Parking

Figure 2-89: 20 SW 8th St.—On-site Ponding

810 SW 1st Ave

Current site conditions. This house, located on SW 1st Avenue, West of 8th Street (Figure 2-90), is next door to the large open corner lot discussed elsewhere in this document as *20 SW 8th St*. The area around the driveway's paving strips (see Figure 2-91) is completely dry (after a brief storm on August 11th, 2005), which is a good sign of high infiltration capacity even with little vegetation. It may also be that the stormwater is draining to the empty lot east of this property.

Figure 2-90: 810 SW 1st Ave

Figure 2-91: 810 SW 1st Ave—Driveway

Cone property

Current site conditions. The Cone property is a totally developed parcel that is a candidate site for redevelopment. The 3.04 acre lot (Figure 2-92) currently has no stormwater BMPs in place. On the southwest side of property, the roof drains connect directly to street as shown in Figure 2-93. A tree island on the northwest side of property is disconnected from street. Runoff from the road drains onto the grassy area shown at right in Figure 2-94 and then flows southbound to a city stormsewer inlet as shown in Figure 2-95.

Figure 2-92: Cone Property—Parking Lot

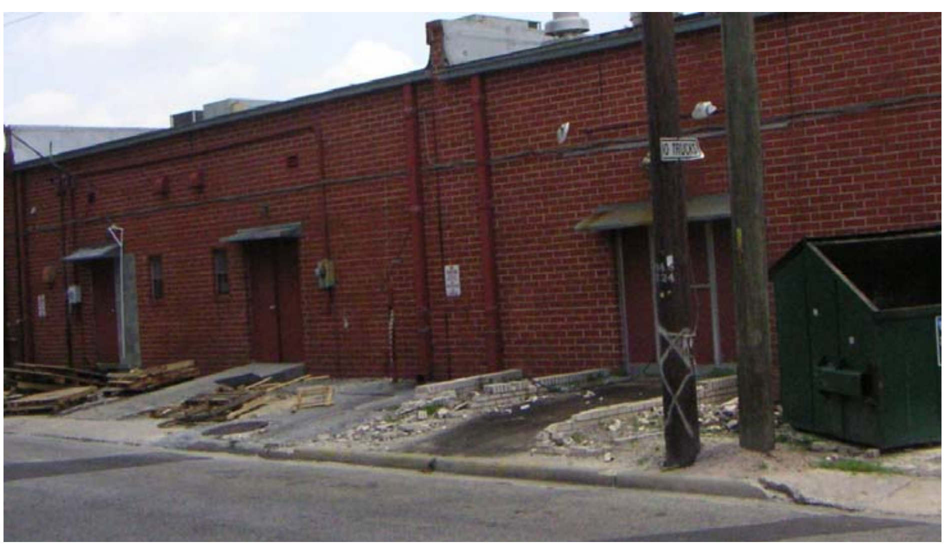

Figure 2-93: Cone Property—West Side

Figure 2-94: Cone Property—Tree Island

Figure 2-95: Cone Property—University Ave

1206 W University Ave

Current site conditions. This vacant lot, located on the North side of University Avenue, presents many opportunities for redevelopment. Currently, a large concrete slab covers 1/3 of property while the remaining space is grass/sand and autonomous abandoned islands. The green area in the center of Figure 2-96 is connected to the pavement, while the tree islands on the edges of the property are not. There appears to be some ponding in the sandy grass covered area due to rains the same day (August 11).

Figure 2-96: 1206 W University Ave.—Gas Station

Summary and Conclusions

During redevelopment, many sites are changed from low intensity single family homes with low cost (albeit large area infiltration solutions) to multifamily structures with higher cost and higher maintenance systems but less greenspace requirements. While infiltration trenches appear to be the most commonly chosen onsite control methods for redeveloped sites in the TCW, some sites have incorporated unique techniques in order to retain water onsite.

Existing properties exhibit a wide range of on-site and off-site controls. Observed control methods are summarized in Table 2-15 and Table 2-16 for post- and pre-redevelopment conditions, respectively. Many of the on-site controls were not designed as such. Non-redeveloped sites use relatively simple LID solutions like disconnected roofs and permeable parking. On-site infiltration controls for new developments require relative sophisticated engineering analysis and design. Most onsite controls in use today serve to store, infiltrate, and evapotranspire stormwater and can be classified under the hydrologic unit process category in Table 2-2.

Many of the properties offer opportunities for stormwater control by localizing parking, creating stormwater parks and ponds, wisely landscaping, carefully grading the site, and using low compaction construction techniques. The collective expertise of urban planners, urban foresters, landscape architects, stormwater engineers, developers, transportation engineers, and local government officials is needed to ensure that the best decisions are being made.

The most difficult task in determining the effectiveness of BMPs is the process of gathering data on their function (including calculation, image, land uses, location, etc), much as was performed for this chapter. This is also a fundamental component of a cyberinfrastructure as defined in Chapter 3.

For more property information, access the Alachua County Tax Assessor's Database (http://www.acpafl.org). Tax parcel information is also summarized in Table 2-17 and Table 2-18 for the reader's convenience. Caution must be taken in verifying that the following information is current before using it.

Table 2-15: Onsite Controls Used on Redeveloped Sites in the University Heights District

Project Status	Redevelopment Site Name	Onsite Control Techniques Used: Disconnected Roof	Forest Infiltration	Dry Ret Pond	Wet Det Pond	Permeable Parking	Infiltration Trench	Rain garden	Xeriscaping / Natural	Swale	Porous Paving
Complete	Woodbury Row			yes							
	Royale Palm Apartments						yes				
	Windsor Hall							yes			
	Heritage Oaks Apartments	yes				yes	yes	yes	yes		yes
	DZ sorority house							yes	yes		
	Alligator Crossing	yes	yes			yes		yes			
Under Construct.	West University Avenue Lofts				central						
	Taylor Square						yes				
	Stratford Court Apartments						yes				
	Oxford Terrace			yes			yes				
	Campus View I			yes			yes				
	Campus View II										

Table 2-16: Onsite Controls Used on Non-Redeveloped Sites in the University Heights District

Project Status	Redevelopment Site Name	Onsite Control Techniques Used									
		Disconnected Roof	Forest Infiltration	Dry Ret Pond	Wet Det Pond	Permeable Parking	Infiltration Trench	Rain garden	Xeriscaping / Natural	Swale	Porous Paving
Planning	1122 SW 3rd Ave.	yes	yes	-	-	-	-	-	yes	-	-
	Visions	yes	-			yes					
	Campus View North	yes	-								
	Campus View III	yes	yes								
	Estates Sorority Row	yes	-			yes					
Opportunity	10th St & 1st					yes					
	SW 1st Ave House	yes				yes					
	Ayers Medical Plaza							yes		yes	
	117 SW 7th St	yes							yes		
	2nd Ave & 7th St Lot									yes	
	Smith Office Property										
	112 SW 6th St.	yes								yes	

Table 2-16. Continued.

Project Status	Redevelopment Site Name	Onsite Control Techniques Used									
		Disconnected Roof	Forest Infiltration	Dry Ret Pond	Wet Det Pond	Permeable Parking	Infiltration Trench	Rain garden	Xeriscaping / Natural	Swale	Porous Paving
	Shands AGH										
	West Univ. Ave. Mall										
	810 SW 1st Ave.	yes				yes					
	20 SW 8th St					yes					
	104 SW 8th St	yes				yes					
	923 SW 1st Ave		yes						yes		
Opportunity	926 SW 2nd Ave	yes	yes			yes		yes	yes		
	E. Shands Parking Lot			yes							
	Shands S. Parking Lot										
	909 5th Ave	yes	yes			yes					
	809 SW 9th St Lot					yes				yes	
	Cone Property										
	1206 W Univ. Ave					yes					

Table 2-17: Land Use Information Provided in Alachua County Tax Assessor's Database

Project Status	Description	Parcel Area (acres)	Building Footprnt (sq ft)	Paving (sq ft)	Drive/ Walkway (sq ft)	D/W Brick (sq ft)
Complete	Woodbury Row	0.52	6824	6875	876	
	Royale Palm Apartments	0.54	13526	8237	1888	
	Windsor Hall	1.65	19256	7046	2328	120
	Heritage Oaks Apartments	0.68	15167	3986	1499	2073
	DZ sorority house	0.22	8639	9459	1880	
	Alligator Crossing	0.27	3118			
Under construct.	West University Avenue Lofts	0.48				
	Taylor Square	0.50				
	Stratford Court Apartments	0.63	4510		725	
	Oxford Terrace	0.73				
	Campus View I	1.08				
	Campus View II	0.50				
Planning	1122 SW 3rd Ave	0.36	2129			
	Visions	0.26	3648		110	
	Campus View North	0.62	4117		666	
	Campus View III	0.47				
	Estates at Sorority Row	0.47	5289		1565	
Opportune Site	SW 1st Ave House 10th St & 1st/2nd Ave	2.00		16695		
	Ayers Medical Plaza	5.19	99436	77006	2350	
	117 SW 7th St 2nd Ave & 7th St Parking Lot	0.85		8835		
	Smith Office Property	0.25		9000		
	112 SW 6th St	0.77	14000	4600		
	Shands AGH	10.77		10000		
	810 SW 1st Ave West University Avenue Mall	2.05	33499	38200	1505	
	20 SW 8th St	0.17				
	104 SW 8th St	0.70	2837			
	923 SW 1st Ave	0.26	2402		100	
	926 SW 2nd Ave	0.45	3750	12000	600	
	East Shands Parking Lot	2.75		48667		
	Shands South Parking Lot 909 5th Ave	3.60	6476	89294		
	809 SW 9th St Parking Lot	0.15				
	Cone Property	2.82	64295	66180		
	1206 W Univ. Ave / Vacant	0.60		14596		
unknown	Henderson Property	0.29	7167	4100		

Data accesses 12-15-05, Alachua County Tax Assessor *http://www.acpafl.org*
Note that some property changes have not yet been reflected in the database.

Canopy (sq ft)	Garage (sq ft)	Lab (sq ft)	Patio (sq ft)	Deck (sq ft)	Slab (sq ft)	Pool (sq ft)
			509		400	
				1400		384
			690		100	
			264			
	360		216	120		
				684		
540		817				
240						
	360					

Table 2-18: Parcel Information for Redevelopment Sites in University Heights

Project Status	Description	Parcel ID	Street Address	Zoning	Parcel Area (ac)	Land Val ($)	Total Val ($)
Complete	Woodbury Row	13143-010-008, 13143-010-000, 13143-010-005, 13143-010-002, 13143-010-001, 13143-010-007, 13143-010-006, 13143-010-004, 13143-010-003	1025 SW 5TH AVE	RHD 8-100 u/a	0.52	79000	1230000
	Royale Palm Apartments	13190-000-000	1015 SW 7TH AVE	RHD 8-100 u/a	0.54	144000	1172900
	Windsor Hall	13439-000-000, 13430-000-000	609 SW 9TH ST, 802 SW 7TH AVE	RHD 8-100 u/a	1.65	432000	3094800
	Heritage Oaks Apartments	14003-000-000, 14002-000-000	117 NW 12th Ter	RHD 8-43 u/a	0.68	197400	1577400
	DZ sorority house	15534-000-000	903 SW 13TH St	RHD 8-100 u/a	0.22	206500	1265900
	Alligator Crossing	13143-000-000	1123 SW 5TH AVE	RHD 8-100 u/a	0.27	72000	252800

Table 2.18. Continued.

Project Status	Description	Parcel ID	Street Address	Zoning	Parcel Area (ac)	Land Val ($)	Total Val ($)
Under const.	West University Avenue Lofts	12936-000-000	609 W UNIVERSITY AVE	Planned Dev.	0.48	216000	216000
	Taylor Square	13163-000-000	621 SW 10TH ST	RHD 8-100 u/a	0.50	125300	125300
	Stratford Court Apartments	13179-000-000, 13180-000-000, 13181-000-000	321 SW 13 ST, 608 & 620 SW 10 ST	RHD 8-100 u/a	0.63	165600	322000
	Oxford Terrace	13446-001-000	847 SW Depot Ave		0.73		
	Campus View I	15519-000-000	975 SW 13TH ST	RHD 8-100 u/a	1.08	282500	282500
	Campus View II	15520-000-000	1245 SW 9TH RD	RHD 8-100 u/a	0.50	98800	98800
Planning	1122 SW 3rd Ave	13058-000-000	1122 SW 3RD AVE	RHD 8-43 u/a	0.36	97200	184000
	Visions	13198-000-000	1016 SW 8TH AVE	RHD 8-100 u/a	0.26	72000	155700
	Campus View North	15512-000-000, 15511-000-000	1208 & 1142 SW 9TH RD	RHD 8-100 u/a	0.62	163100	355700
	Campus View III	15521-000-000, 15520-001-000	1229 & 1237 SW 9TH RD	RHD 8-100 u/a	0.47	123900	272800
	Estates at Sorority Row	15567-007-000, 15567-006-000, 15567-005-000	811 & 815 & 817 SW 11TH ST	RHD 8-43 u/a	0.47	121500	368700

Table 2.18. Continued.

Project Status	Description	Parcel ID	Street Address	Zoning	Parcel Area (ac)	Land Val ($)	Total Val ($)
	SW 1st Ave House 10th St & 1st/2nd Ave	12893-000-000	902 SW 2ND AVE	OR 20 u/a	2.00	688700	949100
Opportune	Ayers Medical Plaza	12928-000-000, 12921-466-000, 12921-258-000, 12921-250-000, 12921-170-000, 12921-458-000, 12921-464-000, 12921-350-000, 12921-151-000, 12921-555-000, 12921-468-000, 12921-452-000, 12921-160-000, 12921-454-000, 12921-155-000, 12921-252-000, 12921-180-000, 12921-254-000*	704 SW 2ND AVE, 720 SW 2ND AVE	Med Services	5.19	1107800	10300900
	117 SW 7th St 2nd Ave & 7th St Parking Lot	12933-000-000	117 SW 7TH ST	Commercial	0.85	289800	298300

Table 2.18. Continued.

Project Status	Description	Parcel ID	Street Address	Zoning	Parcel Area (ac)	Land Val ($)	Total Val ($)
Opportune	Smith Office Property	12937-000-000	0 W UNIVERSITY AVE*	Planned Dev.	0.25	92000	97200
	112 SW 6th St	12938-000-000	112 SW 6TH ST	Commercial	0.77	260900	340000
	Shands AGH	13036-000-000	801 SW 2ND AVE	Med Services	10.77	1680700	18241500
	810 SW 1st Ave	13203-000-000, 13201-000-000, 13200-000-000	810 SW 1ST AVE	Commercial	2.05	846300	2158000
	West University Avenue Mall		805 & 903 W UNIV. AVE	OR 20 u/a			
	20 SW 8th St	13209-000-000	20 SW 8TH ST	OR 20 u/a	0.17	44100	44100
	104 SW 8th St	13265-000-000, 12892-000-000	104 SW 8TH ST, 112 SW 8TH ST	OR 20 u/a	0.70	165400	384500
	923 SW 1st Ave	13271-000-000	923 SW 1ST AVE	OR 20 u/a	0.26	72600	163900
	926 SW 2nd Ave	13274-000-000	926 SW 2ND AVE	OR 20 u/a	0.45	152200	328200
	East Shands Parking Lot	13327-001-000, 13327-000-000	606 SW 3RD AVE	Med Services	2.75	681700	809200
	Shands South Parking Lot	13337-000-000	410 SW 8TH ST	Med Services	3.60	573500	834300
	909 5th Ave		909 5th Ave	RHD 8-100 u/a			
	809 SW 9TH ST Parking Lot	13443-000-000	809 SW 9TH ST	RHD 8-43 u/a	0.15	--	--

Table 2.18. Continued.

Project Status	Description	Parcel ID	Street Address	Zoning	Parcel Area (ac)	Land Val ($)	Total Val ($)
	Cone Property	13659-000-000	10 NW 6TH ST	Commercial	2.82	994500	1218000
	1206 W Univ. Ave / Vacant	13996-000-000	1206 W Universtiy Ave	Commercial	0.60	280000	288400
Unknown	Henderson Property	12929-000-000	621 W UNIVERSITY AVE	Commercial	0.29	130000	316200

Data accesses 12-15-05, Alachua County Tax Assessor *http://www.acpafl.org*)
Note that some property changes have not yet been reflected in the database

CHAPTER 3
CYBERINFRASTRUCTURE FOR CENTRALIZING AND MINING CONTENT

Introduction

As shown in the previous Chapter, in the Tumblin Creek Watershed many properties incorporate functional land areas that perform the functions of infiltration and temporary storage without being considered BMPs. In order to properly evaluate the utility of disaggregated onsite controls, whether or not they are deemed BMPs, the data must be collected in a centralized, easily accessible, manner. The question of how to organize data into a cyberinfrastructure that allows analysts to effectively evaluate these complex systems is addressed in this chapter.

Cyberinfrastructure has been defined as "the coordinated aggregate of software, hardware and other technologies, as well as human expertise, required to support current and future discoveries in science and engineering" (Berman et al. 2005). A recent NSF report provides a more tangible definition.

> The term infrastructure has been used since the 1920s to refer collectively to the roads, power grids, telephone systems, bridges, rail lines, and similar public works that are required for an industrial economy to function. Although good infrastructure is often taken for granted and noticed only when it stops functioning, it is among the most complex and expensive thing that society creates. The newer term cyberinfrastructure refers to infrastructure based upon distributed computer, information and communication technology. If infrastructure is required for an industrial economy, then we could say that cyberinfrastructure is required for a knowledge economy (Atkins et al. 2003, p 5).

There currently exists a great network of information that is readily shared in what is called Web 2.0 (O'Reilly 2006), and many resources have been developed that help foster academic research (CyberInfrastructure Partnership 2006). However, Web2.0 is largely a business and entertainment model, and the resources available to academics are "often disparate and methods are necessary [to] provide a useful, usable, and enabling framework for research and discovery characterized by broad access and "end-to-end" coordination" (Atkins et al. 2003). In the context of BMP analysis, there does not yet exist a solid decision support system that houses geospatial BMP performance data, analysis tools, and publications in one location. A cyberinfrastructure is designed for just such a research environment that supports:

- data acquisition,
- data storage,
- data management,
- data integration,
- data mining,
- data visualization and
- computing and information processing services over the Internet.

Figure 3-1 provides a useful model to optimize future research steps in light of current methods.

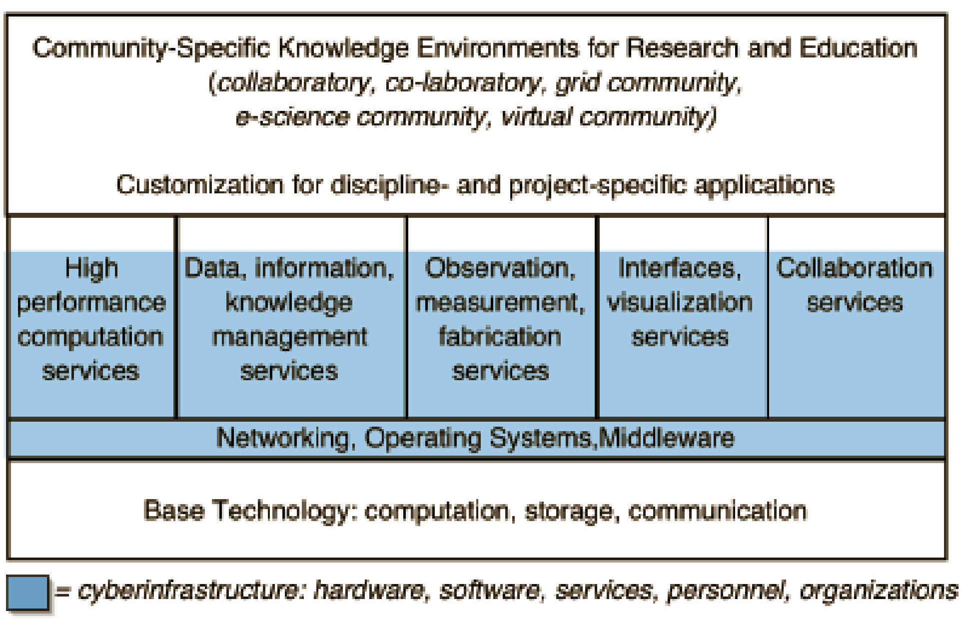

Figure 3-1: Integrated Cyberinfrastructure Services to Enable New Knowledge Environments for Research and Education. (Atkins 2003)

Computation Services

Research analyses performed herein involved the need for computation; however, all tools were used on a contemporary personal computer rather than on a centralized modeling mainframe or similar system. Computational tools used for this thesis were ArcGIS® (ESRI, Redlands, CA) , Excel® (Microsoft, Redmond, WA) , EPA SWMM (EPA, NC) and Frontline Systems Solver® (Frontline Systems Inc., Incline Village, NV). All the tools used were decentralized or used on a personal computer. While highly context-specific stormwater and optimization tools were applied in this study, computational performance was not an issue using current personal computer technology. The greater issue was proper file management.

Information Management

The second block in Figure 3-1 is labeled "Data, information, knowledge management services." In context of this research, the data for the aforementioned computational tools were located in multiple locations and in multiple forms. Spatial data were located both on a local department server and in multiple folders on a personal computer. Rainfall information was obtained in raw .CSV format from the NRDC on local hard drives, in a local Access database file where it had been modified and filtered for easier use with SWMM and Excel, and rainfall information was embedded within SWMM and Excel files. Photographs of local BMPs were stored on one network drive and two personal computers. Cost information and stormwater calculations for BMPs in Tumblin Creek were obtained in paper form from the local city planning department. Reference data were obtained from the University of Florida Electronic Thesis and Dissertations library catalog, peer-reviewed journals with robust knowledge management services, hardcover theses, by personal email, by telephone, and in loose-leaf data printouts. The electronic data were in multiple forms: .TXT, .CSV, Excel®, Word®, Powerpoint®, PDF, GIF, JPEG, and proprietary SWMM formats. Much of the time required to write this thesis was spent gathering data. Data produced by this analysis and writeup (in the form of Word and PowerPoint documents, SWMM output files, GIS files, and JPEG files of GIS maps) are currently located on an ftp site, a local hard drive, flash media, a network drive, and in an email repository. While simply creating a database of regional stormwater data would greatly improve productivity, a number of content management systems are available that both organize data and provide a means of calculating or sharing the data within workgroups as discussed in the next section.

Collaboration Services

While blocks three and four of Figure 3-1 do not relate to this project in any large part, “collaboration services” offer a great benefit to projects such as those discussed in this thesis. Most information for this thesis, aside from reference information, has been shared and is maintained in an inefficient manner by cyberinfrastructure standards. The following GIS spatial data files were obtained by email: sidewalk lines, stormwater pipe networks, campus buildings, roads, and parking lots. Watershed topography and imagery for GIS were obtained on optical media. Watershed layout and subbasin information was downloaded in CAD from the University of Florida Physical Plant (2003). Soils information and GIS spatial data files were downloaded from the Florida Geographic Data Library (2004). The Excel-based rainfall-runoff tool itself was received by email and partly reproduced from textual data located in Heaney and Lee (2006).

The document-reviewing process for this thesis was performed in large part by email and ftp access as well as using file transfer services such as YouSendIt® (Mountain View, CA). One reference document was emailed three times because its location was forgotten and there was no easy way to search for the document by subject or keyword. Email is especially problematic because it is difficult to maintain organized threads of communication centered around a topic, project, or document.

Collaboration services can serve to significantly improve the research process at the University of Florida and elsewhere by organizing the data into a central repository and encouraging collaboration rather than file sending. This collaboration is especially useful when creating a modular watershed simulation such as those discussed in later chapters. Collaboration services can be subdivided into two categories, for the purpose of this thesis. Some services, such as content management systems, provide both central file management and communications opportunities. Other services better integrate data creation and manipulation with centralized storage. A combination of both may provide the foundation for future BMP decision systems by service as information management systems, collaborative analysis tools, and collaborative authoring tools.

Centralized File Management and Communications

Two common examples of centralized file management used in academic settings are WebCT and Blackboard (Washington, DC). Both products are heralded for their content release schedule (adaptive release), defined content submission windows, centralized gradebook system, automatic test administration, and WYSIWYG text editors. The most critical and pervasive problem when sharing information is controlling access (Moore 2005). The Blackboard tool addresses this issue by implementing the WebDAV storage standard which greatly facilitates file searching by keyword, concept, author, etc. and maintains the data in a database rather than a file repository. From a research perspective, the install base of Blackboard and WebCT is attractive because the software is designed to easily share content with other WebCT or Blackboard servers, maintaining file permissions and security between servers. Since most academic institutions often have one or both systems installed, it may prove a relatively simple, although proprietary, solution to sharing data in an academic network.

The enterprise standard in document management is the Microsoft Sharepoint Services and Portal packages. Sharepoint performs similar functions but fully integrates with Office. There are many extensions for it, from integration with the GIS services such as ArcSDE to creating a well defined data structure using an ontology. All documents are contained in redundant databases utilizing the WebDAV system rather than as raw files; hence there are no folders with pictures, documents, or audio files in them. Similar to Blackboard, this facilitates document searching, file versioning and sercurity since there is no way to access the information without going through the Sharepoint database access module. Sharepoint is designed to integrate with Office® and does not "play well" with open source products such as OpenOffice. What greatly increases Sharepoint's value is that it is designed to run on top of MS SQL Server® and so are the ESRI server products.

ESRI's ArcSDE® is the most basic GIS document management product designed to serve GIS content in geodatabases on top of MS SQL Server®. ArcIMS allows these files to be served through common internet browsers. Methods have been described that link searches in Sharepoint to GIS content within ArcSDE (Bain 2003). Conversely, a user can automatically tag shapefiles with document information (served from Sharepoint) from within ArcGIS or ArcIMS.

Centralized File Management and Computational Analyses

An example of combining data storage and computation is the ArcGIS Server tool by ESRI. ArcGIS Server allows a group of users to store information on centralized geodatabase(s) and additionally perform data computation on a central server from any computer. One major advantage to having a product like ArcGIS installed on a central server is upgradeability and scalability. Upgradability refers to the ability to update the core processing software when new releases are available without having to update several user computers, saving time and money. Scalability refers to the ability to increase system capacity in both speed and filespace as the needs of the user base grow. A person with a four year old laptop would have some difficulty in running the latest version of ArcGIS on their computer today but a user with a ten year old computer can edit and save ArcGIS files using ArcGIS Server because the computer largely functions as a terminal. With all of the benefits, there are some disadvantages to centralized computing such as processor load dynamics. It may be most efficient to utilize a mesh or distributed computing approach wherein each autonomous computer contributes computational time to the larger community; however, while this has approach been utilized in other applications, they are nascent and security issues remain (Davies 2004).

Ontological Development

While absent from most cyberinfrastructure literature, ontologies may provide the data sharing opportunities that are highly desired without the need to subscribe to one file standard. Instead, others have created a language that allows for the sharing of mostly text based information at a basic common denominator, extensible markup language (XML). Protocols have been developed that allow a person to tailor the knowledge representation format they desire within, for example, their college, and share it with others by publishing the ontology. The knowledge representation is the ontology, while the protocols used to describe and share ontologies are most notably RDF and OWL, among others. Beck (2002, p 1) has written a detailed introduction to ontologies and describes their purpose as follows:

> Ontologies can be used to better organize information resources and assist users in retrieving relevant information…. Ontologies attempt to exploit domain-specific information by representing the meaning of terms within a domain, and using these meaning representations to organize the collection and make search more accurate.

The BMP Data Clearinghouse developed by Clary et al. (2002) has to be standardized within its own namespace but by using ontologies, information can be shared between this database and another simply by creating a translator that says, for example, the term "Hydrodynamic Unit" in the Clearinghouse is equal to "Hydrodynamic Separator" in another clearinghouse. One can also define which relationships to carry over if combining data (i.e. if the Clearinghouse has knowledge that the CDS is a type of Hydrodynamic Unit, then the other clearinghouse can leverage this and import that relationship if desired).

Ontologies are for the most part academic pursuits at the moment may one day drive the web. A major problem with ontologies is that while they can be defined using simple relationships, i.e.:

- Class: A generic concept
- Object: A particular occurrence of a generic concept
- Subclass: A class that is more specific than a particular class
- Superclass: A class that is more general than a particular class
- PartOf: An object that is part of a particular object
- Association: Two objects are related in general (other than one of the above relationships) (Beck et al., 2002),

the taxonomies that develop can become very complicated with many layers of information. The following are some examples of taxonomies from various projects.

The code below is part of an ontology used to describe physico-chemical phenomena. A lot of information can be gathered from the compact code. The following are two terms with unique IDs and common names. Their definitions are provided and one can find the definition source in the brackets. The "is_a" term shows that agglomeration is an interphase transition and hence is related to term id: REX:0000181.

[Term]
id: REX:0000181
name: interphase transition
def: "A transition that occurs at boundaries between phases." [http://gold.zvon.org/I03119.html]
is_a: REX:0000171 ! phase transition

[Term]
id: REX:0000186
name: agglomeration
def: "The formation and growth of aggregates ultimately leading to phase separation by the formation of precipitates of larger than colloidal size." [http://gold.zvon.org/A00182.html]
is_a: REX:0000181 ! interphase transition
http://obo.cvs.sourceforge.net/*checkout*/obo/obo/ontology/physicochemical/rex.obo

Figure 3-2 is a visual representation of an ontology used to organize experiments involving the use of geospatial data.

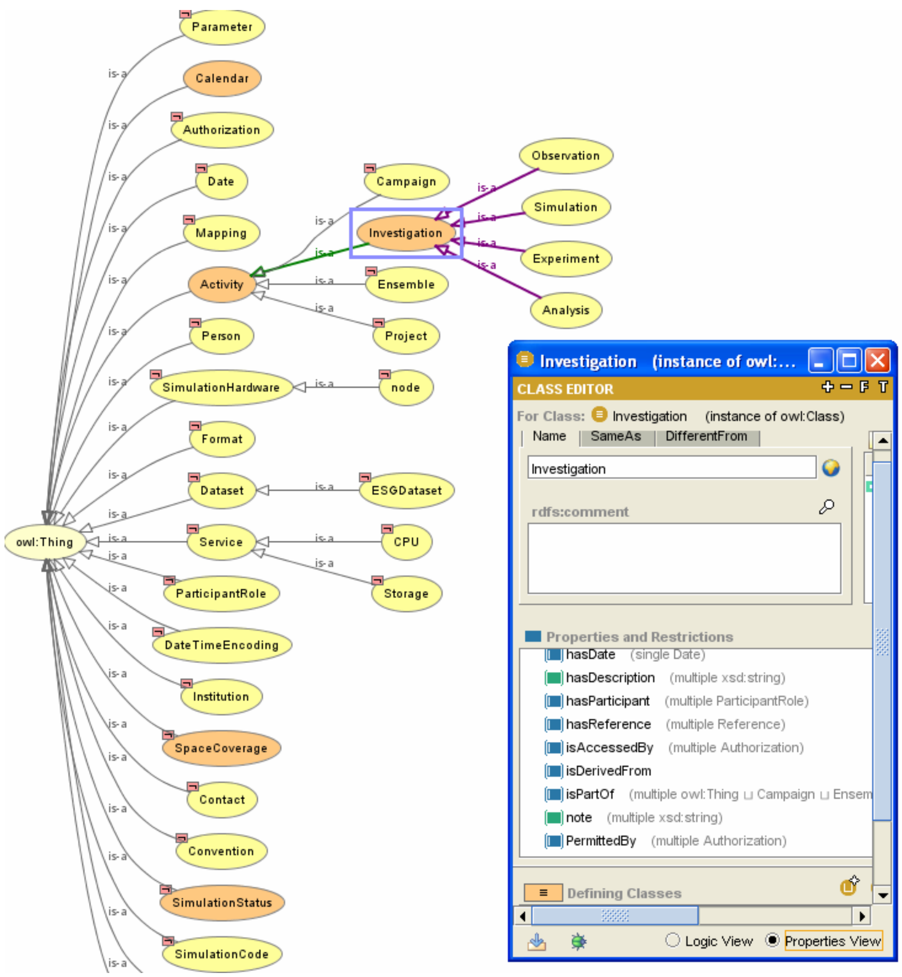

Figure 3-2: Ontology of an Investigative Experiment. (Pouchard 2003)

This image was generated using an open source ontology viewer and generator called Protégé, developed at Stanford University (http://protege.stanford.edu/). This tool is used to make very extensive ontologies that can define an entire research discipline. Figure 3-3 defines waterways and infrastructure in the United States. Relationships can be inferred from this relationship system to begin creating rule based decision tools. If it is known, for example, that watershed A shares characteristics with watershed B and the construction of a new thoroughfare in watershed A has raised the high water mark significantly during recent storm events, an inference can be made stating that if the same were done in watershed B, the same effect would occur.

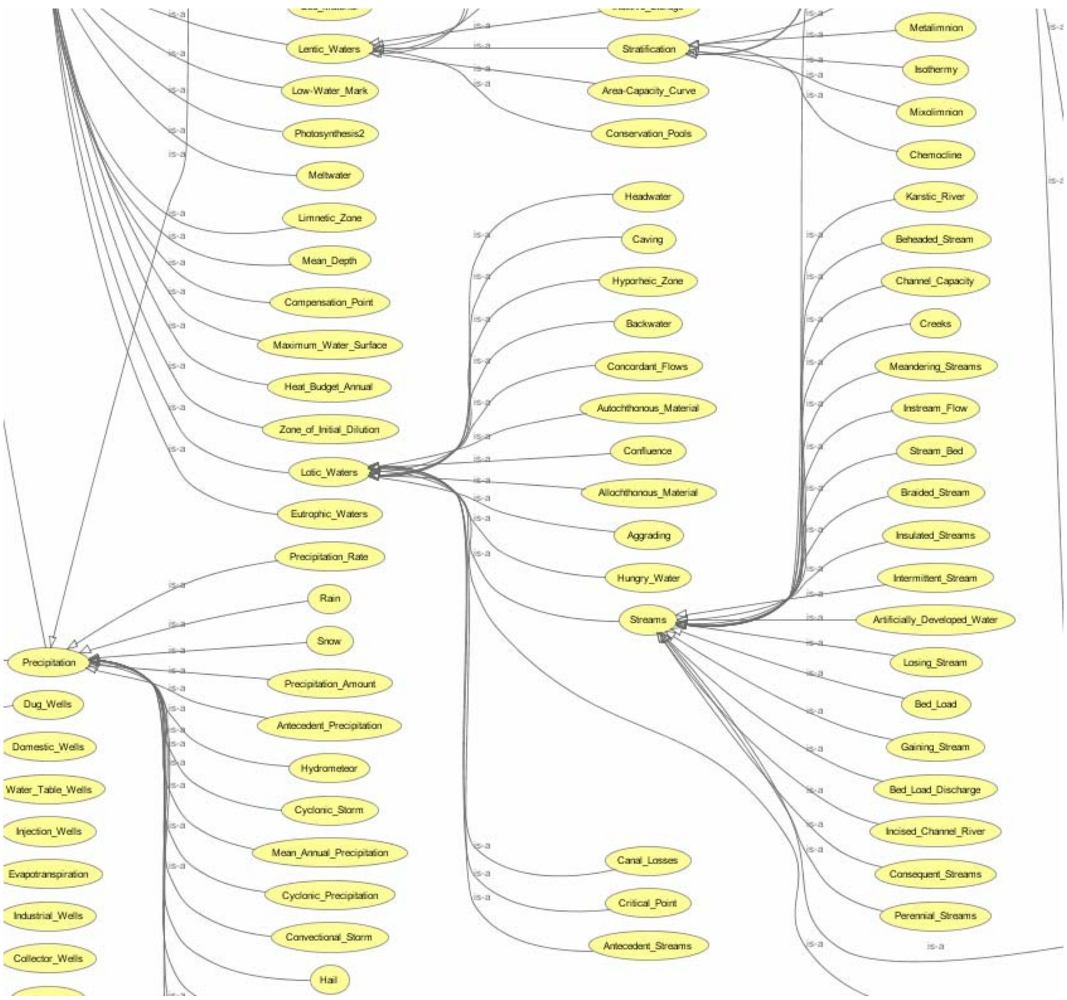

Figure 3-3 Hierarchic Division of Hydrologic Units (Beran, 2005)

A basic ontology was made for this research project using simple relationships (Figure 3-4). For example, an author must be a person and a thesis has an author (not visualized below), so it follows that a thesis may be associated to a person and a person may have written a thesis. Individuals can also populate each circle below. For example, SWMM is listed as an individual in the programs Class. Much more complicated relationships can be made using the properties form and these relationships can be queried. One can quickly determine all the individuals in the Class Person that have written thesis by letting the program search through the ontology tree.

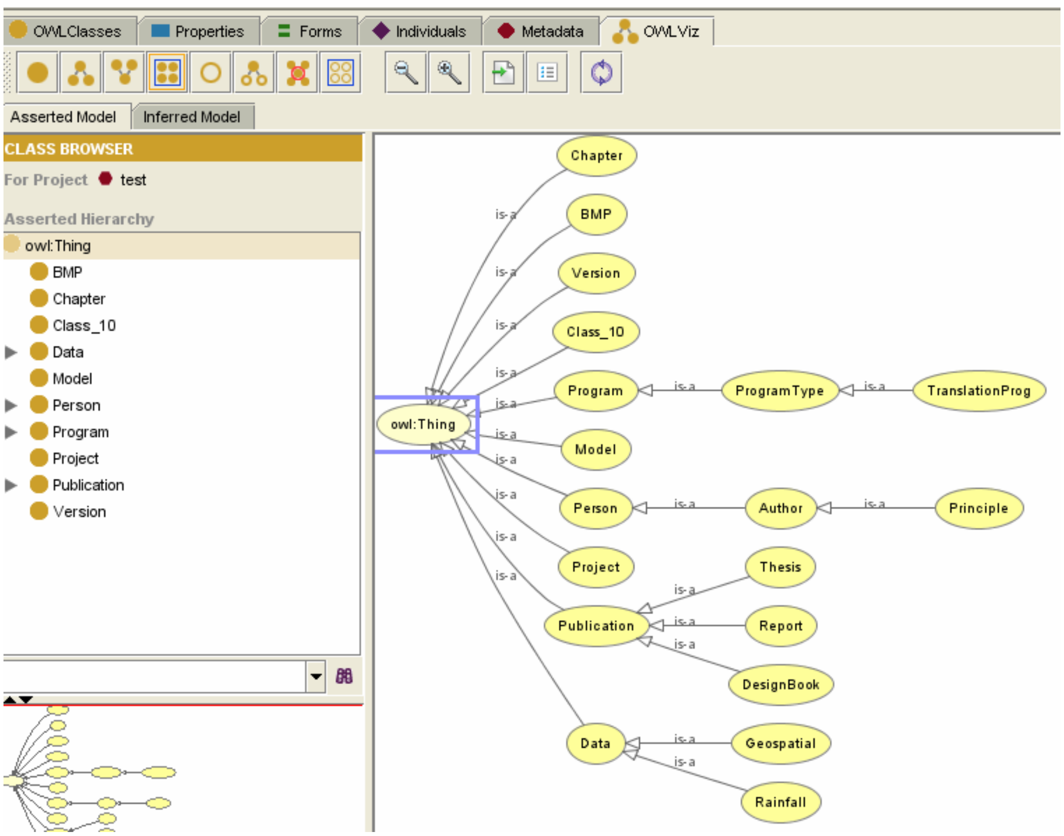

Figure 3-4: Basic Ontology of Research Project

If a content management tool like Sharepoint or Drupal were coupled with the data processing capabilities of a centralized GIS system and statistical analysis system, then the supporting entity would immediately become a hub of information. If an ontology plugin was purchased or developed, then when this information has to one day be shared with another service, such as those mentioned in the following paragraph, it would only be a matter of sharing our ontology with those seeking to integrate our data into their network.

Currently Available Cyberinfrastructure Institutions

Solutions are slowly coming online that provide a centralized data repository, modeling and analysis tools, and collaboration tools. The two projects most directly related to stormwater research are the Collaborative Large-scale Engineering Analysis Network for Environmental Research (http://cleaner.ncsa.uiuc.edu/home/) which specializes in large scale environmental systems research, and the Consortium of Universities for the Advancement of Hydrologic Sciences Hydrologic Information System (http://www.cuahsi.org/his/index.html), which is currently operational but without detailed hydrologic modeling tools such as SWMM. Of the two, the CUAHSI-HIS may be more promising because it provides an opportunity for our university to contribute to the hydrologic observation repository and a network enabled SWMM tool, receiving in return access to weather, hydraulic, hydrologic, and water quality data from other institutions as well as access to a larger decision support system of which the SWMM tool would be a small component. At the moment however, there is no data repository for urban hydrology at the University of Florida.

Content Management and Collaborative Authoring Environment Experiment

Water resource projects at the University of Florida need to share information more easily within the department and between this and other departments within the University. This is at the fulcrum of NSF funding and research as shown in the following quote from the Blue Ribbon Advisory Panel on Cyberinfrastructure:

> Interoperability is important for facilitating multidisciplinary projects as the evolution of discovery dictates. The Panel has learned that new types of scientific organizations and supporting environments ("laboratories without walls") are essential to the aspirations of growing numbers of research communities/projects and that thus they have begun creating such environments under various names including collaboratory, co-laboratory, grid community, e-science community, and virtual community. The NSF through an ACP can now enable, encourage, and accelerate this nascent grass-roots revolution in ways that maximize common benefits, minimize redundant and ineffective investments, and avoid increasing barriers to interdisciplinary research (Atkins 2003, p 13).

In the spirit of research and open standards, an experiment was undertaken to organize data from this project into an open source content management system called Drupal namely by organizing information from the Tumblin Creek BMP analysis into independent but interconnected nodes, publishing this thesis as a book with separate Chapters, publishing the Excel optimization file as a node, publishing a small selection of reference reviews as nodes, and publishing each Appendix as a node. Nodes were related to each other; for example, all nodes were categorized under the project "GainesvilleStormwater;" each chapter will have a list of references published as a separate section within the node and references will be "clickable" if hyperlinks are available; each appendix will have a click through selection that allows the user to navigate to the location(s) which reference the appendices, etc. A permission system was set up where only members of the project group were able to view unfinished documents for the purposes of reviewing. A really simple syndication or RSS link was provided for the Stormwater group page that allows subscribers with modern browsers to view content from the website as it is updated as well as allowing other websites to syndicate publicly available content from this page on their website. Similarly, Journal of American Water Resources Association publications are syndicated on the experimental CMS website. Users can access the website at www.gainesvilleenvironmental.org.

Results indicate that it is possible to create a collaborative authoring and information sharing environment using open source software, but that many steps are necessary to secure private information when using the Drupal CMS. One example of how even this basic type of collaborative environment could foster interdepartmental growth in water resources research is the ability to provide a publicly accessible visually oriented database of water quality monitoring information. Different departmental or even student run groups could take ownership of certain stations and groups could gather together real time to perform spatial statistical analyses and begin co-writing documents all from their respective departments. A more easily visualized example is the ability to create an organized database of BMP implementations throughout Gainesville much like that shown in the previous Chapter. By linking the parcel ID number with Saint Johns River Water Management District database (SJRWMD) and the Alachua County Tax Assessor’s Database (ACTA), combined with photographs of each BMP, one can begin quantifying the net effect of the various LID implementations. Monitoring data could be entered into the database in addition to water volume calculations and detailed parcel level spatial information offered by the SJRWMD and ACTA databases, respectively

Conclusions

Many environmental research scientists in water resources, soils analysis, agricultural hydrology, public health, geology, etc. utilize tools such as Office, ArcGIS, SPSS or SAS products in conjunction with custom soil analytics, hydraulic and hydrologic analysis, and other computational tools. Watershed research at the University of Florida can benefit from a local content management / computational system using products available off the shelf.

After weighing the costs and benefits of some common tools and creating a CMS using open source software, it may be most efficient to utilize a Sharepoint Portal system coupled with an ontology plugin, an ArcSDE or ArcGIS Server system, and a centralized statistical analysis package. If this system were to be implemented immediately, then it may help coordinate upcoming research opportunities at the University of Florida involving water quality control, water quantity control, and educational outreach.

Most importantly, even if computational analyses are performed independently, a CMS is necessary to encourage ad-hoc online meetings and working groups between departments without taking the time needed for in person meetings. A tool has been made available (www.gainesvilleenvironmental.com) where students interested in performing undergraduate or graduate research in the subject are able to join a group called “Stormwater.” Information from this thesis has been made available and can act as a tutorial for analytical approaches to modeling stormwater in the urban environment. Research projects in different departments, including projects, theses, and dissertations, can contribute to an overall objective of managing water quality and quantity in novel ways. It also has been shown that ontologies can be used to share information between a local CMS and other institutions, including the CUAHSI-HIS or CLEANER.

The next three chapters show data that are needed to simulate watershed runoff. Great time was taken to gather data required for computation in the hydrologic and hydraulic simulation tool EPA SWMM. While methods to compare on-site vs. off-site controls have previously been described in Sample et al. (2001, 2003) and Lee et al. (2005), it was realized that data contained in the GIS cyberinfrastructure could be leveraged to describe urban land use at the sub-parcel level (Chapter 6). As a first step towards that goal, Chapter 4 discusses a framework used by The Low Impact Development Center to gather and organize site data to systematically evaluate if candidate practices meet prespecified watershed goals.

CHAPTER 4
SITE SIMULATION AND BEST MANAGEMENT PRACTICE SELECTION METHODOLOGY IN THE LAKE ALICE WATERSHED

Introduction

This chapter begins with a summary of a detailed step-by-step BMP selection framework presented by The Low Impact Development Center (2004). The 5-step methodology focuses on defining and meeting hydrologic, ecologic, and community/economic goals. Beginning in this and continuing in the next two chapters, the framework is applied to each of three case studies in the Lake Alice Watershed to test two hypotheses:

1. Watershed runoff can be simulated quickly and easily, provided that the site is well characterized and the data are organized in a minable cyberinfrastructure.
2. It is possible to select BMPs that increase onsite stormwater control by mining site data for critical flowpaths and using simulation tools to augment strategic functional land units within the watershed.

The three case studies will progress from a larger watershed (1,400 acres) in this chapter, to a medium scale (300 acres) watershed in Chapter 5, to a fine scale (7 acres) watershed analysis and simulation study in Chapter 6. This will show the challenges in simulating the watersheds at each scale (visually summarized in Figure 4-1). The following section presents a brief outline of the planning and evaluation framework identified by the LID Center.

Low Impact Development Center BMP Planning and Evaluation Process

The Low Impact Development Center (2004) developed a prototype BMP planning and evaluation process that involves five steps as shown in Figure 4-1. This framework provides a good guide to selecting the appropriate BMPs.

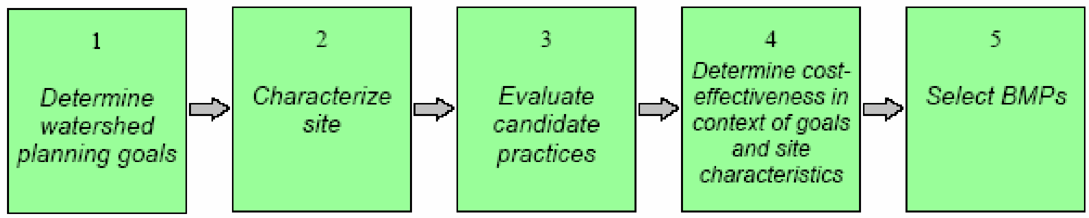

Figure 4-1: 5-step Prototype LID Planning Process. (Low Impact Development Center, 2004)

Goals

Watershed planning goals help influence the type of BMPs chosen. The three main categories of planning goals stated in the LID document are: (a) hydrologic, (b) ecologic, and (c) community and economic development. The prototype provides examples of each, as reproduced below. For more detailed information, please refer to LID Center (2004).

- Hydrologic:
  - Runoff volume
  - Flood control
- Ecologic:
  - Water quality
  - Stream health
  - Antidegradation, i.e. “fishable/swimmable”
- Community and economic development:
  - Green infrastructure
  - Job creation
  - Historic preservation

Site Characteristics

Site characteristics can often enhance the attractiveness of a given LID practice in meeting a watershed planning goal while decreasing the attractiveness of others. Site characteristics can be classified under the following taxonomy: (a) project type (redevelopment or retrofit), (b) land cover, (c) soils, and (d) hotspots. The prototype provides examples of each. Some of the examples provided in the original document have been reproduced below.

- Project type
    - Redevelopment (high flexibility)
    - Retrofit (site design largely fixed)
- Land Cover
    - Land use (high density commercial, medium density residential, etc.)
    - Type of activity (active recreation, high traffic, etc.)
    - Pervious/impervious area distribution
    - Site topography
- Soils
    - Compacted soils
    - Infiltration capacity (soil type and drainage)
- Hotspots
    - Accumulation of debris
    - Erosion, incision

Evaluate Candidate Practices

In step three, LID practices are checked first for functionality and second for compatibility with the desired goals and site characteristics. For this thesis, the method employed to determine the performance of a BMP is to simulate its performance using a stormwater management model (SWMM). While many methods are available for simulating BMPs such as frequency models (Behera 2006) and design event models (Huber 2005), the new version of SWMM provides an easy-to-use interface and is more powerful at simulating BMPs like irrigation practices that rely on depression storage.

Determine Cost Effectiveness

As stated in step four of the prototype BMP selection process, "One of the key lessons of using decentralized controls is the flexibility and the ability of several different types of BMPs to have similar stormwater management capabilities" (LID Center 2004). For this thesis, the method employed to determine a cost-effective solution is to simulate BMPs in the EPA-Storm Water Management Model (SWMM) based on first principles such as storage and infiltration parameters. By placing the BMPs into a virtual landscape, BMP performance can also be evaluated based on spatial location in the runoff network.

Case Study 1: Larger Scale Lake Alice Watershed

Introduction

The goals section will describe stormwater goals for the Lake Alice Watershed as stated in the 2005-2015 Campus Master Plan. The site characterization section aggregates a handful of data sources, including the 2005-2015 Campus Master Plan and previous Master Plans, and other publications. The third section then outlines previous stormwater models applied to the watershed and discusses why it is difficult to generate a reasonable BMP performance model at this scale.

Goals

The University of Florida is required to make a Master Plan "in accordance with a master stormwater permit issued by the St. Johns River Water Management District (SJRWMD)" (University of Florida 2006b). The Master Plan includes, but is not limited to, stormwater control goals in the Lake Alice Watershed. The current permit (valid until 2010) allows the University to increase impervious surfaces by approximately 175 acres. Goals have been established in the new Master Plan which call for the implementation of hard and soft BMPs on campus. The legal authority and criteria addressing stormwater requirements in the Florida Administrative Code still apply (University of Florida 2006b). Hence, the University must make sure its goals are in line with these regulations.

The only stormwater goal listed in the Utilities element of the Master Plan is:

> To Design, Construct and Maintain a Safe, Sustainable, Economical and Environmentally Sound Stormwater Management System that Reduces the Potential of Flooding, Protects Natural Drainage Features, and Preserves and Enhances Desirable Water Quality Conditions. (University of Florida 2006b, p 9-1)

This suggests that the university is focused on at least two of the three watershed goals in the LID Center's prototype framework, namely hydrologic and ecologic (community goals are addressed in policy contained within Appendix A). This goal gains a regulatory framework in Objective 1.1, as stated in the Master Plan:

> Objective 1.1: Meet or exceed all applicable federal and state regulatory requirements for stormwater management and water quality protection... (University of Florida 2006b, p 9-1)

Policies 1.1.1 and 1.1.2 enumerate the various regulatory requirements mentioned in Objective 1.1.

> Policy 1.1.1: The University shall continue to comply with the regulations set forth in the Clean Water Act, Title 40 CFR as applicable. (University of Florida, 2006b, p 9-1)
>
> Policy 1.1.2: The University shall maintain water quality standards for stormwater quantity and quality that are consistent with the St. Johns River Water Management District (SJRWMD), Suwannee River Water Management District and Department of Environmental Protection standards for stormwater management systems as outlined in Section 120.373 and Chapter 403, Florida Statutes and Chapters 62-3, 62-25, 62-40, 40B-1, 40B-2, 40B-4, 40C-1, 40C-4, 40C-8 and 40C-40 through 40C-44, of the Florida Administrative Code (University of Florida 2006b, p 9-1).

Appendix A presents information pertinent to the LAW from the statutes and codes mentioned above. In partial fulfillment of the Clean Water Act, the University has begun Phase II NPDES requirements. Florida Statute 373 establishes that a stormwater treatment pond like Lake Alice is not a water of the state and state surface water regulations do not apply (Florida Senate 2005a). The water management district can still deem Lake Alice a hazard to public health, fish, or wildlife, however. FAC 62-25 has general design and performance standards but also states that "Stormwater discharges to groundwaters shall be regulated under the provisions of Chapters 62-520 and 62-522, F.A.C., and other applicable rules of the Department" (Florida Department of State 2005). Chapter 62-520 establishes that Lake Alice, which drains into a class GII groundwater, must treat to primary but not secondary drinking water standards. This involves, among other things, discharging a TDS < 10,000 mg/L and a maximum N of 10 mg/L. Chapter 62-522 established that quarterly reports must be given to show that maximum discharge criteria are not superseded. FAC 62-40 promotes the use of nonstructural (or soft) solutions to water resource problems. It also suggests that Lake Alice and the Lake Alice network might have to remove 95% of influent pollutants that would violate the state standards. It again stresses water quality monitoring. (Florida Department of State 2005)

As shown above, water regulations are a major driver in the Master Plan. The University specifically addresses the well monitoring requirement in Policy 1.1.5: "…conditions include reporting water levels in monitoring wells quarterly and submission of groundwater and surface water monitoring tests to the water management" (University of Florida 2006b). However, the University goes a step further in Policy 1.3.7: "The University shall continue to monitor Lake Alice and other surface water bodies for compliance with existing standards for water quality in order to meet Class III water quality standards and report findings to the Lakes, Vegetation and Landscape Committee annually" (University of Florida 2006b).

The University, while trying to maintain a compact core of buildings, is facing the problem of deeply incising creeks and downstream sedimentation. Objective 2.1 under the aforementioned goal addresses this issue in part.

> Objective 2.1: Maintain existing stormwater management infrastructure and provide sufficient infrastructure capacity to meet the future needs of the University. (University of Florida 2006b, p 9-2)

It does this in Policy 1.2.7 by encouraging the implementation of "stormwater facility projects to reduce the quantity and improve the quality of stormwater discharge in locations identified as feasible” (University of Florida 2006b). The University is also establishing a policy that may allow one to begin accounting for who or where large contributing sources are. Policy 1.2.8: “The University shall work with the City of Gainesville and Florida Department of Transportation to ensure that stormwater issues that can include: water quality, trash, erosion, and flooding are controlled at points where off-campus stormwater is accepted into the University’s stormwater system and water bodies or when the University’s stormwater system adversely impacts the stormwater systems and water bodies under control of the City of Gainesville or the Florida Department of Transportation” (University of Florida 2006b).

The University focuses heavily on mitigating ecological impact, as shown in Objective 1.3 and Policy 1.3.2 as well as Objective 1.4 and Policy 1.4.1. The University is considering installation of decentralized stormwater control measures throughout the campus as described below.

> Objective 1.3: Protect the natural functions of hydrological areas, maintain water quality and control sedimentation.
>
> Policy 1.3.2: The University shall continue to mitigate University generated stormwater and to minimize stormwater borne pollutants in new and existing facilities through implementation of Best Management Practices (BMPs) that includes, but is not limited to:
>
> • Incorporating stormwater management retention and detention features into the design of parks, trails, commons and open spaces, where such features do not detract from the recreational or aesthetic value of a site.
>
> • Using slow release fertilizers and/or carefully managed fertilizer applications timed to ensure maximum root uptake and minimal surface water runoff or leaching to groundwater. Using pervious materials to minimize impervious surface area
>
> Objective 1.4: Implement sustainable stormwater practices in all campus site development incorporating Low Impact Development techniques where physically, economically, and practically possible.

> Policy 1.4.1: The University shall strive to incorporate stormwater improvements into all new building sites and into modification of existing sites. These improvements include, but are not limited to, rain gardens, roof-top gardens, porous soil amendments, hardscape storage, pervious pavement and other innovative stormwater techniques.

> Policy 1.4.2**:** The University shall identify opportunities for retrofitting existing open space (i.e. land use classifications of Buffer, Urban Park and Conservation) to incorporate rain gardens and other multi-use detention practices that maintain the primary use, but with the added benefit of slowing water discharges into the stormwater system (University of Florida 2006b, pp 9-3 – 9-4).

Lastly, the University is indeed making a case for the implementation of a research or teaching network associated with stormwater control measures.

> Objective 1.5: Inform faculty, staff, students and visitors on stormwater issues through outreach and demonstration projects.

> Policy 1.5.1: The University shall strive where practicable to include interpretive information and educational opportunities that go along with the University's efforts to integrate innovative structural stormwater design and BMP concepts.

> Policy 1.5.2: The University shall maintain financial and personnel support of stormwater related education and awareness programs for the campus community.

> Policy 1.5.3: The University shall pursue grants and other opportunities to fund implementation, outreach and study of stormwater best management practices on campus (University of Florida, 2006b, p 9-4 to 9-5).

There are ancillary goals not explicitly written into Master Plan code such as the following, taken from Master Plan Data and Analysis Reports (University of Florida 2006a). For example, the open space requirement for LEED criteria will no longer be met onsite but will be applied to the campus-wide conservation strategy. Numerous ecological protections are in place for the Lake Alice Watershed (LAW) within the Conservations Area Land Management (CALM) section of the University of Florida Campus Master Plan. Policy written for the CALM states that an average of 50 foot buffer (minimum of 35 feet) shall be protected around all wetlands/water bodies that are not within a Conservation Area before construction.

In summary, the University of Florida addresses all three goals mentioned in the BMP selection framework.

- Ecologic
    - Requiring the University to meet or exceed regulations and permit requirements when draining into the aquifer or lake, respectively
    - Encouraging the construction of structural and implementation of non-structural BMPs (slow release fertilizer) to reduce stream erosion and increase water quality
    - Creating a wetland setback
- Community and economic development: (see Appendix A)
    - Encouraging green infrastructure i.e. pervious paving & green roof
    - Encouraging LEED certification
    - Ensuring future capacity for stormwater control
    - Promoting education and research into stormwater control
- Hydrologic
    - Meeting water volume regulations.
    - Meeting flood control regulations

Characterize Site

The next step in the BMP selection process is to characterize the site. Most projects implemented in the LAW are redevelopment or greenfield development, thus allowing high flexibility. Before discussing land cover, soils, or hotspots, a geographic description of the watershed is presented below.

Geography

Lake Alice is a combination of open lake and marsh systems. The western end of the lake, consisting of open water (Figure 4-2), covers about 32 acres and averages less than six feet in depth, reaching a maximum depth of 10 ft. The eastern end of the lake is approximately 55 acres and is a marshy area characterized by shallow water-hyacinth prairie with an average depth of 2 ft (Korhnak 1996). Bathymetric maps have been prepared for Lake Alice by Mitsch (1975) and LAKEWATCH (2001), shown in Figures 4-2 and 4-3, respectively. A comparison of the two maps underscores the loss in depth over the years due to sedimentation (Figure 4-4).

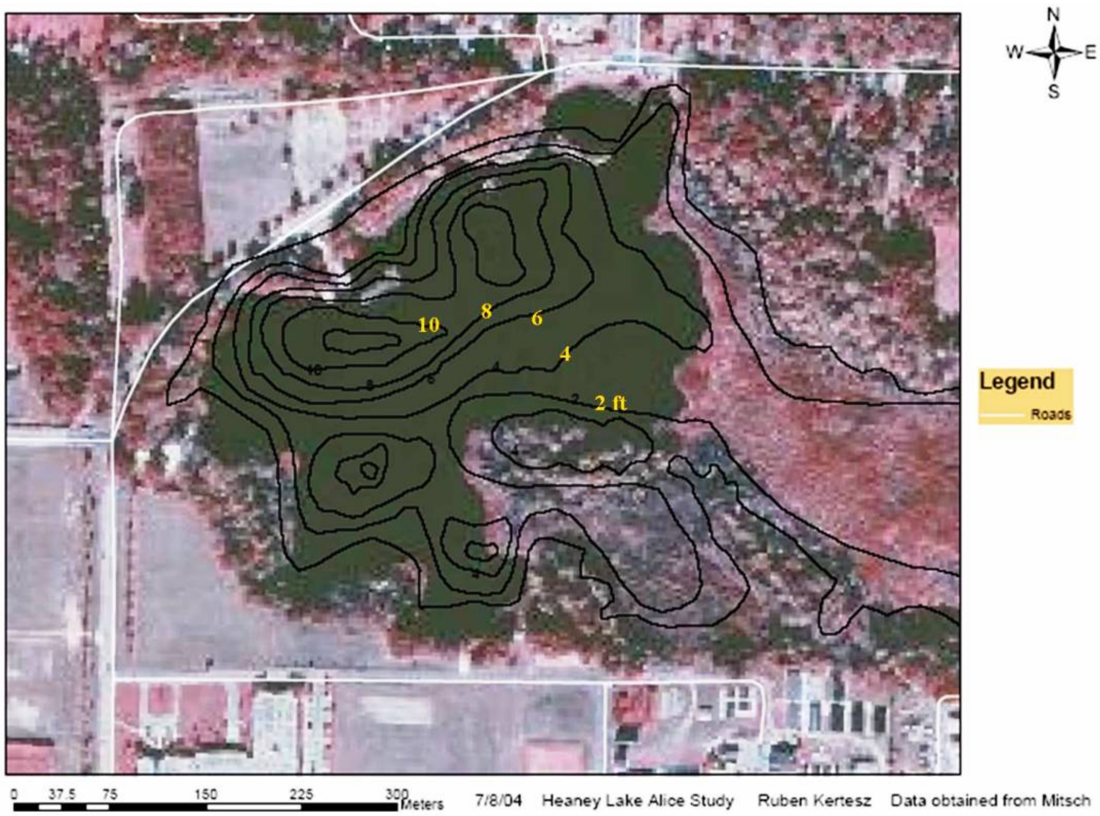

Figure 4-2: Bathymetry of Lake Alice Open Water in 1975

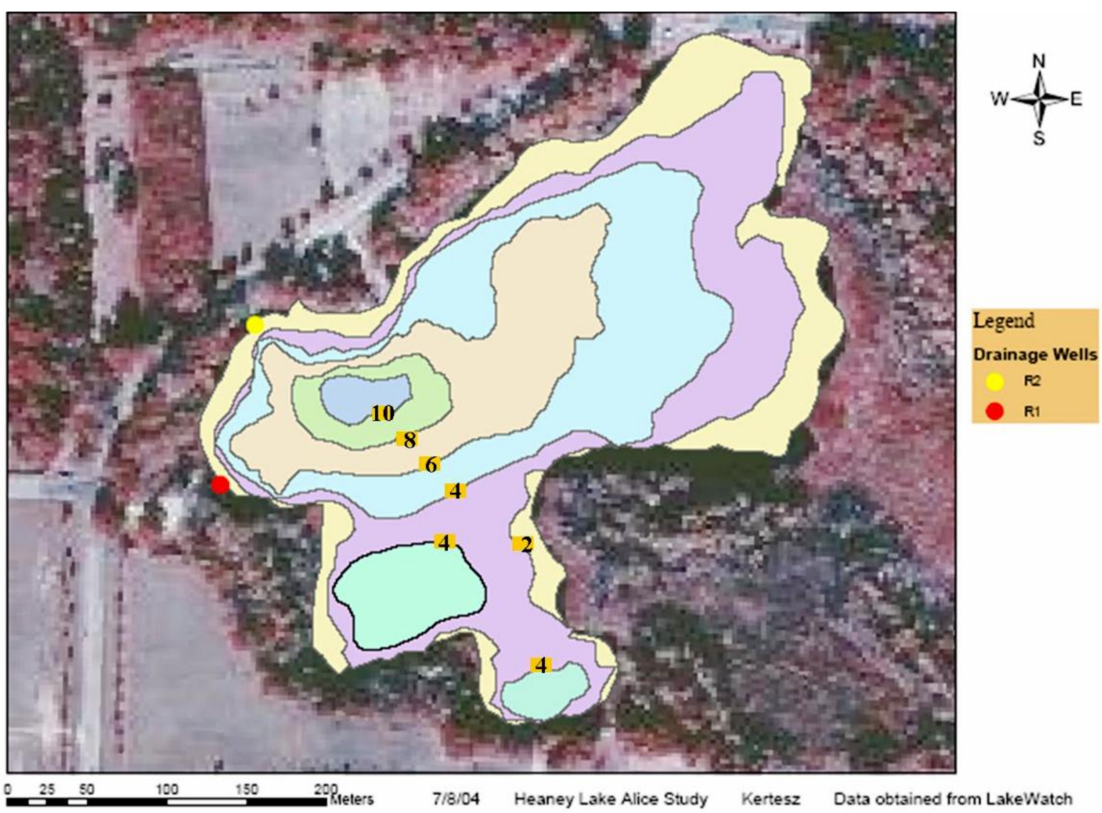

Figure 4-3: Bathymetry of Lake Alice Open Water in 2001

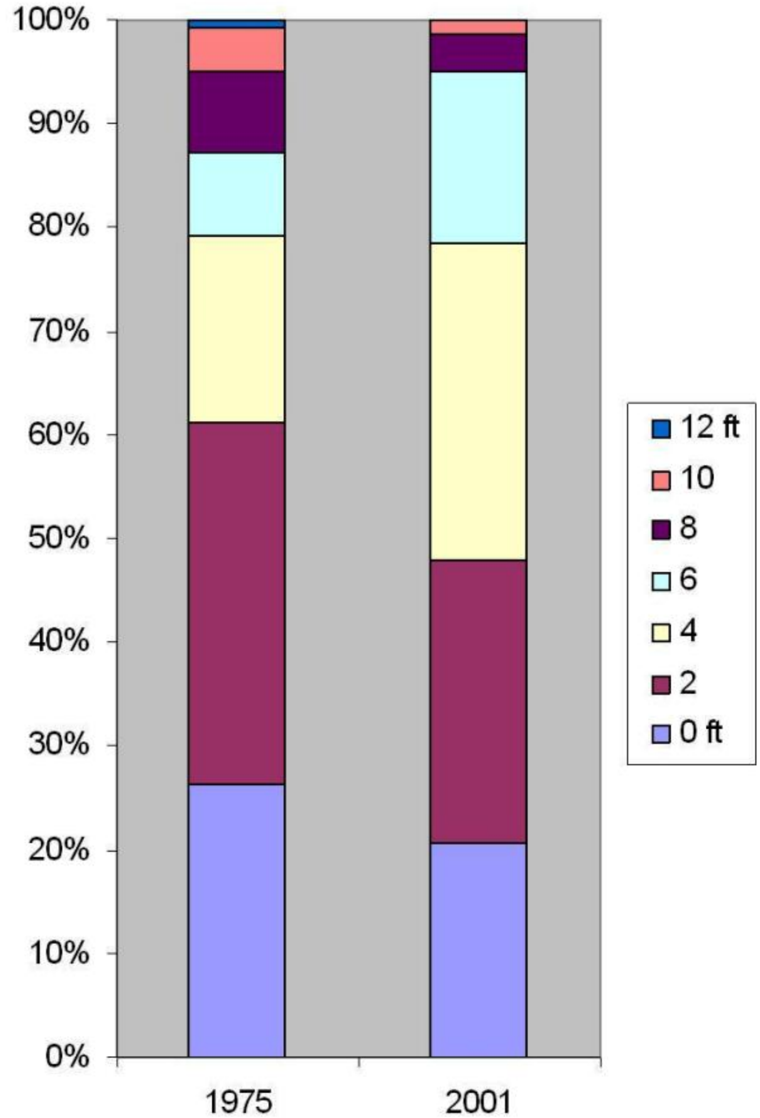

Figure 4-4: Comparison of Bathymetry of Lake Alice Open Water in 1975 and 2001 (in % total area)

Lake Alice is perched on a clay layer underlain by a limestone formation characterized with multiple fractures and caverns. The lake stage is at an elevation of approximately 68.5 ft corresponding to a lake volume of 270 acre-feet, or 88 million gallons (Causseaux 2000). Lake Alice receives inflow from many sources. Two creeks to the north, two creeks to the south and a creek to the east convey stormwater runoff and drainage, cooling water, and groundwater to the lake. Lake Alice receives direct stormwater inputs from five outlet headwalls conveying runoff from Museum Road. The lake receives stormwater from Corry Village. Overland runoff flows into the lake from bordering drainage sub-basins. Direct precipitation and groundwater inflow are also inflow sources. Water exits Lake Alice through two groundwater-recharge wells (R1 and R2); R1 only receives flow during heavy rain events (Korhnak 1996). The lake also loses water directly to evapotranspiration and groundwater outflow.

Land cover

The LAW consists of approximately 1,058 acres encompassing a large portion of campus and off-campus sites to the north and east (Causseaux 2000; University of Florida 2005) – pictured in pink in Figure 4-5. Lake Alice is atypical in that it serves almost every type of land use.

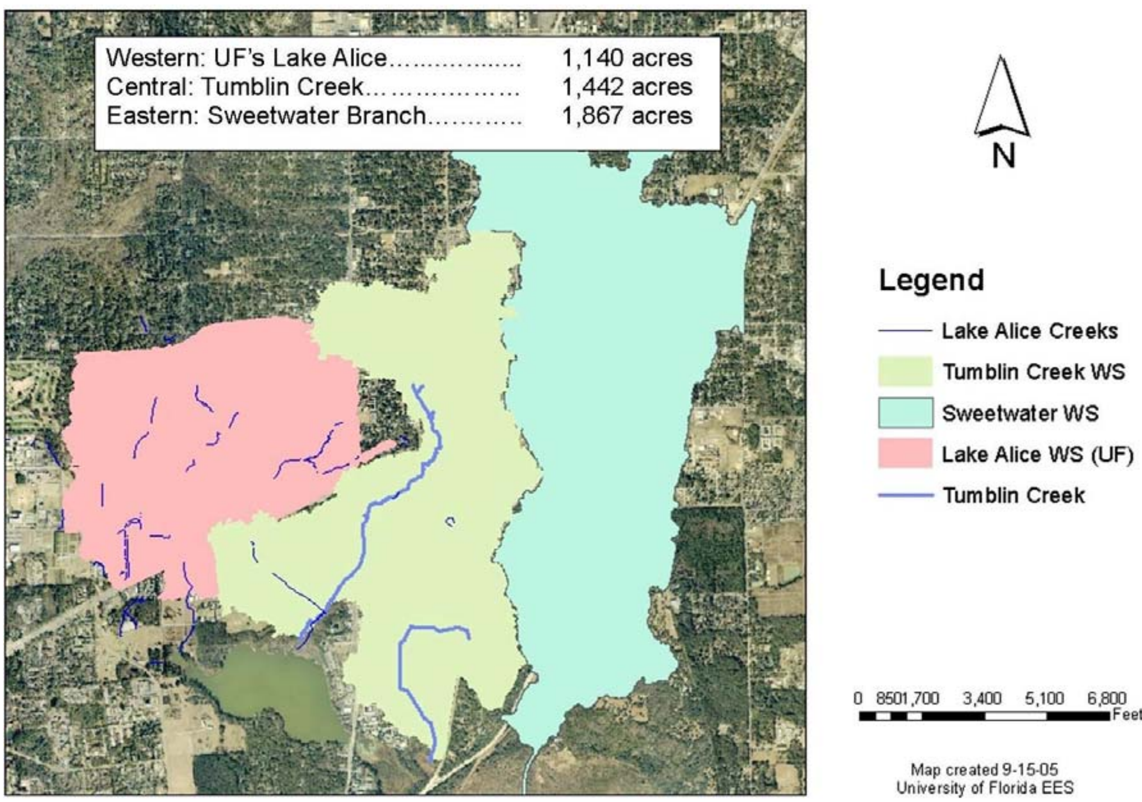

Figure 4-5: Lake Alice, Tumblin Creek, and Sweetwater Branch Watersheds

Neighbored to the east by the Tumblin Creek Watershed, there are numerous urban land uses draining to the wet detention system (WDS): runoff from roads, parking lots, rooftops and sidewalks, typical of an urban area. Baseball and football fields as well as agricultural fields and student gardens drain to the lake, which may release nutrients. Industrial facilities on campus drain towards the lake such as the steam/cooling cogeneration plant, the wastewater treatment plant, a research hospital, vehicle depots, etc. Residential areas throughout campus range from two story condominiums to multistory dormitories. Numerous urban forests on campus and a series of ponds and wetlands are connected by streams throughout the eastern campus. A visual look at the land use activity at the University verifies that numerous land uses are draining to the lake and it shows the high building density, high occupancy part of campus to the North East (Figures 4.6, 4.7).

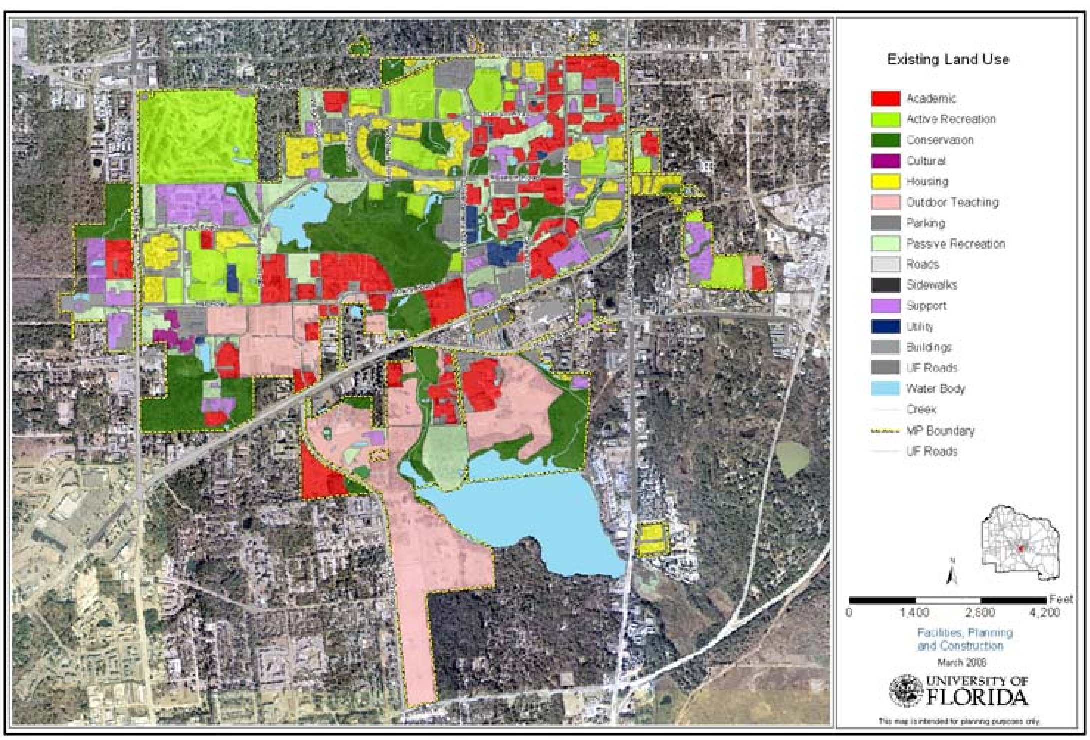

Figure 4-6: Land Use In and Around the LAW (University of Florida 2006a)

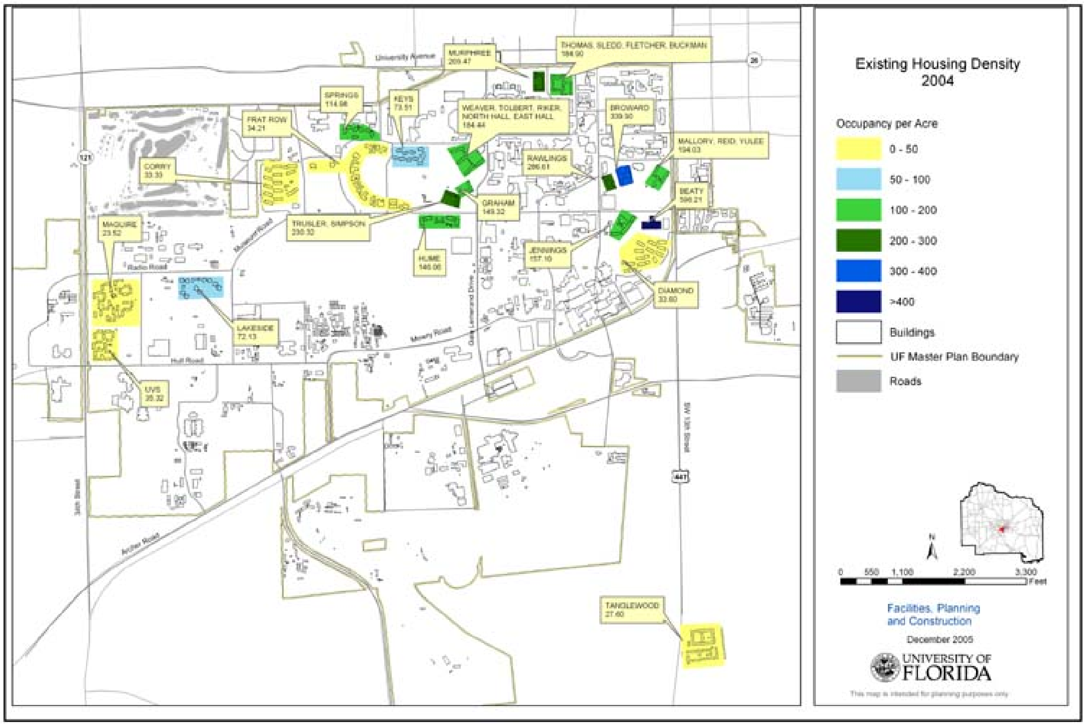

Figure 4-7: Density in the LAW (University of Florida 2006a)

The topography suggests an average grade of about 2% throughout the watershed (CH2MHill 1986), with the maximum elevation in the NE corner of the LAW at 171 ft MSL. Impervious areas for each drainage sub-basins are tabulated in the 2001 and 2006 Stormwater Management Master Plan (SMMP) (Causseaux 2000, University of Florida 2006b) and in the Campus-wide Impervious Table (University of Florida 2006a). Imperviousness within the watershed ranges from 0 to 81% for each subcatchment, with an average of about 41% for the entire watershed. The LAW shows a linear rainfall-runoff response relationship shown in Figure 4-8. Korhnak’s (1996) measurements of rainfall-runoff relationships for the LAW indicate that virtually all of the runoff is from the directly connected impervious areas because the rainfall-runoff relationship is linear and the initial abstraction is negligible (Korhnak 1996).A total of 29 storms were measured with rainfalls from 0.2 to over 8 cm. About 43.3% of the precipitation runs off.

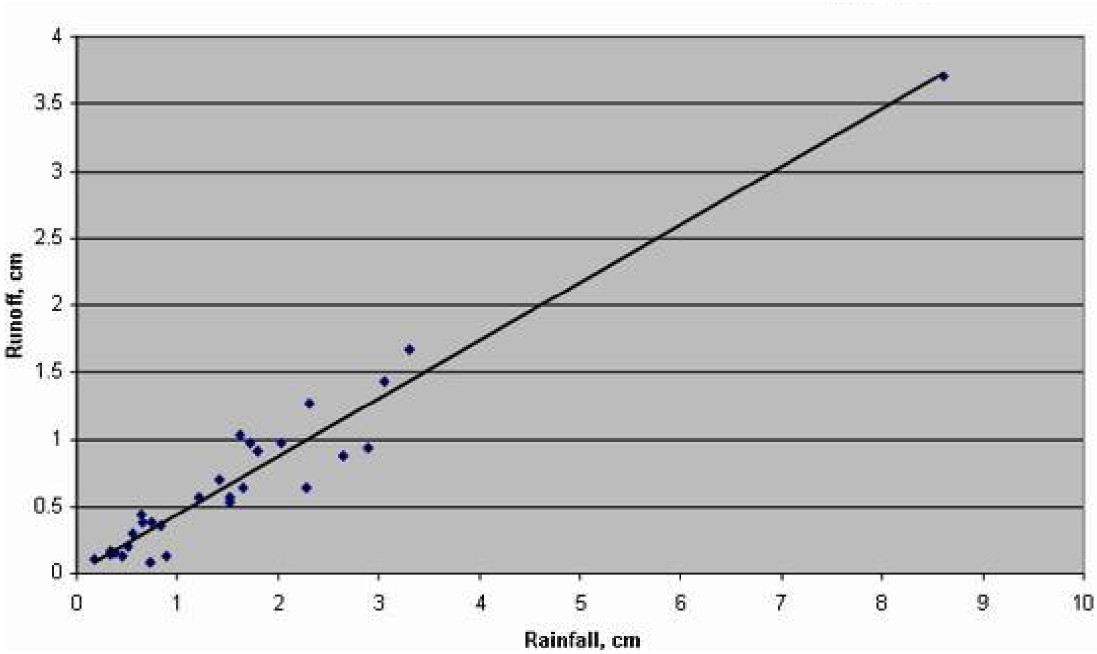

Figure 4-8: Rainfall-Runoff Relationship for HC01 Presented in Korhnak (1996)

The lake receded at a rate of 0.4 to 0.5 feet/day following Hurricane Frances, as measured three times per day or more frequently, correlating to a drawdown flow rate of about 25 cfs, with large aquatic plants against the well grates.

Soils

Generally, soils within the Lake Alice Watershed are of two types. The upland areas are deep, well-drained sands with low surface runoff potential. Available soils data suggests varying degrees of drainage in the western part of the watershed shown in Figure 4-9 (Florida Geographic Data Library 2003). Drainage values for areas in the north and west vary from moderately well to excellent whereas areas bordering the eastern and southern shores of the lake have poor drainage values according to NRCS drainage indices. Areas in the extreme south, near the golf course, north of Shands Hospital, and the forest west of the Reitz Union exhibit poor drainage. Areas around the Welcome Center and near the Shands Cancer Center exhibit moderately well to well drained soils. Soil-type classifications geospatially correlate well with soil drainage as shown in Figure 4-10 with respect to Figure 4-9.

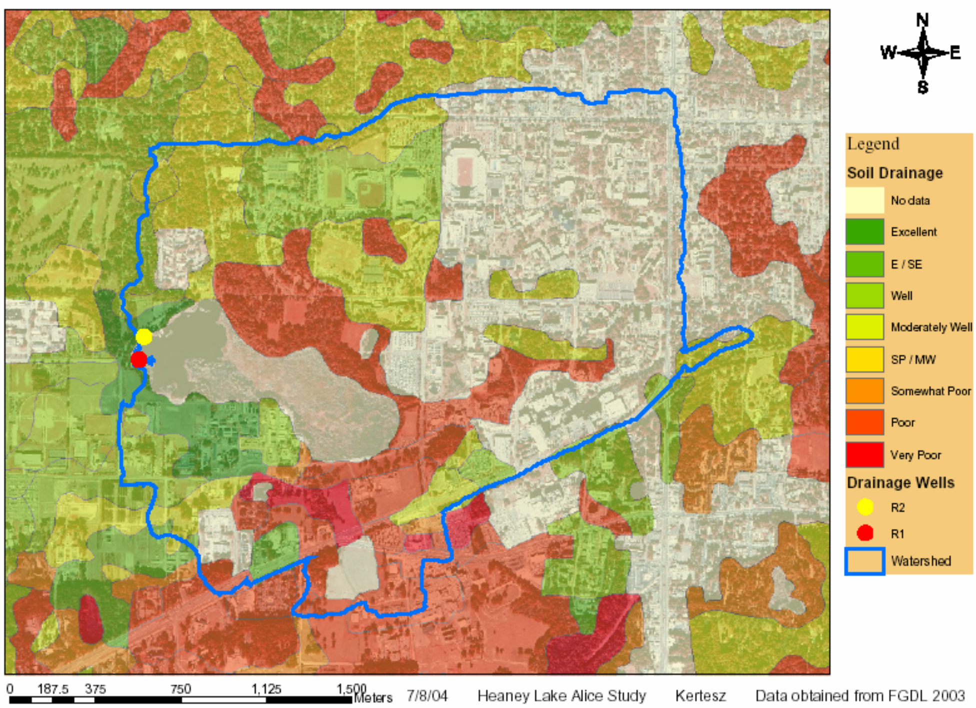

Figure 4-9: Soil Drainage Classification (Florida Geographic Data Library 2003)

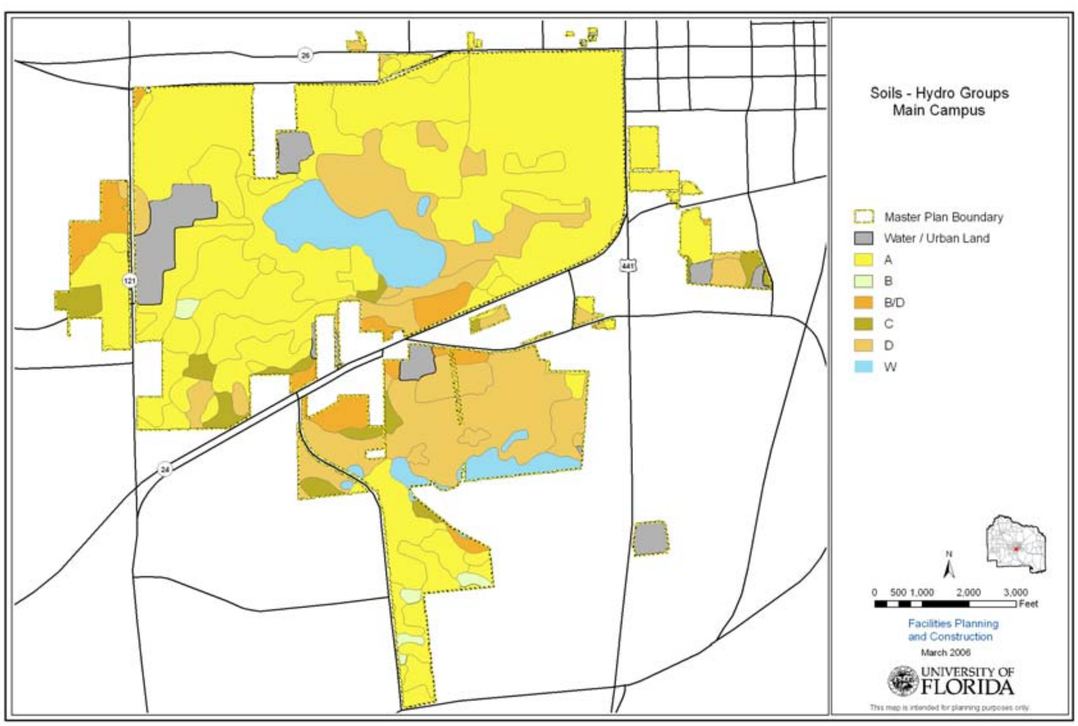

Figure 4-10: Soil Type Classification (University of Florida 2006a)

Hotspots

Deep stream incisions exist in the East Creek Branch leading towards Lake Alice, suggesting very high flow velocities (Figure 4-11). Similar incisions occur in the adjacent Tumblin Creek Watershed as described by Jones Edmunds and Associates (2006, p 1-4).

> Physical evidence of stream bed and bank erosion is apparent….In some cases, piping originally installed below the streambed is now two to three feet above the stream bed.

It is expensive to remediate these incisions. Jones Edmunds provides a rough planning estimate for one sheet pile weir to be between $10,000 and $16,000. A number of these controls may have to be installed in addition to other bank reinforcement techniques through 12 reaches of Tumblin Creek.

Figure 4-11: Stream Incision in East Creek, University of Florida

Evaluate Candidate Processes

Geographic information system shapefiles delineating functional land use areas (including directly and indirectly connected areas) are only available for part of the Lake Alice Watershed. Thus, it was decided that a smaller section of the watershed (East Creek Watershed) would be studied in order to allow for simulation of subbasin flow between the 6 subbasins (of 40 total) shown in Figure 4-12.

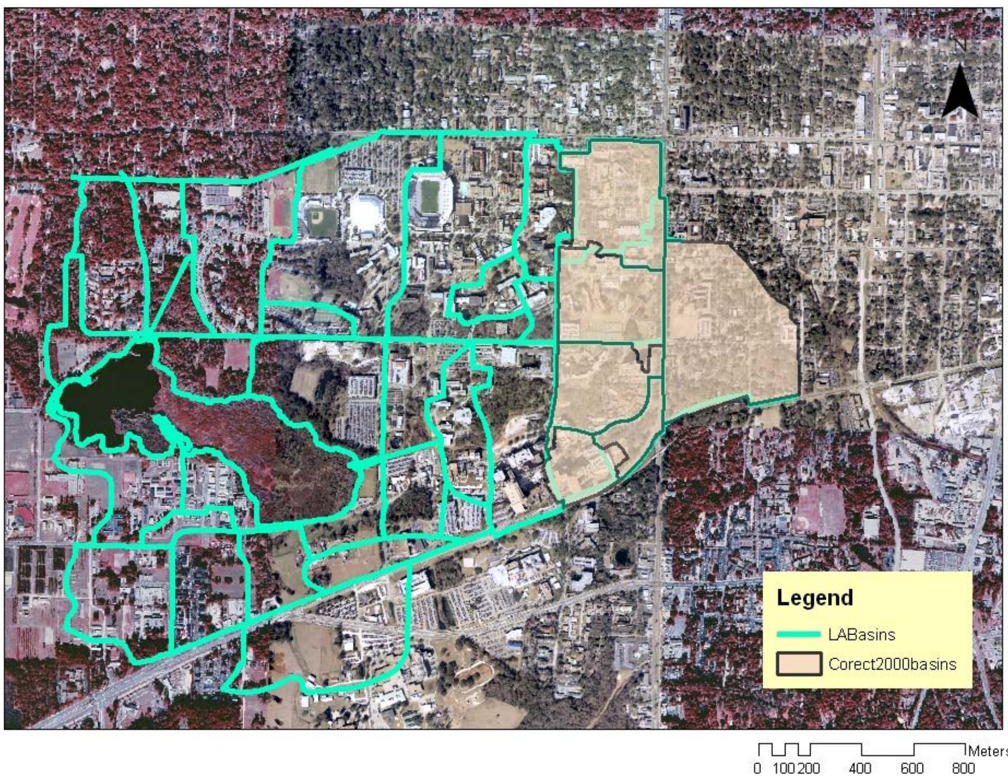

Figure 4-12: East Creek Watershed Highlighted within Lake Alice Watershed.

Conclusions

The Low Impact Development Center's five step framework provides a good means of selecting onsite stormwater controls that meet watershed goals. The University of Florida has clear goals towards hydrologic control, sound ecology, and community involvement in 2005 – 2015 master plan. Site characterization shows that there is a significant amount of relief in the watershed and Lake Alice itself may be receiving sedimentation from contributing creeks. Soils data suggest that onsite infiltration controls should function well in the eastern region of campus, given the Type A soils, however soil drainage maps do not present enough data. In order to properly evaluate any candidate processes, more data are necessary and a more focused scale is desirable so as to simulate more precisely the flow paths throughout the studied watershed.

CHAPTER 5
SITE SIMULATION AND BEST MANAGEMENT PRACTICE SELECTION METHODOLOGY IN THE EAST CREEK WATERSHED

Introduction

This case study begins with a brief discussion of watershed planning goals specific to the East Creek watershed studied at a "medium scale," followed by a very brief site characterization section. The information is presented in the following manner. The section labeled "Evaluate Candidate Practices" is composed of four subsections: Capabilities, Input Attributes, ECW Drainage Network, and Runoff Analysis. The Input Attributes subsection simultaneously describes ECW site characteristics in context of SWMM modeling capabilities, providing a basic tutorial on the modeling tool while also providing information about the ECW. The Drainage Network subsection shows some of the generalizations made when producing the model. The Runoff Analysis subsection presents and discusses results from running the SWMM model of the ECW by comparing it to measured data. The comparison elucidates the advantages of using high quality surface data and the need to use high quality rainfall data to generate sophisticated real-time models.

Goals

This study was begun after the 2004 hurricanes reemphasized the need for proper flood control, drainage, and water quality control. While stormwater management systems (SMS) have historically been designed for flood control and quick drainage (Prymas 2004, Shirahama 1992), the velocity with which stormwater travels through the

East Creek network suggests that BMPs may need to be put in place. Goals mentioned previously for the LAW apply in the ECW as well.

Characterize Site

A catchment within the larger LAW, the ECW drains the eastern portion of the University of Florida (UF) and nearby neighborhoods. The 300 acre area located in Gainesville, Fl consists of five high-density academic land use subcatchments west of 13th St and a sixth subcatchment east of 13th that is characterized by medium to high density single family and mixed use conditions.

The ECW is the portion of the Lake Alice watershed east of Newell Drive as shown in Figure 5-1. The area, located on the eastern side of the UF campus, stretches south from University Avenue to Archer Road and east from Newell to 13th Avenue, with one of the six subcatchments located east of 13th. The area is largely urban, consisting of large academic buildings, roadways, numerous walkways, and isolated forests.

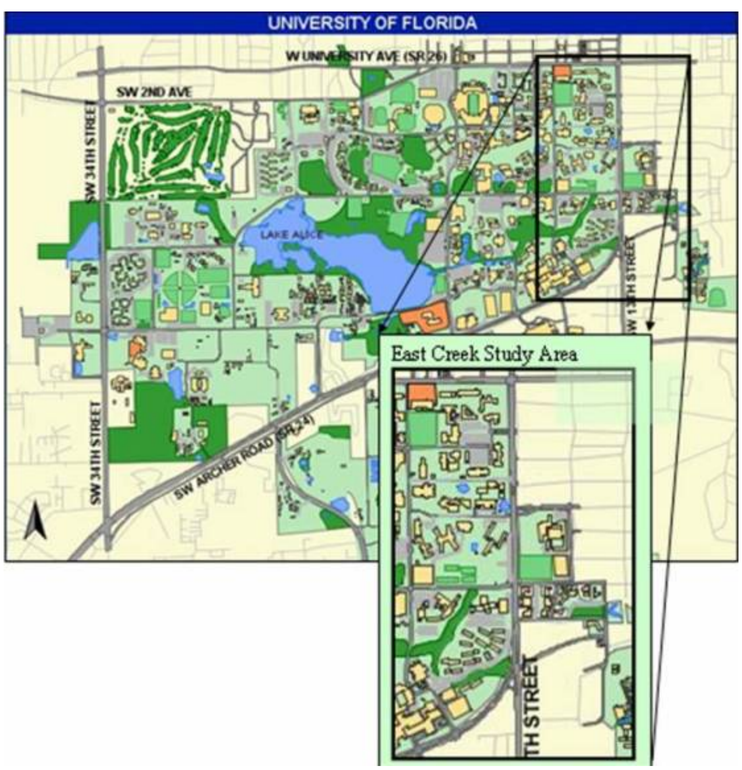

Figure 5-1: East Creek Watershed Study Area (http://campusmap.ufl.edu/)

The boundaries of the subcatchments used in this report are as follows (Figure 5-2):

- Lake Alice 1 (LA-1) has boundaries along SW 13th Street, SW 4th Avenue, SW 10th Street, and SW 9th Avenue.
- LA-2 has boundaries along SW 13th Street, University Avenue, Newell Drive, and Inner Road.
- LA-3 has boundaries along SW 13th Street, Museum Road, Newell Drive, and Inner Road.
- LA-4 borders Museum Road, SW 13th Street, Newell Drive, and an old road that is now blocked to automobile traffic.
- LA-5 and 6 border that same old road as well as Archer Road, Newell Drive, and SW 13th Street.

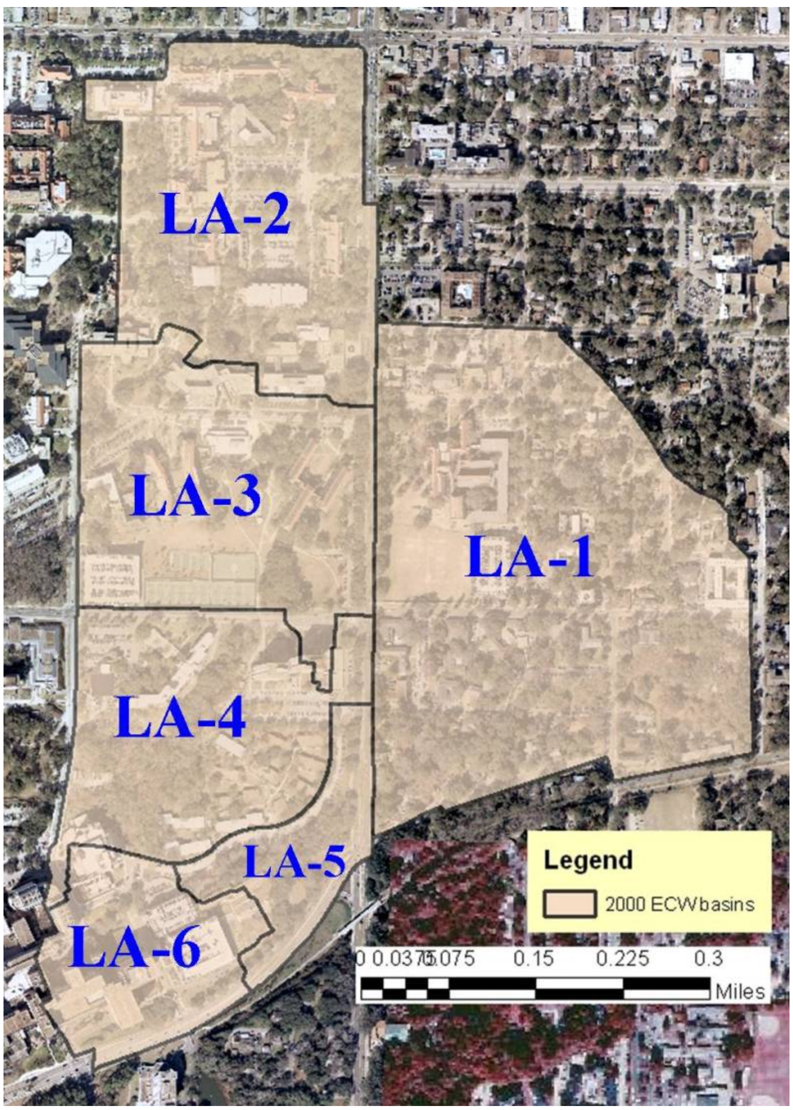

Figure 5-2: Each Creek Watershed Subcatchment Names

A topographical survey of the ECW was performed. It was found that the greater ECW encompasses natural depressions on the southeastern boundary (shown in deep red) while it is largely delineated by roads and man made infrastructure to the North, West, and South as shown in Figure 5-3.

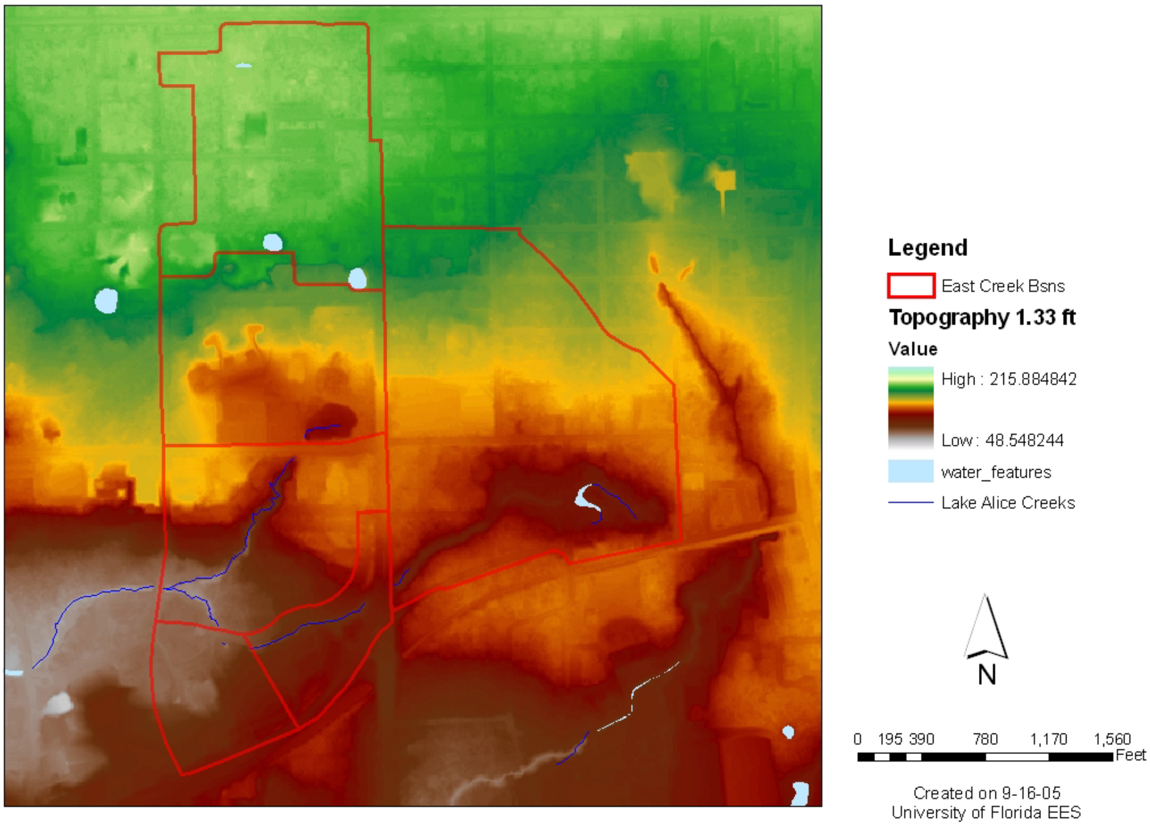

Figure 5-3: Topography of East Creek Watershed

The ECW is characterized by both its physical topography, as previously described, and by its constructed flow routing infrastructure. Data from Causseaux & Ellington (2000), and topographic studies performed herein corroborate that the East Creek subcatchments act as tributaries to East Creek . However Autocad® files leave subcatchment LA-1 “open ended” with no eastern boundaries (Figure 5-4). This east portion of LA-1 is considered a “gray area” by the City of Gainesville and the UF Physical Plant. More detailed site information will be discussed in the following section, in the context of SWMM 5 input parameter needs.

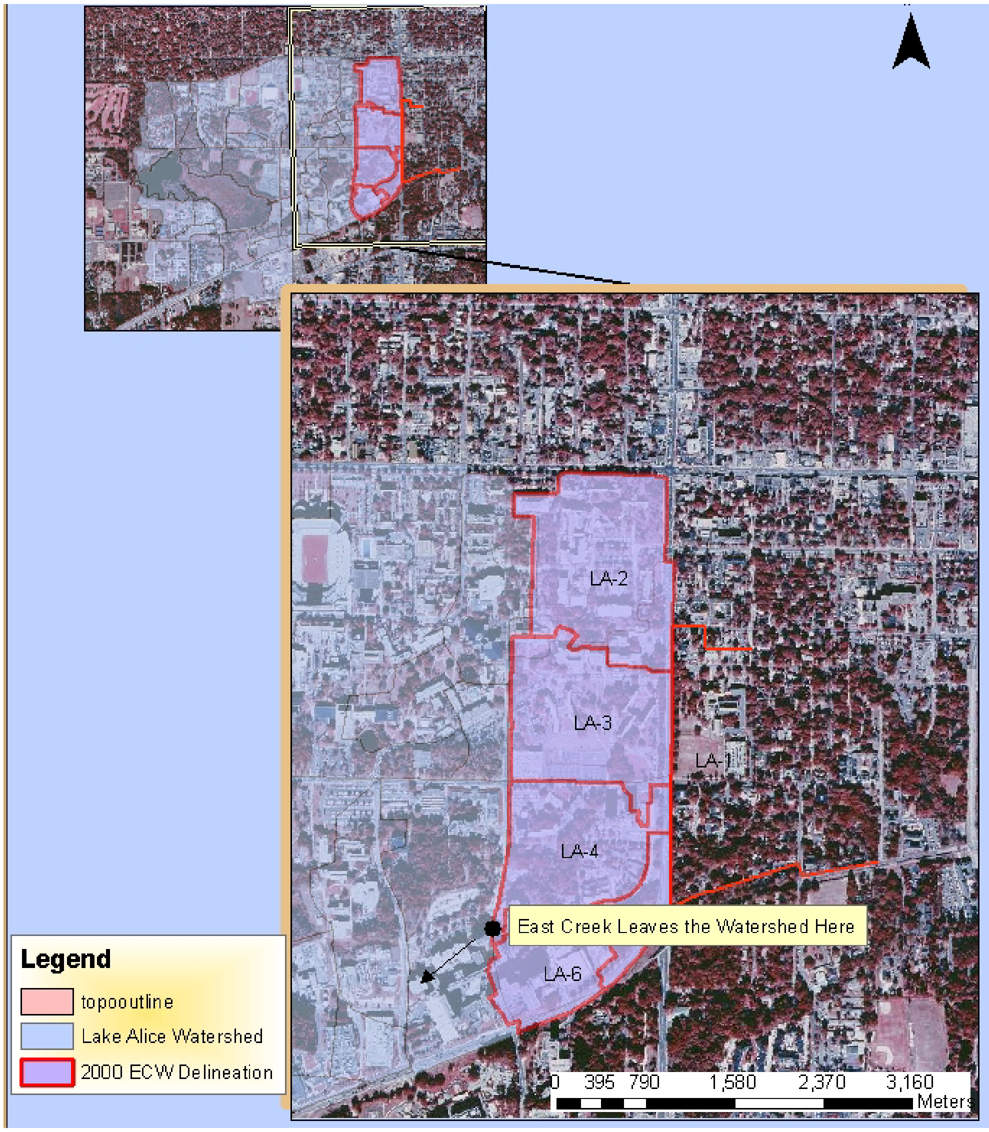

Figure 5-4: 2000 Delineation of the East Creek Branch.(Causseaux and Ellington 2000)

Evaluate Candidate Processes

As mentioned previously, this chapter is divided into two subsections: the first section demonstrates SWMM 5 input parameter needs, providing information from the ECW to set up a basic simulation. The second section compared the results of a 1990 rainfall event to measured data by Korhnak (1996). EPA SWMM 5.0 includes an intuitive graphical user interface which gives the user access to many high-end modeling capabilities down to fine levels of detail. The program requires many parameters to be entered by the user in order to more accurately characterize each subcatchment. Each of these factors is discussed in their respective subsections.

Capabilities

SWMM 5.0 (EPA 2005) is a model designed to simulate runoff quantity and quality from primarily urban areas. It estimates flow rates, flow depths, and water quality during the specified simulation period. The SWMM can be applied to various hydrologic design processes such as the design and sizing of drainage system components for flood control, and sizing detention facilities. It can also be used for flood plain mapping, designing control strategies, evaluating the impact of inflow and infiltration, or evaluating the effectiveness of BMPs (Rossman 2004). The program's numerous capabilities include time-varying rainfall, depression storage, infiltration of rainfall into unsaturated soil layers, percolation of infiltrated water into groundwater layers, and bi-directional flow between groundwater and the drainage system or nonlinear reservoir routing of overland flow. Other useful functions include unlimited system size constraints, compatibility with a wide variety of equipment used in the field, modeling of special elements such as storage/treatment units and flow dividers, applying external flows and water quality inputs from surface runoff, and modeling various flow regimes. User-defined water quality components can be included, such as dry-weather pollutant buildup over different land uses, pollutant washoff, direct contribution of rainfall deposition, reduction in washoff load due to BMPs, routing of water quality constituents through drainage systems, or reduction in constituent concentration through treatment in storage units or by natural processes in pipes and channels.

Input Attributes

The 201-acre ECW has been modeled using a total of 398 attributes or parameters, 334 of which have been estimated. The requirements for SWMM to successfully complete a simulation are the:

- declaration of one or more rain gauges and the rain data associated with them
- declaration of one or more subcatchments and their attributes
- declaration of nodes & links
- selection of infiltration and flow-routing methods in order to complete flow routing calculations (Rossman 2004).

Figure 5-5 is provided as a visual aid for the following detailed descriptions of the rain gauge, subcatchment, node, and link objects. The flow diagram, created in SWMM, color codes varying node invert values, culvert (or link) slopes, and subcatchment areas as described by the legend. The ECW is divided into six subcatchments that are linked by flow conduits and junctions according to the geometry shown in Figure 5-5. The legends provide an approximation of the values of the node, link, and subcatchment objects. The rain gauge location is also shown on the schematic.

Each of the four basic objects shown in Figure 5-5 (subcatchment, node, link, and rain gauge) have between six and thirty attributes that must be specified each time the object is created in SWMM. Figure 5-6 provides a representation of how many numerical attributes must be specified for each object in the top row, with the total number of variables specified for the above stormwater network symbolized by asterisks.

Of the three hundred and ninety-eight parameters entered in order to characterize the East Creek watershed stormwater system, the specific values entered for each object are shown in Table 5-1 and described in detail in the following subsections. In addition, general options, such as the routing method, were chosen from options available in

SWMM. The routing method selected was dynamic wave routing with routing time steps of one minute. Variables that were excluded in this simulation series were climatology (temperature, evaporation, wind speed), ground water inflow and outflow, and water quality attributes.

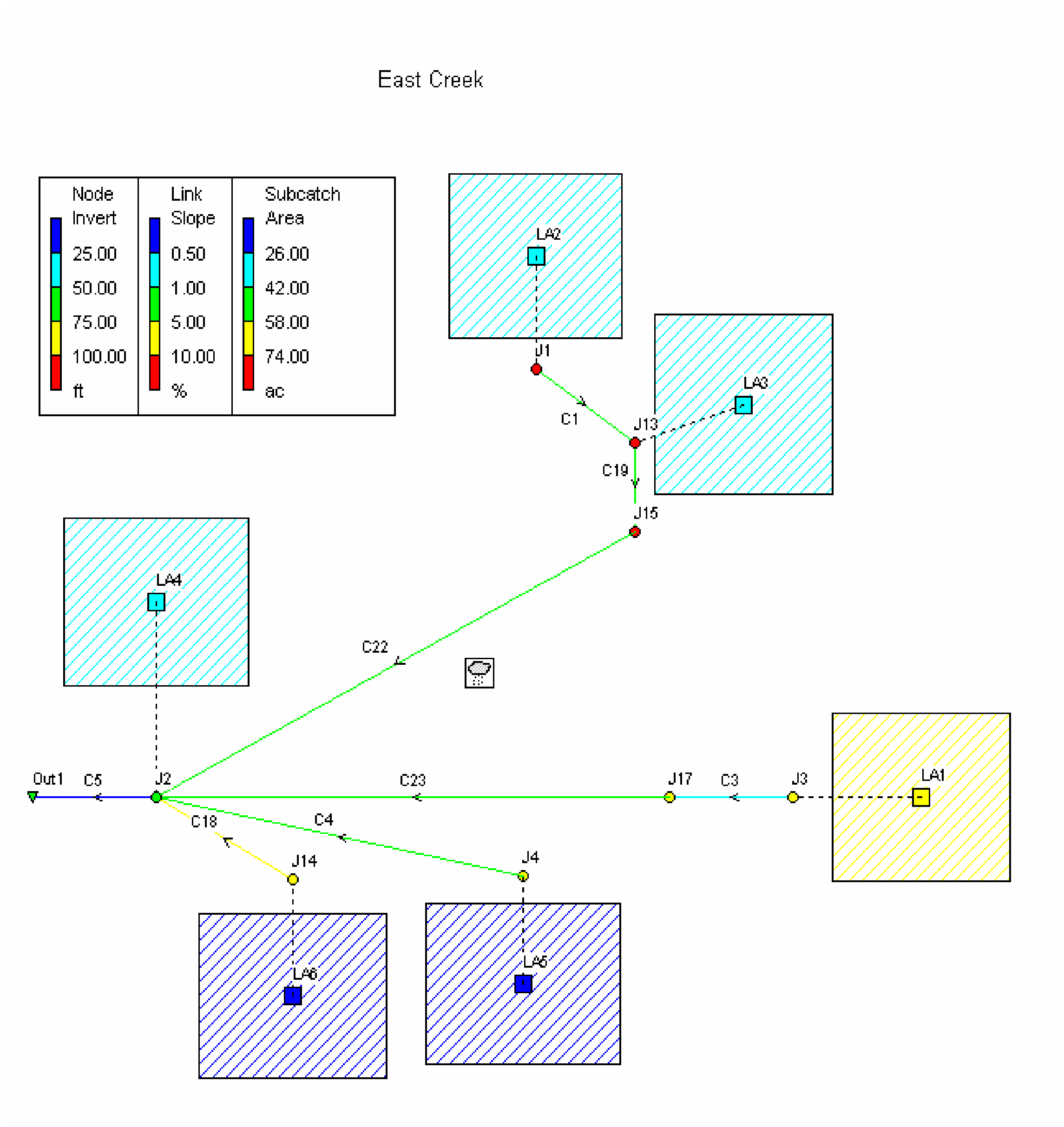

Figure 5-5: SWMM Schematic of ECW

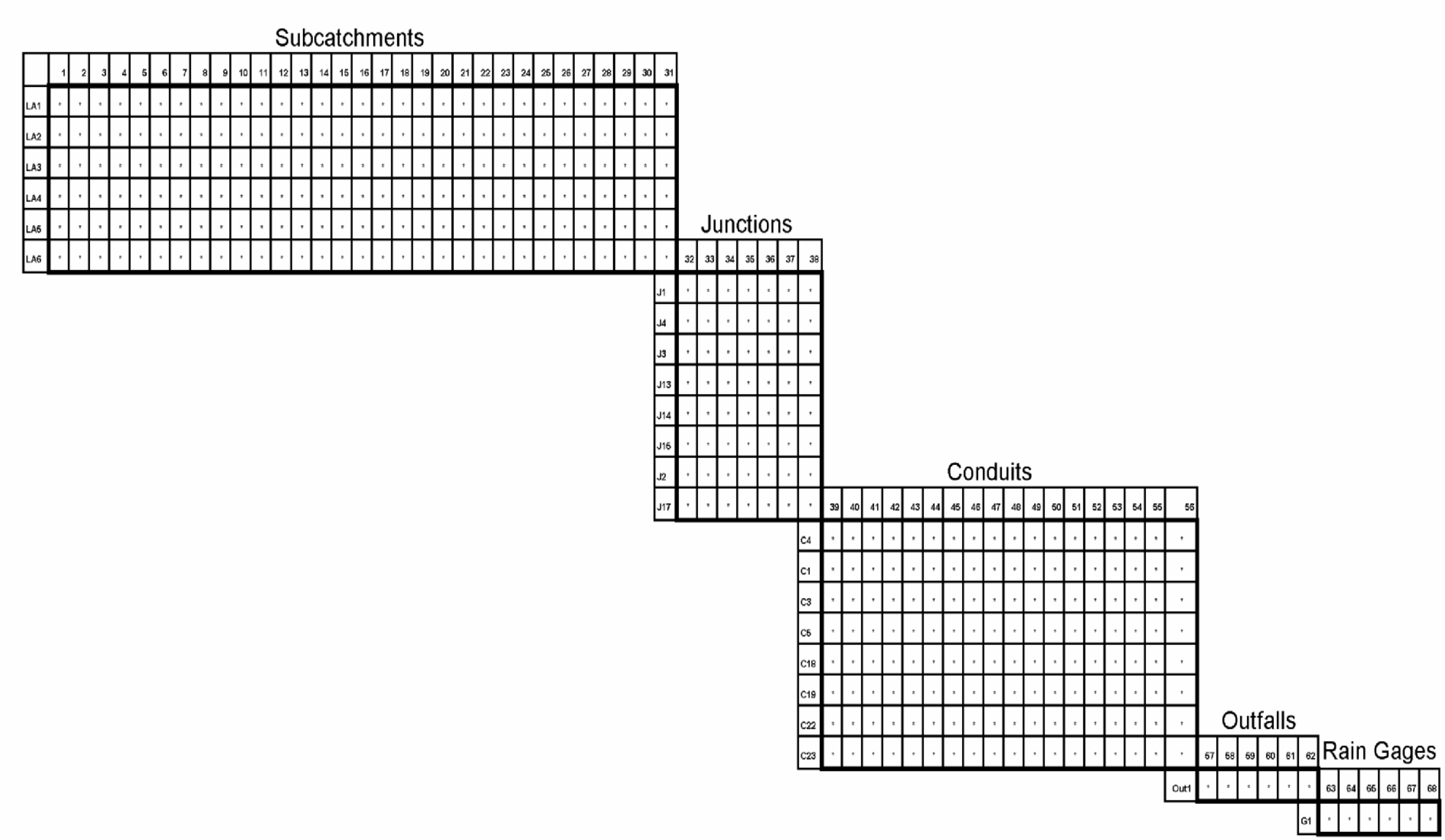

Figure 5-6: General Attribute Layout

Table 5-1: Data Input File for SWMM Run of ECW

SUBCATCHMENTS:

	Rain Gage	Outlet	Area	Width	% Slope	% Imperv	N-Imperv	N-Perv	Dstore-Imperv	Dstore-Perv	%Zero-Imperv	Subarea Routing	Curve Number	Conductivity	Drying Time	Percent Routed	Groundwater	Snow Pack	Initial Buildup	Curb Length	Land Uses	%Agriculture	%Forested	%Open Space	%Landscaped	%Waterbody	%Rooftop	%Parking	%Driveway/Sidewalk	%Street	%Unpaved
LA1	Gage1	J3	71.72	1830	11.21	33.38	0.018	0.134	0.075	0.29	1	outlet	81	0.3	1	100	NO	0	NONE	0	7	0	15.7	5.0	45.9	0.0	10.7	4.5	7.7	10.4	0
LA2	Gage1	J1	40.67	1590	7.27	50.15	0.013	0.133	0.075	0.27	0	outlet	50	0.3	1	100	NO	0	NONE	0	8	0	10.1	8.8	31.0	0.1	19.1	5.4	12.1	13.4	0
LA3	Gage1	J13	32.9	1090	17.87	52.03	0.013	0.208	0.075	0.23	0	outlet	51	0.3	1	100	NO	0	NONE	0	7	0	15.5	22.5	10.0	0.0	14.1	3.3	24.3	10.4	0
LA4	Gage1	J2	30.71	1130	24.28	44.39	0.013	0.353	0.075	0.28	0	outlet	75	0.3	1	100	NO	0	NONE	0	7	0	46.2	7.2	2.2	0.0	13.8	10.1	8.8	11.6	0
LA5	Gage1	J4	12.01	885	24.38	41.95	0.013	0.336	0.075	0.27	0	outlet	63	0.3	1	100	NO	0	NONE	0	7	0	43.8	12.6	1.6	0.0	7.8	0.6	14.9	18.6	0
LA6	Gage1	J14	13.01	864	16.89	73.41	0.013	0.273	0.075	0.28	0	outlet	89	0.3	1	100	NO	0	NONE	0	7	0	15.8	4.4	6.4	0.0	24.0	13.6	17.6	18.3	0

JUNCTIONS:

	Inflows	Treatment	Invert El.	Max. Depth	Initial Depth	Surcharge Depth	Ponded Area
J1	NO	NO	147.34	1.66	0	0	7854
J4	NO	NO	77	3	0	0	0
J3	NO	NO	99.5	3	0	0	0
J13	NO	NO	109.48	13.5	0	0	1E+06
J14	NO	NO	81.8	2	0	0	0
J15	NO	NO	107.73	2	0	0	0
J2	NO	NO	71.97	0	0	0	0
J17	NO	NO	98.24	0	0	0	0

CONDUITS:

	Inlet Node	Outlet Node	Shape	Barrels	Max. Depth	Bottom Width	Left Slope	Right Slope	Max. Depth	Length	Roughness	Inlet Offset	Outlet Offset	Initial Flow	Entry Loss Coeff.	Exit Loss Coeff.	Avg. Loss Coeff.	Flap Gate
C4	J4	J2	RectCl	1	3	6	-	-	3	200	0.01	0	0	0	0	0	0	NO
C1	J1	J13	Circular	1	2	-	-	-	2	1500	0.01	0	0	0	0	0	0	NO
C3	J3	J17	RectCl	1	3	3	-	-	3	200	0.01	0	0	0	0	0	0	NO
C5	J2	Out1	RectCl	1	3	8	-	-	3	100	0.01	0	0	0	0	0	0	NO
C18	J14	J2	Circular	2	2	-	-	-	2	100	0.01	0	0	0	0	0	0	NO
C19	J13	J15	Circular	1	4	-	-	-	4	130	0.01	0	0	0	0	0	0	NO
C22	J15	J2	Trap	1	7	6	0.5	0.5	7	950	0.01	0	0	0	0	0	0	NO
C23	J17	J2	Trap	1	7	5	0.5	0.5	7	1000	0.01	0	0	0	0	0	0	NO

OUTFALLS:

	Inflows	Treatment	Invert El.	Tide Gate	Type	Fixed Stage
Out1	NO	NO	71.9	NO	FREE	0

RAIN GAGES:

	Rain Format	Rain Interval	Snow Catch Factor	Data Source	Series Name	Rain Units
Gage1	Volume	:30	0	TimeSeries	trial2	IN

Rain gauge

One of the most basic objects used in SWMM is the rain gauge. Six attributes must be specified, two of which are variable rain interval and snowcatch factor, resulting in 33% estimated values. The rainfall data available for the ECW are published in Korhnak (1996). Rainfall was measured at an IFAS rain gauge atop Newins-Zeigler Hall, which is directly west the ECW. Shorter time step (5-10 minute) rainfall data are valuable in developing strong runoff models. Such data are available through the Physics Department at http://www.phys.ufl.edu/~weather/text/ and IFAS at ftp://fawn.ifas.ufl.edu/. In addition, the Physics Department logs higher frequency data (1-minute, 0.01 in). These databases did not begin until after 1996. The rainfall measurement time step for the 11/09/1990 storm was 30 minutes. (Korhnak 1996) During the first 30 minutes, 0.55 inches of rain fell followed by an additional 0.25 inches during the next 30 minutes as shown in Table 5-2. Snow catch was not considered in this model.

Table 5-2: 11/9/1990 Precipitation in ECW-Data Taken from Korhnak (1996)

Date	Time	Rain (in)
11/9/1990	0:00	0
11/9/1990	0:30	0.55
11/9/1990	1:00	0.25
11/9/1990	1:30	0
…	….	…
11/9/1990	14:30	0

Subcatchments

Twenty-one subcatchment descriptors must be provided for SWMM as shown in Table 5-1. In the case of the ECW analysis, ten land use types were specified, forming a grand total of 31 attributes for each of the six subcatchments in the ECW. 168 of the 186 subcatchment attribute values are estimated. The following subsections will address how each variable was chosen using the most accurate data available.

Rain gauge. In Table 5-1, “rain gauge” simply specifies which rainfall time series data to use for each subcatchment and is not estimated. Since only one rain gauge was present near the ECW, only one option was available.

Outlets. The outlet of the subcatchment can be either a node or another subcatchment as shown in Figure 5-5. The outlets of each subcatchment have been identified from the stormwater infrastructure map created by PPD. Yulee pit (Figure 5-7), located in LA-3, is the retention basin that drains all the water flowing into and raining onto LA-3 (less initial abstractions). This has been denoted as a node in SWMM and is drained by a large 4 foot diameter conduit (inset).

Figure 5-7: Yulee Pit in LA-3

Curb length. A curb length value represents the total length of curbs in the subcatchment. However, no value has been specified for the subcatchments because this value is not needed for water volume simulation. Curb length can be useful when correlating water quality parameters to urbanized area, based on total curb length.

Area. Area is the estimated surface area of each subcatchment. The subcatchment delineation used in this model is from the 2000 CH2MHill Stormwater Management Master Plan AutoCAD files. The estimated areas of each subcatchment are summarized in Table 5-3, having been measured in ArcGIS® by importing the Physical Plant AutoCAD files into GIS and estimating the shape of subcatchment LA-1.

Table 5-3: Areas of ECW Subcatchments

	2000 Autocad Shapefiles w/est LA-1
Subcatchment	Area (acres)
LA-1	71.72
LA-2	39.38
LA-3	35.18
LA-4	29.62
LA-5	10.32
LA-6	16.20
Total	202

Source: Causseaux & Ellington 2000

Width. Width is the average width of the overland flow path for sheet flow runoff. Each subcatchment's width was measured as the maximum width perpendicular to the flow direction. The widths entered into SWMM are shown in Table 5-4. However, as shown in Figure 5-4, subcatchment LA-5 is not particularly square or rectangular. This approximation can be improved by dividing larger, odd shaped subcatchments into smaller square or rectangular ones.

Table 5-4: Estimated Subcatchment Widths

	2000 AutoCAD Shapefiles w/ est LA-1
Subcatchment	Width (feet)
LA-1	1830
LA-2	1590
LA-3	1090
LA-4	1130
LA-5	885
LA-6	864

Source: CH2MHill 1987

Percent slope. Percent slope is a measure of the subcatchment slope to be used in overland flow calculations. As determined for the ECW using ArcGIS 3D Analyst and both 1-ft LIDAR information (LA-2 through LA-6) and 5-ft topo information (LA-1), the percent slopes for each subcatchment have been measured as shown in Table 5-5:

Table 5-5: Subcatchment Percent Slope

Subcatchment	% Slope
LA6	17 %
LA5	24 %
LA4	24%
LA3	18%
LA2	7%
LA1	11%

The 1-foot LIDAR data that are used to provide the five values for subcatchments LA-1 through LA-5 provide the most accurate slope estimates available for these subcatchments. LA-6 has been characterized using lower resolution 5-foot data. However, even when high quality topographic information is used over a large area (up to 70 acres) error is introduced into slope estimation. Figure 5-8 is a photograph, taken just North of East Creek, showing the steeply sloped Newell Drive in LA-4.

Figure 5-8 Steep Slopes of LA-4 along Newell Drive

Percent Impervious Area: Subcatchments are divided into pervious and impervious areas in SWMM. In the pervious area, surface runoff can infiltrate into the upper soil zone but not in the impervious area. The following land uses were estimated as being >90% impervious and thus were summed to approximate impervious area: Streets, Rooftops, and Drive- & Walkways. The resulting percent imperviousness of each subcatchment and total impervious acreage of each subcatchment are shown in Table 5-6.

Table 5-6 Impervious Area per Subcatchment

	LA-1:	LA-2:	LA-3:	LA-4:	LA-5:	LA-6:
% Impervious	33.38%	50.15%	52.03%	44.39%	41.94%	73.41%
Impervious acreage	23.94	20.39	17.12	13.63	5.04	9.55

Manning's n for impervious area. Table 5-7 shows the range of impervious n-values used in the simulation. Values were taken from DeWiest & Livingston (2000).

Table 5-7 Manning's n Values for Impervious Area Categories

Land Use Classification	Manning's n Range
Rooftops	0.013 - 0.035
Parking Area	0.011 - 0.016
Drive- & Walkways	0.012 - 0.02
Streets	0.011 - 0.013

The rationale for choosing these values for the SWMM simulation is discussed below:

Rooftops: 0.013 - 0.035

Most rooftops on the eastern side of campus are made of concrete material. The residential areas in LA-1 may have concrete, shingled, or metal/plastic rooftops. The range consists of ordinary concrete to rubble which could be similar to shingled rooftops. The value chosen was 0.035 for LA-1 and 0.013 for all others because many of the roofs have asphalt, which is of an even lower n-value than concrete and a majority of the other campus roofs are concrete. In contrast, LA-1 has many shingled roofs which reduces velocity slightly (ASCE 1992).

The specific slopes of each of the roofs are unknown at this time, however Norman Hall and a number of sorority houses have pitched roofs in subcatchment LA-1. A number of buildings in subcatchment LA-2 have pitched roofs. These include the Memorial Auditorium, the Agronomy greenhouse, Anderson Matherly and Criser Halls, the Universtiy Auditorium, the Smathers Library, and the Carlton Auditorium. No major buildings have pitched roofs in subcatchments LA-3, LA-4, LA-5, or LA-6. A majority of the steeply sloped roofs on campus are located in LA-2 (Figure 5-9).

Figure 5-9 University Auditorium in LA-2

Parking Areas: 0.011 - 0.016

Most parking lots consist of smooth to rougher asphalt. The value for rough asphalt is taken from the Florida Stormwater, Erosion, and Sedimentation Control Inspector's Manual (DeWiest 2000). It lists smooth and rough asphalt as 0.013 and 0.016, respectively. However, ASCE (1992) lists a Manning's n value for smooth asphalt as 0.011. A value of 0.012 was chosen as an average of the smooth asphalt values of the two sources.

Drive- and Walkways: 0.012 - 0.020

Walkways on campus are made of smooth to rough concrete. Manning's n values for smooth concrete are between 0.012 (ASCE 1992) and 0.016 (DeWiest 2000). Rough concrete is characterized by a Manning's n of 0.020 (DeWiest 2000). A value of 0.014 was chosen because it is represents newer, smoother drive- and walkways. This is typical of the University of Florida because Physical Plant maintains a high frequency walkway maintenance schedule. Most walkways on campus are not directly connected but instead are nestled in grassy areas, such as on the Reitz Union North Lawn. Notable exceptions are those sidewalks that are adjacent to roads, where water drains to the roadside gutters. Figure 5-10 is the sidewalk network, adjacent to Inner Road in LA-3, representing the vast network of wide smooth concrete sidewalks that crisscross the campus.

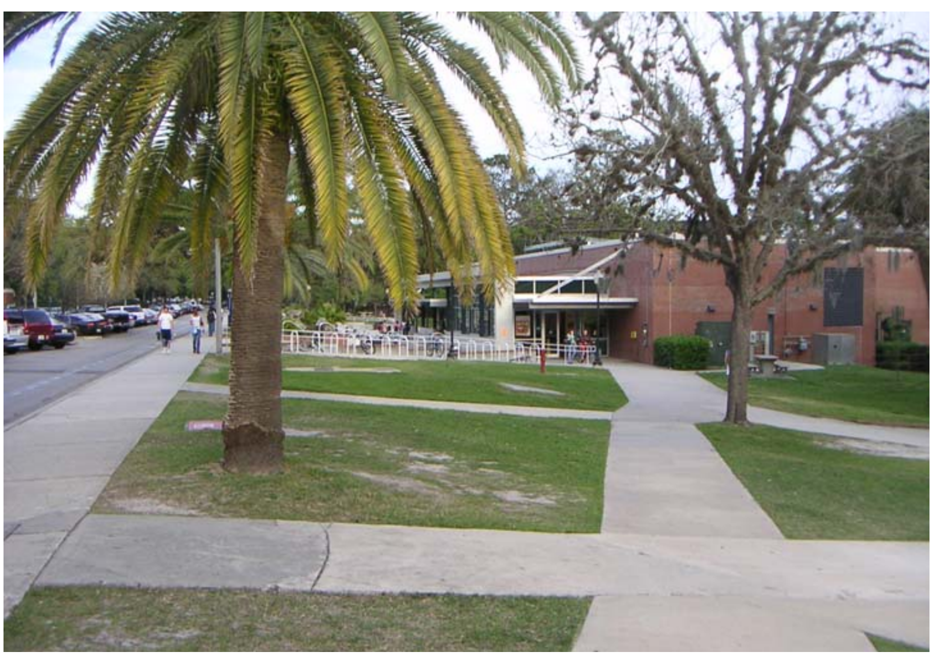

Figure 5-10 An Example of the Layout of Walkways in LA -3

Streets: 0.011-0.016

The same logic used to select a Manning's n for "Parking" can be applied here. An "n" value of 0.012 was chosen for streets. A weighted average of Manning's n in each subcatchment was calculated as a weighted average of the land use type percentages in each. Results are shown in Table 5-8.

Table 5-8 Manning's n Values for Pervious Area per Subcatchment

Subcatchment	Manning's n
LA-1	0.018
LA-2	0.013
LA-3	0.013
LA-4	0.013
LA-5	0.013
LA-6	0.013

Manning's n for pervious area [N-Perv]. Table 5-9 shows the range of n-values provided in the literature for pervious area categories. The values are referenced from ASCE (1992), Arcement Jr. (1984), and DeWiest & Livingston (2000).

Table 5-9 Manning's n Values for Pervious Area Categories

Land Use Classification	Manning's n Range
Forested Land	0.1 – 0.8
Open Space	0.15 – 0.24
Landscaped Area	0.3 – 0.5

The rationale for choosing these values for the SWMM simulation is discussed below:

Forested Land: 0.1-0.8

This range is based on data from the USGS on how to calculate n values for forested flood plains (Arcement, Jr. 1984). Figures within the Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains show areas with n values ranging from 0.1-0.2. However, the Storm Water Management Model Users Manual cites two values for wooded areas: light underbrush = 0.4 and dense underbrush = 0.8 (Rossman 2004). The range of Manning's n values chosen for forested land focuses on the upper boundaries of the range, while understanding that some forested lands may likely have a lower value. A value of 0.4 was chosen, slightly below the average, due to the small size and variable underbrush in the patchwork campus forests.

Open Space: 0.15-0.24

Manning's n values for certain grasses representing open space are given in the SWMM help menu (shown in Table 5-10):

Table 5-10 Manning's n Values for Grasses

Grass Type	Manning's n value
Short, prairie	0.15
Dense	0.24
Bermuda grass	0.41

Source: ASCE 1992

Much of the grass in the watershed is short grass. Grass in LA-1, where many homes are located, would resemble denser lawn grass. LA-2, LA-3, LA-4, LA-5, and LA-6 enclose the eastern part of the UF campus where grasses are generally dense. Most grasses lie between the range of short to dense grass, which is thought to be a fair approximation of the Manning's n value. Most types of grasses in the ECW may also fall within this range because 0.24 is a relatively high n value assuming relatively a unpacked surface. However, it certainly depends on the length of the grass. Bermuda grass is used on golf courses (lower n) and in landscaping (higher n) where the grass could be longer. The Bermuda grass value seems unusually high--greater than that for forested land. The value chosen is 0.15, as most of the grass is trimmed and short. Figure 5-11 is an open area in LA-2 exemplifying the short grass with scattered trees typical of the open areas on campus.

Figure 5-11 An Example of Open Space in LA-2

Landscaped Area: 0.3-0.5

Landscaped areas are characterized by some level of development resulting in compacted soils, mulch, walkways, bushes, trees, etc. This leads to a lower n value than forested areas but higher than open spaces. In this case, it would be safe to assume a Manning's n value around that of Bermuda grass (0.41).

A weighted average of Manning's n in each subcatchment was calculated as a weighted average of the pervious land use type percentages in each. Results are shown in Table 5-11.

Table 5-11 Manning's n Values for Pervious Area per Subcatchment

Subcatchment	Manning's n
LA-1	0.134
LA-2	0.133
LA-3	0.208
LA-4	0.353
LA-5	0.336
LA-6	0.273

Depth of depression storage on impervious area. Impervious areas are divided into two subareas - one with depression storage and one without. Runoff flow from one subarea in a subcatchment can be routed to the other subarea, or both subareas can drain to the subcatchment outlet. Depression storage values are highly variable within the range of a few hundredths. The Dstore impervious value chosen for all the subcatchments was 0.075 inches, which is within the range of impervious surface values. (ASCE 1992)

Depth of depression storage on pervious area. Dstore values were estimated from a table of typical Dstore values for pervious areas as provided by ASCE (1992). Selected values are shown in Table 5-12.

Table 5-12: Ranges of Typical Depression Storage

Surface	Depression Storage
Impervious surfaces	0.05 to 0.10 inches
Lawns	0.10 to 0.20 inches
Forest litter	0.3 inches

Source: ASCE 1992

The Dstore pervious value chosen within each subcatchment was based upon an area-weighted average between 0.15 inches (lawn surfaces) and 0.30 inches (forest litter); results are shown in Table 5-13.

Table 5-13: Dstore Values for Pervious Area per Subcatchment

Subcatchment	LA-1	LA-2	LA-3	LA-4	LA-5	LA-6
Dstore-Perv Value	0.29	0.27	0.23	0.28	0.27	0.28

Percent of impervious area with no depression storage. As mentioned previously, impervious areas are divided onto subareas that do and don’t have depression storage. The percent of the impervious area that was estimated to be truly non-impervious, in the ECW, was 0.15% in LA-1 and 0 in all other subcatchments. Our methods of land-type identification did not allow for an accurate estimation of the water bodies due to tree cover, resulting in no record of water for 5 of the 6 subcatchments. Inclusion of higher quality land-use data would increase the estimation of water body and other zero depression storage areas for all subcatchments.

Subarea routing. Runoff from impervious and pervious areas has been routed to the subcatchment outlet for the purposes of the current model. One may also route flow from impervious to pervious surface areas within the same parcel.

Percent routed. This value represents the percent of runoff routed from each subcatchment. One-hundred percent of the runoff is routed in the current model. Alternatively, one could specify values for evapotranspiration and groundwater flow, effectively lowering the volume of routed runoff.

Infiltration method. The infiltration method is a system-wide parameter selected from three options (Green Ampt, Horton, Curve Number) and is not a subcatchment parameter. However, in the ECW, Curve Number was chosen over Green Ampt and Horton infiltration methods because CN data was readily available alongside existing storm data. Within the Curve Number tab, requirements include curve number value, conductivity and drying time.

Curve Number. CH2MHill used a standard curve number table (Table 5-14) to estimate curve runoff from seven different land use classifications in four hydrologic soil groups (A, B, C, & D). Based upon these CN values, CH2MHill calculated Curve Numbers characterizing entire subcatchments as shown in Table 5-15.

Table 5-14: Curve Numbers for Soil Types and Land Uses Commonly Found on Campus

	Hydrologic Soil Group			
Land Use	A	B	C	D
Impervious Roads and Parking	98	98	98	98
Buildings	98	98	98	98
Limerock Roads and Parking	77	85	90	92
Wooded Area	25	55	70	77
Grassed Area	39	61	74	80
Cultivated	67	76	83	86
Water Bodies	98	98	98	98

Source: CH2MHill 1987

Table 5-15: Curve Numbers for East Creek Watershed Subcatchments

Subcatchment	CN
LA-1	81
LA-2	50
LA-3	51
LA-4	75
LA-5	63
LA-6	89

Source: CH2MHill 1987

Conductivity. “Conductivity” is the soil's saturated hydraulic conductivity in in/hr or mm/hr. This value can be field verified for a small site relatively easily. However, the ECW is a large 201 acre watershed. Therefore, a blanket conductivity value of 0.3 was chosen for all the subcatchments, which corresponds to an A/B soil type. This was chosen because three soil areas surrounding the East Creek watershed are delineated as type A while a small area to the South is B/D. Soils data are shown in Figure 5-12 to represent infiltration capabilities within the ECW. Most of the soils are listed as Type A soils, which indicates high infiltrative capacity. Surrounding the East side of the lake is a claylike low infiltration Type D soil.

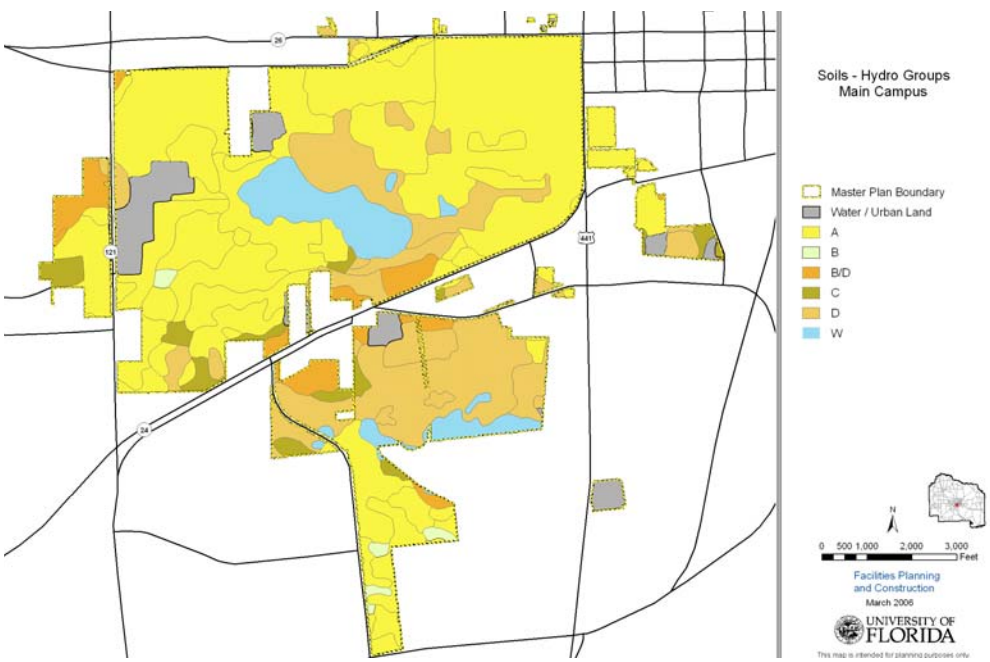

Figure 5-12: Soil Type Classification (University of Florida, 2006)

Drying time. Drying time is the amount of time for a fully saturated soil to completely dry, in days. The estimation used in this model was 1 day. This estimate has not been field verified and should be considered as highly variable. Drying time is also affected by the irrigation schedule for the study area.

Groundwater inflow. Groundwater inflow was ignored because no data are available.

Initial buildup. Initial buildup, a measure of the amount of pollutant buildup over the subcatchment at the start of the simulation, was not selected because no data are available.

Land uses. Using the boundary conditions for East Creek, shown in Figure 5-13, land use was defined using a number coding system in a spreadsheeet (SS). Aerial photographs were placed in a SS and pre-specified ID coding numbers were assigned to the appropriate places in the photo as follows:

1. Agricultural land
3. Forested land (large trees and natural areas)
4. Open space (fields, lawn, etc)
5. Landscaped area (shrubbery and flowers)
6. Water body (wetlands, streams, or lake)
7. Rooftops
8. Parking
9. Driveways and walkways
10. Streets
11. Unpaved streets and parking lots

Figure 5-13 shows a close up sample of the technique used to characterize LA-4. Each cell represents an area of 743.8 ft^2. The same technique was used over the entire East Creek Watershed. The result of using this method for all the subcatchments is shown in Table 5-16, a percent land use breakdown for LA-1 through LA-6. No agricultural area or unpaved streets/parking were observed in any subcatchment.

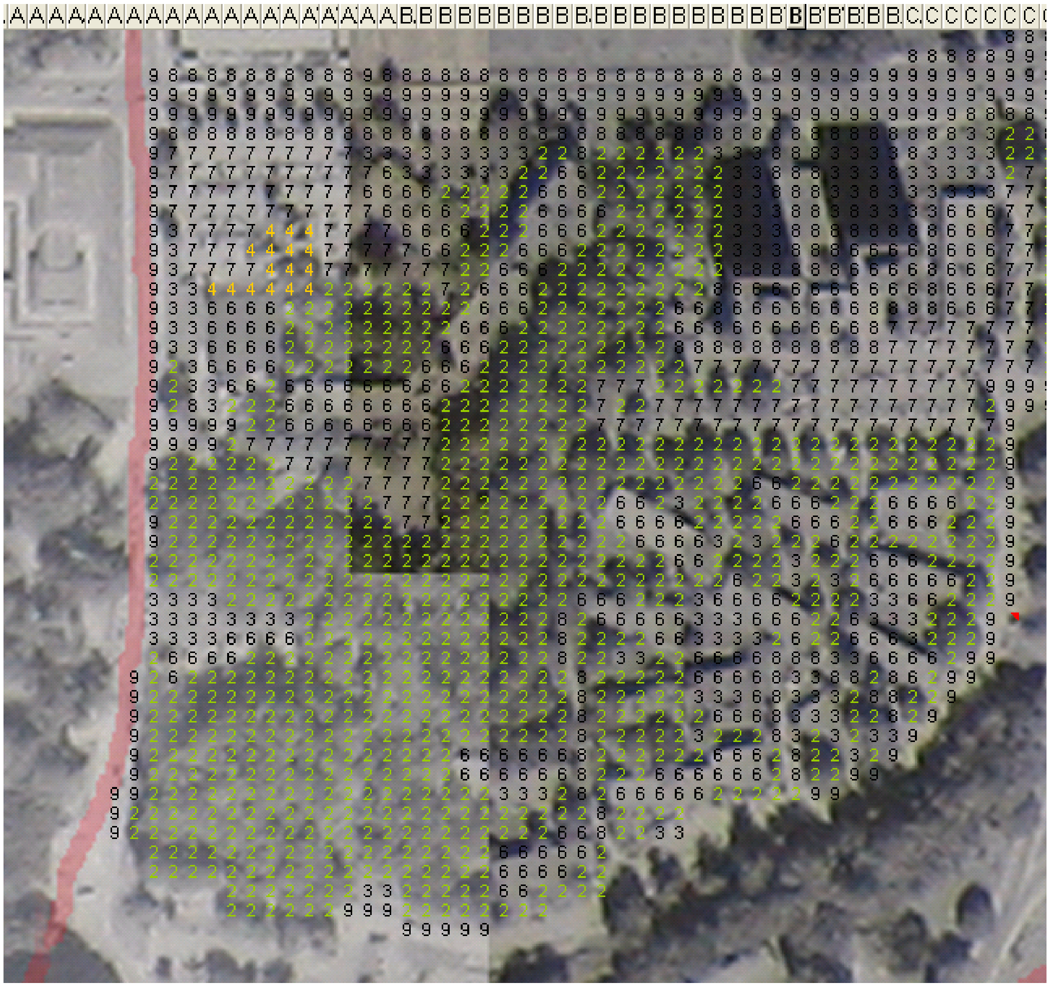

Figure 5-13 Land Use Characterization Map in Subcatchment LA-4

Table 5-16: Land Use Type Percent Breakdown per Subcatchment

	Subcatchment						Catchment
Land Use Type	LA-1:	LA-2:	LA-3:	LA-4:	LA-5:	LA-6:	% Land Use
Forested Land	15.7%	10.0%	15.5%	46.1%	43.8%	15.8%	20.8%
Open Space	5.0%	8.7%	22.4%	7.1%	12.6%	4.4%	9.3%
Landscaped Area	45.8%	31.0%	10.0%	2.2%	1.6%	6.3%	25.1%
Waterbody	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.03%
Rooftop	10.7%	19.1%	14.0%	13.8%	7.8%	24.0%	14.1%
Parking	4.5%	5.3%	3.2%	10.1%	0.5%	13.5%	5.69%
Drive- & walkways	7.7%	12.1%	24.2%	8.8%	14.9%	17.5%	12.57%
Streets	10.4%	13.3%	10.4%	11.6%	18.5%	18.2%	12.20%
Total	100%	100%	100%	100%	100%	100%	100%

Figure 5-14 is a photograph of the Plaza of the Americas in LA-2 that shows the complex land-use composition seen in a small fraction of the LA-2 subcatchment. Other areas in LA-1 through LA-5 show similar complexity.

Figure 5-14: Land Use in LA–2

Connectivity

All subcatchments in the SWMM are connected or drained using links and nodes. Links are the conveyance pieces of a drainage system that always lie between a pair of nodes. Likewise, nodes are points along a conveyance system that connect links together. In addition, nodes are points where external inflows can enter the drainage system and where pollutants can be removed through treatment. There are five different types of links in SWWM (conduits, pumps, orifices, weirs, outlets), of which conduits will be discussed herein. There are four types of nodes in SWMM (junctions, outfalls, dividers, and storage units), of which junctions and outfalls will be discussed further. Figure 5-15 is a photograph, taken below Jenning's Hall, to show a typical curb and gutter node.

Figure 5-15 Curb and Gutter Draining to East Creek in LA – 4

Conduits. Conduits are links (pipes or channels) that move water from one node to another in the conveyance system (Rossman 2004). There are 22 different conduit shapes that can be modeled in SWMM, from open channel concrete trapezoids to double barrel steel pipes, each shape's attributes uniquely modeled in SWMM. As shown in Table 5-1 sixteen different attributes can be selected or entered for each conduit. Approximately 83 percent of the attributes entered for the conduits in SWMM, or 120 of the 144 total attribute values, are highly variable. Because links must connect nodes, the junction and outfall node objects will be discussed before describing how the conduits connect them to each other in the ECW.

Junctions. Junctions are drainage system nodes that join links together. “Physically they can represent the confluence of natural surface channels, manholes in a sewer system, or pipe connection fittings. External inflows can enter the system at junctions. Excess water at a junction can become partially pressurized while connecting conduits are surcharged and can either be lost from the system or be allowed to pond atop the junction and subsequently drain back into the junction” (Rossman 2004). Each of the six subcatchments in the East Creek use junctions as a point of connection between conduits. Table 5-17 shows the various structure names for junctions in their respective subcatchments along with the configuration of their drainage conduits (reinforced concrete pipe vs concrete box culvert), maximum flow capacity, design storm flows, overtopping flows, weir length (when overtopping road), and overtopping depth. Circular and box culvert capacity was estimated by CH2MHill (1987) using nomographs developed by the Federal Highway Association. Closed conduit and open channel drainage facility capacity was estimated by CH2MHill using Manning’s equation, assuming uniform flow capacity assuming full pipe flow. Forty out of fifty-six junction attributes (71%) were estimated. Table 5-18 summarizes stage-storage-discharge values for Gator Pond and Ocala Pond in LA-2, the Radio Rd. and Broward Bowl culvert in LA-3. All drainage facilities are gravity controlled.

Table 5-17 Drainage Structure Specifications as Determined by CH2MHill

				Design Storm Flows (cfs)			Overtopping Flow (cfs)			Overtopping Depth (ft)			
Subcatch	Drainage Structure Location	Control Structure Configuration	Capacity (cfs)	10 yr	25 Yr	100 yr	10 yr	25 yr	100 yr	10 yr	25 yr	100 yr	Weir Length (ft)
LA-1	SW 13th St Culvert	3' x 3' CBC	105	88	95	104	0	0	0	0.0	0.0	0.0	100
LA-2	Ocala Pond Outlet	24" RCP	30	25	40	71	0	10	41	0.0	0.0	0.1	100
LA-3	Broward Bowl Culvert (Yule Pit)	48" RCP	175	52	80	119	0	0	0	0.0	0.0	0.0	200
LA-4	Newell Dr. Culvert	8' x 3' CBC	250	108	122	146	0	0	0	0.0	0.0	0.0	100
LA-5	Emory Diamond Culvert	6' x 3' CDC	140	97	106	121	0	0	0	0.0	0.0	0.0	200
LA-6	Shands Hospital Storm Sewer	2-24" RCP	70	181	213	257	111	143	187	0.4	0.5	0.5	200

Table 5-18 Stage-Storage-Discharge for Major Drainage Facilities in the East Creek Watershed

Ocala Pond		
Elevation (ft msl)	Storage (acre-ft)	Discharge (cfs)
147.34	0	0
148	0.91	10
149	1.09	30
150	1.26	330
Structure	3' x 4' Horizontal Grate with 24" RCP at Invert 144.54 and Slope 3.99%	
Max Discharge	30	Cfs
Invert	147.34	ft msl
Overtops at	149	ft msl
Overtop Width	100	Ft

Gator Pond		
Elevation (ft msl)	Storage (acre-ft)	Discharge (cfs)
154.6	0	0
156	0.53	16
158	1.27	55
159	1.51	55
160	1.74	955
Structure	3.3' x 4' Horizontal Grate with 30" RCP at Invert 151.1 & Slope 2.37%	
Max Discharge	55	cfs
Invert	154.6	ft msl
Overtops at	159	ft msl
Overtop Width	300	ft

Broward Bowl Culvert (Yule Pit)		
Elevation (ft msl)	Storage (acre-ft)	Discharge (cfs)
109.48	0	0
112	0.06	30
114	0.24	80
116	1.19	130
118	3.3	150
120	6.04	170
122	9.89	175
123	12.75	175
124	15.6	775
Structure	48" RCP at Slope 1.95%. Length = 130'	
Max Discharge	175	Cfs
Invert	109.48	ft msl
Overtops at	123	ft msl
Overtop Width	1200	Ft

Outfalls. Outfalls are terminal nodes of the drainage system. Under dynamic wave flow routing, they are used to define final downstream boundaries. Under other types of flow routing they function as a junction. (Rossman 2004) The outfall for the East Creek

Watershed is at the western end of the Newell Drive Box Culvert. Four of the six outfall attributes (66%) were estimated. The box culvert under Newell Drive has a linear stage-discharge relationship and an exponential stage-storage relationship (CH2MHill 1987) as shown in Table 5-19 and Figure 5-16.

Table 5-19 Newell Drive Box Culvert Stage vs Storage vs Discharge

Newell Drive		
Elevation (ft msl)	Storage (acre-ft)	Discharge (cfs)
71.97	0	0
72	0.1	0.7
74	0.2	57
76	0.3	148
78	1	214
79.6	2.6	250
80	3	319
Structure	8' x 3' Concrete Box Culvert	
Max Discharge	250	Cfs
Invert	71.97	ft msl
Overtops at	79.6	ft msl
Overtop Width	100	Ft

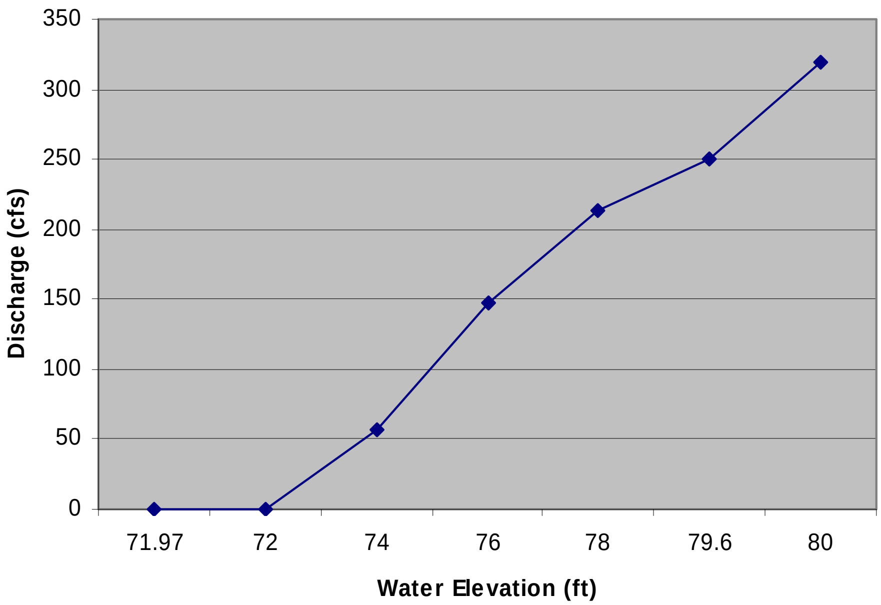

Figure 5-16 Newell Drive Box Culvert Stage vs Discharge Curve

East Creek Watershed Drainage Network

The routing method chosen to model flow of water through the stormwater system was the dynamic wave method, one of three system-wide variables provided by SWMM. The other two options are steady flow and kinematic wave. The west side of the culvert was chosen to define the final boundary of the ECW. The subcatchments were connected using an aggregated drainage network of only the major junctions and conduits, namely those listed in tables 4.18 & 4.19. The following paragraphs describe the methodology used to connect each subcatchment.

LA-1 “junction 3” is estimated to have an invert of 99.5ft from 1987 AutoCAD files. Its maximum depth is 3 ft, surcharge depth is 0 ft., and ponded area is 0. (CH2MHill, 1987) Junction 3 connects to junction 17 using a rectangular closed conduit max depth of 3 ft. as stated in CH2MHill (1987). The conduit length is estimated as 200 ft from AutoCAD. Junction 17 has an invert of 98.24 as notated in AutoCAD, while its maximum depth is zero. C23 is a conduit connecting J17 to J2 (which is the east side of the Newell Dr. box culvert). It represents the stream as being trapezoidal, 1000 ft in length, with a maximum depth of 7 ft., bottom width of 5 ft., and slopes = 0.5 H/V. Unfortunately, these values are estimated from 1987 AutoCAD drawings; a walkthrough would help rectify any erroneous values estimated for the southern fork of East Creek.

LA-2 “junction 1” has an invert of 147.34 ft, max depth 1.66 ft. surcharge depth 0 ft as described by CH2MHill (Table 5-18). The ponded area is 7854 ft^2. However, this value must be verified because the 1987 report cuts Gator Pond between subcatchments LA-2 and LA-3, and Gator Pond conveys almost the same amount of water from LA-2 to LA-3 as Ocala Pond does. In 2000, the Gator Pond was shown to lie wholly within LA-2, suggesting a large error in volume retention calculated for LA-2 in 1987. C1 is a conduit connecting Ocala Pond to Eulee Pit (J13). It is 2 ft in diameter and estimated to be 1500 ft in length from AutoCAD drawings.

LA-3 “junction 13” has an invert of 109.48 ft with a maximum depth 13.52 ft, a surcharge depth = 0, and a ponded area 113,0973 ft^2 as described by CH2MHill (1987). C19 connects it to the beginning of the northern fork of East Creek, C22. J15 has an invert of 107.73 ft as shown in AutoCAD and a maximum depth of two feet (CH2MHill 1987). C19 has a length of 130 ft as stated in the 1987 report and max depth (diameter) of 4 feet. C22 has a length of 950 ft and is trapezoidal with a max depth of 7 ft, max width of 5 ft and 0.5 slope H/Vert. These values are estimated from 1987 Physical Plant AutoCAD drawings.

LA-4 “junction 2” has an invert of 71.97 ft, a max depth of 3 ft, a surcharge depth of 4.63 ft, and a ponded area of 7854 ft^2 as described by CH2MHill (1987). Junction 2 connects to C5, which represents the 8’ by 3’ box culvert, estimated as 100 ft long using AutoCAD drawings. C5 finally drains the watershed via outfall “Out1.” Figure 5-17 is a photograph of the Newell Drive box culvert at the last node of the drainage series. This location, on the East side of Newell Drive, is where runoff measurements were performed in 1990 and published in Korhnak (1996).

LA-5 “junction4” has an invert of 77ft, a max depth of 3 ft, a surcharge depth of 0 ft, and a ponded area = 0 ft as measured by CH2MHill (1987). It is connected to culvert C4, a box culvert, which carries flow to the box culvert. Culvert C4 has a maximum depth of 3 ft., a length of 200 ft. and a bottom width of 6 ft. as estimated using AutoCAD.

LA-6 “junction 14” is drained by double 24 in concrete pipes, with an invert of 81.8 ft, a maximum depth of 2 ft. as estimated using AutoCAD. It is drained by C18, the double pipe culvert system, each pipe being 2 ft diameter as presented by CH2MHill. The length of channel C18 is approximately 100 ft (estimated using AutoCAD).

Figure 5-17: Newell Drive Box Culvert

Runoff Analysis

Using calibration data from Korhnak (1996) measured in 1992, the East Creek Watershed (ECW) was modeled to determine if the watershed can be modeled without including all of the stormwater hydraulic infrastructure but rather including major drainage directions between five suchcatchments ranging from 8 to 73 acres in size.

This section compares actual data from Korhnak (1996) with results from the SWMM simulation. To begin, the section details the methods of calculating the flow values from Korhnak's data. The results are tabulated and values of total rain, total runoff, the centroids of each, and the time lag associated with each storm are displayed. Then, a comparison of all storm events is presented The selected storm event used in this study is displayed graphically followed by a detailed analysis of its characteristics.

The SWMM results are then compared to the actual data. The comparison highlights the differences in the volume, runoff, centroids, and time lags of both the Korhnak (1996) data and the SWMM data. In order to further calibrate the model for an actual storm event, a table of adjustable values is presented to illustrate the present degree of uncertainty in using SWMM to predict runoff over the ECW using coarse data.

Observed rainfall-runoff relationship

Korhnak (1996) contains data on flow and phosphorus concentrations for the East Creek watershed. The data set, titled SFHCO1, was taken upstream of the culvert that conveys East Creek (what Korhnak labels as the Hawthorne Creek) underneath Newell Drive. The acronym SFHC01 represents recorded storm flow measurements at the HCO1 station watershed. The acronym LIO1 is suggested to represent the approximate area where the stream discharges into Lake Alice, hence Lake Inflow (LI). A map reflecting data set areas and measurement locations is shown in Figure 5-18

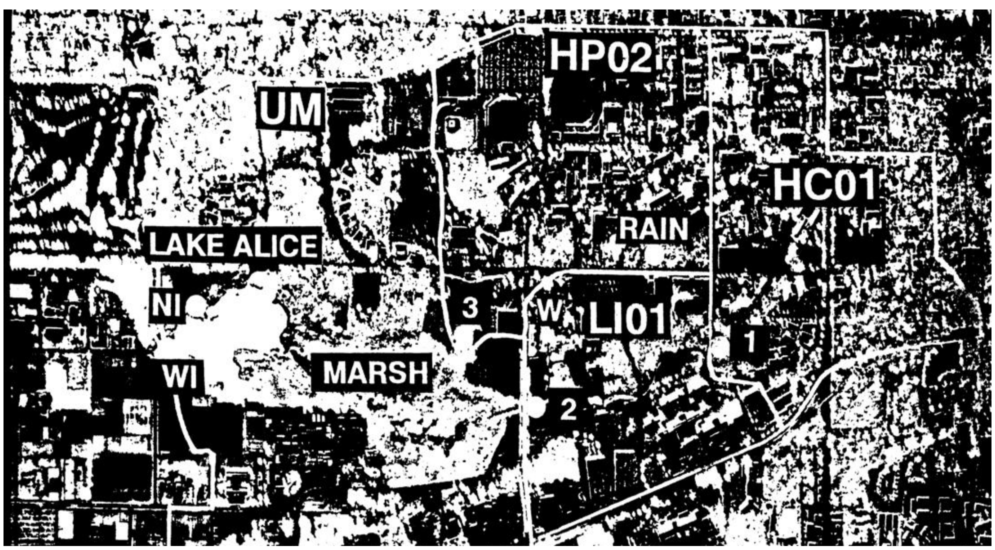

Figure 5-18 Map of Korhnak research area (Korhnak, 1996)

The labels on Figure 5-18 are listed below:

1: HC01 stormflow station receiving inflow from HC01 watershed
2: LI01 stormflow station receiving inflow from LI01 watershed

3:	HP02 stormflow station receiving inflow from HP02 watershed
Rain:	IFAS rain gauge
Lake Alice:	Campus drainage lake
Marsh:	Marsh area of Lake Alice
W:	Water Reclamation Facility
NI:	North injection well
WI:	West injection well
UM:	Unmonitored area

Data recording techniques. Stage measurements were taken by a stage meter at varying time intervals (15 or 30 minutes) and converted to flow measurements in cubic feet per second (cfs) using a stage-discharge rating equation (Eq 5.1) developed by measuring 3 velocities at 3 three depths (9 point velocities).

Flow (cfs) = Stage*26.3248-4.3806 Equation 5.1

The values of baseflow for each storm were subtracted from the flow values calculated above to find the rate of rainfall runoff generated by each storm. The baseflow values for all but one storm event were 15 cfm. The baseflow of Storm Event 1 was provided as 13 cfm. If the flow values calculated from Eq 5.1 were less than the base flow, then Korhnak assumed the amount of runoff was zero.

For each storm event, these final runoff values were reported in units of cfs and compared with the amount of rainfall in inches. To calculate the amount of runoff in inches for the rainfall-runoff curve, the flow rate was converted to a height in inches above the 215 acre East Creek Watershed (CH2MHill 1987).

Results. Table 5-20 provides general information on the 28 available storm events. It lists the beginning date, total rainfall (in), total runoff (in), the centroids of rainfall and runoff, and the time lag interval between the two centroids. The estimated time lag between rainfall and runoff ranges from 15 minutes to over three hours. Figure 5-19 illustrates the linear relationship between total rainfall (in) and total runoff (in).

Table 5-20: Catchment-wide Rainfall vs Runoff Comparison

Beginning Date	Total Rain (in)	Total Runoff (in)	Centroid (Rain)	Centroid (Runoff)	Time Lag* (min)
7/13/1990	0.9	0.3352	6:30 PM	6:00 PM	60
11/9/1990	0.8	0.3750	12:36 AM	1:08 AM	32
1/11/1991	1.3	0.6580	7:15 PM	9:30 PM	150
1/15/1991	0.2	0.0780	9:45 PM	11:00 PM	90
3/17/1991	3.39	1.4596	7:45 PM	8:00 PM	30
3/29/1991	0.6	0.2099	9:15 PM	9:30 PM	30
4/17/1991	0.64	0.4068	11:45 AM	12:45 PM	75
4/20/1991[a]	0.18	0.0510	3:15 PM	4:00 PM	60
4/20/1991[b]	0.68	0.3818	7:45 PM	8:45 PM	75
4/23/1991	0.22	0.1129	1:15 PM	2:00 PM	60
4/25/1991	0.91	0.4810	1:00 PM	3:00 PM	135
5/16/1991	0.13	0.0654	7:00 PM	7:45 PM	60
5/19/1991	0.65	0.2502	1:45 PM	2:45 PM	75
5/20/1991	0.07	0.0435	11:30 PM	12:15 AM	60
5/24/1991	0.29	0.1476	2:30 PM	3:00 PM	45
5/26/1991	0.48	0.2239	2:30 PM	3:30 PM	75
5/27/1991	0.58	0.2557	6:45 PM	7:45 PM	75
5/29/1991	0.35	0.0528	7:45 PM	8:00 PM	30
5/31/1991	0.71	0.3572	3:00 PM	4:00 PM	75
6/4/1991	0.56	0.2772	11:15 PM	12:15 AM	75
6/5/1991	1.2	0.5373	6:00 PM	6:45 PM	60
6/6/1991	0.6	0.2247	5:00 AM	5:45 AM	60
6/17/1991	0.15	0.0555	5:00 PM	5:30 PM	45
6/19/1991	0.14	0.0508	12:00 PM	12:45 PM	60
6/26/1991	1.04	0.3421	12:00 AM	1:00 AM	75
7/29/1991	0.26	0.1440	2:00 PM	5:45 PM	210
7/31/1991	0.9	0.2514	3:00 PM	3:15 PM	30
8/1/1991	0.29	0.0270	1:15 AM	1:30 AM	30

*Estimated Values +/- 15 min.. 7/13/1990 values +/- 30 min. (11/09/1990 not included)

The rainfall-runoff curve suggests that approximately 43.7% of the rainfall is converted to runoff into East Creek from 1990-1991. The curve strongly matches the data as evidenced by the high R^2 of 0.951. A study completed by Lee et al. (2005) states that stormwater runoff occurs when precipitation intensity exceeds on-site depression storage and infiltration capacity. Therefore, the slope of the rainfall-runoff curve represents the percentage of directly connected impervious area located in the East Creek watershed. Based on campus observations, the parking lots will be assumed as directly connected to the creek by way of curb and gutter drainage structures.

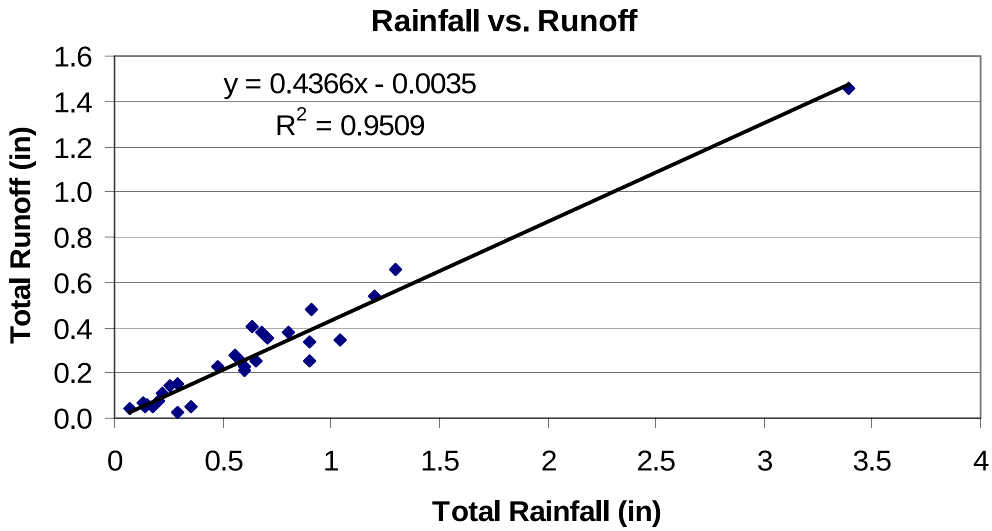

Figure 5-19 Catchment-wide Rainfall vs Runoff Relationship

Results from the present study show the percent impervious area to be around 49.2% for the ECW. The impervious area calculations are based on data and maps circa 1996, several years after Korhnak collected his flow data. During this time span, numerous construction projects took place on the UF campus and surrounding area increasing the amount of impervious area through developmental practices.

The results from the SWMM simulations are calibrated against the actual stormwater runoff data from Korhnak (1996) of a single storm event to produce a model of the stormwater runoff patterns of the ECW. Figure 5-20 represents the actual storm used in the calibration. The flow values in cubic feet per second (cfs) are listed on the ordinate and the rainfall rates (in/hr) corresponding to the flow are inverted on the right ordinate. A total of 0.80 inches of rain fell during a one hour period. This rainfall produced 0.375 inches of runoff over the 201 acre watershed.

A unit hydrograph shows the storm flow generated by one inch of rainfall over a specified period of time. The storm event closely resembles a unit hydrograph since the amount of rainfall is 0.85 inches over an hour and the downward sloping tail is a good prediction of storm flow after a rain event. Furthermore, a typical storm generates storm flow that reaches its peak after a short period of time and then tails off as the rainfall intensity decreases. The rainfall is recorded early in the time series and the tail decreases at a relatively constant rate.

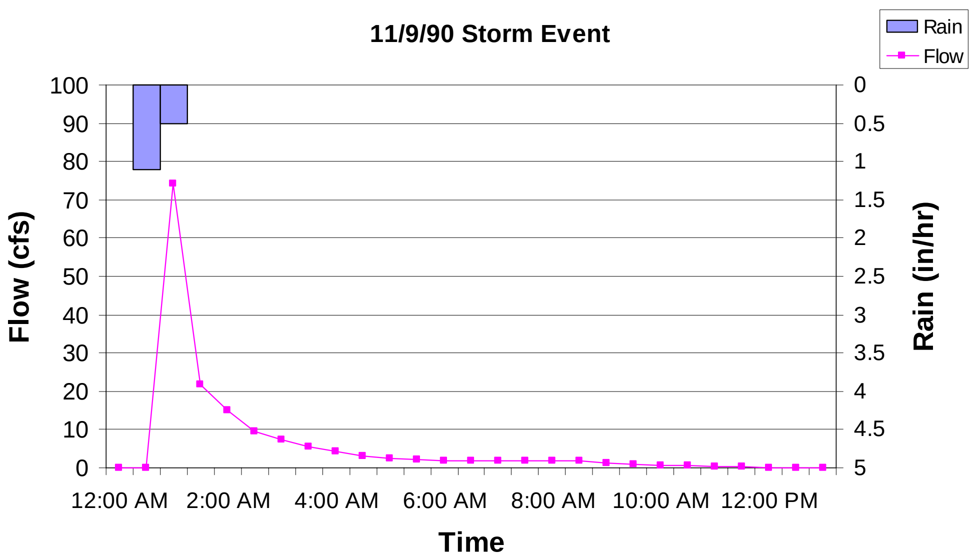

Figure 5-20 Storm Event Used to Calibrate SWMM Results

Calculated rainfall-runoff relationship

The blue plot in Figure 5-21 represents the actual hydrograph from Korhnak's data for the 11/9/1990 storm event. The pink plot shows the hydrograph of the simulated storm using SWMM 5.0. The simulated storm shows an additional 25 cfs of flow at its peak and a shorter tail of the curve. The simulation also appears to plateau between 1 hour and 1 hour and 30 minutes which reflects the impact of the 0.25 inches that fell during the second half hour of rainfall.

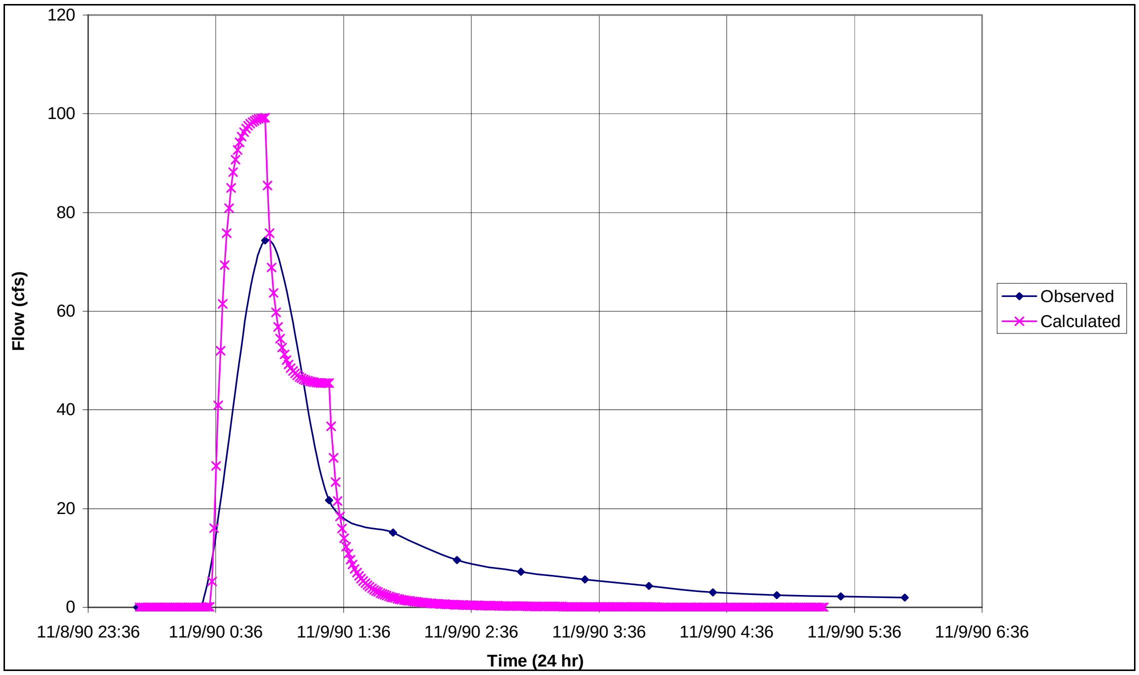

Figure 5-21 Volumetric Runoff Comparison (calculated vs observed)

Calculated vs. observed results comparison

Calculations from Korhnak (1996) and SWMM produce two different sets of data for the 11/09/90 storm event. The observed volume of runoff (area under hydrograph) generated during the storm was measured as 289,000 ft^3. SWMM estimates the volume of runoff for the storm event to be around 236,000 ft^3. Based on these calculations, the SWMM explains roughly 81.5% of the actual storm. In other words, the volume calculated in SWMM is 81.5% of the total volume of the actual storm.

For the 11/9/1990 storm, the 30 minute time step between data points caused more error than the 15 minute time step used for almost all of the other 27 storm events. The SWMM results provide data points at 1 minute time steps, yielding a much higher resolution depiction of the centroid for the SWMM simulation. The locus between two given data points is assumed to have a linear relationship with time. The distribution of rainfall makes it difficult to use linear interpolation to find the centroid. Instead, a polynomial curve is fitted to the actual data and integrated to a value of half of the total rainfall. This procedure shows the 11/9/1990 rainfall centroid as 12:36 a.m., thirty-six minutes after the start of the storm.

The centroid of the runoff from the actual data is calculated by finding the time at which the volume of runoff is equal to half of the total volume generated during the storm. The centroid for the 11/09/90 storm occurs approximately at 1:08 a.m., sixty-eight minutes after the start of the storm. Similar methods were used to calculate the centroid of runoff produced by the SWMM simulation, which found it occur around 1 a.m., an hour after the start of the storm.

The time lag for the storm is the time differential between the centroids of the precipitation and runoff. The actual data from Korhnak (1996) shows the time lag to be 32 minutes, assuming little error in the data collection methods. The SWMM simulation shows a time lag of 24 minutes, resulting in an error of 25% from the actual data, reflecting the coarse data used to model in SWMM. The short lag times illustrate the impact of impervious area and low soil infiltration rates in the watershed.

Conclusions

This model does not appear to be refined enough to confidently determine the effectiveness of a given BMP placed in the ECW. Each subcatchment may have many features which could affect the accuracy of the model. These properties include width, slope, impervious/nonimpervious area, Dstore, and Manning’s n values. One simple but data intensive method to reduce the number of subcatchment generalizations would be to divide each into smaller subcatchments in order to make each attribute more specific to the subdivided area, making it much easier to simulate the effect of Directly Connected Impervious Area (DCIA) on the drainage system. Likewise, BMP placement could be easily simulated by taking an area such as a parking lot, changing its properties to reflect a partially pervious lot, and rerunning the simulation.

The area is still too large to simulate unique functional land units. At this point, there is also too little hydraulic network information of verified accuracy to perform a detailed spatial model, such as the stream profile and underground piping, culverts, etc. Although data are available to develop a functional land unit analysis, there is a need to automate information transfer from GIS into the SWMM modeling environment.

The very jagged runoff hydrograph from the SWMM simulator indicates that more frequent rainfall data should be used when making decisions based upon single storm events. A major source for historical precipitation data is the National Oceanic and Atmospheric Administration (NOAA), which has two gauge locations on the UF campus. Historical data are available for the period from January 1903 to December 1963 for one of the stations, from October 1953 to December 1988 at a second weather station. A third station, located in west-northwest Gainesville, began recording in February 1989 until December 2000. The Gainesville Regional Airport station has a data record beginning in 1960. Rainfall is measured hourly at these locations at 0.01 inch depths from 1903 to 1963 as well as 1989 to 2000 and at 0.1 inch depths from 1953 to 1988 and from 1960 to present. A new weather station was added to the Institute of Food and Agricultural Sciences (IFAS) dairy research unit northwest of Gainesville. This station began operation in April 1999 and is still operational. The gauge records data every 15 minutes. The most valuable source of weather data is the weather station located at the Physics Building on campus. This location is less than one mile from Lake Alice. Continuous data are recorded at 0.01 inch depths every minute. The Physics Building weather station began recording in July 2000. In the next case study, higher frequency (1-minute) rainfall data were used when developing the SWMM model but 1 yr of 1-hr rainfall data were used when calibrating and running the BMP selection tool.

CHAPTER 6
SITE SIMULATION AND BEST MANAGEMENT PRACTICE SELECTION METHODOLOGY IN THE LA-2B WATERSHED

Introduction

Taking a more fundamental approach than previous chapters, this study both focused on a smaller watershed and developed a link between GIS and SWMM to automate the transfer of shapefile information because there are many sources of urban runoff from streets, parking lots, sidewalks, roofs, lawns, and other areas. Runoff can be controlled onsite using LID practices such as grass buffers, rain gardens, etc. (Weinstein et al. 2006). Different BMPs cater to different runoff conditions such as flow, volume, water quality aspects, etc. This study focused first on modeling a single storm event and then evaluating BMPs using a year of hourly rainfall-runoff data. The seven acre LA-2b watershed was modeled at three different levels of aggregation ranging from one to 390 functional elements. Techniques used to simulate BMP implementation to satisfy a specified percent onsite control regulation are discussed.

Lee et al. (2005) shows that the more certainty one has in estimating on-site conditions, largely generated by gathering detailed spatial information, the more accurate the simulated rainfall-runoff pattern for the site. Best management practices have traditionally been modeled as control devices but, in reality, onsite BMPs function both as controls for rainfall/runon and as sources of runoff for downstream elements.

The new EPA SWMM 5 model allows for simulation at multiple levels of spatial and temporal detail (Rossman 2004). It allows users to generate aggregated models while still allowing a portion of runoff from impervious surfaces to flow onto pervious surfaces before flowing to the subcatchment outlet. For example, a rooftop and driveway surface can be routed to a grass surface by routing 100% of the impervious area to the pervious area, representing the entire site as one subcatchment. However, SWMM also allows one to model a site as a series of interconnected functional elements down to any level of detail. For example, runoff from concrete stairs can cascade onto a pervious brick patio before flowing into a stormwater drain. In this case, the patio infiltrates some of the runon while the remainder flows, overland, into the storm drain. It is simulated as serving a specific function with infiltration and surface parameters unique to that surface. This is referred to as a functional land unit in my thesis. The following methods describe the level of data needed to produce such a detailed simulation as well as one way to transfer those data into SWMM.

Goals

This case study has the same goals as those previously mentioned for the LAW. It is also intended as a proof of concept for future modeling exercises and serves to provide both a methology and data repository for detailed modeling in the LAW.

Characterize Site

This study site, called the LA-2b subcatchment, is located within the LA-2 subcatchment (Figure 6-1). This is an ideal study site because it is a headwater and is a very small area (approximately 7 acres) with moderately well defined topography. This site also provides a good mix of high and low intensity land uses and contains an historic building so any proposed changes will likely have to be retrofits. There are multiple facilities using this area which also contains multiple functional land use areas.

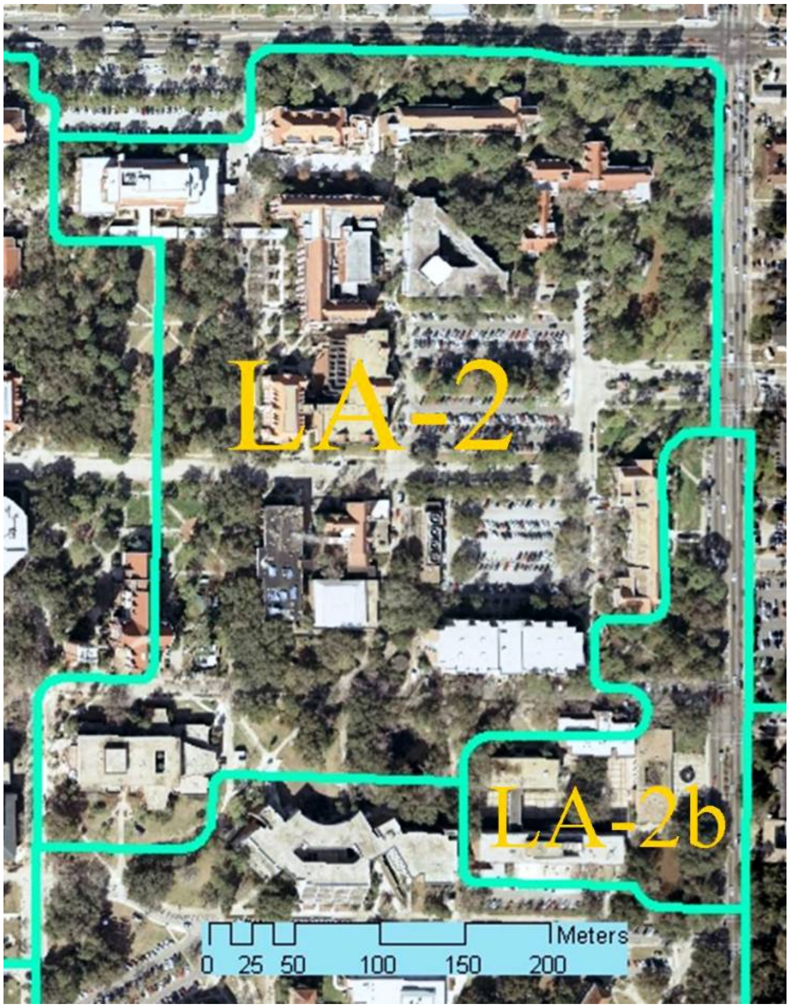

Figure 6-1: LA-2b Study Site in Context of Larger ECW.

Evaluate Candidate Processes

Two methods were employed for evaluating BMP effectiveness. The first involved creating a geodatabase of relevant site information in a GIS, followed by transferring the site information to SWMM using a tool built for this project. ArcGIS software was then used to aggregate the site data into a fictitious 8- and then 1-parcel ownership scenario. These two site representations were also transferred into SWMM, resulting in three levels of site aggregation in three different SWMM files. In the first method, a single rainfall event was used to compare percent onsite control between the three aggregation levels and to evaluate BMP performance using the 8-parcel simulation scenario. The second

BMP candidate evaluation process built upon the disaggregated SWMM file generated previously. However one year of hourly rainfall was used to evaluate the annual performance of two LID control methods. The methods, results, and discussion for the single event simulation scenario are included in the first part of this section, entitled “Single Event Simulation” while the second BMP evaluation process is discussed in the section entitled “Annual Simulation”.

Single Event Simulation

Methodology

The engineer or designer needs to determine what information is available at the beginning of the data gathering process as well as what information needs to be gathered or can be estimated reasonably well. The format that the information is saved in is important because the program developed to transfer data from ArcGIS to SWMM is designed for an ArcGIS geodatabase. Data that are not in the correct format or table layout can be modified to the format required by a Visual Basic program called GIS2SWMM. GIS2SWMM is a program developed by the author that reads data from a particular shapefile’s data table, converts that information into space delimited strings, and then arranges the strings to create a “.INP” or input file that is in a format native to SWMM. The source code for GIS2SWMM is available in Appendix B.

The methodology used to generate each of three SWMM input files was as follows. A database was developed in ArcGIS by setting up the table structure as shown in Table 6-1 for one feature layer. This allows the user to select the proper column title for each SWMM input parameter when running GIS2SWMM. A screenshot of the SWMM parameter selection tab within the program is shown in Figure 6-2.

Table 6-1: GIS Geodatabase Feature Layer Layout

Geodatabase Label	SWMM Parameter
SWMM_NAME	Name
SWMM_PcntSlope	% Slope
SWMM_CurbLen	Curb Length
SWMM_SnowPac	Snow Pack
SWMM_CapSuc	Capillary Suction
SWMM_Conduc	Conductivity
SWMM_InitDef	Initial Deficit
PctImp	% Impervious Area
nImp	Manning's n Impervious Area
nPerv	Manning's n Pervious Area
Simp	Depression Storage Impervious Area
Sperv	Depression Storage Pervious Area
PctZro	Percent Zero Pervious Area
RteTo	Route to
PctRted	% Routed
SWMM_Area	Area
SWMM_Width	Width
SWMM_Raingage	Raingage
SWMM_Outlet	Outlet

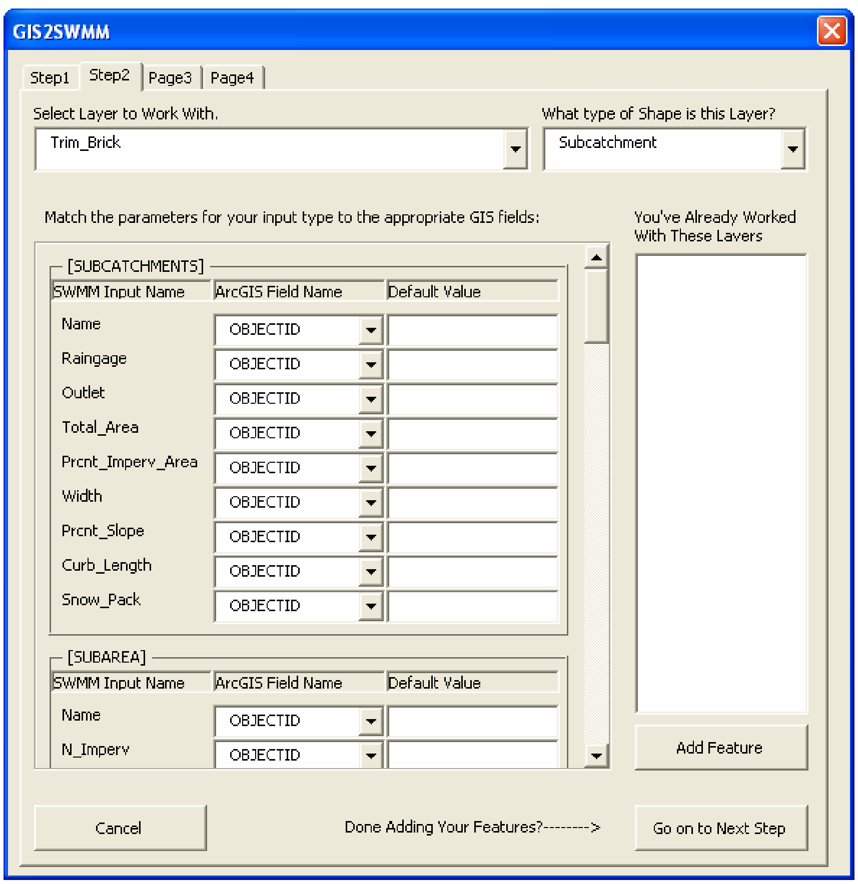

Figure 6-2: GIS2SWMM Interface

Initially, one feature layer was developed for each land use, resulting in nine different feature layers, all with the same table layout. The following land uses were evaluated: building rooftops, brick trimming, pervious brick paving, concrete sidewalks, bushes, grass, packed sand, parking, and roads. These separate feature layers were later combined into one layer for ease of use but the subcatchments could still be distinguished from each other by name. Subcatchments ranged in size from 4E-5 to 0.5 acres. An example of the high level of disaggregation is shown inset within Figure 6-3.

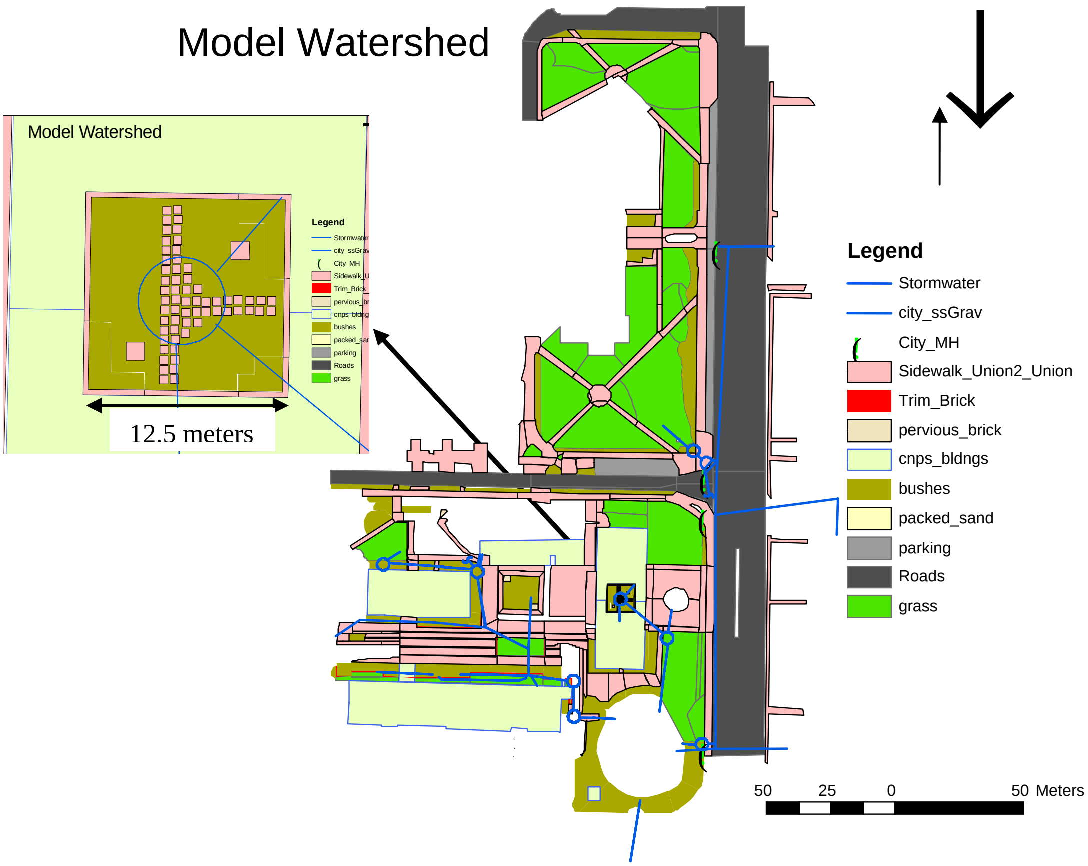

Figure 6-3: Visual Representation of UF Study Area in GIS with High Detail Inset

A one-foot topographic map created by LIDAR data was used to establish initial flow boundaries within the study area. A ground truthing survey was then used to make any needed corrections to the subcatchments. Due to the non-uniform shapes of the subcatchments, width was measured using the measuring tool in GIS. Percent slope was calculated by first turning the LIDAR data from a TIN file to a slope raster file using the 3D Analyst tool within ArcGIS. Then the Spatial Analyst tool was used to perform zonal statistics on the single GIS layer containing all of the 390 subcatchments. This produced a mean percent-slope value for each of the elements or subcatchments within the layer. Area is calculated in square meters using the HARN projection as was used for this research project. The calculator tool was used to convert these values to the native acre units used by SWMM. Manning’s n values and depression storage values entered into the geodatabase were as suggested by ASCE (1992), Rossman (2004) and DeWiest (2000). Suction head, conductivity, and initial deficit values were as suggested by Rossman (2004). Only one land use (pervious brick) was set to use subrouting from impervious to pervious areas within a subcatchment, all others routed directly to their outlets. The outlet field was populated by hand although it is possible to create a route network within GIS. The rain gage field was populated with “rg1” to represent the rain gage used to represent rainfall on the entire subcatchment. The rain gage is located approximately 0.5 miles west at the Physics Building. It is a 0.01 inch tipping bucket gage recording at 1 minute intervals. A Green-Ampt infiltration scheme was chosen because it is possible to measure each of the parameters in the equation although the GIS2SWMM software also accepts CN and Horton’s infiltration parameters. No snowpacks were used, all curb length values were entered as 0 and all Percent Zero pervious values were 0. The information from the GIS feature layer was then extracted and transferred to a space delimited, text based SWMM input file by selecting the appropriate column headers when prompted by GIS2SWMM. The resultant file was opened within SWMM and pipes and nodes were added by hand from within the SWMM graphical user interface using information contained in CH2MHill (1987) and Causseaux & Ellington (2000). A visual representation of the stages involved is shown in Figure 6-4.

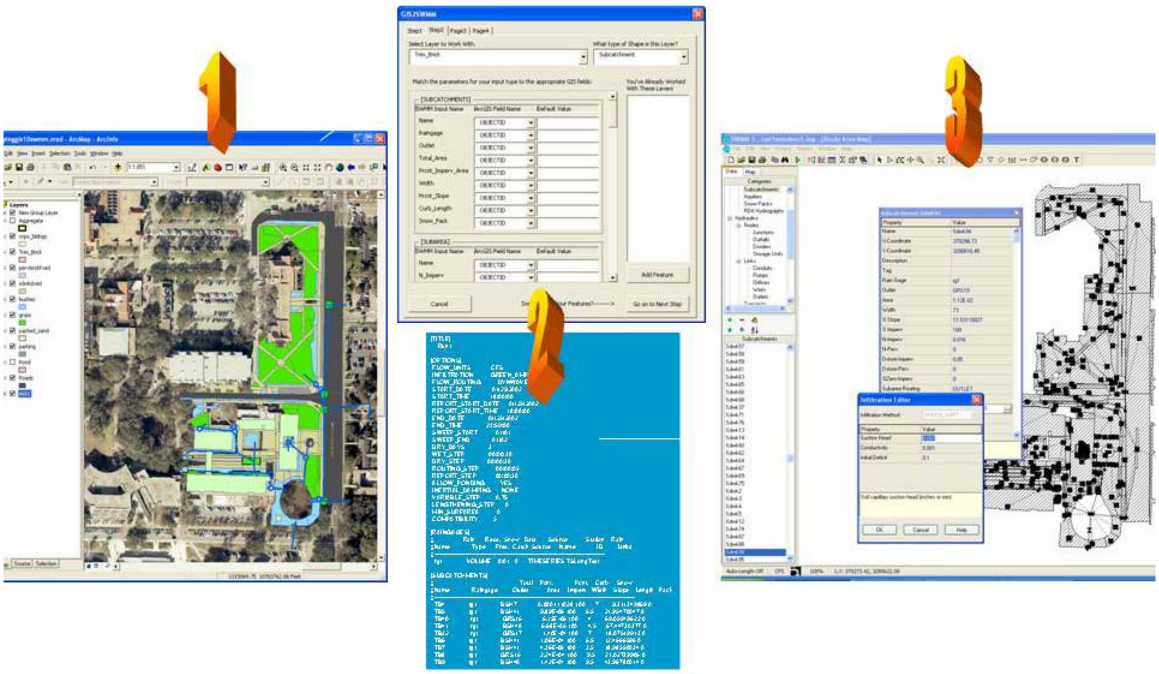

Figure 6-4 UF GIS2SWMM Tool Connecting ArcGIS to SWMM.

Next, eight polygons were created on a second layer within GIS to represent a fictitious multi-owner situation of eight parcels for the study area. The polygons were titled Owner1 – Owner5, DOT1, SchoolRd1, and one area titled CommonArea. Information was taken from the disaggregated layer to each of the eight polygons in part by calculating a weighted average for percent-impervious area, Manning's n and depression storage values, and infiltration parameters (suction head, conductivity, initial deficit). All other elements such as area, slope, width, etc. were entered or calculated for each of the eight parcels as discussed previously.

The method used to create weighted average values for the percent impervious area was to first create a raster of the percent impervious area values contained within the disaggregated or functional element layer using the ArcGIS Spatial Analyst tool and then apply the mean values to each of the eight parcels using the Zonal Statistics tool. Next, a new layer was exported from the pervious areas of the functional element layer. The same ArcGIS tools were used to create rasters of the pervious Manning's n, pervious depression storage, suction head, conductivity, and initial deficit values. Mean values from the resultant rasters were then applied to each of the eight parcels using the Zonal Statistics tool. Similarly, a new layer was exported from the impervious areas of the functional element layer and the same processes were used to create weighted-average values of impervious n and depression storage values for each of the eight parcels in the aggregated layer. The data were exported to SWMM using the GIS2SWMM tool and node and link elements were added to the SWMM file manually.

The unified (1 subcatchment) shapefile was created and populated with data using the same processes used to create the eight parcel shapefile. All simulations were run using the same rainfall pattern and run conditions. The rainfall distribution is shown in Figure 6-5 and the run conditions are shown in Table 6-2. The storm distributes 0.270 inches over 0.2 hours at 1 minute time steps. The simulation results were then compared to ensure similar runoff values. Finally, attributes were changed within SWMM to accommodate the 50 % onsite control requirement when necessary. These values were easily changed from within SWMM when altering the large one and eight catchment simulations but can be changed within GIS instead.

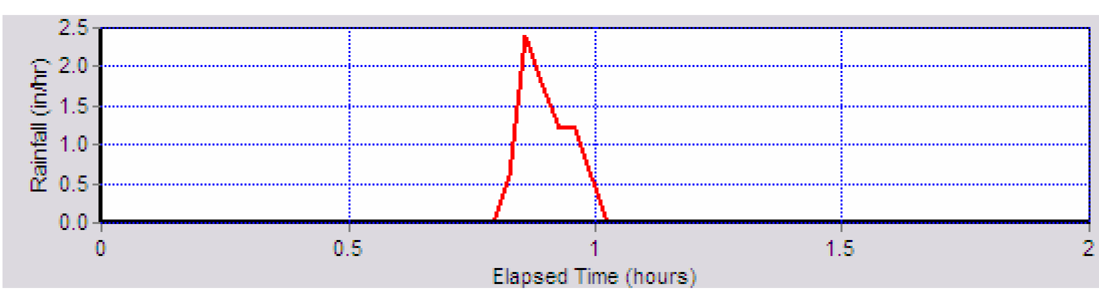

Figure 6-5: Rainfall Pattern for Detailed Rainfall-Runoff Analysis

Table 6-2: Run Conditions

Variable	Value
Flow Units	CFS
Infiltration Method	GREEN_AMPT
Flow Routing Method	KINWAVE
Starting Date	JAN-28-2002 17:00:00
Ending Date	JAN-29-2002 00:00:00
Antecedent Dry Days	3
Report Time Step	0:01:59
Wet Time Step	0:00:50
Dry Time Step	0:01:00
Routing Time Step	5.00 sec

Results

The information recorded into the ArcGIS geodatabase for each of the three levels of aggregation: 390 parcels, 8 parcels, and 1 parcel is shown in Tables 6-3, 6-4, and 6-5, respectively. In addition, Tables 6-4 and 6-5 contain a final column of the percent onsite control within each parcel. Figure 6-6 represents the site as 390 parcels. Figure 6-7 shows the eight different parcels used in the 8 parcel simulation. Figure 6-8 shows the site represented as 1 parcel. Simulation summary results for each of the aforementioned aggregation levels are shown in Table 6-6 along with a control run simulating 100% impervious area.

Table 6-3: Geodatabase Information for 390 Parcel Simulation

Subcatchment	Raingage	Outlet	Area (acres)	Width (ft)	% Slope	%-Imperv	N-Imperv	N-Perv	Dstore-Imperv	Dstore-Perv	%Zero-Imperv	Subarea Routing	% Routed	Sunction Head	Conductivity	Initial Deficit
TB1-TB35	rg1	#	#	#	#	100	0.015	NA	0.075	NA	0	Out	100	NA	NA	NA
Brick1-Brick15	rg1	#	#	#	#	95	0.015	0.1	0.075	0.1	0	Perv	100	6.57	0.24	0.25
Bldng1-Bldng10	rg1	#	#	#	#	100	0.013	NA	0.05	NA	0	Out	100	NA	NA	NA
Sdwk1-Sdwk207	rg1	#	#	#	#	100	0.016	NA	0.05	NA	0	Out	100	NA	NA	NA
Bsh1-Bsh74	rg1	#	#	#	#	0	NA	0.5	NA	0.3	0	Out	100	8.66	0.06	0.15
GRS1-GRS36	rg1	#	#	#	#	0	NA	0.2	NA	0.2	0	Out	100	8.66	0.06	0.15
Sand1	rg1	j8	0.003	5	15	0	NA	0.15	NA	0.1	0	Out	100	1.93	4.74	0.38
Parking1-P3	rg1	#	#	#	#	100	0.013	NA	0.1	NA	0	Out	100	NA	NA	NA
Rd1-Rd10	rg1	#	#	#	#	100	0.015	NA	0.1	NA	0	Out	100	NA	NA	NA

Table 6-4: Geodatabase Information for 8-Parcel Simulation

Subcatchment	Raingage	Outlet	Area (acres)	Width (ft)	% Slope	%-Imperv	N-Imperv	N-Perv	Dstore-Imperv	Dstore-Perv	%Zero-Imperv	Subarea Routing	% Routed	Sunction Head	Conductivity	Initial Deficit	% control
SchoolRd1	rg1	DOT1	0.46	33.8	11.4	90.2	0.015	0.500	0.077	0.300	0	Out	100	8.660	0.060	0.154	36.6%
DOT1	rg1	cb4	1.56	74.0	3.6	100.0	0.015	NA	0.096	NA	0	Out	100	NA	NA	NA	21.5%
Owner1	rg1	DOT1	2.24	590.0	9.9	42.4	0.015	0.246	0.069	0.215	0	Out	100	8.660	0.060	0.154	68.7%
Owner2	rg1	j136	0.37	65.5	7.8	67.8	0.014	0.366	0.050	0.254	0	Out	100	8.627	0.063	0.156	45.3%
Owner3	rg1	j21	0.11	32.0	3.3	100.0	0.013	NA	0.050	NA	0	Out	100	NA	NA	NA	19.9%
Owner4	rg1	outfall	1.15	169.0	12.1	47.7	0.015	0.340	0.050	0.247	0	Out	100	8.660	0.060	0.154	61.4%
Owner5	rg1	j9	0.55	81.0	13.4	71.1	0.013	0.374	0.051	0.256	0	Out	100	8.536	0.139	0.158	42.6%
CommonArea	rg1	cb9	0.58	61.0	9.8	76.3	0.016	0.385	0.052	0.253	0	Out	100	8.380	0.084	0.167	38.9%
Total Runoff																	51.5%

Table 6-5: Geodatabase Information for 1 Parcel Simulation

Subcatchment	Raingage	Outlet	Area (acres)	Width (ft)	% Slope	%-Imperv	N-Imperv	N-Perv	Dstore-Imperv	Dstore-Perv	%Zero-Imperv	Subarea Routing	% Routed	Sunction Head	Conductivity	Initial Deficit	% Control
1 Parcel	rg1	outfall	7.0	432.0	9.0	66.2	0.015	0.298	0.071	0.232	0	Out	100	8.632	0.067	0.155	51.8%

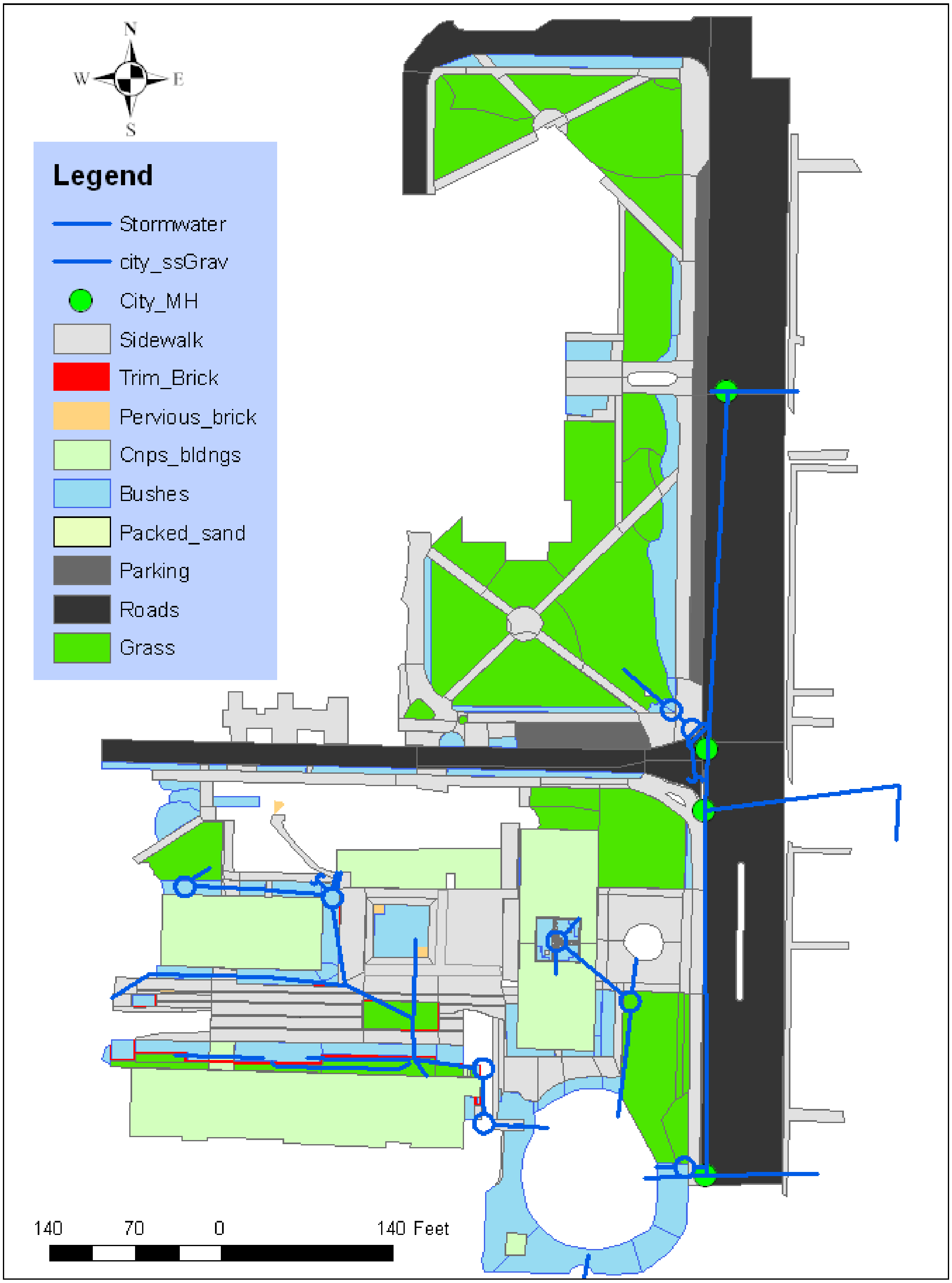

Figure 6-6: GIS Representation of Functional Elements for 390 Parcel Simulation

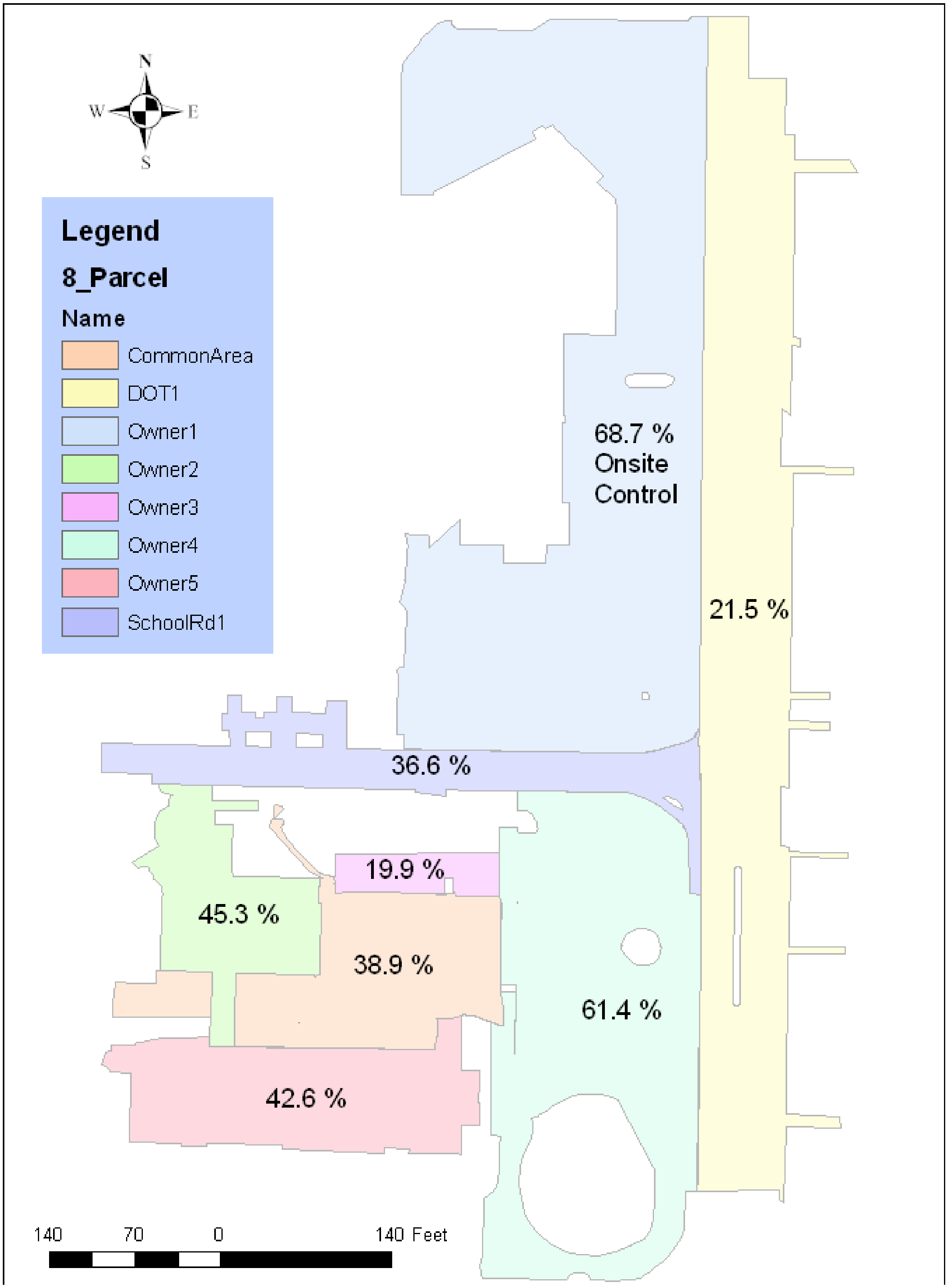

Figure 6-7: GIS Representation of 8 Parcels and Estimated % Runoff Control

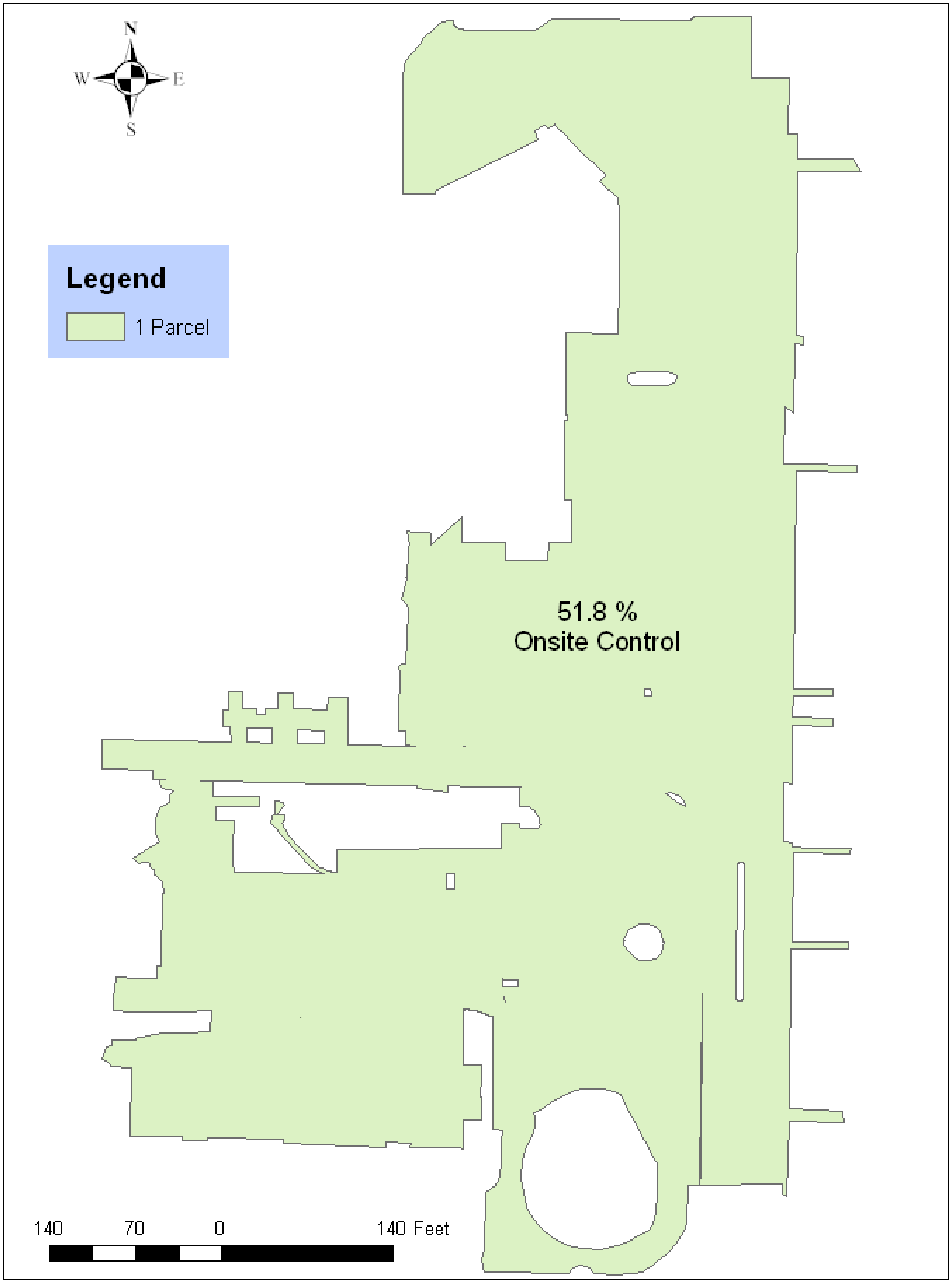

Figure 6-8: GIS Representation of 1 Parcel Simulation and % Runoff Control

Table 6-6: Rainfall-Runoff & Percent Onsite Control vs Aggregation Level

Item	Value	Units		Value	Units
Total rainfall depth	0.27	in		0.0%	% control
Total rainfall volume	6872.92	ft^3		0.0%	% control
Runoff Simulation 390 Parcels	3092.76	ft^3		55.0%	% control
Runoff Simulation 8 Parcels	3354.12	ft^3		51.2%	% control
Runoff Simulation 1 Parcel	3310.56	ft^3		51.8%	% control
Runoff Control (100% impervious)	5009.4	ft^3		27.1%	% control

All levels of aggregation show the study area meeting the necessary 50% onsite control as set out at the beginning of the study. However, only two of the eight fictitious parcel owners in the 8-parcel simulation show over 50% onsite control of rainfall on their area, with the DOT1 parcel receiving runoff from both Owner1 and SchoolRd1. This is represented in Table 6-7. The most right-hand column in Table 6-7 shows an increase in percent onsite control from 45.3% to 67.3% for the parcel denoted Owner2, achieved by routing 40% of the impervious area within the subcatchment to the pervious area within the same subcatchment.

Table 6-7: Percent Onsite Control Values for Each Subcatchment in 8 Parcel Simulation

Subcatchment	Rainfall (ft^3)	Runon	Runoff	% control before rerouting	% control after rerouting
SchoolRd1	446.6	0	283.258	36.6%	36.6%
DOT1	1531.3	968.6	1962.323	21.5%	21.5%
Owner1	2192.3	0	685.349	68.7%	68.7%
Owner2	358.9	0	117.492	45.3%	67.3%
Owner3	106.1	0	84.932	19.9%	19.9%
Owner4	1129.9	0	436.203	61.4%	61.4%
Owner5	538.3	0	308.944	42.6%	42.6%
CommonArea	569.5	0	347.902	38.9%	38.9%
Total	6872.9	NA	3257.796	51.5%	52.6%

If the same site owned by Owner2 were to be represented as functional units, then more educated decisions could be made about proper BMP placement. Figure 6-9 and Table 6-8 show the spatially disaggregated characteristics of parcel Owner2. By running the detailed simulation, it is seen that many of the bush areas are functioning as headwaters while GRS18 treats a volume of stormwater higher than the volume of direct precipitation that falls on the functional unit. Hence, a functional unit can provide over 100 % onsite control as shown in Table 6-9.

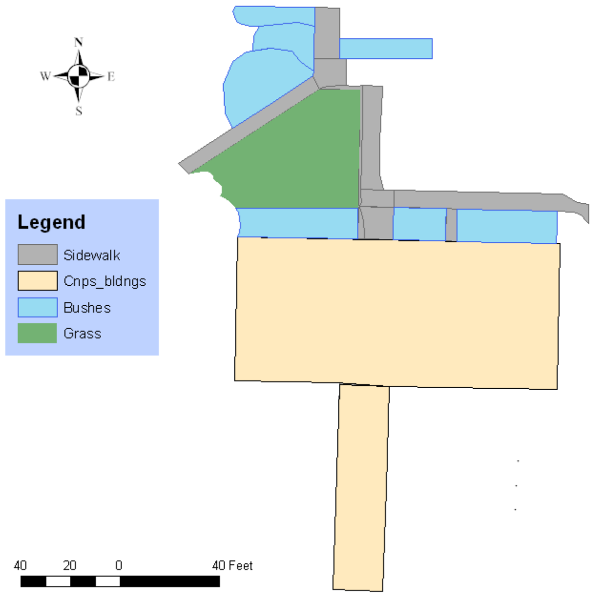

Figure 6-9: Detailed Spatial Representation of site Owner2

Table 6-8: Detailed Geodatabase Information for Site Owner2

Subcatchment	Raingage	Outlet	Area (acres)	Width (ft)	% Slope	%-Imperv	N-Imperv	N-Perv	Dstore-Imperv	Dstore-Perv	%Zero-Imperv	Subarea Routing	% Routed	Sunction Head	Conductivity	Initial Deficit
Bldng3	rg1	Bldng4	0.039	21.0	13.4	100	0.013	NA	0.050	NA	0	Out	100	NA	NA	NA
Bldng4	rg1	j20	0.176	59.0	5.5	100	0.013	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk84	rg1	GRS18	0.009	65.0	11.2	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk85	rg1	Sdwk117	0.001	5.0	9.5	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk92	rg1	GRS18	0.002	48.0	8.3	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk93	rg1	Sdwk118	0.004	12.0	12.7	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk99	rg1	Sdwk118	0.007	8.0	8.3	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk117	rg1	Sdwk115	0.012	7.5	7.7	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk118	rg1	Sdwk117	0.002	7.5	6.5	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk119	rg1	Sdwk84	0.003	13.5	9.9	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk120	rg1	sdwk119	0.005	10.0	10.6	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
Sdwk173	rg1	BSH28	0.001	13.0	24.4	100	0.016	NA	0.050	NA	0	Out	100	NA	NA	NA
BSH21	rg1	Sdwk117	0.006	21.0	10.1	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH22	rg1	Sdwk84	0.016	37.0	10.3	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH23	rg1	Sdwk120	0.007	12.0	13.1	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH26	rg1	Sdwk120	0.007	8.0	13.2	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH27	rg1	Sdwk120	0.005	6.0	21.2	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH28	rg1	GRS18	0.013	48.0	15.1	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
BSH29	rg1	BSH30	0.012	13.0	7.4	0	NA	0.500	NA	0.300	0	Out	100	8.660	0.060	0.154
GRS18	rg1	cb14	0.051	51.0	10.4	0	NA	0.200	NA	0.200	0	Out	100	8.660	0.060	0.154

Table 6-9: SWMM Simulation Runoff for Functional Units for Site Owner2

Functional unit	precip (in)	runon (in)	evap (in)	infilt (in)	runoff (in)	peak runoff	coeff runoff	% control	Headwater
Bldng3	0.27	0	0	0	0.22	0.07	0.817	18.5%	yes
Bldng4	0.27	0.048	0	0	0.268	0.35	0.843	18.5%	no
Sdwk84	0.27	0.212	0	0	0.438	0.03	0.91	16.3%	no
Sdwk85	0.27	0	0	0	0.223	0	0.827	17.4%	yes
Sdwk92	0.27	0	0	0	0.225	0	0.834	16.7%	yes
Sdwk93	0.27	0	0	0	0.224	0.01	0.828	17.0%	yes
Sdwk99	0.27	0	0	0	0.221	0.01	0.818	18.1%	no
Sdwk117	0.27	0.264	0	0	0.485	0.05	0.908	18.1%	no
Sdwk118	0.27	1.138	0	0	1.363	0.03	0.968	16.7%	no
Sdwk119	0.27	0.322	0	0	0.547	0.02	0.924	16.7%	no
Sdwk120	0.27	0	0	0	0.222	0.01	0.822	17.8%	no
Sdwk173	0.27	0	0	0	0.225	0	0.834	16.7%	yes
BSH21	0.27	0	0	0.27	0	0	0	100.0%	yes
BSH22	0.27	0	0	0.27	0	0	0	100.0%	yes
BSH23	0.27	0	0	0.27	0	0	0	100.0%	yes
BSH26	0.27	0	0	0.27	0	0	0	100.0%	yes
BSH27	0.27	0	0	0.27	0	0	0	100.0%	yes
BSH28	0.27	0.007	0	0.277	0	0	0	102.6%	no
BSH29	0.27	0	0	0.27	0	0	0	100.0%	yes
GRS18	0.27	0.084	0	0.354	0	0	0	131.1%	no

Discussion

Because all the simulations met the 50% onsite control criteria, no changes were made to either the 390 Parcel or the 1 parcel simulations. However, changes were made within the 8 Parcel simulation. The following paragraph discusses the implications of the changes made as well as the advantage to modeling at a functional element scale.

If the total percent onsite control for the eight parcel “neighborhood” is set at 50%, then it affords an opportunity to do one of two things: (1) cost share based upon the average percent onsite control for the entire study area, or (2) require each individual parcel owner to meet the onsite criteria. One cost sharing scenario could occur whereby the DOT, Owner2, Owner3, and Owner5 could pay Owner1 and Owner4 for a portion of their percent control using some basic cost sharing rules (Heaney 1997). Another cost sharing option would be for the owners to contribute to renovating the common area so as not to disturb their own properties but yet satisfy percent onsite control requirements jointly. If however, each land owner needed to provide 50% onsite control, then Owner2, for example, could route rooftop flow to the landscaped area which was found to have extra storage capacity for this small volume storm. This was simulated by routing 40% of the impervious area to the pervious area; however because, in the 8-parcel simulation, the roof is not represented as a separate functional element from the bushes and sidewalks on the parcel denoted Owner2, it is difficult to determine how much of the landscaped area's total capacity is used by the rooftop runoff. It is also difficult to measure possible flooding from a saturated landscape area onto the sidewalk surrounding it because water cannot be routed from the impervious to the pervious and back to the remaining impervious area. In contrast, the most detailed site information available would represent the same area owned by Owner2 as shown in Figure 6-9 and in tabular format in

Table 6-8. This representation allows for more discrete analyses wherein the percent contribution of runoff from the northern bushes to the diagonal sidewalk segment and subsequent runoff from the sidewalk, south, to the grass can be numerically identified separately from the percent contribution from the building rooftop. A graphical representation of the percent onsite control per functional unit in the Owner2 parcel of land is shown in Figure 6-10.

This graphical representation allows the user to site locations that may already function as good onsite control measures due one or more of the following (1) site drainage characteristics (2) infiltration, storage, and runoff parameters, and (3) spatial parameters. However, Figure 6-10 does not explicitly convey the network topology. It does however show that BSH21–27 and BSH29 are likely headwaters because they infiltrate exactly the amount of precipitation that falls upon them.

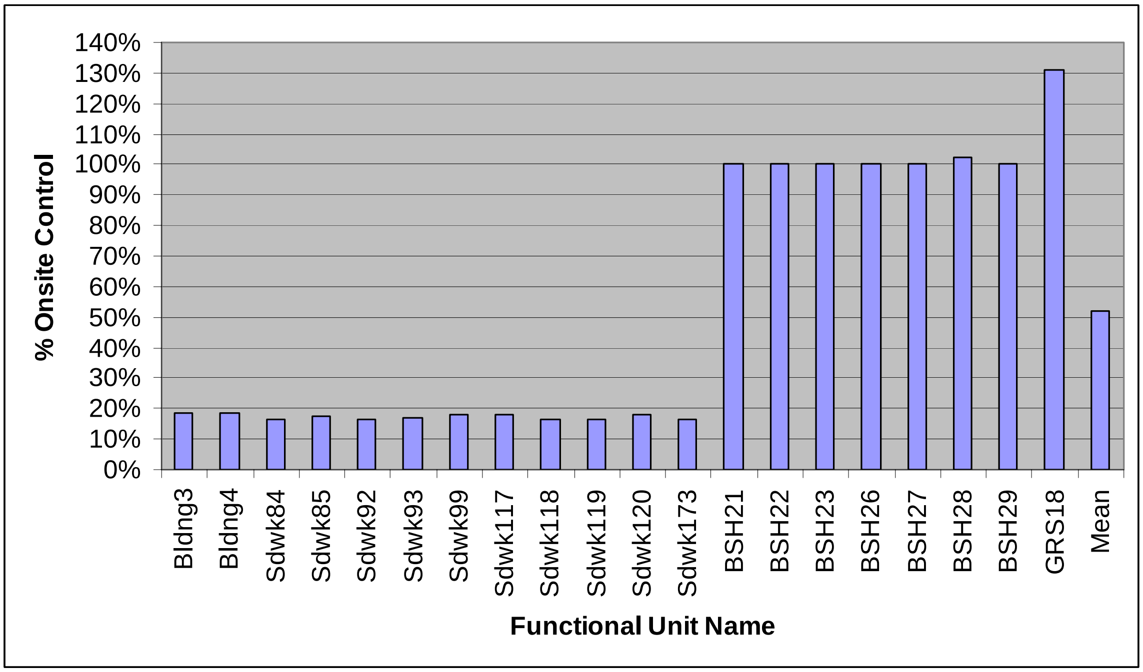

Figure 6-10: Chart of Percent Onsite Control per Functional Unit in Site Owner2

In the future, it may be possible, using ArcGIS software to create a network topology. This topology can be used to identify critical flowpaths in the future which allows for a more educated BMP siting. This does, however, allow one to experiment with redirecting flow from the building rooftops in site Owner2 through various bush (BSH) functional units to infiltrate a sufficient volume of water to meet 50 % onsite control at a minimum cost. An annual simulation can be used to provide a better value of percent onsite control and BMP performance by including storms ranging from the “micro” storms like 0.25 inches to larger storms over 1-2 inches. The next section will show how to obtain and apply annual rainfall data to the LA-2b 390 functional unit watershed simulation as well as show how runoff can be routed to more efficiently use BMPs.

Annual Simulation

The model developed for the LA-2b watershed in the previous section provides a sound foundation for testing BMPs quickly and easily, the simplest method of which is simply “trying out” different BMPs, for example increasing the infiltration of a sidewalk by decreasing its percent impervious area and augmenting the following parameters: depression storage, Manning’s n for surface flow, suction head (wetting front), conductivity, and/or initial deficit. This methodology is used to evaluate the annual performance of two onsite control methods in two different locations to determine which one meets percent onsite control requirements while minimizing cost.

Methodology

In order to test SWMM’s capability to assess average annual onsite BMP effectiveness, one year of rainfall-runoff analyses were necessary. One year of rainfall data were downloaded from the NOAA as described in Heaney et al. (2006) but an additional procedure was necessary to prepare the data for cataloging in Access. — A short visual basic for applications (VBA) script included in Appendix B-CODE 2 is designed to generate an .XML file from within Excel® by simply pasting the appended text into a macro. This file can then be opened in a database program like Access®. — Hourly rainfall data recorded at 0.01 inch depths for the year 2003 was then entered into the detailed 390 functional unit SWMM simulation along with monthly evaporation records, producing a runoff hydrograph.

BMPs were selected for use in the locations shown in the map below (Figure 6-11). Note that the bioretention BMP may service a maximum area bound in red and the permeable pavement may service the area bound in yellow. A matrix was developed to represent the two different BMPs and their properties (Table 6-10). The column labeled

DS represents depression storage values for the respective BMPs, in inches of depth. The column labeled *Conductivity* represents general infiltration properties for the BMP, in inches/hr. Values for *DS* and *Conductivity* were taken from the literature. Infiltration information was gathered from Pitt et al. (2002) and *DS* from Abida (2006). Porous pavement information was taken from The Low Impact Development Center (2005). Manning's n values were provided in the SWMM User's Manual documentation. A mock objective was designated as 20% onsite control, which could be met by using either one or both of the two BMPs.

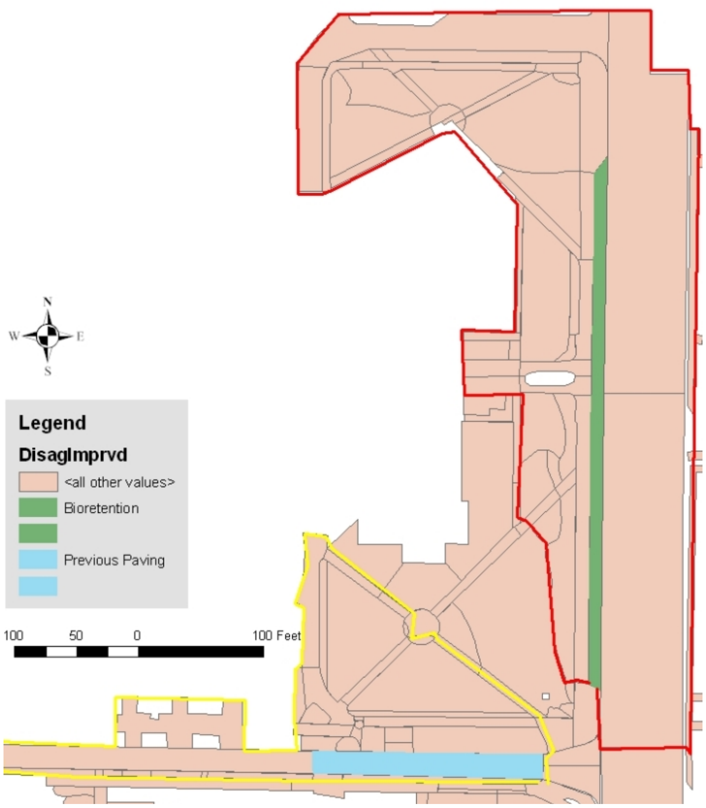

Figure 6-11: Contributing Watersheds for Three Different BMPs

Table 6-10: Annual Simulation BMP Comparison Matrix

BMP	Contributing Area (acres)	Mann n	DS (in)	Conductivity (in/hr)	Area BMP (acres)
Bioretention	2.116	0.2	.15	5	0.102
Porous pavement	0.7275	0.013	.16	6	0.081

Results

The total rainfall for the year 2003 in Gainesville, Fl was measured as 45.2 inches as published by the NCDC. In order to meet 20% onsite control, 9 inches of rainfall must be captured onsite, thus only 36.2 inches are allowed to run off. In volumetric terms, over the 6.1 acres of surface area, this is 800,691 ft^3 of runoff. Using the detailed SWMM model, entering the values shown in Table 6-10, the resultant outflow for the entire watershed was 880,792 ft^3 with no BMP. This shows that almost half of the required amount is met without any additional land use changes. Using the Bioretention BMP, the runoff volume was calculated to be 696,382 ft^3, well over the 20% threshold, reaching 30% onsite control for the LA-2b watershed. The runoff volume calculated when using the pervious paving is 791,224, or just over 20% onsite control.

Table 6-11 shows SWMM simulation output information for the two BMPs described previously in Table 6-10. Both BMPs control over 1000% of the precipitation that falls directly on their surface due to runon from the contributing watersheds.

Table 6-11: BMP Performance Matrix Output from Annual SWMM Simulation

BMP	precip (in)	runon (in)	evap (in)	infilt (in)	runoff (in)	peak runoff	coeff runoff	% control
Bioretention	45.263	665.73	1.178	502.219	207.709	3.35	0.292	1112%
Pervious Paving	45.263	443.59	0.974	474.285	57.971	1.05	0.118	1050%

An experiment was performed to determine the performance of the bioretention BMP if the lower stretch of 13th Street was unable to be rerouted into the bioretention BMP for some reason. This is the rectangular parcel directly to the right (East) of the lower half of the bioretention BMP shown in Figure 6-11. When sending this runoff directly to the outfall of the LA-2b watershed, the bioretention area only provides 842% onsite control because it has not been used to its optimal capacity for annual infiltration and evaporation (Table 6-12).

Table 6-12: Annual Evaluation of Bioretention Performance with Varying Contributing Area

BMP	precip (in)	runon (in)	evap (in)	infilt (in)	runoff (in)	peak runoff	coeff runoff	% control
bioretention	45.263	665.73	1.178	502.219	207.709	3.35	0.292	1112%
bioretention without lower DOT roadway section	45.263	432.751	1.178	380.111	96.807	2.09	0.203	842%

Discussion

The value of a certain BMP lay not only in its infiltration and depressional storage capacity but also in the location of the function unit within the watershed. This is shown by the comparison of percent onsite control when using the bioretention BMP to treat different runon contributing areas. While the BMP has the capacity to infiltrate far more than the direct precipitation on the BMP, it is used in a more cost effective manner when treating a larger surface area. Future work could involve using a drainage network in the GIS to identify key functional land units that receive significant annual volumes of runoff. These functional units could then be augmented to “overtreat” or treat an area larger than the functional unit itself, possibly resulting a lower cost than if a headwater was altered. Benefits can also be compared between two or more BMPs within a watershed. For example, the comparison of bioretention and permeable paving functional units in Table 6-11 shows that the bioretention facility, while providing a comparable percent onsite control in terms of the ratio of runon treated to direct precipitation, it does not reflect percent control for the entire watershed. Thus, because the bioretention area receives runoff from a larger area of the watershed than the permeable paving area (665 vs. 443 inches runon), it provides a greater service to the LA-2b watershed. Its larger area also allows for a larger volume of evaporation from the BMP. Thus, the performance of a BMP (represented as a functional unit) within the watershed is based on (1) site drainage flow paths (2) infiltration, storage, and runoff parameters of the BMP, and (3) spatial parameters of the BMP. All of these can be represented and manipulated using ArcGIS and/or EPA SWMM to achieve a high performing BMP implementation.

Conclusions

Most of the data obtained for this study were readily available from the University of Florida and City of Gainesville, most significantly being the topographic data as well as building and sidewalk shapefiles. While literature values were used for Manning’s n, depression storage, and Green-Ampt parameters, it is easy to obtain a few key point infiltration estimates within the study area and to determine if depression storage should be better characterized by performing a sensitivity analysis in the future.

Breaking a site into functional elements is not very difficult considering the pervasiveness of CAD data used to generate stormwater routing information, landscape and landscape architecture maps, and other structural information such as building/drivewalk/sidewalk boundaries. The rule of percent onsite control is well suited for urban retrofit environments but future research can explore the scalability of simulation information to draw more general conclusions about the effect of a BMP on a larger watershed.

The optimal simulation scenario involves creating a number of small manageable simulations for subwatersheds (7 acres) within a larger watershed (300 acres) and grouping or scaling them to apply to the larger watershed. Components of each simulation can be aggregated (simplified) and disaggregated in a centralized geographic information system (GIS) and BMPs can be chosen based on desired goals and first principles. If “Owner2,” as described in the single event simulation section of this chapter, were to redevelop the property Owner2, he/she could work with design professionals to develop a site design that satisfies his/her needs and meets the onsite control requirements. It is shown that the SWMM model can be used to evaluate the expected performance of this design. While cost equations were not explicitly applied to these analyses, some cost-related conclusions can be made to in-part satisfy “Step 4” of the LID Center LID Planning Process when comparing BMPs in the annual simulation.

The cost of removing currently available hardscape surface parking along 13th Street and replacing it with a bioretention strip may be, for the purposes of this example, stated as comparatively more expensive than replacing current road surface with pervious pavement on a section of Inner Rd on campus, based on literature research from the Low Impact Development Center and the Federal Highway Administration (2002) and the cost of parking on the University of Florida campus. Furthermore, while both the pervious paving and bioretention BMPs met onsite control requirements in the annual event simulation, the question of which one is more cost effective in terms of site goals and characteristics suggests that the bioretention strip should be used because it provides 10% more than the required 20% onsite control stated in the problem statement of the annual simulation section, above.

The extra control may provide future capacity or capacity that may be tradeable with other watersheds within the larger Lake Alice Watershed. An ancillary benefit to selecting the bioretention BMP is that it in-part addresses University Master Plan Policy 1.2.8 mentioned in Chapter 4. However, installing the bioretention strip removes parking space for the University. These costs and benefits can thus be weighed against each other effectively after knowing runoff values using highly detailed long-term watershed simulations.

CHAPTER 7
SUMMARY AND CONCLUSIONS

This thesis can be thought of as a microcosm of environmental research today. Many dissimilar tasks need to be performed because they are interrelated. Chapter 2 discusses current LID characteristics and criteria followed by a thorough review of different onsite control methods used in an urban watershed. Detailed descriptions of many properties in the University Heights Redevelopment District within the Tumblin Creek Watershed form a mini-database, albeit a non-searchable one. It is shown in chapter 2 that BMPs are ubiquitous but are often not called BMPs or are not intended as onsite stormwater control methods when installed. This is especially true of older buildings throughout the Tumblin Creek Watershed. It is seen that even one parcel of land can be represented by multiple functional land units such as those shown in Heritage Oaks. Chapter 3 describes the cyberinfrastructure necessary to organize data like those collected in chapter 2 for group discussion and authoring. It is shown that data can also be analyzed using a centralized system. A demonstration is provided showing how open source tools are also available to assist in collaboration but other products may provide better security tools and allow for the use of an ontology to promote future compatibility with other institutions. Chapters 4, 5, and 6 show that small scale site analyses provide the best chance of obtaining manageable and minable high quality site data. These chapters also implement the LID Center's LID analysis framework, a tool for guiding BMP decision making. Chapter 4 describes how University of Florida policy indicates that the University is very interested in innovative onsite control methods and encourages active research and implementation in this field. This may provide an excellent opportunity for a renowned stormwater research network at the University, provided there is a strong cyberinfrastructure to facilitate collaboration. Chapter 5 provides a primer of the EPA SWMM 5 urban watershed simulation tool. Chapter 6 shows how the SWMM tool can be used to simulate BMPs at the functional land unit level. It also shows how site data can be aggregated and disaggregated quickly using a GIS without greatly affecting results of small single event simulations. The section entitled “Annual Simulation” within Chapter 6 shows the power of simulating at the functional unit level by expressing a BMPs performance in terms of (1) contributing watershed area and surface type (2) infiltration, storage, and runoff parameters of the BMP, and (3) spatial parameters of the BMP. In the context of regulatory conduct both on campus and in the Gainesville community, percent onsite control thus provides a unique and simple way of viewing the traditional rainfall-runoff relationship wherein the percent onsite control of rainfall can be used as a credit by focusing on the storage and infiltration capacity rather than runoff produced. Landscaping, natural areas, and other pervious areas potentially can receive credit not only for controlling the rainfall that falls on them but in many cases for runon from upstream land surfaces.

The tasks of information gathering, data manipulation and calculation, collaborative engineering, etc., although distinctly different, all need to be mastered to some degree in order to fully understand how to build a decision support system that enables everyday users to make decisions about which stormwater BMPs to implement and why. In performing research for chapter 2, the author participated in a Gainesville Stormwater Workshop where it was apparent that the information gathered about LID implementations in even a very small part of the City of Gainesville is very useful to developers, contractors, landscape architects, stormwater engineers, and planners. It also served to show the varied tools each discipline can bring to the table.

The “optimal” solution may not always be the lowest cost solution because there are multiple interests at stake when building or redeveloping property and since it is nearly impossible to know enough about all aspects of development, working groups of easily connected individuals are vital to implementing BMPs that satisfy all needs as well as possible.

In the context of the future of Lake Alice, the lake itself may also one day face water quality concerns and the LAW is already facing erosion and sedimentation problems. It has been shown that with the proper tools and data, BMP performance predictions can be made quickly and precisely, still using rigorous computational analyses. It is hoped that in the future, provided two major components of a good cyber infrastructure, namely a quality database of spatial information and proper software, a person can characterize their own watershed within the LAW quickly and easily without mining data that were previously mined. As described in chapter 6, it is vitally important that this is done on a site by site scale such as a one acre lot in the Tumblin Creek watershed or building by building in the LAW. The process should begin at a headwater, and the input/output data, reports, and models should be made available in a format that facilitates a synergy of modular research findings to draw more global conclusions.

There are a number of future research possibilities that use the SWMM detailed site modeling methodology described in Chapter 6. Parameters such as suction head and initial deficit were not measured in the field. These parameters are generally gathered for the Green-Ampt equation by documenting the subsurface soil type and looking up related literature values. A sensitivity analysis performed on these and other parameters needed by SWMM affect runoff values. Future research involving multi-event runoff analyses can be used to compare percent onsite control of the LA-2b watershed between the three levels of aggregation described in Chapter 6 under various event volumes and intensities. Results from such research could determine if aggregated watershed models produce rainfall-runoff relationships comparable to the highly disaggregated simulation during larger storm events.

Although water quantity control was discussed to this point, water quality control is of high importance as well. The concept of percent onsite control need not apply only to water volume control. Future research can use SWMM to simulate loading released (and loading captured) by a subcatchment of any size. Just as with water quantity, the ability to represent a subcatchment as both a control and a source allows one to simulate a path of pollutant or nutrient transfer throughout the watershed and place a BMP in the optimal location so as to control water quantity, quality, or both.

APPENDIX A
REGULATIONS PERTAINING TO LAKE ALICE

Clean Water Act

The University of Florida has written a succinct summary of the Clean Water Act (CWA) and its implications for the Lake Alice Watershed (LAW) and Tumblin Creek Watershed (TCW). The document states “This legislation gives the U.S. Environmental Protection Authority (EPA) the responsibility for setting national water quality standards to protect public health and welfare, while giving states the job of determining how best to meet those standards” (University of Florida 2006b). In Florida, The Florida Department of Environmental Protection (FDEP) has oversight over the five water management districts. The LAW falls within the jurisdiction of the Saint John’s River Water Management District (SJRWMD). It is the responsibility of the SJRWMD to ensure water quality is acceptable under the CWA. It does this by creating water quality and quantity rules, creating design manuals, and monitoring both point and non-point source discharges. Point discharges are nominally from sewage facilities and non-point is nominally surface runoff. As described in more detail in University of Florida (2006b), the state has created two programs that impact the University of Florida: the Total Maximum Daily Load (TMDL) and National Pollutant Discharge Elimination System (NPDES) programs. The TMDL program affects the University outside of the LAW such as in the neighboring TCW and it requires the state to develop TMDLs for pollutants of identified impaired waters. The NPDES program (found in section 402 of the CWA) does apply to the LAW and allows the EPA to regulate pollution discharge into water bodies. A permit must be obtained to discharge from municipal separate storm sewer systems (MS4s) when constructing or redeveloping. At the university, school programs and research by Dr. Mark Clark and others has partially fulfilled the following requirements: public participation, illicit discharge detection and elimination, public education and outreach, construction site runoff control, post-construction runoff control and pollution prevention/good housekeeping (Clark 2006).

Florida Statute 373

While not able to find Section 120.373 of the FS as mentioned in the 2006 Master Plan, Chapter 373 concerns water resources of Title 28. The University is affected by 373.4142 in that Lake Alice is considered a stormwater treatment pond. Florida Senate (2005a) says “State surface water quality standards applicable to waters of the state, as defined in s. 403.031(13), shall not apply within a stormwater management system which is designed, constructed, operated, and maintained for stormwater treatment in accordance with a valid permit or noticed exemption issued pursuant to chapter 17-25, Florida Administrative Code.” This only applies to “that part of the stormwater management system located upstream of a manmade water control structure permitted, or approved under a noticed exemption, to retain or detain stormwater runoff in order to provide treatment of the stormwater” (Florida Senate 2005a). Essentially, this means that the University has to meet water quality regulations at the drainage wells, the points of discharge from Lake Alice into groundwater. The University is also affected by the following statement (also located in s. 373.4142): “This section shall not affect the authority of the department and water management districts to require reasonable assurance that the water quality within such stormwater management systems will not adversely impact public health, fish and wildlife, or adjacent waters" (Florida Senate 2005a). Hence, water quality control should be a concern in addition to water quantity if the water management district were to find any troubling results.

Florida Statute 403

Chapter 403 of the Florida Statutes contains policy concerning water resources restoration, pollution control of surface waters, water reuse, etc. Legislation pertaining to the water budget at Lake Alice are 403.085, which states that a sanitary sewage plant that discharges effluent through disposal wells "shall provide for secondary waste treatment and, in addition thereto, advanced waste treatment as deemed necessary and ordered by the former Department of Environmental Regulation," (Florida Senate 2005b) and section 403.0885 which concerns NPDES programs, stating that "…it is in the public interest to promote effective and efficient regulation of the discharge of pollutants into waters of the state and eliminate duplication of permitting programs by the United States Environmental Protection Agency under s. 402 of the Clean Water Act...." (Florida Senate 2005b). These apply because the university discharges unreused wastewater into a groundwater well and Lake Alice receives stormwater runoff and drains into a one of two groundwater wells, ultimately draining into a water of the state, as defined by the FS.

Florida Administrative Code 62-3

This code has been repealed

Florida Administrative Code 62-25

This code contains design and Performance Standards. 62-25.025 states that "No discharge from a stormwater discharge facility shall cause or contribute to a violation of water quality standards in waters of the state" and that "Detention basins shall again provide the capacity for the specified treatment volume of stormwater within 72 hours following a storm event," (Florida Department of State 2005) establishing basic water quality and quantity criteria for Lake Alice. 62-25.001 also states that "Stormwater discharges to groundwaters shall be regulated under the provisions of Chapters 62-520 and 62-522, F.A.C., and other applicable rules of the Department" (Florida Department of State 2005).

Florida Administrative Code 62-520

62-520.410 defined a CLASS G-II groundwater as water for potable use and that "which has a total dissolved solids content of less than 10,000 mg/l, unless otherwise classified by the Commission" (Florida Department of State 2005). Lake Alice drains into G-II groundwater. While 62-520.420 states that water discharging into G-II groundwater must meet primary and secondary drinking water standards, Lake Alice is exempt according to 62-520.520 which states "An existing installations discharging to Class G-II ground water is exempt from compliance with secondary drinking water standards unless the Department determines that compliance with one or more secondary standards by such installation is necessary to protect ground water used or reasonably likely to be used as a potable water source" (Florida Department of State, 2005). Therefore, discharged water must contain a total dissolved solids (TDS) content of less then 10,000 mg/L and a total coliform standard of 4 per 100 mL as well as meeting primary drinking water standards established pursuant to the Florida Safe Drinking Water Act. (FAC, 2003, (62-550)). In addition to inorganic toxicity levels, 62-550.310 states that "The maximum contaminant level for nitrate (as N) applicable to transient non-community water systems is 10 milligrams per liter" (Florida Department of State 2005).

Florida Administrative Code 62-522

FAC section 62-522 provides a groundwater monitoring methodology for sources of groundwater discharge. "On a quarterly basis thereafter, or such other frequency specified in the permit, the permittee shall submit reports on all monitoring wells indicating the type, number and concentration of discharge constituents or parameters…that have been approved by the Department as appropriate criteria to monitor in the monitoring program based upon their potential to exceed the minimum criteria contained in Rule 62-520.400, F.A.C., and the appropriate standards for the particular class of water adjacent to the zone of discharge as described in Rules 62-520.420 through 62-520.460, F.A.C." (Florida Department of State 2005).

Florida Administrative Code 62-40

Section 62-40.310 of the FAC states that water management programs should seek to: "Encourage nonstructural solutions to water resource problems and consider nonstructural alternatives whenever structural works are proposed" (Florida Department of State, 2005). This lays the foundation for so called soft-BMPs, or BMPs that are practices rather than structures. Section 62-40.432 provides a presumptive criteria for the LAW SMS system by stating "When a stormwater management system complies with rules establishing the design and performance criteria for such systems, there shall be a rebuttable presumption that the discharge from such systems will comply with state water quality standards" (Florida Department of State 2005). However, the same section also states that "The Department and the Districts…shall, when adopting rules pertaining to stormwater management systems, specify design and performance criteria for new stormwater management systems which: 1. Achieve at least 80 percent reduction of the average annual load of pollutants that would cause or contribute to violations of state water quality standards. 2. Achieve at least 95 percent reduction of the average annual load of pollutants that would cause or contribute to violations of state water quality standards in Outstanding Florida Waters" (Florida Department of State 2005). Section 62-40.540 states that "Appropriate monitoring of water quality and water withdrawal shall be required of permittees" (Florida Department of State, 2005). This suggests that while the permit may be presumptive, water quality monitoring is still necessary.

APPENDIX B
PROGRAMMATIC CODE

CODE 1

The following Visual Basic for Applications code is the source code for the GIS2SWMM tool presented in this thesis.

```
' GIS2SWMM (C) 2005 Ruben Kertesz

'This program is free software; you can redistribute it and/or
'modify it under the terms of the GNU General Public License
'as published by the Free Software Foundation; either version 2
'of the License, or (at your option) any later version.

'This program is distributed in the hope that it will be useful,
'but WITHOUT ANY WARRANTY; without even the implied warranty of
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'The author may be contacted by email at rubenk@ufl.edu or rubenkertesz@hotmail.com
'You may also contact Ruben by post at P.O. Box 116450; Gainesville FL 32611


Option Explicit
' make these global variables
  Dim pMxDoc As IMxDocument ' Create pointer object to identify doc
  Dim pMap As IMap ' point to map
  Dim pFeatureLayer As IFeatureLayer ' point to layer
  Dim pFeatureClass As IFeatureClass ' point to type of feature in layer
  Dim pLayer As ILayer ' point to layer
 ' Dim txtOutput2 As String
  'Dim txtOutput3 As String
  Dim strArray1() As String ' holds the selected layer's attributes for swmm
  Dim strArray2() As String ' hold x/y data for export to swmm
  Dim strReturn As String ' return command
  Dim lstcbxCol As New Collection  '- publicly dimmed
  Dim lstcbxCov As New Collection  '- publicly dimmed
  Dim lsttxtCol As New Collection
  Dim lsttxtCov As New Collection
  Dim lstLabels As New Collection
```

```
  Dim lstCovLabels As New Collection
  Dim R As Long ' R represents the numer of rows or feature records in the current layer
  Dim RPoints As Long ' RPoints represents the numer of rows of Point (Vertex) Records in the current
layer

Private Sub lblWetStep_Click()

End Sub

Private Sub optCovNo_Click()
    optCovYes = False
End Sub

Private Sub optCovYes_Change()
    If optCovYes = True Then
        frameCoverages.Enabled = True ' contains sweeping parameters
        frameCoverages.Visible = True ' contains sweeping parameters
    Else
        frameCoverages.Enabled = False
        frameCoverages.Visible = False

        cbxCovSubc.Enabled = False
        TextBox53.Enabled = False

        Dim cbxCovObj As ComboBox
        Dim txtCovObj As TextBox

        For Each cbxCovObj In lstcbxCov
            cbxCovObj.Enabled = False
        Next cbxCovObj

        For Each txtCovObj In lsttxtCov
            txtCovObj.Enabled = False
        Next txtCovObj

    End If
End Sub


Private Sub UserForm_Initialize()

Dim Num As Long
    For Num = 1 To lstcbxCol.Count
        lstcbxCol.Remove 1
    Next
    For Num = 1 To lstcbxCov.Count
        lstcbxCov.Remove 1
    Next
    For Num = 1 To lsttxtCol.Count
        lsttxtCol.Remove 1
    Next
    For Num = 1 To lsttxtCov.Count
        lsttxtCov.Remove 1
    Next
    For Num = 1 To lstLabels.Count
        lstLabels.Remove 1
```

```
Next
For Num = 1 To lstCovLabels.Count
   lstCovLabels.Remove 1
Next

R = 0 ' used to set matrix at 0 to 0 initially
RPoints = 0

strReturn = Chr(13) & Chr(10) ' return command

' THIS IS FOR THE 1ST PAGE \/ \/ \/
cbxFlow.AddItem "CFS" ' flow units
cbxFlow.AddItem "GPM"
cbxFlow.AddItem "MGD"
cbxFlow.AddItem "CMS"
cbxFlow.AddItem "LPS"
cbxFlow.AddItem "MLD"
cbxFlow.ListIndex = 0

cbxInfilt.AddItem "HORTON" ' infiltration
cbxInfilt.AddItem "GREEN_AMPT"
cbxInfilt.AddItem "CURVE_NUMBER"
cbxInfilt.ListIndex = 0

cbxRouting.AddItem "STEADY" ' routing method
cbxRouting.AddItem "KINWAVE"
cbxRouting.AddItem "DYNWAVE"
cbxRouting.ListIndex = 0

cbxPonding.AddItem "YES" ' allow ponding?
cbxPonding.AddItem "NO"
cbxPonding.ListIndex = 0

cbxInertialDamp.AddItem "NONE" ' damping
cbxInertialDamp.AddItem "PARTIAL"
cbxInertialDamp.AddItem "FULL"
cbxInertialDamp.ListIndex = 0

cbxCompat.AddItem "5" ' compatibility
cbxCompat.AddItem "4"
cbxCompat.AddItem "3"
cbxCompat.ListIndex = 0

'THIS IS FOR THE FIRST PAGE ^ ^ ^ ^
'-------------------------------------------------
'THIS IS FOR THE SECOND PAGE \/ \/ \/ \/


 ' Get all the layers in the Map and populate combobox
  Set pMxDoc = ThisDocument 'Application.Document
  Set pMap = pMxDoc.FocusMap ' get ahold of the map
  Set pFeatureLayer = pMap.Layer(0) ' get ahold of the layer

  Dim intlayernumber As Integer ' calcs total number of layers
   intlayernumber = pMap.LayerCount - 1 '
```

```
    Dim i As Long
        For i = 0 To intlayernumber
          If TypeOf pMap.Layer(i) Is FeatureLayer Then
            Set pFeatureLayer = pMap.Layer(i) ' point to selected layer
            cbxSelectLayer.AddItem pFeatureLayer.Name ' populates listbox


          End If
        Next i ' next layer

     cbxSelectLayer.ListIndex = 0 ' selects top of list also calls cbxselectlayer when form loads
    'Call cbxSelectLayer_Change

End Sub

Private Sub cbxInfilt_Change()

'  NEed to put code in here that says (if there is info in the rightr bar in step 2:
' This will erase all Features that you have already added in step two.
' If this is okay, click OK.


' Only allows user to enter values on step 2 for the chosen parameter in step 1'
   If cbxInfilt.List(cbxInfilt.ListIndex) = "HORTON" Then

      MultiPage2.Item(0).Enabled = True
      MultiPage2.Item(1).Enabled = False
      MultiPage2.Item(2).Enabled = False

      MultiPage2.Item(0).Visible = True
      MultiPage2.Item(1).Visible = False
      MultiPage2.Item(2).Visible = False
      MultiPage2.Value = 0 ' goes to the 1st tab

   ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "GREEN_AMPT" Then
      MultiPage2.Item(0).Enabled = False
      MultiPage2.Item(1).Enabled = True
      MultiPage2.Item(2).Enabled = False

      MultiPage2.Item(0).Visible = False
      MultiPage2.Item(1).Visible = True
      MultiPage2.Item(2).Visible = False
      MultiPage2.Value = 1 ' goes to the 2nd tab

   ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "CURVE_NUMBER" Then
      MultiPage2.Item(0).Enabled = False
      MultiPage2.Item(1).Enabled = False
      MultiPage2.Item(2).Enabled = True

      MultiPage2.Item(0).Visible = False
      MultiPage2.Item(1).Visible = False
      MultiPage2.Item(2).Visible = True
      MultiPage2.Value = 2 ' goes to the 3rd tab
   End If
```

```
End Sub
Private Sub cmdCancelTitOpt_Click()
  Unload Me
End Sub

Private Sub cmdContinueTitOpt_Click()
  MultiPage1.Value = 1 ' goes to the 2nd tab
End Sub

Private Sub cbxRouting_Change()
  If cbxRouting.List(cbxRouting.ListIndex) = "DYNWAVE" Then
    frameIfDynamic.Visible = True ' contains parameters associated with dynamic wave

    If txtRouteStep.Text = "00:05:00" Then
      txtRouteStep.Text = "00:01:00" ' contains wet routing timestep
    End If

    MsgBox "With Dynamic Wave, use a short route step."

  Else
    frameIfDynamic.Visible = False
  End If
End Sub

Private Sub optSwpYes_Change()
  If optSwpYes = True Then
    frameSweeping.Visible = True ' contains sweeping parameters
  Else
    frameSweeping.Visible = False
  End If
End Sub
Private Sub optSwpNo_Click()
  optSwpYes = False
End Sub

' --\/-- Page "Step 2" ------\/----- '

  Private Sub cbxSelectLayer_Change()
  Dim i As Integer
  i = cbxSelectLayer.ListIndex ' selected layer

   Set pMxDoc = ThisDocument 'Application.Document
   Set pMap = pMxDoc.FocusMap ' get ahold of the map
   Set pFeatureLayer = pMap.Layer(i) ' points to layer selected in cbxSelectLayer combobox
   Set pFeatureClass = pFeatureLayer.FeatureClass ' need to keep this for the record count routine later



  'Depending on layer that is selected, show certain options in cbxLayerType
   ' Polygon
   If pFeatureLayer.FeatureClass.ShapeType = esriGeometryPolygon Then
     cbxLayerType.Clear
     cbxLayerType.AddItem "Subcatchment"

    'Point
```

```
        ElseIf pFeatureLayer.FeatureClass.ShapeType = esriGeometryPoint Or
pFeatureLayer.FeatureClass.ShapeType = esriGeometryMultipoint Then
         cbxLayerType.Clear
         cbxLayerType.AddItem "Raingage"
         cbxLayerType.AddItem "Junction"
         cbxLayerType.AddItem "Outfall"
         cbxLayerType.AddItem "Weir"

         'Line
        ElseIf pFeatureLayer.FeatureClass.ShapeType = esriGeometryLine Or
pFeatureLayer.FeatureClass.ShapeType = esriGeometryPolyline Then
         cbxLayerType.Clear
         cbxLayerType.AddItem "Conduit"
      End If

    cbxLayerType.ListIndex = 0 'select the first one in the list also calls the layertype program
'    Call cbxLayerType_Change

End Sub

Private Sub cbxLayerType_Change()

Dim Num As Long
    For Num = 1 To lstcbxCol.Count
        lstcbxCol.Remove 1
    Next
    For Num = 1 To lstcbxCov.Count
        lstcbxCov.Remove 1
    Next
    For Num = 1 To lsttxtCol.Count
        lsttxtCol.Remove 1
    Next
    For Num = 1 To lsttxtCov.Count
        lsttxtCov.Remove 1
    Next
    For Num = 1 To lstLabels.Count
        lstLabels.Remove 1
    Next
    For Num = 1 To lstCovLabels.Count
        lstCovLabels.Remove 1
    Next


    If cbxLayerType.Text = "Subcatchment" Then
        framePolygon.Visible = True ' allows user to view polygon frame

       ' Dim lstcbxCol As New Collection  '- publicly dimmed
        lstcbxCol.Add cbxSubName
        lstcbxCol.Add cbxSubRain
        lstcbxCol.Add cbxSubOut
        lstcbxCol.Add cbxSubTotArea
        lstcbxCol.Add cbxSubPctImp
        lstcbxCol.Add cbxSubWidth
        lstcbxCol.Add cbxSubPctSlope
        lstcbxCol.Add cbxSubCrbLen
        lstcbxCol.Add cbxSubSnow
```

```
    lstcbxCol.Add cbxSubAName
    lstcbxCol.Add cbxSubANImp
    lstcbxCol.Add cbxSubANPerv
    lstcbxCol.Add cbxSubASImp
    lstcbxCol.Add cbxSubASPerv
    lstcbxCol.Add cbxSubAPctZero
    lstcbxCol.Add cbxSubARoute
    lstcbxCol.Add cbxSubAPctRouted

    lstcbxCol.Add cbxHortSubcat
    lstcbxCol.Add cbxHortMaxRate
    lstcbxCol.Add cbxHortMinRate
    lstcbxCol.Add cbxHortDecay
    lstcbxCol.Add cbxHortDryT
    lstcbxCol.Add cbxHortMaxInf

    lstcbxCol.Add cbxGASubcat
    lstcbxCol.Add cbxGACapSuc
    lstcbxCol.Add cbxGACond
    lstcbxCol.Add cbxGAInitDef

    lstcbxCol.Add cbxCNSubcat
    lstcbxCol.Add cbxCNCN
    lstcbxCol.Add cbxCNCond
    lstcbxCol.Add cbxCNDryT
    lstcbxCol.Add cbxGWName
    lstcbxCol.Add cbxGWAquifer
    lstcbxCol.Add cbxGWNPerv
    lstcbxCol.Add cbxGWNode
    lstcbxCol.Add cbxGWSurf
    lstcbxCol.Add cbxGWA1
    lstcbxCol.Add cbxGWB1
    lstcbxCol.Add cbxGWA2
    lstcbxCol.Add cbxGWB2
    lstcbxCol.Add cbxGWA3
    lstcbxCol.Add cbxGWTW

'   lstcbxCov.Add cbxCovSubc
    lstcbxCov.Add cbxCovLU1
    lstcbxCov.Add cbxCovLU2
    lstcbxCov.Add cbxCovLU3
    lstcbxCov.Add cbxCovLU4
    lstcbxCov.Add cbxCovLU5
    lstcbxCov.Add cbxCovLU6
    lstcbxCov.Add cbxCovLU7
    lstcbxCov.Add cbxCovLU8
    lstcbxCov.Add cbxCovLU9
    lstcbxCov.Add cbxCovLU10
    lstcbxCov.Add cbxCovLU11
    lstcbxCov.Add cbxCovLU12
    lstcbxCov.Add cbxCovLU13
    lstcbxCov.Add cbxCovLU14
    lstcbxCov.Add cbxCovLU15
    lstcbxCov.Add cbxCovLU16
    lstcbxCov.Add cbxCovLU17
```

```
lstcbxCov.Add cbxCovLU18
lstcbxCov.Add cbxCovLU19
lstcbxCov.Add cbxCovLU20
lstcbxCov.Add cbxCovLU21
lstcbxCov.Add cbxCovLU22
lstcbxCov.Add cbxCovLU23
lstcbxCov.Add cbxCovLU24
lstcbxCov.Add cbxCovLU25
lstcbxCov.Add cbxCovLU26
lstcbxCov.Add cbxCovLU27
lstcbxCov.Add cbxCovLU28
lstcbxCov.Add cbxCovLU29
lstcbxCov.Add cbxCovLU30

 '----------------------

lsttxtCol.Add TextBox5
lsttxtCol.Add TextBox6
lsttxtCol.Add TextBox7
lsttxtCol.Add TextBox8
lsttxtCol.Add TextBox9
lsttxtCol.Add TextBox10
lsttxtCol.Add TextBox11
lsttxtCol.Add TextBox12
lsttxtCol.Add TextBox13
lsttxtCol.Add TextBox14
lsttxtCol.Add TextBox15
lsttxtCol.Add TextBox16
lsttxtCol.Add TextBox17
lsttxtCol.Add TextBox18
lsttxtCol.Add TextBox19
lsttxtCol.Add TextBox20
lsttxtCol.Add TextBox21

lsttxtCol.Add TextBox23
lsttxtCol.Add TextBox24
lsttxtCol.Add TextBox25
lsttxtCol.Add TextBox26
lsttxtCol.Add TextBox27
lsttxtCol.Add TextBox28

lsttxtCol.Add TextBox30
lsttxtCol.Add TextBox31
lsttxtCol.Add TextBox32
lsttxtCol.Add TextBox33

lsttxtCol.Add TextBox34
lsttxtCol.Add TextBox35
lsttxtCol.Add TextBox36
lsttxtCol.Add TextBox37

lsttxtCol.Add TextBox38
lsttxtCol.Add TextBox39
lsttxtCol.Add TextBox40
lsttxtCol.Add TextBox41
lsttxtCol.Add TextBox42
```

```
lsttxtCol.Add TextBox43
lsttxtCol.Add TextBox44
lsttxtCol.Add TextBox45
lsttxtCol.Add TextBox46
lsttxtCol.Add TextBox47
lsttxtCol.Add TextBox48

lsttxtCov.Add TextBoxLUT1
lsttxtCov.Add TextBox54
lsttxtCov.Add TextBoxLUT2
lsttxtCov.Add TextBox55
lsttxtCov.Add TextBoxLUT3
lsttxtCov.Add TextBox56
lsttxtCov.Add TextBoxLUT4
lsttxtCov.Add TextBox57
lsttxtCov.Add TextBoxLUT5
lsttxtCov.Add TextBox58
lsttxtCov.Add TextBoxLUT6
lsttxtCov.Add TextBox59
lsttxtCov.Add TextBoxLUT7
lsttxtCov.Add TextBox60
lsttxtCov.Add TextBoxLUT8
lsttxtCov.Add TextBox61
lsttxtCov.Add TextBoxLUT9
lsttxtCov.Add TextBox62
lsttxtCov.Add TextBoxLUT10
lsttxtCov.Add TextBox63
lsttxtCov.Add TextBoxLUT11
lsttxtCov.Add TextBox64
lsttxtCov.Add TextBoxLUT12
lsttxtCov.Add TextBox65
lsttxtCov.Add TextBoxLUT13
lsttxtCov.Add TextBox66
lsttxtCov.Add TextBoxLUT14
lsttxtCov.Add TextBox67
lsttxtCov.Add TextBoxLUT15
lsttxtCov.Add TextBox68
lsttxtCov.Add TextBoxLUT16
lsttxtCov.Add TextBox69
lsttxtCov.Add TextBoxLUT17
lsttxtCov.Add TextBox70
lsttxtCov.Add TextBoxLUT18
lsttxtCov.Add TextBox71
lsttxtCov.Add TextBoxLUT19
lsttxtCov.Add TextBox72
lsttxtCov.Add TextBoxLUT20
lsttxtCov.Add TextBox73
lsttxtCov.Add TextBoxLUT21
lsttxtCov.Add TextBox74
lsttxtCov.Add TextBoxLUT22
lsttxtCov.Add TextBox75
lsttxtCov.Add TextBoxLUT23
lsttxtCov.Add TextBox76
lsttxtCov.Add TextBoxLUT24
lsttxtCov.Add TextBox77
lsttxtCov.Add TextBoxLUT25
```

```
lsttxtCov.Add TextBox78
lsttxtCov.Add TextBoxLUT26
lsttxtCov.Add TextBox79
lsttxtCov.Add TextBoxLUT27
lsttxtCov.Add TextBox80
lsttxtCov.Add TextBoxLUT28
lsttxtCov.Add TextBox81
lsttxtCov.Add TextBoxLUT29
lsttxtCov.Add TextBox82
lsttxtCov.Add TextBoxLUT30
lsttxtCov.Add TextBox83

lstLabels.Add ";;" & Label1
lstLabels.Add Label2
lstLabels.Add Label3
lstLabels.Add Label4
lstLabels.Add Label5
lstLabels.Add Label6
lstLabels.Add Label7
lstLabels.Add Label8
lstLabels.Add Label9

lstLabels.Add ";;" & Label10
lstLabels.Add Label11
lstLabels.Add Label12
lstLabels.Add Label13
lstLabels.Add Label14
lstLabels.Add Label15
lstLabels.Add Label16
lstLabels.Add Label17

lstLabels.Add ";;" & LabelH18
lstLabels.Add LabelH19
lstLabels.Add LabelH20
lstLabels.Add LabelH21
lstLabels.Add LabelH22
lstLabels.Add LabelH23

lstLabels.Add ";;" & LabelGA18
lstLabels.Add LabelGA19
lstLabels.Add LabelGA20
lstLabels.Add LabelGA21

lstLabels.Add ";;" & LabelCN18
lstLabels.Add LabelCN19
lstLabels.Add LabelCN20
lstLabels.Add LabelCN21

lstLabels.Add ";;" & Label24
lstLabels.Add Label25
lstLabels.Add Label26
lstLabels.Add Label27
lstLabels.Add Label28
lstLabels.Add Label29
lstLabels.Add Label30
lstLabels.Add Label31
```

```
lstLabels.Add Label32
lstLabels.Add Label33
lstLabels.Add Label34

lstCovLabels.Add ";;" & Label35
lstCovLabels.Add Label36
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label37
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label38
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label39
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label40
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label41
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label42
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label43
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label44
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label45
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label46
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label47
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label48
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label49
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label50
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label51
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label52
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label53
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label54
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label55
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label56
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label57
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label58
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label59
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label60
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label61
```

```
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label62
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label63
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label64
lstCovLabels.Add "%_Area"
lstCovLabels.Add Label65
lstCovLabels.Add "%_Area"


Dim mycbxColobject As ComboBox ' for lstcbxCol collection
For Each mycbxColobject In lstcbxCol
   mycbxColobject.Clear
Next mycbxColobject

   cbxCovSubc.Clear

Dim mycbxCovobject As ComboBox ' for lstcbxCov collection
For Each mycbxCovobject In lstcbxCov
   mycbxCovobject.Clear
Next mycbxCovobject

Dim pFields As IFields ' pointer points to the fields in the current featureclass
Dim i As Long
   Set pFields = pFeatureClass.Fields ' sets pointer to current FeatureClass
   Dim pField As IField ' will populate each combobox on tab2("step2) with fields of current FClass
   Dim numFields As Long
   numFields = pFields.FieldCount
      For i = 0 To numFields - 1
         Set pField = pFields.Field(i)
         ' Populate all comboboxes with Field(i)
         For Each mycbxColobject In lstcbxCol
            mycbxColobject.AddItem pField.Name
         Next mycbxColobject

         cbxCovSubc.AddItem pField.Name

         For Each mycbxCovobject In lstcbxCov
            mycbxCovobject.AddItem pField.Name
         Next mycbxCovobject
      Next i

' will allow user to enter default values
For Each mycbxColobject In lstcbxCol
   mycbxColobject.AddItem "(default)"
   mycbxColobject.ListIndex = 0
Next mycbxColobject

cbxCovSubc.AddItem "(default)"
cbxCovSubc.ListIndex = 0

For Each mycbxCovobject In lstcbxCov
   mycbxCovobject.AddItem "(default)"
   mycbxCovobject.AddItem "(none)"
   mycbxCovobject.ListIndex = 0
```

```
        Next mycbxCovobject


    'Call optGWYes_Change
    'Call optCovYes_Change

    ElseIf cbxLayerType.Text = "Raingage" Or cbxLayerType.Text = "Junction" Or cbxLayerType.Text =
"Outfall" Or cbxLayerType.Text = "Weir" Then
        framePolygon.Visible = False
    ElseIf cbxLayerType.Text = "Conduit" Then
        framePolygon.Visible = False
    ' need to add other frames like frameConduit
    End If

End Sub

Private Sub cbxSubCrbLen_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubName_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubOut_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubPctImp_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubPctSlope_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubRain_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubSnow_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubTotArea_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubWidth_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCNCN_Change()
    Call TextEntryOnOff
End Sub
```

```
Private Sub cbxCNCond_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCNDryT_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCNSubcat_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU1_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU10_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU11_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU12_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU13_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU14_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU15_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU16_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU17_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU18_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU19_Change()
    Call TextEntryOnOff
End Sub
```

```
Private Sub cbxCovLU2_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU20_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU21_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU22_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU23_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU24_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU25_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU26_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU27_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU28_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU29_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU3_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU30_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU4_Change()
    Call TextEntryOnOff
End Sub
```

```
Private Sub cbxCovLU5_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU6_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU7_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU8_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovLU9_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxCovSubc_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGACapSuc_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGACond_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGAInitDef_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGASubcat_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWA1_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWA2_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWA3_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWAquifer_Change()
    Call TextEntryOnOff
End Sub
```

```
Private Sub cbxGWB1_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWB2_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWName_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWNode_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWNPerv_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWSurf_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxGWTW_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortDecay_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortDryT_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortMaxInf_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortMaxRate_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortMinRate_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxHortSubcat_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubAName_Change()
    Call TextEntryOnOff
End Sub
```

```
Private Sub cbxSubANImp_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubANPerv_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubAPctRouted_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubAPctZero_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubARoute_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubASImp_Change()
    Call TextEntryOnOff
End Sub

Private Sub cbxSubASPerv_Change()
    Call TextEntryOnOff
End Sub

Private Sub TextEntryOnOff()

   Dim cbxColObj As ComboBox ' for combobox collection
   Dim txtColObj As TextBox ' for textbox collection
   Dim cbxCovObj As ComboBox ' for combobox coverage collection
   Dim txtCovObj As TextBox ' for textbox coverage collection

   Dim z As Integer
   z = 1 ' iterates through collection, must start at 1 b/c list has no zero value

      For Each cbxColObj In lstcbxCol
         Set txtColObj = lsttxtCol.Item(z)
            If cbxColObj = "(default)" Then
               txtColObj.Enabled = True
            Else
               txtColObj.Enabled = False
            End If
         z = z + 1
      Next cbxColObj

   If cbxCovSubc = "(default)" Then
      TextBox53.Enabled = True
   Else
      TextBox53.Enabled = False
   End If

   z = 1
      For Each cbxCovObj In lstcbxCov
```

```
            Set txtCovObj = lsttxtCov.Item(z)
                If cbxCovObj = "(default)" Then
                    txtCovObj.Enabled = True
                Else
                    txtCovObj.Enabled = False
                End If
            Set txtCovObj = lsttxtCov.Item(z + 1) ' the second entry field
                If cbxCovObj = "(default)" Then
                    txtCovObj.Enabled = True
                Else
                    txtCovObj.Enabled = False
                End If
            z = z + 2 ' because of the two entry fields
        Next cbxCovObj


End Sub

Private Sub optGWYes_Change()
    If optGWYes = True Then
        frameGroundwater.Enabled = True ' contains sweeping parameters
        frameGroundwater.Visible = True ' contains sweeping parameters
    Else
        frameGroundwater.Enabled = False
        frameGroundwater.Visible = False

        TextBox38.Enabled = False
        TextBox39.Enabled = False
        TextBox40.Enabled = False
        TextBox41.Enabled = False
        TextBox42.Enabled = False
        TextBox43.Enabled = False
        TextBox44.Enabled = False
        TextBox45.Enabled = False
        TextBox46.Enabled = False
        TextBox47.Enabled = False
        TextBox48.Enabled = False

        cbxGWName.Enabled = False
        cbxGWAquifer.Enabled = False
        cbxGWNPerv.Enabled = False
        cbxGWNode.Enabled = False
        cbxGWSurf.Enabled = False
        cbxGWA1.Enabled = False
        cbxGWB1.Enabled = False
        cbxGWA2.Enabled = False
        cbxGWB2.Enabled = False
        cbxGWA3.Enabled = False
        cbxGWTW.Enabled = False

    End If
End Sub
Private Sub optGWNo_Click()
    optGWYes = False
```

```
End Sub


Private Sub cmdAddFeature_Click()

Dim i As Long
Dim j As Long

If cbxLayerType.Text = "Subcatchment" Then

'---------------------\/ Check for empty textboxes \/ --------------------------
    Dim mytextobj As TextBox ' for combobox
    Dim myobject As ComboBox ' for texbox - used to iterate through list, populating array
    Dim myCovtextobj As TextBox ' for combobox
    Dim myCovobject As ComboBox ' for texbox - used to iterate through list, populating array

    ' Check for blank enabled defaults
    For Each mytextobj In lsttxtCol
      If mytextobj.Enabled = True And mytextobj.Text = "" Then
        MsgBox "One or more Default Value Boxes is Enabled" & strReturn & "but no content is
entered!", vbExclamation, "Empty Box"
      End If
    Next mytextobj

'------------\/ Check for letters where numbers should be \/ ----------------
    If TextBox8.Enabled = True And Not IsNumeric(TextBox8) Or TextBox9.Enabled = True And Not
IsNumeric(TextBox9) Or TextBox10.Enabled = True And Not IsNumeric(TextBox10) Or
TextBox11.Enabled = True And Not IsNumeric(TextBox11) Or TextBox12.Enabled = True And Not
IsNumeric(TextBox12) Then
      MsgBox "One or more Default Values for" & strReturn & "Total Area, %Imperv Area, Width,
%Slope, or Curb Length" & strReturn & "are non numeric. Only enter numbers in those fields",
vbExclamation, "Use Numeric Value"
    End If

' may have to fix this
    For j = 15 To 20

      If TextBox15.Enabled = True And Not IsNumeric(TextBox15) _
      Or TextBox16.Enabled = True And Not IsNumeric(TextBox16) _
      Or TextBox17.Enabled = True And Not IsNumeric(TextBox17) _
      Or TextBox18.Enabled = True And Not IsNumeric(TextBox18) _
      Or TextBox19.Enabled = True And Not IsNumeric(TextBox19) _
      Or TextBox20.Enabled = True And Not IsNumeric(TextBox20) Then

        MsgBox "One or more Default Values for" & strReturn & "Impervious N, Perv N, S Imperv, S
Perv, % Zero Perv, or % Routed" & strReturn & "are non numeric. Only enter numbers in those fields",
vbExclamation, "Use Numeric Value"
      End If
    Next j

    If cbxInfilt.List(cbxInfilt.ListIndex) = "HORTON" Then
      If TextBox24.Enabled = True And Not IsNumeric(TextBox24) _
      Or TextBox25.Enabled = True And Not IsNumeric(TextBox25) _
      Or TextBox26.Enabled = True And Not IsNumeric(TextBox26) _
      Or TextBox27.Enabled = True And Not IsNumeric(TextBox27) _
```

```
          Or TextBox28.Enabled = True And Not IsNumeric(TextBox28) Then
            MsgBox "One or more Default Values for" & strReturn & "Horton's Max Rate, Min Rate, Decay,
Dry Time, or Max Infiltration" & strReturn & "are non numeric. Only enter numbers in those fields",
vbExclamation, "Use Numeric Value"
          End If

        ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "GREEN_AMPT" Then
          If TextBox31.Enabled = True And Not IsNumeric(TextBox31) _
          Or TextBox32.Enabled = True And Not IsNumeric(TextBox32) _
          Or TextBox33.Enabled = True And Not IsNumeric(TextBox33) Then
            MsgBox "One or more Default Values for" & strReturn & "Green Ampt's Capillary Suction,
Conductivity, or Initial Deficit" & strReturn & "are non numeric. Only enter numbers in those fields",
vbExclamation, "Use Numeric Value"
          End If

        ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "CURVE_NUMBER" Then
          If TextBox35.Enabled = True And Not IsNumeric(TextBox35) _
          Or TextBox36.Enabled = True And Not IsNumeric(TextBox36) _
          Or TextBox37.Enabled = True And Not IsNumeric(TextBox37) Then
            MsgBox "One or more Default Values for" & strReturn & "CN's CN, Conductivity, or Dry Time"
& strReturn & "are non numeric. Only enter numbers in those fields", vbExclamation, "Use Numeric
Value"
          End If
        End If

        If optGWYes = True Then
          If TextBox40.Enabled = True And Not IsNumeric(TextBox40) _
          Or TextBox42.Enabled = True And Not IsNumeric(TextBox42) _
          Or TextBox43.Enabled = True And Not IsNumeric(TextBox43) _
          Or TextBox44.Enabled = True And Not IsNumeric(TextBox44) _
          Or TextBox45.Enabled = True And Not IsNumeric(TextBox45) _
          Or TextBox46.Enabled = True And Not IsNumeric(TextBox46) _
          Or TextBox47.Enabled = True And Not IsNumeric(TextBox47) _
          Or TextBox48.Enabled = True And Not IsNumeric(TextBox48) Then
            MsgBox "One or more Default Values for" & strReturn & "Groundwater's N-Perv, Suface
Elevation, A1, B1, A2, B2, A3, or depth to water" & strReturn & "are non numeric. Only enter numbers in
those fields", vbExclamation, "Use Numeric Value"
          End If
        End If

'-------------------^ Checks for letters where numbers should be -^------------

' ----------------\/ Populate Matrix \/ --------------------

    Dim lngCheckRZero As Long
    lngCheckRZero = R

'---------\/ Used to resize the array when "add feature" is clicked  \/-----
    'Get ahold of Record
    Dim pTable As ITable
    Set pTable = pFeatureClass

    ' Find the number of selected records
    Dim lngCounter As Long
    lngCounter = 0
    lngCounter = pTable.RowCount(Nothing)
```

```
    R = R + lngCounter
'--------------^ used to resize str1 array when "add feature" is clicked ^----

' just double checking

' double check

        ' Get Feature Entry Count
        Dim lngLabels As Long
        lngLabels = lstLabels.Count
        Dim lngCovLabels As Long
        lngCovLabels = lstCovLabels.Count

'       MsgBox (lstLabels.Count + lstCovLabels.Count - 30)
'       MsgBox (lstcbxCol.Count + lstcbxCov.Count + 1)
'       MsgBox (lsttxtCol.Count + lsttxtCov.Count + 1 - 30)

        Dim S As Long
        S = lngLabels + lngCovLabels - 1

        ' Redim to get proper array size, note that array is 1 row longer than number of rows in FeatureClass
        ' because it needs to hold the labels/headings
'       ReDim Preserve strArray1(0 To R, 0 To S) As String
        ReDim Preserve strArray1(0 To S, 0 To R) As String


        If lngCheckRZero = 0 Then
            For i = 0 To lngLabels - 1
                strArray1(i, 0) = lstLabels.Item(i + 1)
            Next i
                j = i
            For i = 0 To lngCovLabels - 1
                strArray1(j + i, 0) = lstCovLabels.Item(i + 1)
            Next i
        End If

'----------Populates first part of matrix (i.e. everything but coverage info).-----------


' NOTE that the user's geodatabase must Not Contain ANY blank or null cells, this will
' Completely shift and destroy the input file for SWMM
' Also note that NO spaces can be in any of the cells either, for the same reason.

Dim pFeatureCursor As IFeatureCursor
Dim pFeature As IFeature
Dim lngFldIndex As Long


        j = 0 ' i = row; j = column
        For Each myobject In lstcbxCol
            If myobject.Enabled = True Then
                If myobject <> "(default)" Then
                    ' point to all records
                    Set pFeatureCursor = pFeatureClass.Search(Nothing, False)
                    For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
```

```
                ' create index to point to current field
                 lngFldIndex = pFeatureClass.FindField(myobject)

                 ' get 1st row
                 Set pFeature = pFeatureCursor.NextFeature
                 ' pop matrix with current cell
                 strArray1(j, i) = pFeature.Value(lngFldIndex)
                 ' go to next row, same field
               '  Set pFeature = pFeatureCursor.NextFeature - don't need?
              Next i
            ElseIf myobject = "(default)" Then

              For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
                 Set mytextobj = lsttxtCol.Item(j + 1) ' add one because a list starts at one, not zero
                 strArray1(j, i) = mytextobj
              Next i
            End If
        "    Next i - removed because I put the next i s above
         End If
      ' go to next column
      j = j + 1
      Next myobject
'---------^^ Populates first part of matrix ^^-----------------
'---------\/ Populates second part of matrix \/------------------

' i = row; j = column

   If frameCoverages.Enabled = True Then
         If cbxCovSubc <> "(default)" Then

            ' point to all records
            Set pFeatureCursor = pFeatureClass.Search(Nothing, False)
            For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
               ' create index to point to current field
                lngFldIndex = pFeatureClass.FindField(cbxCovSubc)

                ' get 1st row
                Set pFeature = pFeatureCursor.NextFeature

                ' pop matrix with current cell
                strArray1(j, i) = pFeature.Value(lngFldIndex)
                ' go to next row, same field
               '  Set pFeature = pFeatureCursor.NextFeature - delete not necessary?
            Next i

         ElseIf cbxCovSubc = "(default)" Then
            For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
              strArray1(j, i) = TextBox53.Text
            Next i
         End If
    j = j + 1

      Dim lngCovCounter As Long
      lngCovCounter = 1

      For Each myCovobject In lstcbxCov
```

```
        If myCovobject <> "(none)" Then
          If myCovobject <> "(default)" Then
            ' point to all records
            Set pFeatureCursor = pFeatureClass.Search(Nothing, False)
            For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
                          'strArray1(i, j) = myCovtextobj(lngCovCounter)
               strArray1(j, i) = myCovobject.Text

              ' create index to point to current field
               lngFldIndex = pFeatureClass.FindField(myCovobject)

               ' get 1st row
               Set pFeature = pFeatureCursor.NextFeature

               ' pop matrix with current cell
               strArray1(j + 1, i) = pFeature.Value(lngFldIndex)
               ' go to next row, same field
             '    Set pFeature = pFeatureCursor.NextFeature - don't need
            Next i
            ElseIf myCovobject = "(default)" Then
              For i = lngCheckRZero + 1 To R ' use 1 because the zero row contains the titles headings
               Set myCovtextobj = lsttxtCov.Item(lngCovCounter) ' do not need to add one - gets default
name
               strArray1(j, i) = myCovtextobj
               Set myCovtextobj = lsttxtCov.Item(lngCovCounter + 1) ' gets the default value
               strArray1(j + 1, i) = myCovtextobj
              Next i
            End If
        End If

        ' go to next column
        j = j + 2
        lngCovCounter = lngCovCounter + 2
      Next myCovobject
    End If

    '---------------\/ Get total number of vertices in layer \/----------------

      i = 0
      Dim pGeom As IGeometry
      Dim pPtColl As IPointCollection

      Set myobject = lstcbxCol.Item(1) ' gets the "field selected in "Name"
         If myobject <> "(default)" Then
           Set pFeatureCursor = pFeatureClass.Search(Nothing, False)
           lngFldIndex = pFeatureClass.FindField(myobject)

          Set pFeature = pFeatureCursor.NextFeature
           Do While Not pFeature Is Nothing
               Set pGeom = pFeature.Shape 'polygon
               Set pPtColl = pGeom

               Dim PtCollCount As Long
               PtCollCount = pPtColl.PointCount ' total number of vertices for shape

               i = i + PtCollCount 'number of vertices for entire layer
```

```
            Set pFeature = pFeatureCursor.NextFeature
        Loop

          Dim TotalPtCnt As Long
          TotalPtCnt = i

        Dim lngCheckRPointsZero As Long
        lngCheckRPointsZero = RPoints
        RPoints = RPoints + TotalPtCnt

        ReDim Preserve strArray2(0 To 2, 0 To RPoints) As String

         If lngCheckRPointsZero = 0 Then
          strArray2(0, 0) = "Name"
          strArray2(1, 0) = "X-coord"
          strArray2(2, 0) = "Y-Coord"
         End If

    '-------------\/ Populate vertices for each shape to an array \/------

        Set pFeatureCursor = pFeatureClass.Search(Nothing, False)
        Set pFeature = pFeatureCursor.NextFeature

          Do While Not pFeature Is Nothing
            Set pGeom = pFeature.Shape
            Set pPtColl = pGeom
            PtCollCount = pPtColl.PointCount

            Dim strNameHolder As String ' will contain name for current feature
            strNameHolder = pFeature.Value(lngFldIndex)

            For i = 0 To PtCollCount - 1 ' the zero value point exists

              strArray2(0, lngCheckRPointsZero + i + 1) = strNameHolder
              strArray2(1, lngCheckRPointsZero + i + 1) = pPtColl.Point(i).x
              strArray2(2, lngCheckRPointsZero + i + 1) = pPtColl.Point(i).y
            Next i

            lngCheckRPointsZero = lngCheckRPointsZero + i

            Set pFeature = pFeatureCursor.NextFeature ' next feature
          Loop

    '------------\/ If the user does not specify a name field \/-----------
       Else
          MsgBox "You cannot produce a Map Object without a unique name & strReturn & for each
feature."
       End If

Else 'If cbxLayerType.Text = "_______" Then
  MsgBox "I'm sorry, this is temporarily unavailable"
End If

lstCompleted.AddItem cbxSelectLayer.Text
```

```
End Sub
Private Sub CommandButton1_Click()
    Unload Me
End Sub

Private Sub CommandButton4_Click()
 '  MultiPage1.Value = 2 ' goes to the 3nd tab
   MultiPage1.Value = 3 ' goes to the 4th tab currently, 3rd is under development

End Sub

Private Sub cmdBrowseCancel_Click()
    Unload Me
End Sub

Private Sub cmdBrowse_Click()
   On Error GoTo err

    Dim sPath As String
    sPath = Trim(BrowseToSave)
        txtBoxSave.Text = sPath
'        createShapefile sPath
    Exit Sub

err:    MsgBox err.Description, vbExclamation, "CommandButton1_Click"
    ' Having a problem with the browser window putting a .txt on when filename already contains .txt


End Sub

Private Sub cmdSave_click()

    Dim sPath As String

    If txtBoxSave.Text <> "" And txtBoxSave.Text <> ".txt" Then
        sPath = txtBoxSave.Text
        createShapefile sPath
'        frmBrowseDialog.Hide
        Unload Me
    Else
    sPath = Trim(BrowseToSave)
        createShapefile sPath
'        frmBrowseDialog.Hide
        Unload Me
    End If

End Sub

Public Function BrowseToSave() As String

  On Error GoTo err
  BrowseToSave = "" 'initial value

  Dim pFilter As IGxObjectFilter
  Dim sTitle As String
```

```
  Set pFilter = New GxFilterTextFiles 'change this filter as needed e.g. GxFilterTables
  sTitle = "Save SWMM Input textfile as"

   'create the dialog, set proper filter:
  Dim pGxDialog As IGxDialog
  Set pGxDialog = New GxDialog

  With pGxDialog 'set the parameters and the filter
    .AllowMultiSelect = False 'only file is selected
    .title = sTitle
    Set .ObjectFilter = pFilter

    If .DoModalSave(0) Then      ' Open the save dialog:
        Dim strPath As String
        strPath = pGxDialog.FinalLocation.FullName
        Dim strName As String
        strName = pGxDialog.Name
        Dim strText As String
        strText = strPath & "\" & strName
        BrowseToSave = strText
    End If
  End With

  Exit Function

err:    MsgBox err.Description, vbExclamation, "BrowseToSave"
End Function

Private Sub createShapefile(strPath As String)
    Dim fs As Variant
    Dim a As Variant
    Dim i As Long
    Dim txtOutput As String ' hold data before sending to SWMM input file
'   Dim txtOutput2 As String ' hold data before sending to SWMM input file

        ' Creates file and will write over an old one
        Set fs = CreateObject("Scripting.FileSystemObject")
        Set a = fs.CreateTextFile(strPath, True)
        a.WriteLine (";;Thank you for choosing GIS2SWMM (C) 2005 Ruben Kertesz")
        a.WriteLine (";;This software is protected by the GNU General Public License")
        a.WriteLine (";;If you alter or otherwise include this code in another program, please reference it")
        a.WriteLine (";;More information is provided in the code")
        a.WriteLine (";;GIS2SWMM comes with ABSOLUTELY NO WARRANTY")


    txtOutput = lblTitle & strReturn & txtTitle & strReturn & frameOptions.Caption & strReturn _
    & lblFlow & cbxFlow & strReturn & lblInfilt & cbxInfilt & strReturn & lblRouting & cbxRouting &
strReturn _
    & lblPonding & cbxPonding & strReturn & lblStartDate & txtStartDate & strReturn & lblStartTime &
txtStartTime & strReturn _
    & lblEndDate & txtEndDate & strReturn & lblEndTime & txtEndTime & strReturn & lblReportStartD
& txtReportStartD & strReturn _
    & lblReportStartT & txtReportStartT & strReturn & lblDryDays & txtDryDays & strReturn &
lblWetStep & txtWetStep & strReturn _
    & lblDryStep & txtDryStep & strReturn & lblRouteStep & txtRouteStep & strReturn & lblReportStep &
txtReportStep & strReturn _
```

```
   & lblInertialDamp & cbxInertialDamp

      a.WriteLine (txtOutput) ' This contains the Selected Options information

   If cbxRouting = "Dynamic" Then
      txtOutput = lblVarStep & txtVarStep & strReturn & lblLengthStep & txtLengthStep & strReturn _
      & lblMinSurf & txtMinSurf & strReturn & lblCompat & cbxCompat
      a.WriteLine (txtOutput) ' Contains Dynamic Variable info
   End If

   If optSwpYes.Value = True Then
      txtOutput = lblSwpStart & txtSwpStart & strReturn & lblSwpEnd & txtSwpEnd
      a.WriteLine (txtOutput) ' Contains Sweeping Variables
   End If

   a.WriteLine ("") '  Puts a space in between lines to clear up input file

   ' \/ Used for iteration through writelines \/
   Dim strArray1LowerR As Long
   Dim strArray1UpperR As Long

   strArray1LowerR = LBound(strArray1, 2)
   strArray1UpperR = UBound(strArray1, 2)


   '--\/ Row by row, enter data from strArray1-----\/--'

' First, the subcatchment
   a.WriteLine (frameSubcatchment.Caption)
   For i = strArray1LowerR To strArray1UpperR
      txtOutput = strArray1(0, i) & " " & strArray1(1, i) & " " & strArray1(2, i) & " " & strArray1(3, i) & "
" & strArray1(4, i) & " " & strArray1(5, i) & " " & strArray1(6, i) & " " & strArray1(7, i) & " " &
strArray1(8, i)
      a.WriteLine (txtOutput)
   Next i

' Second, the subarea
   a.WriteLine (frameSubArea.Caption)
   For i = strArray1LowerR To strArray1UpperR
      txtOutput = strArray1(9, i) & " " & strArray1(10, i) & " " & strArray1(11, i) & " " & strArray1(12, i)
& " " & strArray1(13, i) & " " & strArray1(14, i) & " " & strArray1(15, i) & " " & strArray1(16, i)
      a.WriteLine (txtOutput)
   Next i

' Third, infiltration
   a.WriteLine (frameInfiltration.Caption)
   If cbxInfilt.List(cbxInfilt.ListIndex) = "HORTON" Then
      For i = strArray1LowerR To strArray1UpperR
         txtOutput = strArray1(17, i) & " " & strArray1(18, i) & " " & strArray1(19, i) & " " & strArray1(20,
i) & " " & strArray1(21, i) & " " & strArray1(22, i)
         a.WriteLine (txtOutput)
      Next i
    ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "GREEN_AMPT" Then
      For i = strArray1LowerR To strArray1UpperR
         txtOutput = strArray1(23, i) & " " & strArray1(24, i) & " " & strArray1(25, i) & " " & strArray1(26,
i)
```

```
        a.WriteLine (txtOutput)
      Next i
     ElseIf cbxInfilt.List(cbxInfilt.ListIndex) = "CURVE_NUMBER" Then
      For i = strArray1LowerR To strArray1UpperR
        txtOutput = strArray1(27, i) & " " & strArray1(28, i) & " " & strArray1(29, i) & " " & strArray1(30,
i)
        a.WriteLine (txtOutput)
      Next i
    End If

' Fourth, the groundwater
    If optGWYes = True Then
      a.WriteLine (frameGroundwater.Caption)
        For i = strArray1LowerR To strArray1UpperR
          txtOutput = strArray1(31, i) & " " & strArray1(32, i) & " " & strArray1(33, i) & " " &
strArray1(34, i) & " " & strArray1(35, i) & " " & strArray1(36, i) & " " & strArray1(37, i) & " " &
strArray1(38, i) & " " & strArray1(39, i) & " " & strArray1(40, i) & " " & strArray1(41, i)
          a.WriteLine (txtOutput)
        Next i
    End If

' Last, the Coverages
    If optCovYes = True Then
      a.WriteLine (frameCoverages.Caption)
        For i = strArray1LowerR To strArray1UpperR
          txtOutput = strArray1(42, i) & " " & strArray1(43, i) & " " & strArray1(44, i) & " " &
strArray1(45, i) & " " & strArray1(46, i) & " " & strArray1(47, i) & " " & strArray1(48, i) & " " &
strArray1(49, i) & " " & strArray1(50, i) & " " & strArray1(51, i) & " " & strArray1(52, i) & " " & _
          strArray1(53, i) & " " & strArray1(54, i) & " " & strArray1(55, i) & " " & strArray1(56, i) & " "
& strArray1(57, i) & " " & strArray1(58, i) & " " & strArray1(59, i) & " " & strArray1(60, i) & " " &
strArray1(61, i) & " " & strArray1(62, i) & " " & strArray1(63, i) & " " & _
          strArray1(73, i) & " " & strArray1(74, i) & " " & strArray1(75, i) & " " & strArray1(76, i) & " "
& strArray1(77, i) & " " & strArray1(78, i) & " " & strArray1(79, i) & " " & strArray1(80, i) & " " &
strArray1(81, i) & " " & strArray1(82, i) & " " & _
          strArray1(83, i) & " " & strArray1(84, i) & " " & strArray1(85, i) & " " & strArray1(86, i) & " "
& strArray1(87, i) & " " & strArray1(88, i) & " " & strArray1(89, i) & " " & strArray1(90, i) & " " &
strArray1(91, i) & " " & strArray1(92, i) & " " & _
          strArray1(93, i) & " " & strArray1(94, i) & " " & strArray1(95, i) & " " & strArray1(96, i) & " "
& strArray1(97, i) & " " & strArray1(98, i) & " " & strArray1(99, i) & " " & strArray1(100, i) & " " &
strArray1(101, i) & " " & strArray1(102, i)

          a.WriteLine (txtOutput)
        Next i
    End If

'----------------^----- End of string array 1 to input file transfer ^-----------

    ' \/ Used for iteration through writelines of x,y matrix \/
    Dim strArray2LowerR As Long
    Dim strArray2UpperR As Long
    strArray2LowerR = LBound(strArray2, 2)
    strArray2UpperR = UBound(strArray2, 2)

    a.WriteLine " "
    a.WriteLine "[Polygons]"
```

```
   '--\/ Row by row, enter data from strArray2-----\/--'
   For i = strArray2LowerR To strArray2UpperR
       txtOutput = strArray2(0, i) & " " & strArray2(1, i) & " " & strArray2(2, i)
       a.WriteLine (txtOutput)
   Next i

   a.Close

   Dim OpenNotepad
   OpenNotepad = Shell(Environ("SystemRoot") & "\system32\notepad.exe" & " " & strPath,
vbNormalFocus)

End Sub
```

CODE 2

The following code is used to extract NCDC rainfall data from a .CSV file into an XML file so that it can easily be imported into Access in a two column (date/time, rainfall) format.

```
Option Explicit
Sub newone()

Dim i As Long
Dim j As Long
Dim qt As String
Dim fs As Variant
Dim a As Variant
Dim string1 As String
Dim strPath As String
Dim OpenNotepad

Dim C As String
Dim D As String
Dim E As String
Dim F As String
Dim G As String


qt = Chr(34)

strPath = "C:\Documents and Settings\heaneygs\Desktop\data.txt"

Set fs = CreateObject("Scripting.FileSystemObject")
Set a = fs.CreateTextFile(strPath, True)

a.writeline ("<RainData>")

For i = 3 To 8162
   C = "<COOPID>" & Cells(i, 1).Value & "</COOPID>"
   D = "<CD>" & Cells(i, 2).Value & "</CD>"
```

```
  E = "<ELEM>" & Cells(i, 3).Value & "</ELEM>"
  F = "<UN>" & Cells(i, 4).Value & "</UN>"
  G = "<DATE>" & Cells(i, 5).Value & "-" & Cells(i, 6).Value & "-" & Cells(i, 7).Value & "</DATE>"



  j = 8
  Do While j < 108
    a.writeline ("<site>")
    a.writeline (C)
    a.writeline (D)
    a.writeline (E)
    a.writeline (F)
    a.writeline (G)

    a.writeline ("<Time>" & Cells(i, j).Value & "</Time>")
    a.writeline ("<Rainfall>" & Cells(i, j + 1).Value & "</Rainfall>")
    a.writeline ("<Flag1>" & Cells(i, j + 2).Value & "</Flag1>")
    a.writeline ("<Flag2>" & Cells(i, j + 3).Value & "</Flag2>")
    a.writeline ("</site>")
   j = j + 4
  Loop

Next i

a.writeline ("</RainData>")

'OpenNotepad = Shell(Environ("SystemRoot") & "\system32\notepad.exe" & " " & strPath,
vbNormalFocus)

End Sub
```

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BIOGRAPHICAL SKETCH

Ruben Kertesz was born in 1981 in the Pacific Northwest. Growing up, he had an affinity for four things: to know more about why he exists; to learn more about how things work; to spend time in the local forest; and to share his passion with others. Growing up, Ruben had many opportunities to explore the urban landscape on his bicycle at a young age as well as mountain bike on small dirt trails.

Ruben has always felt blessed by his parents, friends, and the location where he was raised. Encouraged to carefully and cautiously explore with friends, he ventured into a scattering of different subjects throughout his scholastic career. Attending a high school in Tacoma, WA, Ruben was invited to join an honors group innocuously named the Environmental Science Club. This afforded him an opportunity to perform hands on research on artificial reefs. Ruben realized the joy of building and testing, recording data by moonlight and presenting his findings.

Throughout college, Ruben has participated in numerous environmental action and recreation groups while obtaining a bachelor's degree in biology. His move to Gainesville, FL, was spurred by his interest in having a positive environmental impact that reached beyond his personal life. His work in the Department of Environmental Engineering Sciences has proved educational and rewarding. Ruben still carries a passion for integrating research, social awareness, and technology. He reminds himself everyday that his wellbeing and those of our children rely on sound and conscious environmental and social decisions even at the most fundamental level.