PREDICTIVE MODELING WITH THE SOIL AND WATER ASSESSMENT TOOL (*SWAT2012*) PRIOR TO DESIGN DEVELOPMENT IN LANDSCAPE ARCHITECTURE: LEARNING FROM THE SOUTHWESTERN MEDICAL DISTRICT IN DALLAS, TEXAS

by

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Presented to the Faculty of the Graduate School of
The University of Texas at Arlington in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF LANDSCAPE ARCHITECTURE

THE UNIVERSITY OF TEXAS AT ARLINGTON

December 2016

Acknowledgements

First and foremost, I would like to express my sincere gratitude to my thesis chair, Dr. Taner R. Özdil for his continuous guidance, support, patience, contributions, and mentorship throughout my academic journey at UTA, especially during my research efforts. I would also like to thank my thesis committee members, Dr. Charles Allan Jones and Dr. Amy Archambeau, for their time, constructive feedback, encouragement, and contributions to the realization of this research. I would like to thank Dr. Jaehak Jeong and Dr. Raghavan Srinivasan, from the Department of Biological and Agricultural Engineering at Texas A&M University, for sharing their expertise, and for their technical support and feedback throughout the past year. I would like to thank the project team for the Southwestern Medical District at Design Workshop™ and at Texas Trees Foundation, for providing me with data and information related to the research site.

To my professors at the Program in Landscape Architecture, who have been an integral part of my academic and professional journey: Dr. Pat D. Taylor, for his support and guidance; Professor David Hopman for his commitment and mentorship; Professor John Fain, for his advice and motivation; and Professor James Richards for his inspiration and creative influence. To all my friends, who have become my family, each of you holds a dear place in my heart and I am forever thankful for your continuous support, inspiration, and smiles. My heartfelt appreciation goes to the Ross family; I am forever grateful.

To George, Maguy, and Nadine - your endless love, unwavering support, prayers, and patience are what keep me standing; I dedicate this to you.

November 15, 2016

Abstract

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Landscape Architecture has recently seen a significant rise in evaluative studies among the scientific and professional community, perhaps as a result of growing concerns related to rapid urbanization, climate change, and environmental degradation (LAF, 2016; Ozdil, 2014). Several methods adopted in evaluative landscape architecture research have typically focused on landscape performance in post implementation conditions, with a relatively superficial use of technology to address contemporary urban problems. However, with the advancement of computer technologies, opportunities to assess and predict environmental landscape performance prior to design development in the site planning process have emerged.

The purpose of this research is to apply a predictive modeling approach to assess and predict stormwater runoff and its impact on a site and watershed scale using Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT2012*), specifically during the design development stage of the site planning process. Recent technological developments in GIS have allowed the application of geoanalytical methods that challenge conventional data collection and analysis methods and broaden the design approach using quantifiable measures. These methods have also opened up the inquiry of scientific knowledge for research in urban areas within landscape architecture, planning, and other allied fields.

This study utilizes quantitative predictive modeling methods and tools to study surface hydrological conditions prior to design development in an urban landscape context. The study adopts the case of the Southwestern Medical District in Dallas, Texas, which encompasses 350 hectares of the Headwaters Turtle Creek watershed. The study tests four hypothetical scenarios; pre-development, existing conditions, scenario 1, and scenario 2, using *SWAT* in order to understand the tool’s applicability and relevance to landscape architectural studies and practice. Predictive modeling is a method that utilizes computer simulation and monitoring data collected over time and space to visualize various land use changes (Gregersen et al., 2007). *SWAT* is an example of a predictive modeling tool, which presents opportunities for hydrological modeling in landscape architecture practice and research.

This research is an attempt to investigate water quality and quantity in an urbanized watershed before project construction and completion. The research findings highlight the importance of predictive modeling in landscape architecture and planning, especially prior to design development. This scenario-based evaluation suggests that *SWAT* could be an effective predictive modeling tool that can inform landscape architecture planning and practice on impacts of design on water quality and quantity. The strength of the *SWAT* modeling tool lies in its ability to simulate water flow and quality at a given site, under various parameters that can be adjusted by the researcher. Results also suggest that the quantity and quality of water generated on a complex urban site, such as the Southwestern Medical District, can have an impact on watershed performance, if green infrastructure systems and low impact development strategies are applied.

The research also illustrates the applicability and relevance of *SWAT* in today’s landscape architecture practice, and informs relevant professions about the capability of assessing stormwater runoff quality and quantity prior to design development using geospatial techniques and methods. Thus landscape architects and allied professions can have a more comprehensive and responsive approach that informs the built and natural environment in urban contexts.

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Chapter 1

INTRODUCTION

1.1 Introduction

This research is to evaluate stormwater runoff quality and quantity prior to design development using Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT*) in landscape architecture. The research adopts the Southwestern Medical District in Dallas, Texas as a study location to test various scenarios in order to understand the applicability and value of predictive modeling and *SWAT* in landscape architecture studies and practice. This chapter presents a background for the study, purpose, research questions, definitions of terms, research methodology, and significance and limitations. This section highlights the scope throughout which this research is presented, and provides a framework for the use of predictive modeling as a tool in landscape architecture.

1.2 Background

Landscape architecture has recently seen a significant rise in evaluative studies among the scientific and professional community, perhaps as a result of growing concerns related to rapid urbanization, climate change, and environmental degradation (LAF, 2016; Ozdil, 2014). Several methods adopted in evaluative landscape architecture research have typically focused on landscape performance in post implementation conditions, with a relatively superficial use of technology to address contemporary urban problems. However, with the advancement of computer technologies, opportunities to assess and predict environmental landscape performance prior to design development in the site planning process have emerged. Opportunities for improving the quality of landscape, by intentionally designing for landscape performance, have been guided by the growing knowledge of landscape architects and planners in addressing environmental, ecological and community health related issues with performance and evidence-based approaches (Lovell & Johnston, 2009). Designing landscapes for performance by integrating ecological principles in landscape features has become a relevant concern, specifically in relation to retrofitting existing developments and in challenging traditional methods of development in urban areas (Tzoulas, et al., 2007). The North Central Texas region is currently facing critical challenges due to the impacts of urbanization and rapid development. Communities in the Dallas-Fort Worth area have become increasingly concerned with urban sprawl and its effects on watersheds, natural drainage systems, and stormwater runoff (Vision North Texas, 2010). The North Central Texas region is a suitable case for studying and testing methods for environmental retrofit and mitigation; therefore, a predictive modeling approach to assess alternative future landscapes with consideration to environmental landscape performance is crucial.

The traditional site planning process in landscape architecture research and practice typically includes Post-Implementation and Post-Occupancy Evaluations in the final stages of a project to assess performance (Ozdil, 2016; Gottfredson, 2014; Murphy, 2005; Marcus & Francis, 1998). Furthermore, few research studies have focused on the impact of ecological planning approaches and stormwater management practices on a watershed-scale in urban contexts. In addition, Hilde and Paterson indicated based on other studies (such as Criterion Planners, 2012; Calthorpe Associates, 2011) that the use of highly-developed models for assessment of landscape performance prior to design development have “lagged in practice” (Hilde & Paterson, 2014, p. 524).

1.2.1 Landscape architecture and the urban environment

In the past few decades, landscape architects have been concerned with the quality of the urban environment. On June 1st and 2nd, 1966, Ian McHarg, John Simonds, and other leading landscape architects of the time held an assembly with the Landscape Architecture Foundation (LAF) and announced a 'Declaration of Concern' at Independence Hall in Philadelphia:

> "We urge a new, collaborative effort to improve the American environment and to train a new generation of Americans equipped by education, inspiring example and improved organizations to help create that environment" (Declaration of Concern, 2016, p. 1)

In that Declaration, it was noted that a crucial factor in developing solutions for the environmental crisis lies within the field of landscape architecture, which is a "profession dealing with the interdependence of environmental processes" (Declaration of Concern, 2016, p. 1). Fifty years after the initial Declaration, on June 10th and 11th, 2016, the Landscape Architecture Foundation held *The New Landscape Declaration: Summit on Landscape Architecture and the Future*. A diverse group of distinguished professionals and academics convened to discuss how the landscape architecture profession will contribute to the future and the expected challenges (Landscape Architecture Foundation, 2016). Among the topics addressed in the declarations was how to develop landscapes of resource management, especially in relation to water quality and quantity (Nawre, 2016; O'Donnell, 2016). It was noted that the crisis of water management is expected to rise with "impending climate change and rapid urbanization" (Nawre, 2016, p. 1). Critical resources, such as water, are at risk due to rampant development, which highlights the need to address water quality and quantity through better resource management in landscapes (ESRI, 2016; Nawre, 2016; O'Donnell, 2016). Furthermore, the significance of the profession of landscape architecture was highlighted, by noting its understanding of multi-functional resource infrastructure.

Developing and using “interdisciplinary approaches that integrate biological, social, and other sciences to provide a better understanding of the challenges of land use planning and management” is necessary and crucial for studying urban environments (Tzoulas, et al., 2007, p. 168).

The profession of landscape architecture contributes to restoring and “re-establishing healthy relationships between humans and their environment” (Nawre, 2016, p. 1). Landscape architects have the ability to address water resource management issues by improving and retrofitting existing landscapes, and have the ability to create alternative solutions for improved resource management through “shaping new built environments” (Landscape Architecture Foundation, 2016, p. 1).

The American Society of Landscape Architects (ASLA) Code of Environmental Ethics highlights the profession’s commitment to “environmental stewardship, quality of life, and professional affairs” (ASLA Code of Professional Ethics, 2015, p. 1), which builds upon the foundation of “dedication to the public health, safety, and welfare and recognition and protection of the land and its resources” (ASLA Code of Professional Ethics, 2015, p. 1). This highlight’s the profession’s “effort to enhance, respect, and restore the life-sustaining integrity of the landscape and seek environmentally positive, financially sound, and sustainable solutions to land use, development, and management opportunities” (ASLA Code of Professional Ethics, 2015, p. 1).

1.2.2 Environmental factors in landscape performance

The degradation of green space in urban and peri-urban areas could negatively impact ecosystems as well as human health and well-being (Tzoulas et al., 2007). Green spaces within urban areas have been proven to positively affect the people living, working, and recreating in the vicinity (Vandermeulen et al., 2007). Causal relationships between green infrastructure elements and human health are “difficult to establish and quantify" (Tzoulas et al., 2007, p. 168), therefore it is critical to understand the effects of green infrastructure in urban areas, and to plan future development with consideration to environmental and landscape performance prior to design development and project implementation.

Assessing environmental factors as part of landscape performance research, by studying the effectiveness of Low Impact Development (LID) strategies, is crucial for the development of stormwater management plans that contribute to the improvement and mitigation of urban hydrological processes (Gilroy & McCuen, 2009). Several studies have reported the effectiveness of LIDs in reducing the amount of runoff and pollutants (Ahiablame, Engel, & Chaubey, 2012). However, limited research has been focused on the effectiveness of LIDs on a watershed-scale, due to the limited availability of tools that simulate LIDs using "process-based modeling techniques (Elliott & Trowsdale, 2007; Roy et al., 2008; Gilroy & McCuen, 2009). Few studies exist that address ecological planning approaches and their relation to quantitative measures of stormwater management (Yang, Li, & Huang, 2009).

1.2.3 Landscape performance and predictive modeling

The field of environmental software and modeling has recently improved our understanding of the complexity of urban stormwater management and landscape infrastructure (Jeong et al., 2016). The development of empirical models using literature data and predictive modeling enable *a priori* judgements to be made in relation to issues such as watershed development and planning (France, 2006). Adopting a holistic watershed framework towards development projects "must be presented and reiterated…until it becomes the status quo" (France, 2006, p. 66). Empirical predictive planning can be applied to individual site-specific designs and be conceptually reconnected to the larger landscape (American Water Works Association, 2010).

Such methods can be used for ecosystem restoration and the “creation of environmentally benign project designs” (France, 2006, p. 66).

Recent technological developments in GIS, landscape architecture, planning, and other allied fields have allowed the application of geoanalytical methods that challenge conventional data collection methods, and have opened up the application of scientific knowledge specifically for research in urban areas. Predictive modeling is a method that utilizes computer simulation and monitoring data collected over time and space to visualize various land use changes (Gregersen et al., 2007). It is an approach that has not been utilized extensively in landscape architecture research and practice. Literature illustrates that geospatial and empirical modeling can be developed using existing data and research for applications in predictive modeling. Modeling approaches can be applied to assess the impacts of development on water flow and quality on a watershed scale (Santhi et al., 2006). They can also estimate the improvements needed to retrofit existing conditions through restorative tree planting, road consolidation, pavement removal, and other LID practices (France, 2006).

The *Soil and Water Assessment Tool* (*SWAT*) is an example of a predictive modeling tool, which presents opportunities for hydrological modeling in landscape architectural research studies and practice. *SWAT* is a physically-based simulation model developed that assesses continuous-time landscape processes and streamflow with a high level of spatial detail (Santhi et al., 2006). With further research, the *SWAT* can be an instrumental tool for landscape architects in pre-construction planning and design development phases. Effective planning and design combined with stormwater best management practices can improve the quality and quantity of stormwater runoff in urbanized watersheds and landscapes (Parker, 2010).

1.2.4 Predictive modeling prior to design development in landscape architecture

Presenting various scenarios for development provides landscape architects and planners with the tools for forecasting and reducing environmental stresses by proactively designing landscapes to minimize unfavorable environmental impacts. The development of spatially explicit landscape analyses through predictive modeling can help identify relationships between human activities and the changes that occur in natural systems (Hulse et al., 2000). The use of GIS and its associated tools prove useful in representing the past, present, and potential future conditions of natural systems. Predictive modeling methods can be applied in the site planning process to identify changes over space and time in human communities and natural systems. A set of values and anticipated future conditions can be applied in order to evaluate the effects of alternative future landscapes on water quality and quantity using “hydrological and ecological effects models” (Hulse et al., 2000, p. 1). Hence the significance of predictive modeling and scenario planning prior to design development in landscape architecture practice.

1.3 Purpose of Study

The purpose of this research is to assess and predict stormwater runoff and its impact on a site and watershed scale using Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT2012*), specifically prior to design development in the site planning process. The research is an attempt to investigate water quality and quantity in an urbanized watershed prior to project construction and completion. The research uses *SWAT*, a physically-based model that presents opportunities for hydrological modeling. The study adopts the case of the Southwestern Medical District in Dallas, Texas, which encompasses 350 hectares of the Headwaters

Turtle Creek watershed. The study looks into the proposed Urban Streetscape Master Plan for the district, and assesses various scenarios using *SWAT2012*.

This research addresses the need for predictive modeling prior to design development within the practice of landscape architecture. The study evaluates the applicability of the Soil and Water Assessment Tool (*SWAT*) as a tool for predictive modeling in landscape architecture.

1.4 Research Questions

This research addresses the following:

1. Can *SWAT*, a predictive modeling tool, be utilized in an urban context in landscape architecture practice?
2. How can *SWAT* be utilized to assess various scenarios prior to design development in landscape architecture?
3. Is *SWAT* an effective tool for landscape architects to learn and adopt in order to assess stormwater quality and quantity?

1.5 Definition of Terms

The following list includes the terms repeatedly used in this thesis. Definitions and acronyms are used in relation to the focus of this research.

Bioretention – also known as a rain garden, is a swale or channel that absorbs, holds, and slowly releases excess water. A rain garden section is composed of compacted soils, sand and drainage materials, planting soil, and vegetation native to the region (ASLA, 2016).

Best Management Practices (BMP) – are methods that have been determined to be effective and practical means of preventing and reducing pollution from non-point sources (Peterson et al., 2015). BMPs are physical controls, operational activities, or educational measures that are implemented to reduce the discharge of pollutants into receiving water bodies, and refer to nonstructural and structural practices that have a direct impact on the transport, release, and discharge of pollutants (EPA, 2004).

Case Study Investigation (CSI) – is a program designed by the Landscape Architecture Foundation that matches student-faculty research teams with leading professionals and practitioners, in order to document and assess the benefits of high-performing landscape architecture projects. Methods and results quantify the environmental, social, and economic value of landscapes and are produced under LAF's Case Study Briefs (Landscape Architecture Foundation, 2016).

Clean Water Act (CWA) – passed in 1972 as a set of laws that established the regulation of water pollution in the United States, and formed the basis for water quality protection in surface water and groundwater sources (Peterson et al., 2015)

Clean Water Act (CWA) Section 303(d) – refers to the section of the CWA that requires states to develop a list of water bodies that do not meet water quality standards (Peterson et al., 2015).

Coefficient of Runoff – is a dimensionless number ranging between 0 and 1.0 that refers to the proportion of rainfall available for overland flow after infiltration has taken place (Marsh, 2010).

Design Development – the phase of the project where the schematic design is refined. Design details are included and materials are selected. Tasks build on the client-approved schematic design (AIA, 2015).

Detention System –refer to urban best management practices that are designed to intercept and temporarily store stormwater runoff for gradual release into a storm sewer system or a receiving body of water (Peterson et al., 2015).

Ecosystem Health – generally defined as the “occurrence of normal ecosystem processes and functions” (Costanza, 1992).

Geodesign – provides a design framework and related technologies for design and planning professionals to “leverage geographic information, resulting in designs that more closely follow natural systems” (ESRI, 2016). It is a design and planning method that allows the creation of design proposals with impact simulations informed by geographic context (Wilson, 2015; Flaxman, 2011).

Geographic Information System (GIS) – is a computer system that captures, stores, and displays data that can be analyzed, visualized, and questioned to understand relationships, patterns, and trends (ESRI, 2016; National Geographic Society, 2016)

Green Infrastructure – refers to the network of strategically managed open and natural spaces which provide ecological benefits in urbanized areas, specifically for human and wildlife populations (Tzoulas, et al., 2007; Benedict & McMahon, 2006). Also defined as the “network of open spaces, airsheds, watersheds, woodlands, wildlife habitat, parks, and other natural areas that provides may vital services that sustain life and enrich the quality of life” (Girling & Kellett, 2005, p. 59).

Human Health – as defined by the World Health Organization, is “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (World Health Organization, 1948).

Hydrologic and Water Quality System (HAWQS) – is a web-based interactive water quality modeling system that uses *SWAT* as its core modeling engine. It is funded by the EPA’s Office of Water (EPA, Texas A&M University, Texas A&M Agrilife Research, & USDA, 2016).

Hydrologic Response Unit (HRU) – is a lumped area of land within the subbasin that is composed of unique land cover, soil, and management combinations (Neitsch et al., 2009).

Hydrologic Unit – the watersheds of the United States are delineated by the U.S. Geological Survey under a national standard hierarchal system, based on surface hydrologic features. Watersheds are classified into four types: first-field i.e. region; second-field i.e. sub-region; third-field i.e. accounting unit; fourth-field i.e. cataloguing unit, fifth-field i.e. watershed, sixth-field i.e. subwatershed. Each Hydrologic Unit is defined by a unique Hydrologic Unit Code (HUC) comprised of two to twelve digits (USDA, 2016).

Hydrologic Unit Modeling of the United States (HUMUS) – An advanced, state-of-the-art total water quantity and quality modeling system with databases, interfaces and models, developed to evaluate the impacts of land management alternatives, pollution control, and climate change scenarios on the quantity and quality of water at a national scale (HUMUS, 2016). The main components of the system are *SWAT* (Soil and Water Assessment Tool) to model the surface and sub-surface water quantity and quantity; and GIS (Geographic Information System) for collecting and managing data inputs and outputs; and related databases of non-spatial data to run the model (Arnold et al., 2010).

Land Use – is a description of how people use land, most commonly recognized as urban or agricultural use. Land use can also be classified as institutional, residential, recreational, etc. (Fisher, Comber, & Wadsworth, 2005).

Landscape Performance – measures the value of which “landscape solutions fulfill their intended purpose and contribute to sustainability”. (Landscape Performance, 2016).

Low Impact Development (LID) – are methods and measures that mitigate urbanization impacts on water quantity and quality (Dietz, 2007; Ahiablame, Engel, & Chaubey, 2012; Roy et al., 2008). LIDs are types of structural and non-structural BMPs that are specifically designed to reduce the volume and pollutant load of urban runoff (Peterson et al., 2015). LIDs are designed and implemented to reduce stormwater runoff at the source level, which subsequently leads to decreased velocity and prolonged travel time of downstream runoff (Jeong et al., 2016).

Model – is a representation of an environmental system, acquired by the application of mathematical equations or relationships (Peterson et al., 2015).

NCTCOG – North Central Texas Council of Governments.

Non-Point Source Pollution – refers to a source of pollution without a single point of origin, and not introduced into a receiving body of water from a specific outlet. Pollutants are generally carried on the surface by stormwater runoff. The most common sources of non-point source pollution are agriculture, urban areas, construction, and mining (Peterson et al., 2015).

Performance Controls – refer to the regulations used to enforce specific standards and goals, such as limits on the percentage impervious cover and surfaces that have direct linkages to natural water features. Broader requirements refer to requirements to integrate stormwater management with open space planning and design (Marsh, 2010).

Porous Pavement – is a method used to reduce the volume of surface water that is generated by precipitation on a given site. It is a paved surface that is made of a gravel layer and a soil base between the porous pavement and the native soil and allows for infiltration (Jeong et al., 2016).

Post Occupancy Evaluation (POE) – is the process of evaluating building or outdoor spaces in a systematic and rigorous manner after they have been built and occupied for some time. They provide insights into the consequences of past design decisions and the resulting performance. This knowledge forms a sound basis for creating better buildings in the future (Modi, 2014; Preiser, Rabinowitz, & White, 1988).

Predictive Modeling – is a method that utilizes computer simulation and data collected over time and space to visualize various land use changes (Gregersen et al., 2007).

Rain Garden – is an artificial surface depression that stores stormwater and allows it to infiltrate. Stored water infiltrates into the soil and slowly percolates into the native soil (Jeong et al., 2016).

Rational Formula or Rational Method – method to calculate the runoff generated in the form of overland flow or stormwater. It is based on a formula that combines the coefficient of runoff with the intensity of rainfall and the area of the watershed. The result indicates the peak discharge (maximum rate of flow) for one rain storm event at the mouth of the watershed. It is represented by $Q = CiA$ where Q is the discharge in cubic feet per second; C is the coefficient of runoff; i is the intensity of rainfall in inches or feet per hour; and A is the area of the watershed in acres (Marsh, 2010).

Runoff – describes the portion of precipitation, snow melt, or irrigation water that flows on the surface into streams or other water bodies. Runoff typically occurs when the rate of precipitation exceeds the rate of absorption and infiltration of water into the ground (Peterson et al., 2015).

Scenario Planning – a process that creates an analytical framework and a methodological analysis to explore and assess various development and alternative futures (Hilde & Paterson, 2014).

Stormwater Runoff – refers to the portion of precipitation or snowmelt that accumulates in natural and/or constructed storage and stormwater systems during and immediately following a storm, and flows over land surface into stream channels. Stormwater becomes polluted as it flows over driveways, streets, parking lots, construction sites, agricultural fields, industrial zones, and other urban areas (Marsh, 2010).

Soil and Water Assessment Tool (*SWAT*) – is a watershed-scale model that was developed to predict the impacts of land management practices on water quality. The model uses specific weather information, soil data, topography, land cover, and land use to evaluate hydrological conditions in large complex watersheds over a period of time. *SWAT* was developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (Neitsch et al., 2009). It is a physically based watershed model developed to simulate continuous-time landscape processes and stream flow with a high level of spatial detail by allowing the river/watershed to be divided into sub-basins or sub-watersheds (Santhi et al., 2006).

Stream Flow – also known as discharge, describes the volume of water that moves across a designated point over a fixed period of time (Peterson et al., 2015).

Surface Water – refers to water that is on the ground, i.e. precipitation that does not infiltrate or return to the atmosphere by processes of transpiration by plant leaves or evaporation from soil or water bodies (Peterson et al., 2015).

Texas Commission on Environmental Quality (TCEQ) – formerly known as Texas Natural Resources Conservation Commission, is involved in identifying impairments in water bodies and in TMDL programs to restore water quality (Santhi et al., 2006).

Texas State Soil and Water Conservation Board (TSSWCB) – involved in TMDL programs to restore water quality, and implements several Best Management Practices to reduce nonpoint source pollution loadings from agriculture (Santhi et al., 2006).

Time of Concentration – refers to the time taken for runoff to flow from the perimeter to the mouth of the watershed; varies with the size and conditions of the watershed (Marsh, 2010).

Total Maximum Daily Load (TMDL) – is a written, quantitative assessment of water quality problems and contributing pollutant sources. It specifies the amount of a pollutant or other stressor that needs to be reduced to meet water quality standards, and allocates pollution control responsibilities among pollution sources in a watershed, and provides a basis for taking actions needed to restore a water body (Santhi et al., 2006).

Water Quality – refers to the chemical, physical, and biological characteristics of water, in relation to its suitability for a designated use or purpose (Peterson, et al., 2015). It is a standard that outlines the water quality goals of a water body, or portion thereof, by describing the uses of the water and by assigning criteria that protect these designated uses. Water quality standards are provided by State or Federal Law and are meant to protect the health and welfare of the public, and to enhance the quality of water bodies, and to serve the purpose of the Clean Water Act of 1972 (U.S. Government Publishing Office, 2016).

Water Quantity – describes the amount or volume of water that is available in the water supply (Peterson et al., 2015).

Watershed – is a geographic land area that drains into a waterway such as a lake, stream, channel, estuary, or ocean (Peterson et al., 2015). A watershed is comprised of the land, water, and biota located within the boundaries of a drainage divide. A watershed boundary defines the areal extent of surface water flow draining into a point, and follows the highest ridgeline around the stream channels, and joins at the lowest or bottom point of the land, where water flows out of the watershed (USDA, 2016).

Watershed Approach – an adaptive framework for the management of water quality and quantity within a specified watershed boundary. The approach includes the following: identifying and prioritizing water quality and quantity issues, developing awareness and public involvement, coordinating efforts within related agencies, and measuring success through monitoring efforts and data collection (Peterson et al., 2015).

Watershed Boundary Dataset (WBD) – outlines the areal extent of surface water drainage to a point, including all land and surface areas. A watershed boundary is strictly defined by hydrologic principles, not administrative boundaries. A watershed boundary determines Hydrologic Units (HU), which establish the standard for drainage boundaries (USGS, 2016).

1.6 Methodology

This research uses quantitative methods and empirical analysis to assess stormwater quality and quantity in an urbanized watershed under various scenarios. A quantitative research approach provides a framework for examining the relationship among variables that are being tested by the researcher (Creswell, 2014; Deming & Swaffield, 2011)

Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT*2012) are applied in this study to simulate stormwater runoff in a portion of the Headwaters Turtle Creek watershed, specifically in the Southwestern Medical District in Dallas, Texas. The study presents a predictive modeling approach using GIS and *SWAT* to assess stormwater runoff generated in the study area. The study compares different scenarios of development to assess hydrological conditions as they relate to design elements in the urban landscape. Procedures are documented to evaluate the applicability of a predictive modeling approach using GIS and *SWAT* in landscape architecture.

1.7 Significance and Limitations

This research addresses the need for predictive modeling in landscape architecture practice prior to design development. To date, there have been few studies and efforts that address the criticality of integrating GIS and its associated tools prior to design development in landscape architecture (Wilson, 2015; Parker, 2010). Since this approach has not been extensively used in landscape architecture research and practice, this study is an attempt to present landscape architects with a predictive modeling tool to evaluate land use changes and mitigation practices on urban hydrology.

The procedural methods followed in this study may help inform landscape architects of *SWAT*'s applications, capabilities, and constraints. Evaluation of the existing site conditions and the proposed scenario development may help inform decision-making in the site planning process prior to design development.

This study utilizes secondary data obtained from various sources, either publicly available data or baseline data embedded within the *SWAT2012* interface. The researcher edited secondary data from dated years to better represent current site conditions. This process is intended to remove inaccuracies in the datasets used in the watershed model. Furthermore, the *Soil and Water Assessment Too*l (*SWAT*) was initially developed for application in rural and agricultural settings by third party scientists and professionals. It is a digital modeling tool that has embedded predictive and estimation algorithms, therefore the researcher has no control over its accuracy or reliability. In addition, few research, literature, and guiding procedures exist for applications of *SWAT2012* in highly urbanized environments with various land use types.

1.8 Summary

This introductory chapter presents the background and framework for why this research study is undertaken. The chapter explains the purpose and the significance of applying a predictive modeling and scenario planning approach in landscape architecture. The synopsis of the methodology applied for analysis is presented, and the overall significance and limitations of the study are discussed. Chapter 2, Literature Review, presents a review of related research, and discusses the relevance of environmental landscape performance, predictive modeling, and *SWAT*'s application in the design and planning fields. Chapter 3, Methodology, introduces the detailed quantitative procedures and methods applied to acquire data related to stormwater quality and quantity in the Southwestern Medical District in Dallas, Texas. Chapter 4, Analysis and Findings, introduces the various scenarios developed in GIS and *SWAT2012*, presents the results acquired from the watershed model, and assesses the capabilities of using *SWAT2012,* specifically prior to design development in the site planning process. Chapter 5, Conclusions, summarizes and discusses the findings of the study. Furthermore, the relevance of the study to landscape architecture is discussed, and suggestions for future research are presented.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents literature related to environmental landscape performance, landscape planning process and predictive modeling, and the Soil and Water Assessment Tool (*SWAT*). This chapter discusses the relevance of environmental landscape performance studies in landscape architecture, specifically prior to design development in the site planning process. Literature related to predictive modeling and scenario planning in landscape architecture practice is presented. The development of the Soil and Water Assessment Tool is discussed, and its value and application capabilities in the field of landscape architecture are presented.

2.2 Environmental Factors in Urban Landscapes

2.2.1 Water in the urban environment

Water quality in urban environments has become a relevant concern in the United States (Nawre, 2016; Santhi et al., 2006). Significant efforts relating to environmental protection, based primarily on strategies related to engineering and regulatory solutions, have been developed to mitigate stormwater runoff and pollution (Hulse et al., 2000). According to the Environmental Protection Agency's Clean Water Act, individual states are obligated to implement a Total Maximum Daily Load (TMDL) process, which is a quantitative assessment of water quality problems and contributing pollutant sources (Santhi et al., 2006; USEPA, 2002). The TMDL indicates the amount of pollutants or other contributing factors which need to be reduced in order to meet water quality standards. It also offers a basis for actions required to 'restore a water body'

(Santhi et al., 2006, p. 1142). The Texas Commission on Environmental Quality (TCEQ) and the Texas State Soil and Water Conservation Board (TSSWCB) are involved in the TMDL programs that aim at restoring water quality (Figure 2-1).

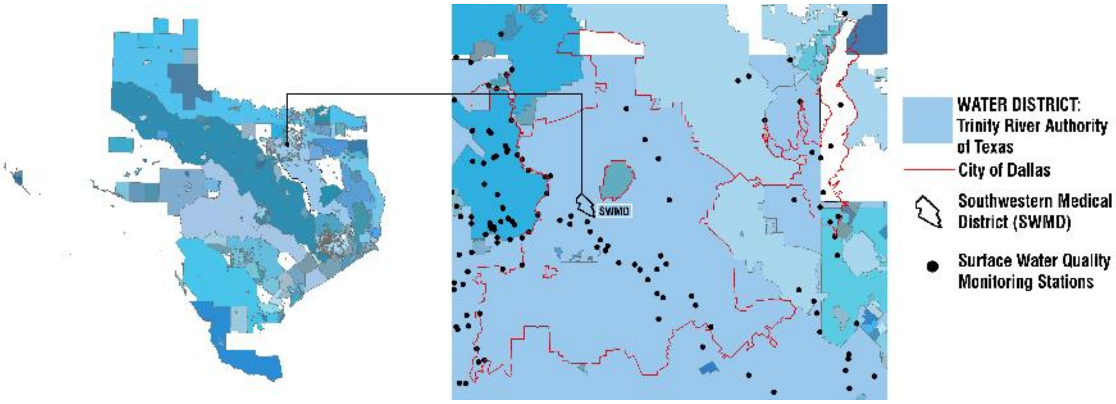


Figure 2-1 TCEQ water districts and study area

(Source: ArcMap; TCEQ Surface Water Quality Viewer; Dallas City Hall GIS Services, 2016)

2.2.2 Water quality and projected development in North Central Texas

North Central Texas is a region encompassing sixteen counties, including the Dallas/Fort Worth metropolitan area (Figure 2-2). Vision North Texas was established as a partnership between private, public, and academic organizations that work towards increasing public awareness about the projected growth for the North Texas region. It works to find alternatives to the pattern of urban growth, and has defined fifteen alternative development scenarios that could enhance the “quality of life, sustainability, and economic vitality” for North Texas communities (Vision North Texas, 2010, p. 3).

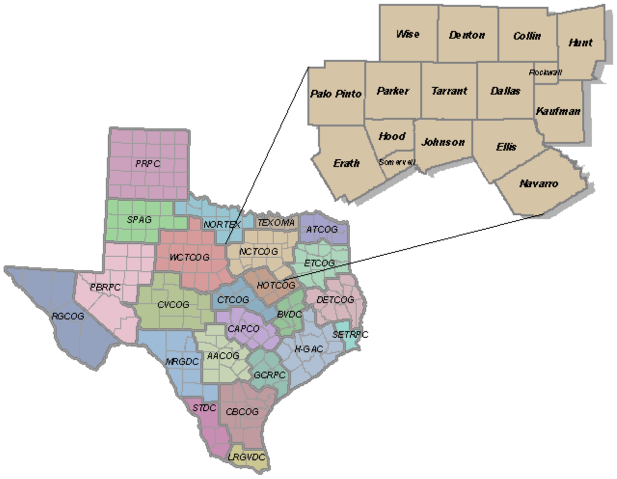


Figure 2-2 NCTCOG region map

(Source: North Central Texas Council of Governments, 2015)

The North Central Texas Council of Governments predicts that the Dallas-Fort Worth Metroplex area’s population will reach 12 million by the year 2050 (Vision North Texas, 2010). Furthermore, it is noted that the area’s current infrastructure is “not adequate to meet the needs of this growth” (Vision North Texas, 2010, p. 1). A continuation in the past trends of development patterns will lead to “significant impacts on the region’s air, water, land, and natural resources” (Vision North Texas, 2010, p. 1). The Dallas/Fort Worth region has witnessed rapid development, which has contributed to the increase in the amount of impervious surfaces, leaving a direct impact on the environment (Vision North Texas, 2010; Parker, 2010). Communities in the Dallas-Fort Worth area have become increasingly concerned with urban sprawl and its effects on watersheds, natural drainage systems, and stormwater runoff (Vision North Texas, 2010).

2.2.3 Urban hydrology, land use, and stream impairment

Land use change is primarily driven by urbanization. More than 75% of the population living in the United States resides in urban areas (Paul & Meyer, 2009). Hilde indicates that “more than half of the world’s population will reside in urban regions” in the upcoming century (Hilde & Paterson, 2014, p. 524). Despite the fact that the general land area occupied by urban growth remains relatively small when compared to the total area of the United States, its impact on the environment is large (Folke et al., 1997). Widespread and increasing urbanization poses a risk to stream ecosystems and urban hydrology (Paul & Meyer, 2009). Water quality and quantity “are related to both land and water management” (McHarg, 1992, p. 56). Urban hydrologists recognize that water quality of highly urbanized watersheds are directly affected by increased impervious cover (Jeong et al., 2013; Kim et al., 2011; Sung & Li, 2010). Significant literature exists relating to “urbanization-induced hydrological alterations” (Yang et al., 2009, p. 3). With the rising concern relating to the environmental impact of increased urban runoff, several authorities have been implementing regulations and the implementation of structural treatments that “maintain the post development peak flow at a rate that is not to exceed the predevelopment peak flow of the same rainfall event” (Jeong, et al., 2013, p. 838). As noted in the discussions above, North Central Texas is currently facing critical challenges due to the impacts of urbanization and rapid development. The Southwestern Medical District in Dallas, Texas is located within the Trinity River Authority of Texas water district. Figure 2-3 demonstrates the impaired stream segment located south of the study site.

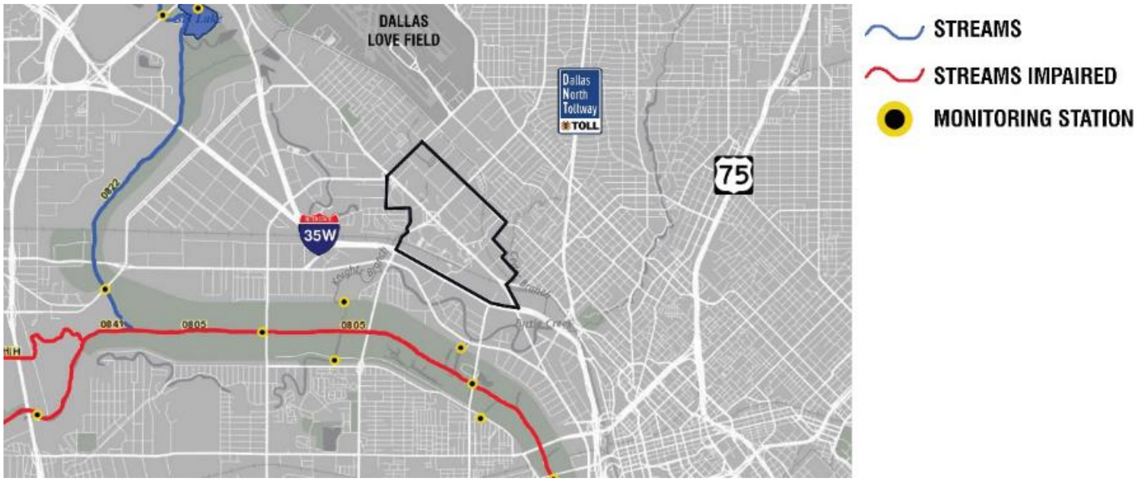


Figure 2-3 Impaired stream segments adjacent to study area

(Source: Texas Commission on Environmental Quality; Surface Water Quality Viewer, 2016)

2.2.4 Landscape performance and environmental factors

A review of the literature indicates that Post-Occupancy Evaluations (POE) gave rise to project performance assessments, and became more common in landscape architecture literature and practice starting from the early 1990s (Ozdil, 2016). In recent years, environmental landscape performance studies and indicators have been highlighted by the Landscape Architecture Foundation’s Case Study Investigation program (LAF-CSI). These studies have adopted case study methods that inform the knowledge base in the landscape architecture profession (Modi, 2014). Furthermore, the Landscape Architecture Foundation has highlighted the importance of performance measures to “demonstrate impact and show how design solutions contribute to sustainability” (ASLA, 2015, p. 1). Furthermore, Marsh indicates that environmental performance is the basis for environmental management and is the guiding tool for future development (2010). In watershed planning and management, performance goals must be established in order to identify the Best Management Practices (BMP) that optimally suit the planning process. Determining performance goals and defining a BMP strategy involves an analysis at the local site scale, and a consideration of the larger-scale regional factors. Furthermore, policies that relate to development density, stormwater management, and open space, should be addressed in the planning process in order to properly manage upstream and downstream settings (Marsh, 2010). While planning new development, or retrofitting existing sites, it is crucial to account for all changes in land use and in land cover within the watershed in order to determine whether particular measures or strategies need to be incorporated to meet specific goals (Marsh, 2010). Understanding the performance of a watershed by studying its composite character and its particular range of land use, soils, and hydrology, is necessary for proposing performance controls and mitigation methods (Marsh, 2010).

2.2.5 Green infrastructure and stormwater management in the urban landscape

A wide range of environmental principles can be considered valuable for land management and ecological planning, specifically in the design and development of green infrastructure systems. Green infrastructure is largely defined based on the scale that it is being applied to in the landscape (Rowe & Bakacs, 2016). At its broadest definition, green infrastructure refers to an "interconnected network of green space that conserves natural systems and provides assorted benefits to human populations" (Benedict & McMahon, 2006, p. 1). Green infrastructure can also refer to the network of strategically managed open and natural spaces which provide ecological benefits in urbanized areas, specifically for human and wildlife populations (Tzoulas et al., 2007; Benedict & McMahon, 2006). Recent research and studies have established a relationship between green infrastructure, human health, and ecological health in urban environments (Frumkin & Louv, 2007; Tzoulas, et al., 2007). The concept of green infrastructure serves as a guiding tool for environmental planning strategies and as a basis for smart growth, by providing a framework for conserving natural assets and connecting people to their natural environment (ESRI, 2016). Green infrastructure provides ecological services that address multiple functions and systems (Rottle, 2010). For example, urban forests provide stormwater control, habitat, community spaces, and climate control. For a green infrastructure system to be functional and healthy, it must address the following open space principles (Rottle, 2010, p. 17):

- Regionally responsive
- Integrated and multi-functional
- Equitable and accessible
- Connected and coherent
- Health and safety
- Ecology and integrity
- Feasibility, flexibility, and stewardship

Green infrastructure can also refer to the techniques used to implement Low Impact Development (LID) strategies for stormwater management. In recent years, several practices that effectively manage stormwater have been introduced. The application of mitigation programs and design strategies such as Low Impact Development (LID) and Integrated Stormwater Management (iSWM) can significantly reduce and improve stormwater runoff quantity and quality (Parker, 2010). LID is an approach to land management that aims to restore or maintain pre-development hydrological conditions. At a site scale, LID strategies can be used to manage stormwater by applying methods that allow water to infiltrate using vegetation or porous surfaces, or by capturing it and storing it for later use. Several benefits have been attributed to the application of green infrastructure and low impact development in the landscape. These benefits can be broadly organized into three main categories: improved stormwater management, reduced costs, and enhanced individual and community well-being (Rowe & Bakacs, 2016). The benefits of improved stormwater management relate to reducing stormwater volume, reducing impervious cover, decreasing and delaying peak discharge, filtering pollutants, and recharging groundwater. In addition, several green infrastructure benefits relate to individual and community health and well-being, by improving water quality and decreasing the incidence of flooding and reducing exposure to waterborne pathogens and toxic chemicals. Other benefits include improving neighborhood aesthetics, improving air quality and cooling urban environments, and increasing recreation opportunities and property values (Rowe & Bakacs, 2016). Green infrastructure relies on source control of stormwater, meaning that it enables "infiltration of rainwater close to or at its point of origin, where it can be filtered into the soil before either being taken up by trees, recharging groundwater, or flowing slowly to streams as interflow" (Condon, 2010, p. 187). This infrastructure approach reduces stream peak flows and flooding downstream, which ultimately contributes to positive watershed performance (Condon, 2010).

2.3 Landscape Planning Process and Predictive Modeling

2.3.1 Site planning and design process

The design process in landscape architecture outlines the procedures or approach undertaken "in search for form or answers to design questions" (Gottfredson, 2014, p. 7). Schön notes that landscape architects "collectively work to develop processes and procedures that can be examined and improved over time and used to train new practitioners (Gottfredson, 2014, p. 11; Schön, 1983). Furthermore, landscape architecture is a profession that follows a methodology and standards, and applies scientific theory and technique (Schön, 1983).

The traditional site planning and design process (Figure 2-4) in landscape architecture research and practice typically includes Post-Implementation and Post-Occupancy performance evaluations in the final stages of a project (Ozdil, 2016; Murphy, 2005; Marcus & Francis, 1998; Simonds, 1998; Toth, 1988; Lynch & Hack, 1984). Lynch and Hack's (1984) site planning process includes nine steps, beginning with problem definition, site analysis, programming, schematic design, design development, contract documents, bidding and contracting, construction, and ending with occupation and management. Toth's (1988) site planning process includes nine steps that begin with problem formulation, data inventory, analysis, criteria evaluation, concept development, concept selection, site planning, site design, and ending with implementation. Simonds' (1998) site planning process begins with commission, research, analysis, synthesis, construction, and ends with operation and performance evaluation. This review of the literature indicated that in the typical site planning process, a performance evaluation is typically done after project construction and implementation. This revealed that the scope of landscape performance evaluations prior to design development in landscape architecture practice has not been fully explored or established.

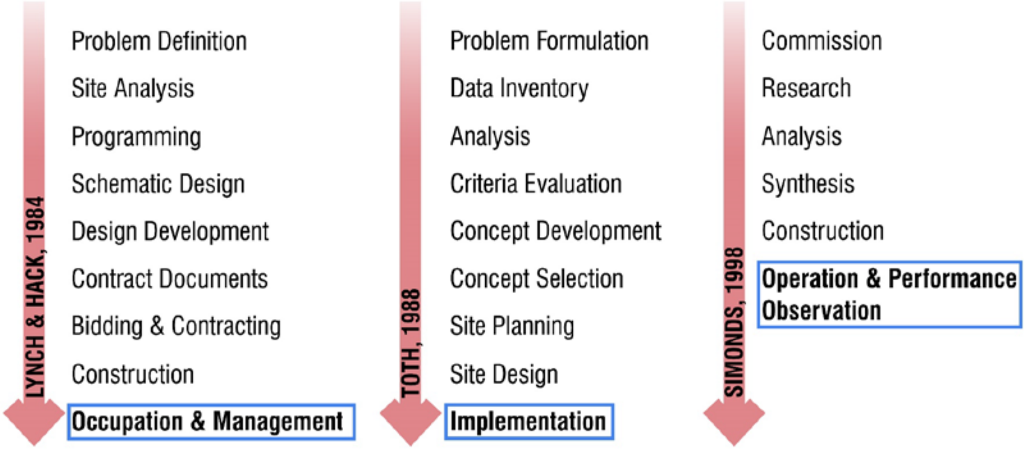


Figure 2-4 Traditional site planning and design process

However, recent technological developments in GIS, landscape architecture, planning, and other allied fields have allowed the application of geoanalytical methods that challenge the traditional and conventional site planning process, and have opened up the application of scientific knowledge specifically for research in urban areas. Several modeling tools have been developed in recent years, therefore this research is an attempt to investigate and assess a predictive modeling approach that may contribute to the formation of a landscape performance evaluation method in landscape architectural studies and practice prior to design development.

2.3.2 Predictive modeling, scenario planning, and geodesign in landscape architecture

Predictive modeling is a method that utilizes computer simulation and monitoring data collected over time and space to visualize various land use changes (Gregersen et al., 2007; France, 2005). It is an approach that has not been utilized extensively in landscape architecture research and has “lagged in practice” (Hilde & Paterson, 2014, p. 524)

Predictive modeling can be used for ecosystem restoration and for proposing design solutions that have positive environmental impacts (American Water Works Association, 2010; France, 2006). With the current trends of urban growth and expansion, planners and landscape architects have been addressing means and tools related to inventory and analysis, simulation, and forecasting change, through a variety of tools and approaches that can be utilized for modeling landscapes within ArcGIS and other platforms (ESRI, 2016). GIS is used for modeling, visualizing, and communicating various and alternative scenarios for development. Modeling tools are designed to provide guidance and recommendations for design and implementation, using data pertaining to landscape conditions and specific characteristics such as soil, topography, and land cover (ESRI, 2016).

Geodesign provides technologies for design and planning professionals to "leverage geographic information, resulting in designs that more closely follow natural systems" (ESRI, 2016, p. 1). It is a design and planning method that allows the creation of design proposals with impact simulations informed by geographic context (Wilson, 2015; Flaxman, 2011). A significant feature of Geodesign is its ability to measure the effects of a proposed change in a virtual manner while in the planning or design phase. Scenario planning processes are facilitated by GIS-based software tools that allow the assessment of alternative development scenarios. The use of Geographic Information System and its associated tools prove useful in representing the past, present, and potential future conditions of natural systems (Wilson, 2015; France, 2005). Developing spatially explicit landscape analyses can be useful in identifying changes over space and time, and the relationships between human activities and the changes that occur in natural systems (Wilson, 2015; Hulse et al., 2000). A set of values and anticipated future conditions can be applied with predictive modeling tools in order to evaluate the effects of alternative future landscapes on water quality “using hydrological and ecological effects models” (Hulse et al., 2000, p. 1).

Several tools are available for evaluating the performance of low impact development (LID) systems. However, few modeling tools are available that can demonstrate the hydrological and water quality impacts of LIDs while considering the complex and variety of land uses in an urban watershed (Jeong et al., 2016). Large-scale watershed models can be used to simulate the hydrological processes of LIDs, while considering the performance of green roofs, rain gardens, cisterns, and porous pavement (Jeong et al., 2016). The implementation of LID practices allows for urban stormwater to be managed on site. Since urban stormwater is manageable at the source level, low impact development practices are a successful tool for mitigating the adverse impacts of urbanization on stormwater quality and quantity, which do not necessitate the retrofit of existing sewer systems (Jaber et al., 2012). Furthermore, the assessment of the performance of LID practices at the catchment scale can positively contribute to the management of urban watersheds and to the protection of water quality in an urban setting (Jeong et al., 2016). This allows for an assessment of the performance and effectiveness of LIDs, to evaluate environmental landscape performance and stormwater management practices prior to project construction and implementation.

2.4 Soil and Water Assessment Tool

2.4.1 Development

SWAT refers to the Soil and Water Assessment Tool, which is a river basin or watershed scale model, initially developed by Dr. Jeff Arnold for the USDA Agricultural Research Service in the early 1990s (Neitsch et al., 2009). *SWAT* was created in order to simulate the effects of land use management practices on hydrological processes and water quality (Gassman et al., 2007). The model was initially developed to assess the long term impact of land management practices on sediment, water, and agricultural chemical yields within large and complex watersheds that have various land use, soils, management, and climate. Since its release, *SWAT* has undergone continuous review to validate its capabilities, and its developers are regularly expanding its functions and tools (Neitsch et al., 2009).

2.4.2 Applications and performance

SWAT is a physically based model that requires specific data relating to land management practices, weather, soil, topography, and vegetation. The model simulates physical processes related to water, nutrient cycling, and sediment movement. Changes in management practices, land use, climate, or vegetation, and their associated impact on water quality can be quantified with *SWAT*. In *SWAT* modeling, a large and complex watershed may be divided into various subwatersheds or basins, and various land uses and soils are incorporated to reflect their impact on hydrology. The watershed-scale model can incorporate the various functions of low impact development systems in hydrological process simulations. Several reviews of existing models that simulate the functions of LID systems can be found in the literature, (Her et al., 2016; Li et al., 2014; Elliott & Trowsdale, 2007; Zoppou, 2001). *SWAT* and its integrated functions have the capability to simulate hydrological processes at various spatial scales, from HRUs (Hydrologic Response Units) to subwatersheds and watersheds. This application allows for “detailed descriptions of heterogeneous watershed landscape processes and placements of LIDs at the HRU level” (Jeong, et al., 2016, p. 5). Additionally, *SWAT* is capable of performing a continuous simulation of watershed hydrology by including soil water content, infiltration, evapotranspiration, and percolation between occurrences of storm events (Neitsch et al., 2009). According to Jeong et al., (2010; 2011; 2013) and

Kannan et al. (2014), the latest improvements made to *SWAT* have enhanced its utility and performance in sub-hourly simulation and in urban stormwater modeling, indicating that the tool has become an efficient option compared to other models, thus producing a reliable assessment for long-term urban watershed processes and “temporal analysis of urban watershed hydrology” (Jeong et al., 2016, p. 5).

SWAT has several applications for landscape analysis, such as hydrology, water quality, land use, and climate change. *SWAT* uses historical weather data to simulate hydrological conditions in a watershed, and can be used to assess the effects of stormwater management structures and urbanization on stream water quality and quantity. *SWAT* simulates water quality indicators, and evaluates pollutant load content such as nitrogen and phosphorus. *SWAT* can be used to estimate the impacts of changing land use on water quality and quantity in streams, specifically the effects of decreasing or increasing tree cover, and increasing the density of urban land uses. Furthermore, *SWAT* can be used to analyze the effects of climate change on the hydrology of watersheds, and can be a useful tool for understanding and mitigating the undesirable impacts of climate change (Neitsch et al., 2009; Santhi et al., 2006).

In recent years, *SWAT* has been used in landscape architecture research studies to assess environmental impacts of projects after construction and implementation. Parker (2010) utilized *SWAT2005* to perform a post construction evaluation of environmental impacts in mixed-use developments on stormwater runoff and water pollution. Parker’s research findings indicated that *SWAT* could be utilized in the profession of landscape architecture as a “pre-construction evaluation” tool (Parker, 2010, p. 86). In addition, Yang, Li, and Huang (2009) used SWAT to compare planning methods for neighborhoods by performing a quantitative measurement of the impact of low-density cluster development versus high-density development. Therefore, this study builds on previous landscape architecture research that utilized *SWAT*, and attempts to test the use of *SWAT2012* prior to design development by assessing the environmental performance of various scenarios on urban hydrology.

2.5 Summary

This chapter presented literature and research related to environmental landscape performance, landscape planning process and predictive modeling, and the Soil and Water Assessment Tool (*SWAT*). Research related to environmental landscape performance, water quality, urban hydrology and land use, and green infrastructure are discussed. The traditional site planning and design process is presented, with emphasis on significance of incorporating predictive modeling and scenario planning prior to design development in landscape architecture. Literature related to the development of the Soil and Water Assessment Tool (*SWAT*) are presented, along with *SWAT*'s current applications and integration of urban stormwater modeling capabilities.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter reviews the research methodology applied in this study, beginning with the research design and the study location. Data collection methods and sources are presented, followed by the predictive modeling tools and scenario development methods for watershed simulation.

3.2 Research Design

This research study uses quantitative methods and empirical analysis to assess stormwater quality and quantity in an urbanized watershed. A quantitative research approach provides a framework for examining the relationship among variables that are being tested as scenarios by the researcher (Figure 3-1). A quantitative method includes "collecting, analyzing, interpreting, and writing the results" of a specific study (Creswell, 2014, p. 23). The variables under study can be measured in order for numerical data to be analyzed (Creswell, 2014; Deming & Swaffield, 2011).

Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT2012*) are utilized in this study to simulate stormwater runoff in a portion of the Headwaters Turtle Creek watershed, specifically in the Southwestern Medical District in Dallas, Texas. The study specifically presents a predictive modeling approach using GIS and *SWAT2012* to evaluate stormwater quality and quantity in an urban landscape. This study utilizes GIS for site inventory and data analysis, and *SWAT2012* for scenario development, watershed simulation, and predictive modeling.

This study tests four scenarios; pre-development, existing, scenario 1, and scenario 2. Given the location of the study area, the pre-development scenario condition is assumed to be Blackland Prairie. The existing scenario is based on the current land use conditions. Scenario 1 is based on the conceptual Urban Streetscape Master Plan for the Southwestern Medical District (Design Workshop™ and Texas Trees Foundation, 2016). Scenario 2 is an exaggerated low impact development scheme. The study utilizes *SWAT2012* in an attempt to understand its applicability and relevance as a predictive modeling tool in landscape architectural studies and practice.

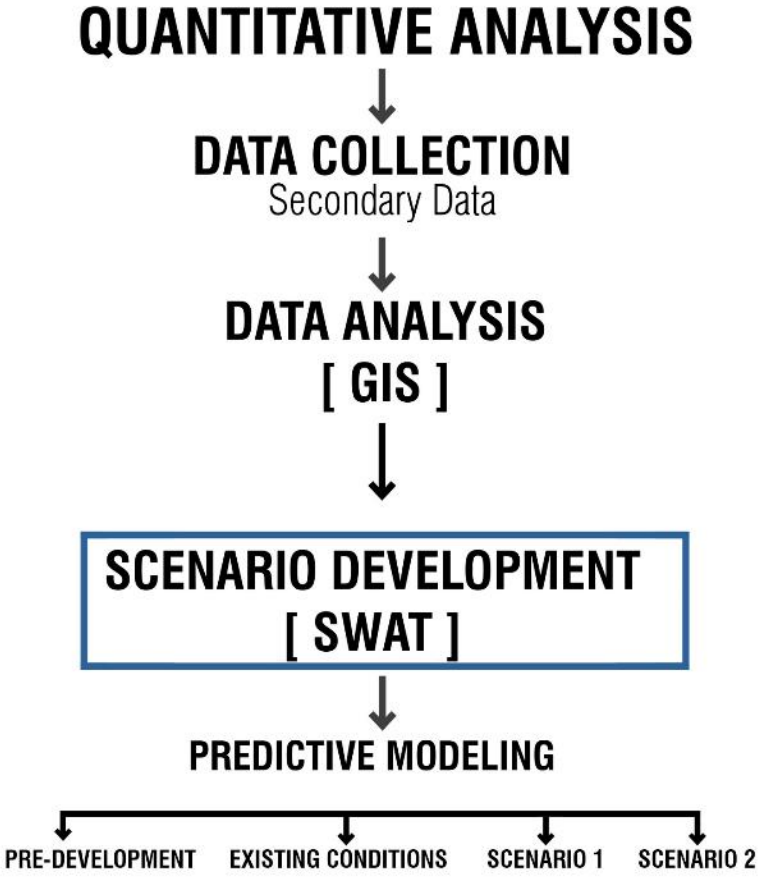


Figure 3-1 Research Design

3.3 Study Location

As briefly covered in the previous sections, the study area for this research is the Southwestern Medical District in Dallas, Texas. This site is selected to assess stormwater runoff quality and quantity in a highly urbanized watershed using GIS and *SWAT2012*. The site is chosen based on its existing urban land uses and its recently proposed development relating to urban streetscape and low impact development. The site's proximity to the Trinity River, and its potential for becoming a model for other urban districts nationwide, made it a suitable case to evaluate with GIS and *SWAT*. The study area is located in the Upper Trinity Watershed (12030105 USGS Hydrologic Unit Code; Figure 3-2), which encompasses the Headwaters Trinity River watershed (1203010501 USGS Hydrologic Unit Code; Figure 3-3), which includes the Headwaters Turtle Creek watershed (USGS 120301050101 Hydrologic Unit Code; Figure 3-4). The Southwestern Medical District encompasses a 350-hectare portion of the Headwaters Turtle Creek watershed (Figure 3-5).

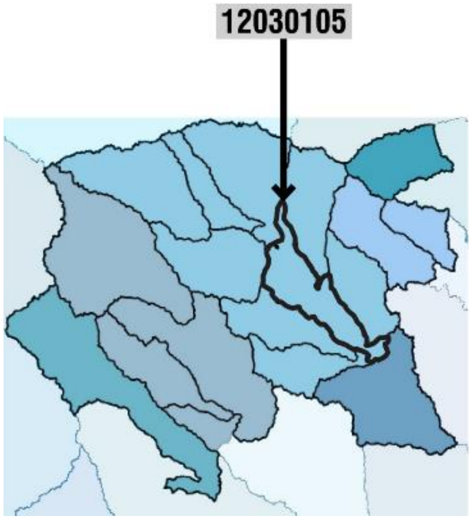


Figure 3-2 Upper Trinity Watershed

(Source: ESRI, ArcGIS, USGS National Hydrography Dataset, 2016)

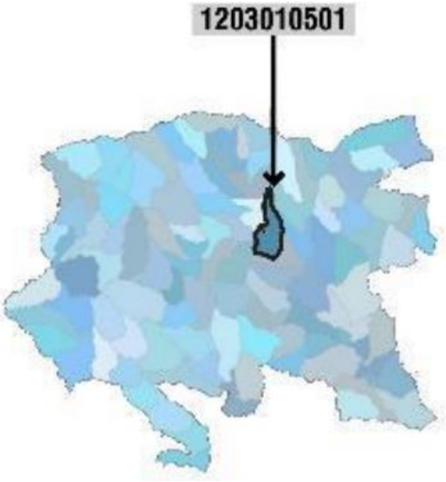


Figure 3-3 Headwaters Trinity River

(Source: ESRI, ArcGIS, USGS National Hydrography Dataset, 2016)

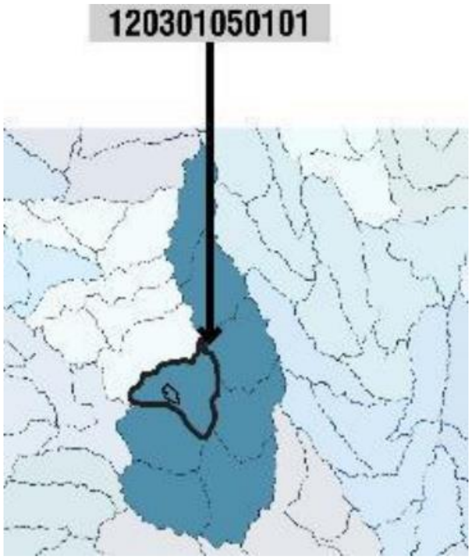


Figure 3-4 Headwaters Turtle Creek

(Source: ESRI, ArcGIS, USGS National Hydrography Dataset, 2016)

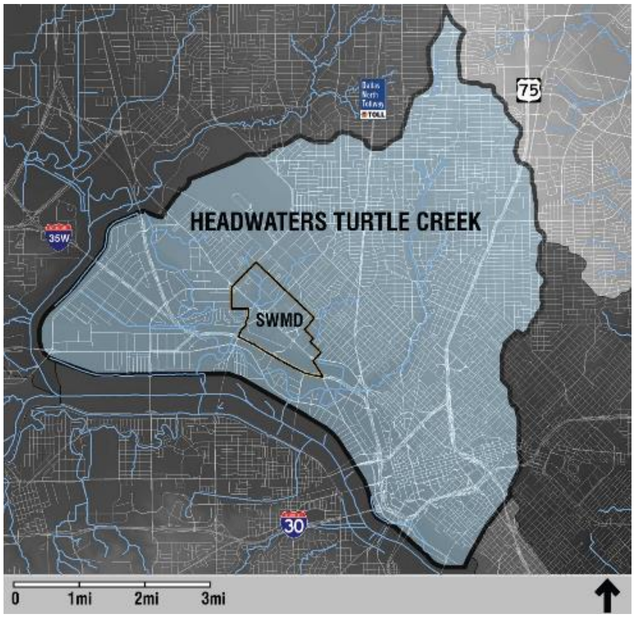


Figure 3-5 SWMD within the Headwaters Turtle Creek watershed

(Source: ESRI, ArcGIS, 2016)

The study area is bound by Interstate Highway 35E (Stemmons Freeway), Maple Avenue, Medical District Drive, and Mockingbird Lane (Figure 3-6). The researcher adopted the study area boundaries based on the Southwestern Medical District Urban Streetscape Master Plan (Texas Trees Foundation & Design Workshop, January 2016). The total district area is 350 hectares, comprised of 46% impervious surfaces (parking, roads, and utilities), and 14% tree canopy.

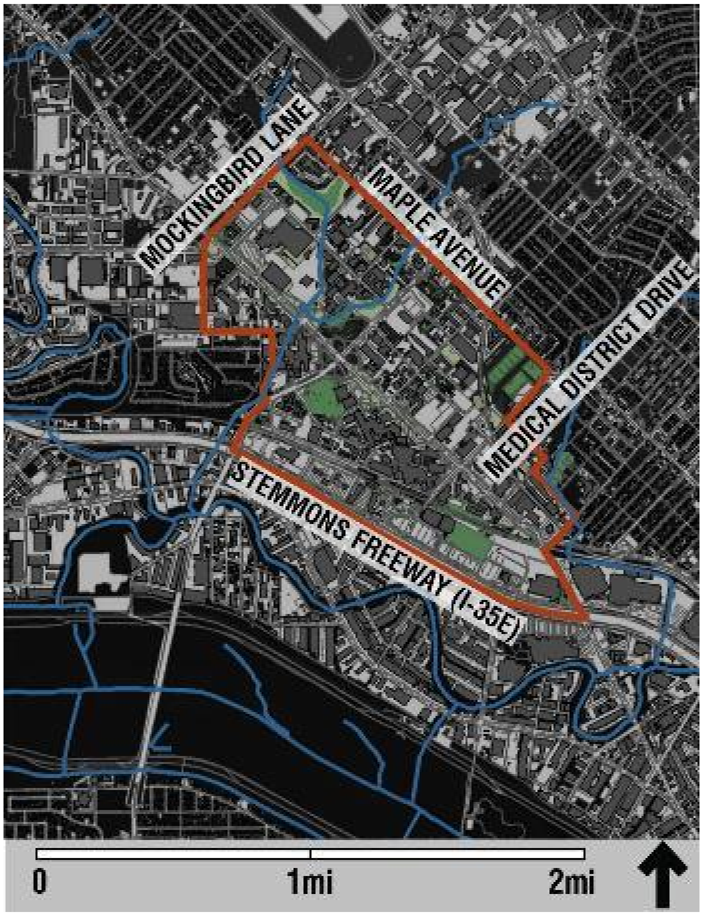


Figure 3-6 Study Area: SWMD

(Source: ESRI, ArcGIS, Google Earth Pro, 2016)

The study area is located within the Stemmons Corridor, which encompasses the Southwestern Medical District. The Stemmons Corridor area is expected to grow considerably in the upcoming decades. NCTCOG predicts that the area will absorb about five percent of Dallas' overall projected growth (Vision North Texas, 2010).

Figure 3-7 SWMD; Harry Hines Boulevard

(Source: photo taken by researcher; October 2016)

It is also predicted that the area will absorb about ten percent of Dallas' overall employment growth, and that an additional 22,000 households will be located in the Stemmons Corridor-Southwestern Medical District (City of Dallas, 2010). The Stemmons Corridor-Southwestern Medical District area is one of the most significant areas within the City of Dallas, and encompasses "more than 5,000 businesses, more than 100,000 employees" (City of Dallas, 2010), and contributes to an estimated one-fourth of the total taxes collected by the city.

Figure 3-8 SWMD; Parkland Memorial Hospital

(Source: photo taken by researcher; October 2016)

The Southwestern Medical District, located within the Stemmons Corridor, is distinguished by its considerable number of medical facilities, which have collaborated in order to develop unified plans for growth and expansion that build upon major opportunities for economic development within the larger Stemmons Corridor. The Southwestern Medical District has developed plans for growth in order to maintain and expand its excellence and progress within the medical field (City of Dallas, 2010).

The Texas Trees Foundation, in partnership with DESIGN WORKSHOP™ (Landscape Architecture, Planning, and Urban Design firm), and the Southwestern Medical District, have collaborated to create an Urban Streetscape Master Plan for the area (Texas Trees Foundation & Design Workshop, March 2016). The premise of the project was identified through findings from the 2015 State of the Dallas Urban Forest Report. The results of the study indicated that the Southwestern Medical District was a major urban heat island (Texas Trees Foundation, 2015).

Figure 3-9 SWMD; impervious surfaces

(Source: photo taken by researcher; October 2016)

Consequently, the project's design team is collaborating to produce the district's Urban Streetscape Master Plan, which addresses several issues relating to healthy environments and human welfare.

1. Urban heat island effect; which leads to "increased temperatures in cities compared to their surrounding rural and suburban areas" (Southwestern Medical District, January 2016)
2. According to a 2014 study on climate control, Dallas is up to 19°F hotter in the city than adjacent rural areas (Southwestern Medical District, January 2016; Climate Central, 2014)
3. Infrastructure; street infrastructure is failing (Southwestern Medical District, January 2016)

The Southwestern Medical District (SWMD) Urban Streetscape Master Plan aims to create a functional design that responds to ecological requirements, provides a safer pedestrian and vehicular environment, and contributes to reducing stress and supports the Medical District community and its visitors (Southwestern Medical District, January 2016). The foundation for the design approach of the Southwestern Medical District Urban Streetscape Master Plan is based on three principles (Figure 3-10):

1. “PRIORITIZE a healthy environment (tree canopy, rain gardens, stormwater management, urban forests).
2. ESTABLISH healthy systems (way-finding, site furnishings, safe intersections, lighting).
3. ENCOURAGE healthy people (biking, running, walking, and resting). (Texas Trees Foundation & Design Workshop, Southwestern Medical District, January 2016)


DISTRICT MASTER PLAN

Source: 2009 Southwestern Medical District Master Plan

Figure 3-10 SWMD Urban Streetscape Conceptual Master Plan

(Source: Design Workshop™, Texas Trees Foundation, 2016)

This research looks into the environmental aspect of the Urban Streetscape Master Plan, and extracts the elements that relate to increasing tree canopy in the district and filtering stormwater through rain gardens (Figure 3-11). This scheme is referred to as “Scenario 1” in the *SWAT2012* analysis.

Figure 3-11 SWMD Urban Streetscape Concept

(Source: Design Workshop™, Texas Trees Foundation, 2016)

3.4 Data Collection

The basic data categories required for the *SWAT* watershed simulation model to function are elevation, climate, land use, soil, and hydrology. Secondary sources from publicly available platforms were used to extract datasets related to slope, soil, climate, hydrology, and existing land use (Table 1). These data are required to build the watershed simulation model. The researcher acquired data relating to proposed tree cover and rain gardens from the Southwestern Medical District Urban Streetscape

Conceptual Master Plan, and converted data from CAD (.dwg) format to Shapefile (.shp) format with the ArcGIS Toolbox. These data were used to develop Scenario 1.

The researcher built on scenario 1 and increased low impact development features such as green roofs, porous pavement, and rain gardens in order to develop Scenario 2.

DATA SET	**SOURCE**
Slope	USDA Natural Resources Conservation Service
Soil	USDA Natural Resources Conservation Service
Climate	USDA Natural Resources Conservation Service
Hydrology	USGS National Hydrography Dataset
Existing Land Use	North Central Texas Council of Governments
Proposed Tree Cover	Urban Streetscape Master Plan (Conceptual Design)
Proposed Rain Gardens	Urban Streetscape Master Plan (Conceptual Design)
LID: Green Roofs	Incorporated by researcher
LID: Porous Pavement	Incorporated by researcher
LID: Rain Gardens	Incorporated by researcher

Table 1 Data Sources

A technical and procedural approach was followed to run the *SWAT2012* model and produce a set of results. The following methods were adopted to assess the applicability of *SWAT* and its use in landscape architecture prior to design development:

- Obtain necessary data to run the model
- Data preparation and validation by researcher
- Input data in GIS for inventory and analysis
- Convert data to values that are compatible with the *SWAT* interface
- Set up *SWAT* simulation
- Run model for existing site conditions
- Incorporate land use changes
- Assign low impact development strategies for various land use types
- Run model for alternative scenarios
- Display and compare results for existing and proposed conditions

3.5 Data Analysis

As mentioned in the research design section, this study assesses four different scenarios; pre-development, existing conditions, scenario 1, and scenario 2. The analysis for the four scenarios was run in *SWAT2012* in order to assess its applicability and relevance to landscape architectural studies and practice. The study area, Southwestern Medical District, encompasses 350 hectares of the Headwaters Turtle Creek watershed. The study area was input in the model, and a 810-hectare watershed was generated by the model to run the analysis (Figure 3-12). In the following chapter, Analysis & Findings, results are clipped to the 350- hectare study area.

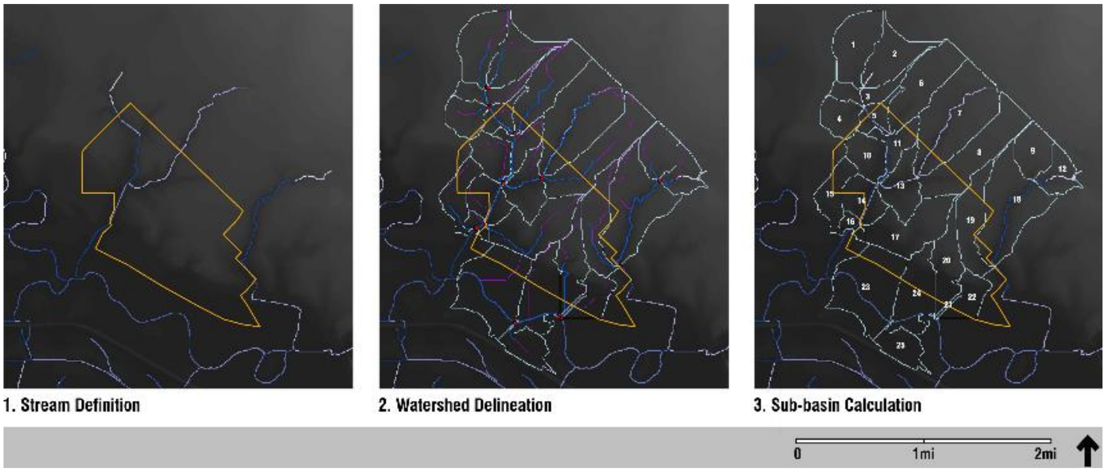
Figure 3-12 Watershed and study area

Geographic Information System (GIS) was utilized for site inventory and analysis. This method of analysis involves analyzing data obtained from secondary sources to display information relating to slope, hydrology, soil, and land use. Datasets were projected to the NAD83 coordinate system. Data were converted within Geographic Information System by the *SWAT* interface using the Watershed Delineator Tool (Figure 3-13).

3.5.1 SWAT *scenario development*

As introduced in previous sections, scenarios were developed in *SWAT2012* to compare various hydrological conditions in a highly urbanized watershed. A watershed delineation process (Figure 3-13) is followed for each scenario; pre-development, existing conditions, scenario 1, and scenario 2.

1. Stream Delineation
2. Watershed Delineation
3. Sub-Basin Calculation



1. Stream Definition

2. Watershed Delineation

3. Sub-basin Calculation

Figure 3-13 SWAT watershed delineation

(Source: ArcGIS, *SWAT2012*, 2016)

Slope, soil, and land use data were reclassified by the *SWAT* interface into values that are compatible with the watershed model:

- Slope Analysis (Figure 3-14)
- Soil Analysis (Figure 3-15); discrepancy between GIS and SWAT, possible software or user error during processing.
- Land Use Analysis (Figure 3-16)

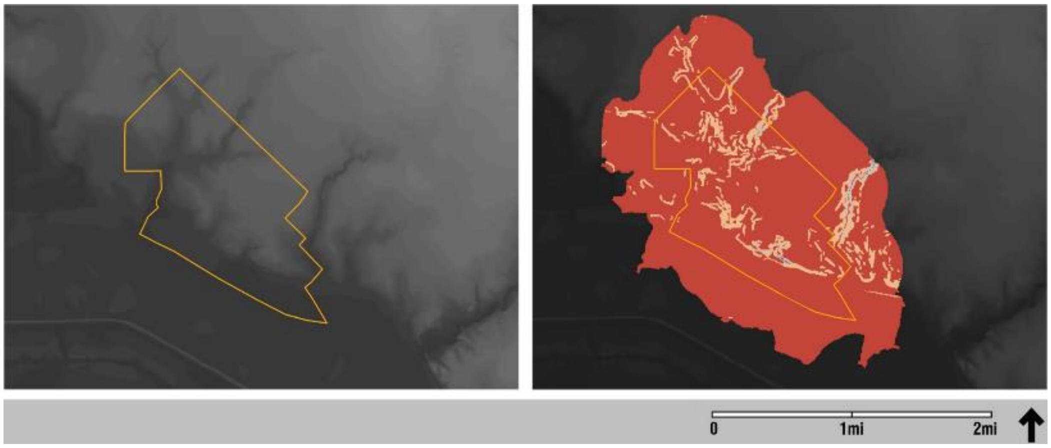


Figure 3-14 Slope analysis

SLOPE LEGEND

🟥 0-2% slope

🟧 2-5% slope

⬜ 5-10% slope

🟦 10-99% slope

Figure 3-15 Soil analysis

SOIL LEGEND (STATSGO; State Soil Geographic)

🟧 TX235 – Houston Black Clay (59.11%)

🟫 TX574 – Trinity Clay (40.89%)

Figure 3-16 Land Use analysis

LAND USE LEGEND

🟧 [URHD] – Residential, High Density (7.8%)

🟨 [URBN] – Residential, Medium-Low Density (14.6%)

🟥 [UCOM] – Commercial (16.3%)

🟪 [UIDU] – Industrial (1.8%)

⬛ [UTRN] – Transportation, Parking, and Utilities (44.6%)

🟦 [UINS] – Institutional (9.8%)

🟩 [PARK] – Parks and Open Spaces (1.2%)

⬜ [VCNT] – Vacant Land (3.9%)

SWAT links to a Microsoft Access database that includes each land use type, correlated with a FIMP factor (fraction total impervious area in urban land type), and with a FCIMP (fraction of directly connected impervious area), refer to Table 2 – Land Use Types.

LAND USE (URBNAME)	**DESCRIPTION**	**FIMP**	**FCIMP**
URHD	Residential, High Density	0.6	0.44
URBN	Residential, Medium-Low Density	0.38	0.4
UCOM	Commercial	0.67	0.62
UIDU	Industrial	0.84	0.79
UTRN	Transportation, Parking, and Utilities	0.98	0.95
UINS	Institutional	0.51	0.47
PARK	Parks and Open Spaces	0.1	0.01
VCNT	Vacant Land	0.75	0.65

Table 2 - Land Use Types

After data inputs were reclassified by *SWAT*, a Hydrological Response Unit (HRU) Analysis was run. HRUs are derived from an overlay of slope, soil, and land use (Figure 3-17). Each HRU is a unique combination of these three features. A Hydrological Response Unit is used to simplify the watershed simulation by categorizing similar soils, land uses, and slopes into manageable features with readable outputs. A HRU report is produced listing the details of each unit (refer to Appendix B).

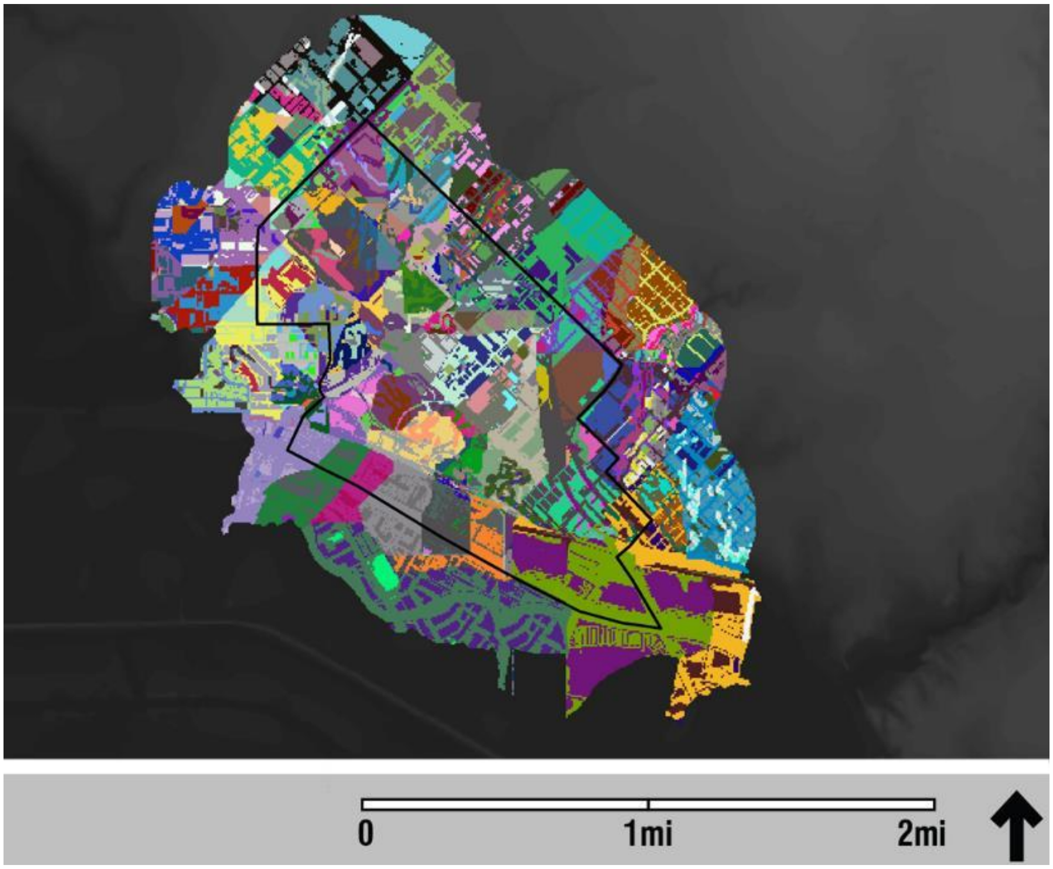


Figure 3-17 Hydrologic Response Unit overlay analysis

In the *SWAT* model, the watershed was divided into a total of 37 subbasins based on drainage networks. These subbasins were further subdivided into 373 Hydrologic Response Units. The generated HRUs were based on a 0-3-3 threshold: 0% for land use type, 3% for soils, and 3% for slope.

3.5.2 SWAT watershed simulation

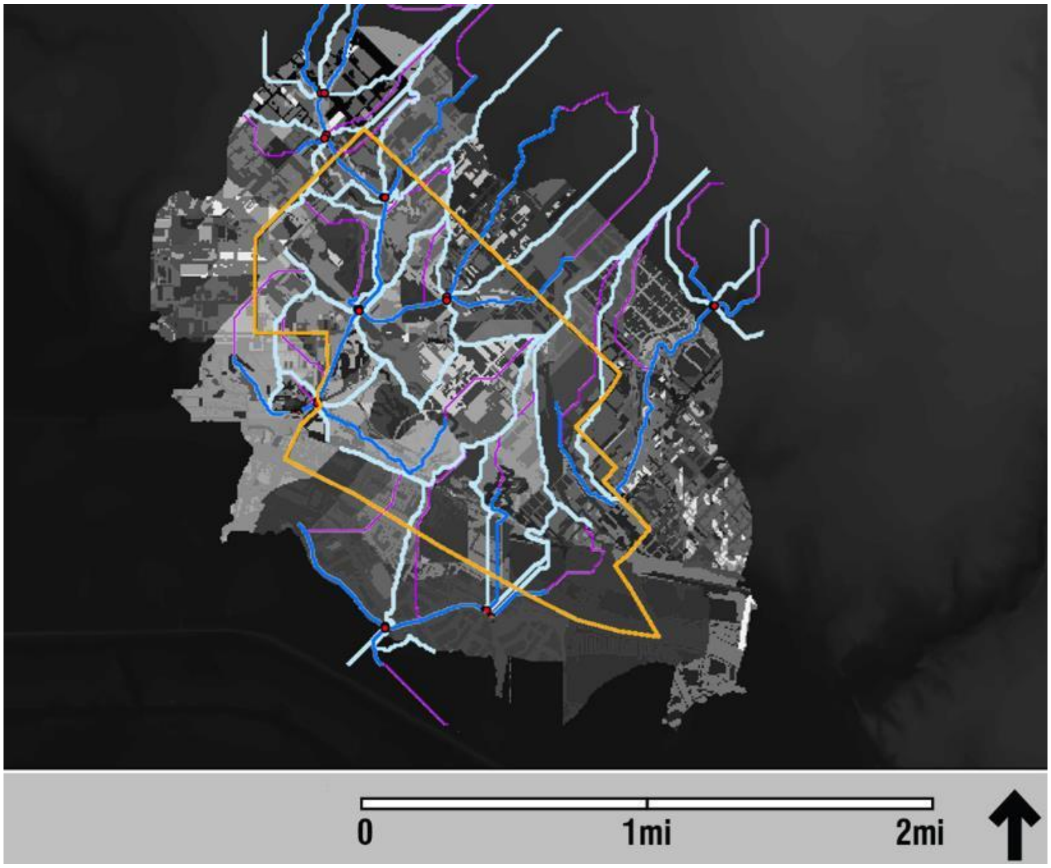


Figure 3-18 SWAT watershed simulation

SWAT2012 was utilized to analyze hydrological conditions for the existing conditions scenario (Figure 3-18). A watershed simulation process was run by the researcher for a 2-year period. Daily weather data were obtained from the Dallas FAA AP station (ID: TX2244), which is located at 1.5 miles from the center of the study area. The following procedures were followed in *SWAT2012* for watershed simulation and hydrological modeling (Winchell et al., 2013; Neitsch et al., 2009). A summary of the procedures followed in *SWAT* is described briefly below and illustrated in Figure 3-19.

1- Create new *SWAT* project

2- Assign a watershed delineation based on the Digital Elevation Model (DEM)

3- Apply a stream definition based on the DEM and run the flow direction function

4- Create a stream network and outlets

5- Delineate the watershed and calculate subbasin parameters

6- Define the land use grid and assign each value an urban grid code

7- Define the soils grid

8- Define the slope and number of classes

9- Overlay land use, soils, and slope to create Hydrologic Response Units (HRU)

10- Assign a weather station, and rainfall and temperature data

11- Write the *SWAT* input files

12- Edit the *SWAT* input files if needed

13- Setup *SWAT* run

14- Run *SWAT*

15- Run *SWAT* check to detect possible errors in model

16- Read output file

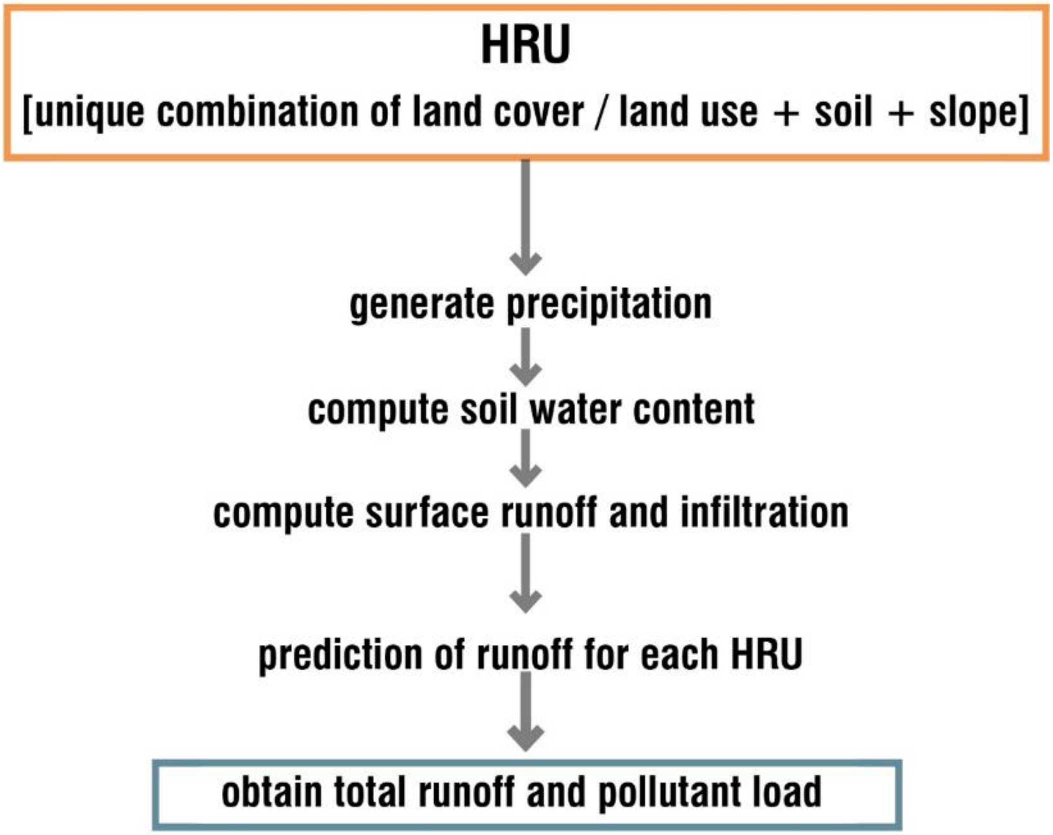


Figure 3-19 SWAT Summary of procedures

After the watershed model creates unique Hydrologic Response Units, the model simulates weather for a user-specified time period, and computes soil water content and surface runoff and infiltration for the study area. Runoff is predicted for each Hydrologic Response Unit, and total runoff and pollutant load is calculated (Figure 3-19).

3.6 Bias and Error

SWAT has undergone several upgrades and modifications over the years, leading to improved accuracy in quantifying the impact of land management practices over large and complex watersheds (Gassman et al., 2007). However, despite its extensive application in rural and agricultural studies, few research studies have evaluated *SWAT*'s ability to simulate, at a site level, the hydrological and land management processes associated with highly urbanized environments (Parker 2010).

This study utilized secondary data from various sources. Although attempts were made to attain accurate data, inherent errors may still have existed within the datasets that could not be accounted for by the researcher. The data acquired were processed and cleansed to a certain extent by the researcher, and may have been subjected to human error. Furthermore, running the *SWAT* watershed simulation model required data reclassification, and software limitations may have generated additional errors during conversion or processing. In addition, some data were converted by the researcher from *.DWG* (AutoCAD) to *.SHP* (ArcGIS) format and may have been subjected to additional human error.

More importantly, the scenarios that were tested in this research analysis were created by the researcher to demonstrate impacts of different site conditions on stormwater quality and quantity. The scenarios are not intended to represent the actual impacts of the proposed development of the Urban Streetscape Master Plan on the Southwestern Medical District. The proposed development set forth by the Urban Streetscape Master Plan incorporates economic, social, and other environmental factors that were not accounted for in this research. Therefore, the findings of this research should not be considered conclusive or definitive.

In addition, this study is primarily focused on environmental landscape performance as it relates to stormwater runoff quality and quantity, other factors related to urban hydrology are not addressed as part of this research. Data analyses related to flooding, single-storm events, and channel erosion are not within the scope of this study.

3.7 Summary

This chapter presented the research methodology adopted for analysis using Geographic Information Systems (GIS) and the Soil and Water Assessment Tool (*SWAT2012*). The methodology related to data analysis of existing site conditions is reviewed, by demonstrating the processes followed by the researcher for watershed simulation. In the following chapter, analysis for pre-development, existing conditions, scenario 1, and scenario 2, are presented and analyzed in *SWAT2012* to compare stormwater quality and quantity under different site conditions.

Chapter 4

ANALYSIS & FINDINGS

4.1 Introduction

This chapter presents the analysis and findings of the watershed simulation model for various scenarios of development: pre-development, existing conditions, scenario 1, and scenario 2. Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT2012*) were used to evaluate the various scenarios and to assess the hydrological conditions in a portion of the Headwaters Turtle Creek watershed in Dallas, Texas, specifically stormwater runoff quality and quantity in the Southwestern Medical District. The methodology outlined in the previous chapter is adopted for each scenario. The procedures and methods are documented to assess the applicability of a predictive modeling approach using GIS and *SWAT* prior to design development in landscape architectural studies and practice.

4.2 *SWAT* Analysis and Scenarios

The *SWAT* watershed simulation model for this study was developed to compare four different scenarios in the Southwestern Medical District in Dallas, Texas. The first scenario represented pre-development conditions, which were assumed to be Blackland Prairie given the location of the study area. The second scenario represented the existing conditions of the site. The third scenario, referred to in this study as “scenario 1”, represented some elements of the conceptual design proposal of the Urban Streetscape Master Plan (Design Workshop™ and Texas Trees Foundation, 2016), which included increased tree canopy and low impact development elements. The fourth scenario, referred to in this study as “scenario 2” represented a hypothetical and exaggerated low impact development scheme, which included increased tree canopy, green roofs, porous pavement, and rain gardens. Figure 4-1 briefly summarizes the parameters in each scenario, except for pre-development conditions. This scenario assumes that the site is Blackland Prairie and that it does not include such elements.

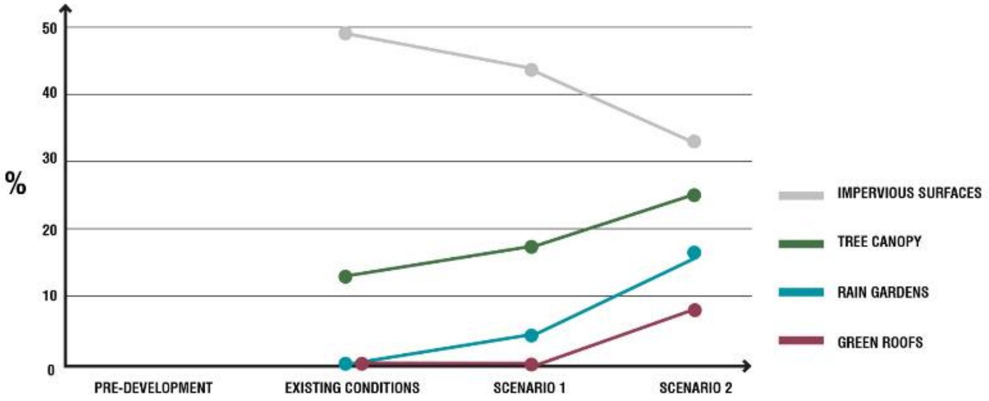


Figure 4-1 Landscape elements in *SWAT* scenarios

As illustrated in Figure 4-1, impervious surfaces in the 350-hectare district were reduced from 47% in existing conditions to 42% in scenario 1, and further reduced to 32% in scenario 2. Tree canopy coverage in the 350-hectare district was increased from 12% in existing conditions to 16% in scenario 1, and further increased to 26% in scenario 2. Rain gardens were added to 4% of the district area in scenario 1, and were further increased to 10% of the 350-hectare district in scenario 2. Green roofs were introduced in scenario 2 to cover 8% of the 350-hectare district.

4.2.1 SWAT Analysis: scenario for pre-Development

For assessment of hydrological conditions in the pre-development scenario, land cover is assumed to be Blackland Prairie given the location of the study area (Figure 4-2). The scenario is analyzed to assess water quality, quantity, and surface flow, based on site topography, soils, and land cover.

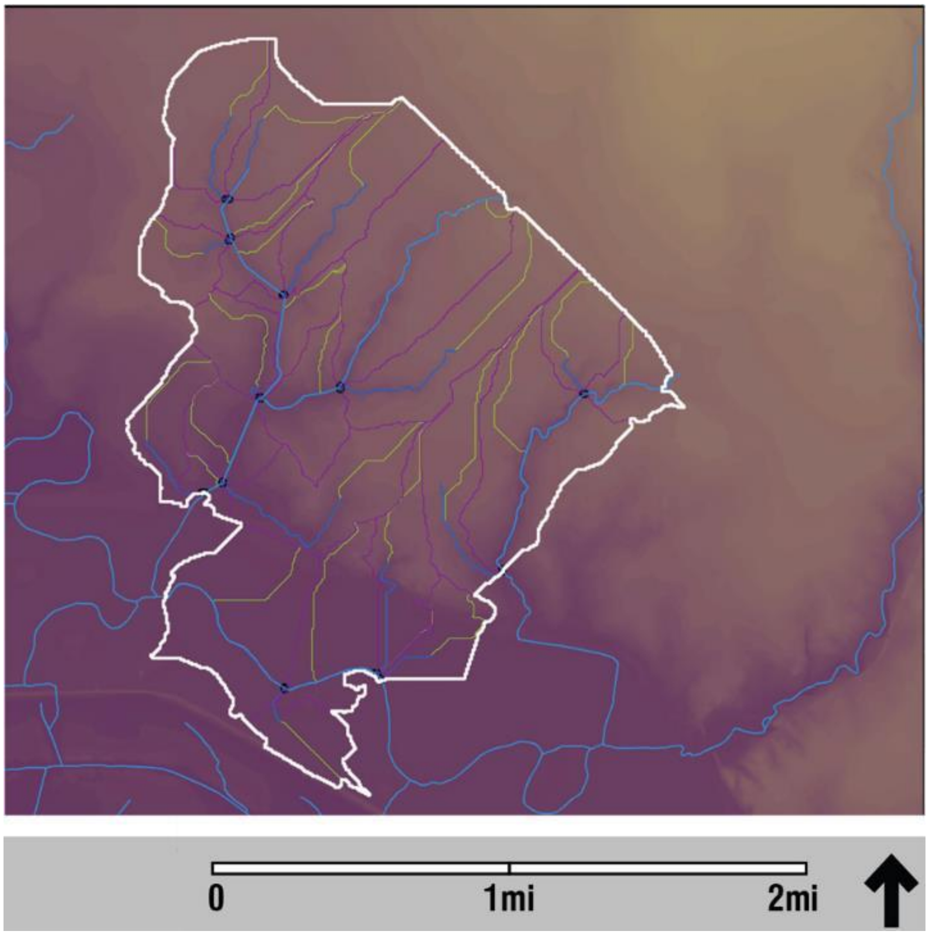


Figure 4-2 Scenario for pre-development

4.2.2 SWAT Analysis: scenario for existing conditions

For assessment of hydrological conditions in the existing site conditions scenario, land use data are based on NCTCOG's 2015 Land Use report (Figure 4-3). This scenario is analyzed to assess water quality, quantity, and surface flow, based on site topography, soils, and land use. Each land use is linked to a FIMP factor, which is a fraction of total impervious area for each land use type. This allows the model to predict the amount of surface runoff that is generated by each urban land use type.

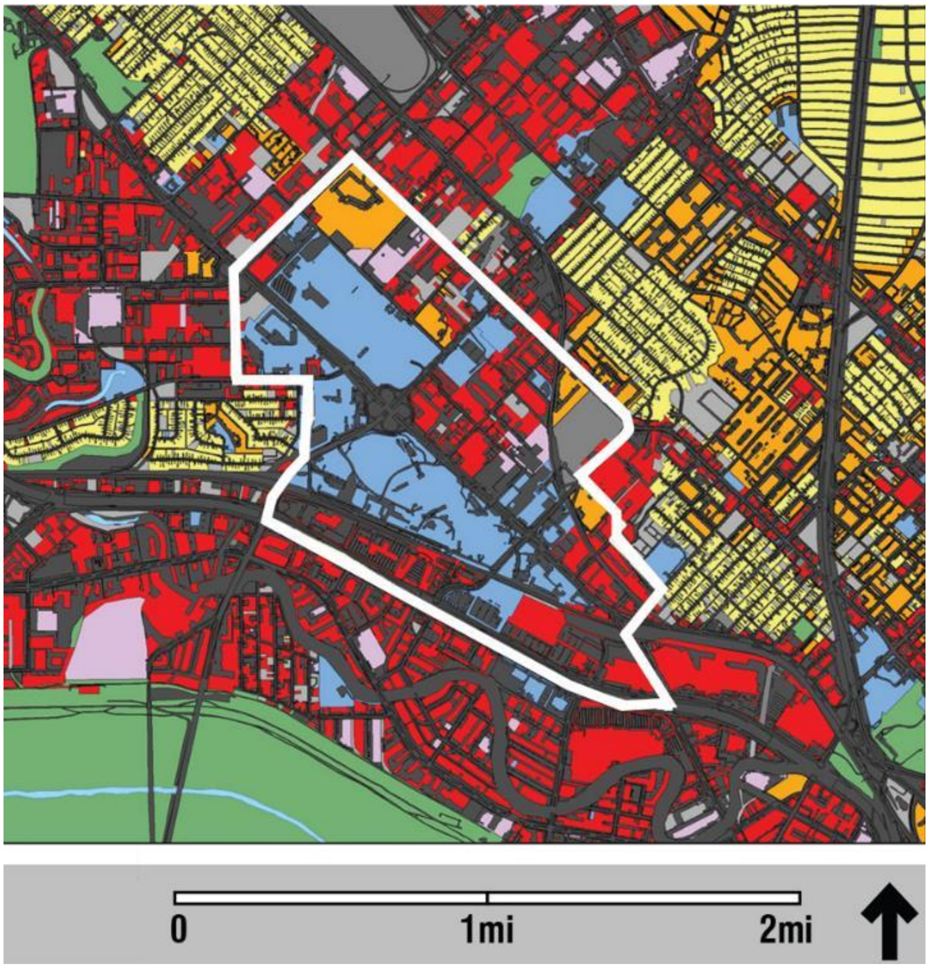


Figure 4-3 Scenario for existing conditions

4.2.3 SWAT Analysis: scenario 1

For assessment of hydrological conditions in scenario 1, data were input in the watershed model to represent the conceptual design proposal of the Urban Streetscape Master Plan (Design Workshop™ and Texas Trees Foundation, 2016), which included increased tree canopy and low impact development elements such as rain gardens (Figure 4-4). This research was done when the master plan for the Southwestern Medical District was under development.

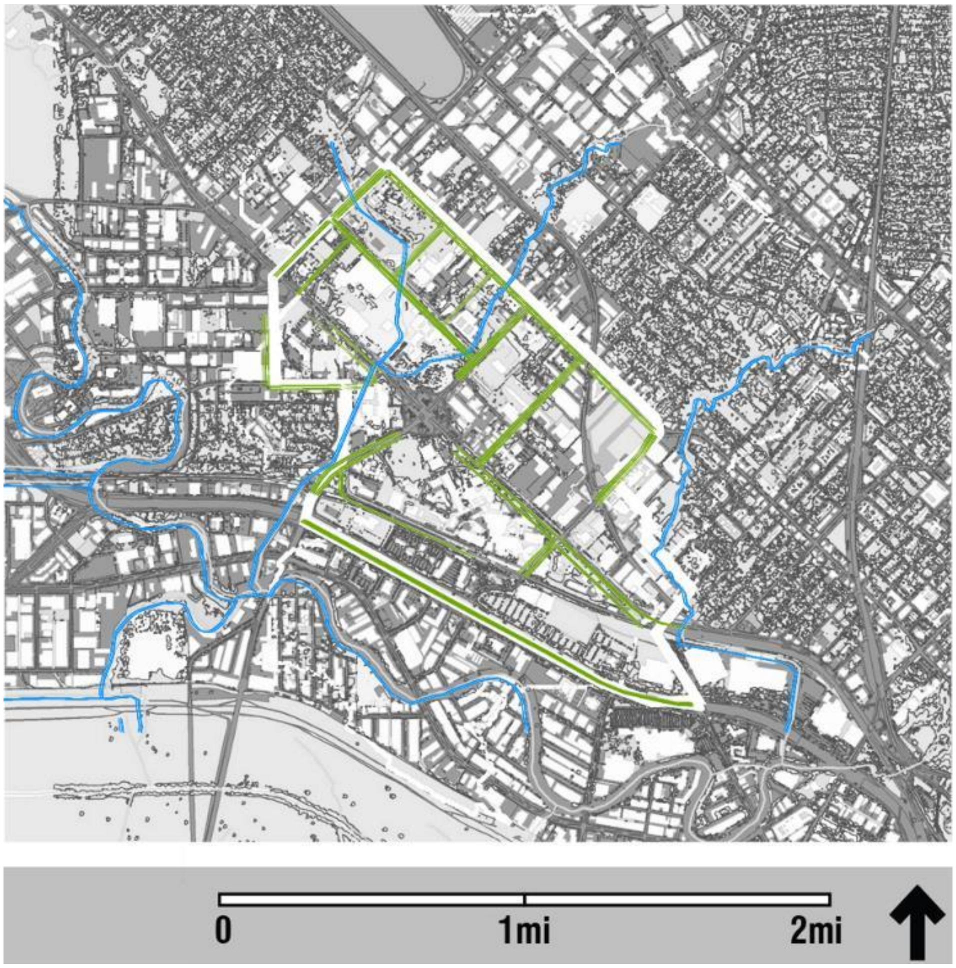


Figure 4-4 Scenario 1

4.2.4 SWAT Analysis: scenario 2

For assessment of hydrological conditions in scenario 2, the researcher exaggerated the low impact development elements that were proposed in scenario 1, and increased rain gardens, and incorporated porous pavement and green roofs (Figure 4-5).

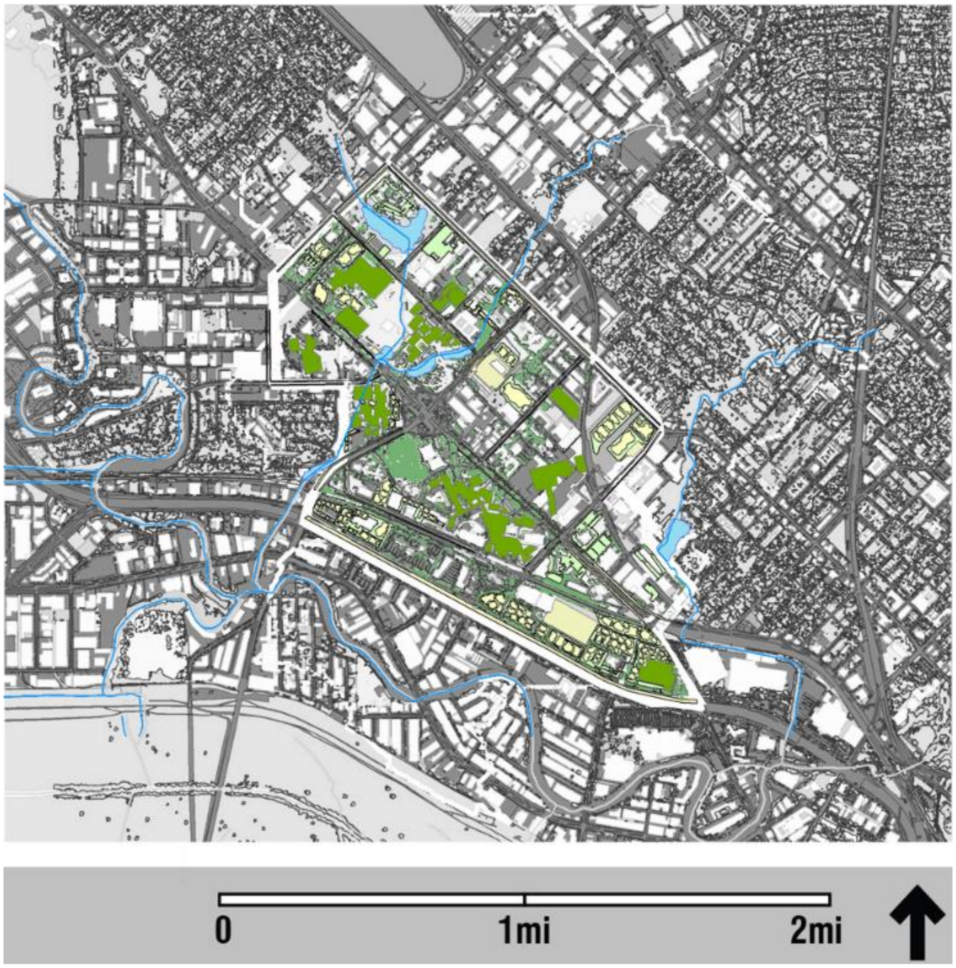


Figure 4-5 Scenario 2

4.3 Analysis Results

The four scenarios were developed in the *SWAT* watershed simulation model in order to assess hydrological conditions under varying parameters in the landscape, specifically stormwater runoff quality and quantity.

Each scenario required a considerable amount of time to develop, however once the model was initiated, running the analysis required significantly less time. Table 3 displays the results obtained from the output of each scenario, specifically annual precipitation, surface runoff, amount of water stored in the soil profile, and pollutant load (Nitrate, Nitrogen, and Phosphorus).

SWAT SCENARIO	**Simulation Period (Year)**	**Annual Precipitation (mm)**	**Surface Runoff (mm)**	**Amount of Water Stored in Soil Profile (mm)**	**Nitrate in Surface Runoff (kg/ha)**	**Organic Nitrogen in Surface Runoff (kg/ha)**	**Organic Phosphorus in Surface Runoff (kg/ha)**
Pre-Development	**1**	**1160.8**	**91.66**	**855.2**	**0.42**	**1.19**	**0.16**
	2	**1323.1**	**104.48**	**1089.5**	**0.48**	**1.35**	**0.18**
Existing Conditions	**1**	**1160.8**	**753.24**	**89.3**	**3.38**	**9.82**	**1.53**
	2	**1323.1**	**812.17**	**72.75**	**5.08**	**10.33**	**1.62**
Scenario 1	**1**	**1160.8**	**667.6**	**103.52**	**2.99**	**8.72**	**1.36**
	2	**1323.1**	**746.88**	**79.17**	**3.4**	**9.93**	**1.55**
Scenario 2	**1**	**1160.8**	**557.4**	**256.81**	**2.35**	**7.01**	**0.82**
	2	**1323.1**	**601.01**	**294.1**	**2.87**	**6.91**	**0.98**

Table 3 - Analysis Results

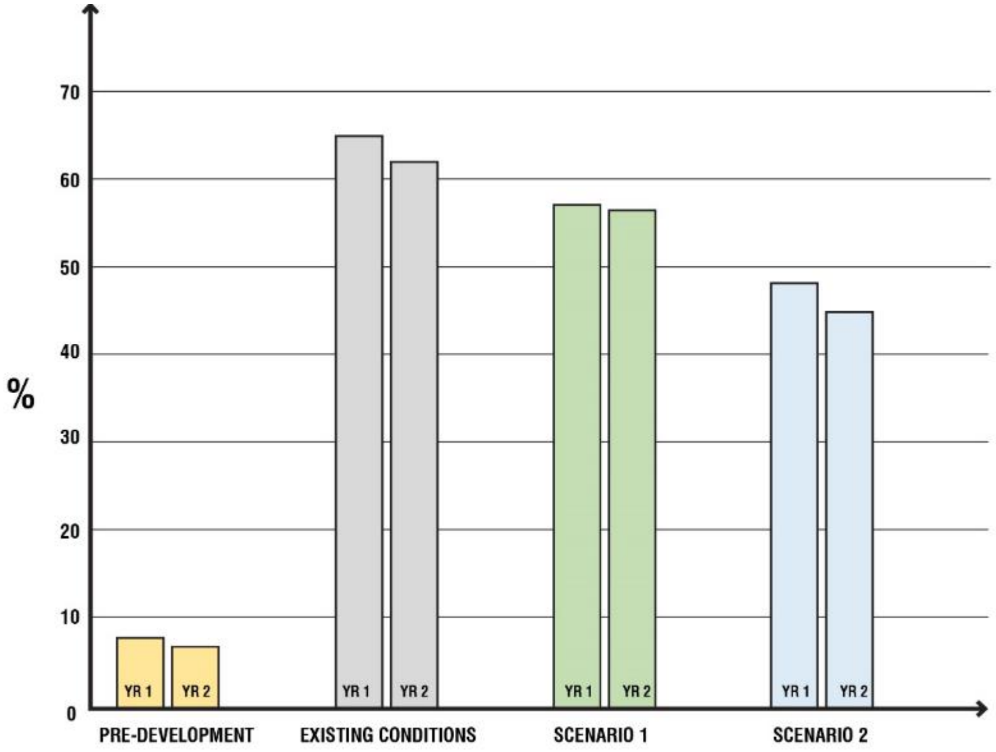


Figure 4-6 Percent of total precipitation discharged as runoff from site

Figure 4-6 displays the percentage of total precipitation that was discharged from the study area during the years that the watershed simulation was run. The model was run for 2 years in order to cover a greater simulation period and to acquire results for more than one year of precipitation. A significant increase in the percentage of precipitation discharged as runoff is seen between pre-development and existing conditions. Percentage of precipitation that is discharged as runoff is slightly reduced with the introduction of low impact development elements in scenario 1 and scenario 2.

Figure 4-7 displays the results of the watershed model for the surface runoff output. The results displayed a significant increase in runoff from pre-development to existing conditions. Surface runoff seems to decrease from existing conditions to scenario 1 with the increasing tree canopy and incorporating rain gardens. Surface runoff is decreased further from scenario 1 to scenario 2, by increasing low impact development elements in the landscape, through the incorporation of green roofs, porous pavement, and rain gardens. The watershed simulation model reported the following output for surface runoff (annually, in mm) for the different *SWAT* scenarios (Figure 4-7):

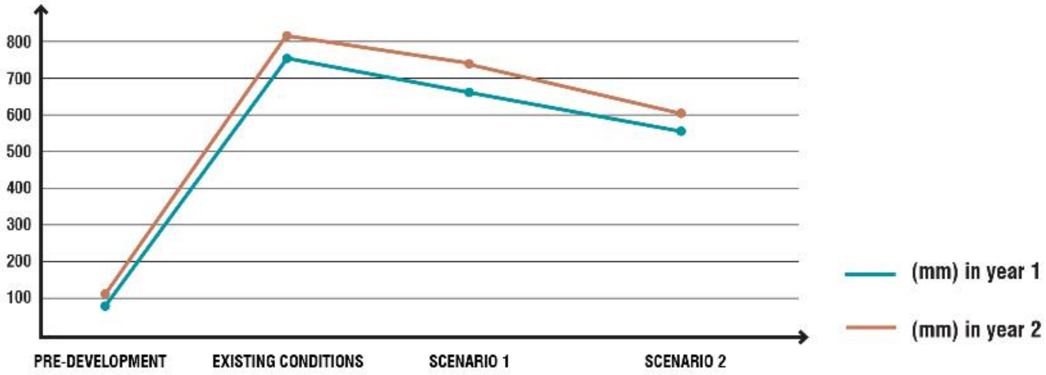


Figure 4-7 Surface runoff in *SWAT* scenarios

Figure 4-8 displays the results of the watershed model for the amount of water stored in the soil profile. The results displayed a significant decrease in amount of water stored in soil from pre-development to existing conditions. Amounts are slightly increased with the introduction of low impact development elements in scenario 1 and scenario 2. The watershed simulation model reported the following output for amount of water stored in the soil profile (annually, in mm) for the different scenarios (Figure 4-8):

Figure 4-8 Amount of water stored in soil profile

Figure 4-9 displays the results of the watershed model for the amount of Nitrate loading to the stream in surface runoff. The results displayed a significant increase in amount of Nitrate from pre-development to existing conditions. Amounts are slightly reduced with the introduction of low impact development elements in scenario 1 and scenario 2. The watershed simulation model reported the following output for Nitrate loading to stream in surface runoff (annually, in kg/ha) for the different scenarios (Figure 4-9):

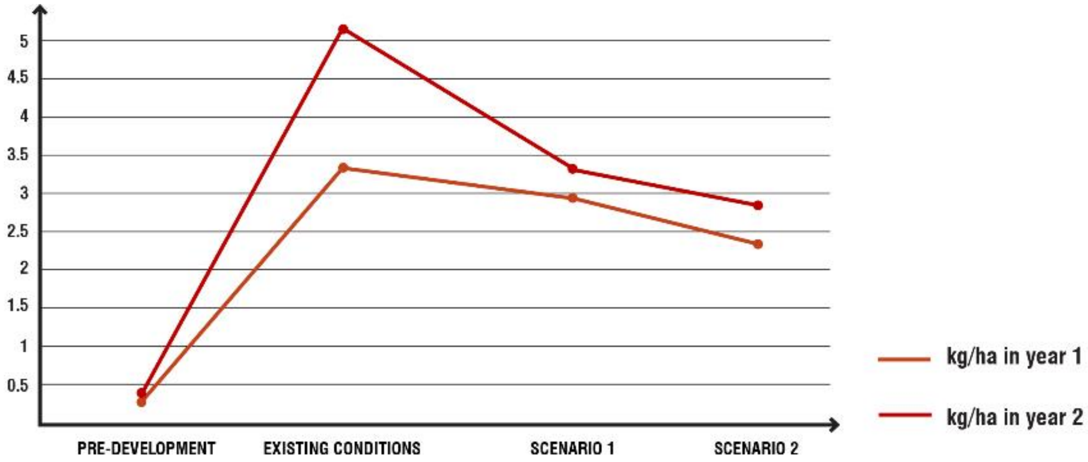


Figure 4-9 Nitrate loading to stream in surface runoff

Figure 4-10 displays the results of the watershed model for the amount of Nitrogen loading to the stream in surface runoff. The results displayed a significant increase in amount of Nitrogen from pre-development to existing conditions. Amounts are slightly reduced with the introduction of low impact development elements in scenario 1 and scenario 2. The watershed simulation model reported the following output for amount of organic Nitrogen loading to the stream (annually, in kg/ha) for the different scenarios (Figure 4-10):

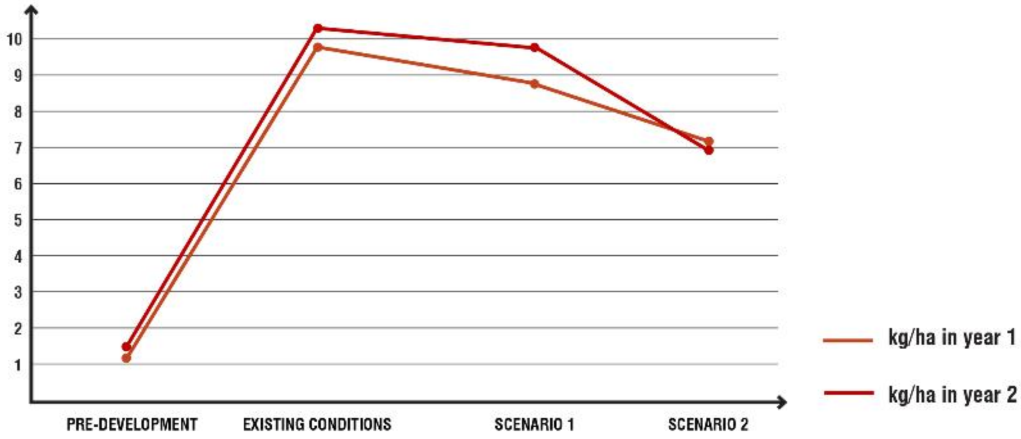


Figure 4-10 Organic Nitrogen loading to stream

Figure 4-11 displays the results of the watershed model for the amount of Phosphorus loading to the stream in surface runoff. The results displayed a significant increase in amount of Phosphorus from pre-development to existing conditions. Amounts are slightly reduced with the introduction of low impact development elements in scenario 1 and scenario 2. The watershed simulation model reported the following output for amount of organic Phosphorus loading to the stream (annually, in kg/ha) for the different scenarios (Figure 4-11):

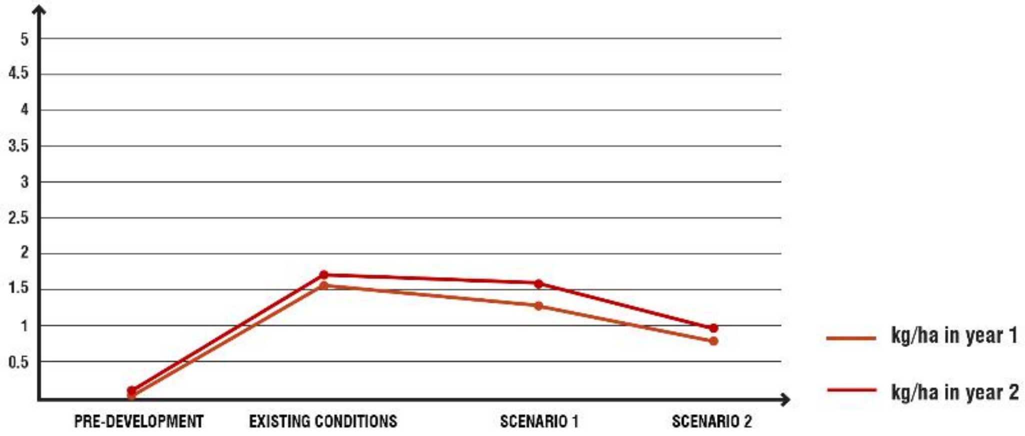


Figure 4-11 Organic Phosphorus loading to stream

4.6 Summary of Findings

The *SWAT* watershed simulation model for this study assessed four different scenarios: pre-development, existing conditions, scenario 1, and scenario 2. The objective of this research was to evaluate the impact of different land uses on urban hydrological conditions, in terms of stormwater quality and quantity. The development of various scenarios with *SWAT* required a considerable amount of time for data preparation and for model setup.

For consistency across the different scenarios, soil, elevation, and slope data were kept constant. The researcher adjusted variables to assess hydrological conditions under different parameters in the landscape. As illustrated in Figure 4-12, the *SWAT* watershed simulation results suggested an 87% increase in surface runoff from the pre-development scenario to the existing conditions scenario, and a 14% decrease in runoff in from existing conditions to the scenario 1. The model also suggested a 16% decrease in runoff from scenario 1 to scenario 2. The results also suggested an 88% increase in pollutant load from the pre-development scenario to the existing conditions scenario, and a 12% decrease in pollutant load from the existing conditions to the scenario 1. The model also suggested a 21% decrease in pollutant load (Nitrate, Nitrogen, and Phosphorus) from scenario 1 to scenario 2. Scenario 1 included design elements in the landscape such as increased tree canopy cover and rain gardens. Scenario 2 included features such as green roofs, porous pavement, rain gardens, and tree canopy cover. Analyzing the results of the various scenarios provided the researcher with insight into the impact of design elements such as tree canopy, rain gardens, green roofs, and porous pavement. Findings suggested that design elements in the landscape relate to environmental landscape performance. The outputs of the various scenarios provided the researcher with data about stormwater runoff quality and quantity.

The largest surface coverage in the existing conditions is attributed to transportation and road infrastructure. This indicates that these areas require some level of treatment or mitigation such as road-side rain gardens that capture and treat polluted runoff before it is discharged into nearby stream segments. Parks, median islands, and open spaces have the capacity to capture, mitigate, and treat stormwater. The research findings suggest that the incorporation of stormwater management techniques such as rain gardens along road infrastructure can reduce stormwater generated on site. Porous pavement, rain gardens, and increased tree canopy cover are site-scale mitigation techniques that can contribute to positive environmental landscape performance.

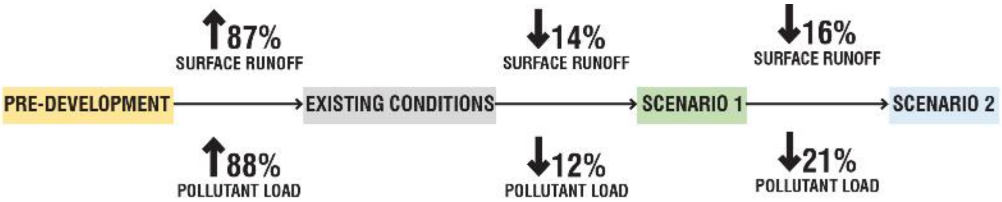


Figure 4-12 Synthesis

4.7 Summary

This chapter presented the analysis and findings of the watershed simulation model for various scenarios of development: pre-development, existing conditions, scenario 1, and scenario 2. The researcher evaluated the various scenarios with *SWAT2012* to assess the hydrological conditions in the Southwestern Medical District in Dallas, Texas. The procedures and methods were documented to assess the applicability of a predictive modeling approach using GIS and *SWAT* prior to design development in landscape architectural studies and practice.

Chapter 5

CONCLUSIONS

5.1 Introduction

The purpose of this research was to assess and predict stormwater runoff and its impact on a site and watershed scale using Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT*), specifically prior to design development in the site planning process. The study adopted the case of the Southwestern Medical District in Dallas, Texas, which encompasses 350 hectares of the Headwaters Turtle Creek watershed. It tested four hypothetical scenarios; pre-development, existing conditions, scenario 1, and scenario 2, in order to understand *SWAT*'s applicability and relevance to landscape architectural studies and practice. The research is an attempt to investigate water quality and quantity in an urbanized watershed before project construction and completion. The study focuses on predictive modeling with *SWAT2012* and its applicability prior to design development in landscape architecture practice.

5.2 Research Summary

A methodological approach was adopted to document and evaluate the procedures required to run a *SWAT* watershed simulation model for various scenarios. The case of the Southwestern Medical District is adopted to assess the applicability of *SWAT* in landscape architecture practice, specifically to evaluate changes in stormwater quality and quantity in a highly urbanized landscape. The watershed model was developed for four scenarios in a portion of the Headwaters Turtle Creek watershed in Dallas, Texas. Scenarios were developed for pre-development, existing conditions, scenario 1, and scenario 2. Soil, topography, and weather data were kept constant across the four scenarios, and parameters relating to land use, land cover, and landscape design elements were adjusted in the scenarios to demonstrate impact on surface flow and hydrology. The research used *SWAT2012*, a physically-based model that presents opportunities for hydrological modeling. The findings from the literature review and analysis are presented as a summary of the research questions addressed.

5.2.1 Research Question 1

Can SWAT, a predictive modeling tool, be utilized in an urban context in landscape architecture practice?

Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT*) proved to be valuable tools in landscape architectural studies for analysis of different scenarios in a highly urbanized watershed. Results suggested that GIS and *SWAT* can be adopted in the site planning process in landscape architecture practice. The results of the study and the procedural methods followed may help inform landscape architects of the predictive modeling approach, and of *SWAT*'s applications, capabilities, and constraints for application in urban contexts. Furthermore, landscape architects can utilize GIS and predictive modeling tools prior to design development to examine varying scenarios of land use change on urban hydrology. Given the impending challenges faced in today's urban settings, predicting the environmental impacts prior to design development for projects in urban landscapes is crucial. *SWAT* can be used to examine varying scenarios of development and their effect on urban runoff and pollutants in the landscape. Given that urban runoff, which includes runoff from impervious surfaces such as streets, parking lots, buildings, lawns and other paved areas is one of the leading causes of water quality impairment related to land use and human activities, assessing landscape performance with *SWAT* prior to design development is valuable for retrofitting urban landscapes, such as the Southwestern Medical District.

5.2.2 Research Question 2

How can SWAT be utilized to assess various scenarios prior to design development in landscape architecture?

The use of *SWAT* as a predictive modeling and scenario planning tool in this research suggested that LID strategies and other land management scenarios can be tested to some capacity to understand water quality and quantity issues in landscape architectural studies and practice. Findings suggested that LID strategies can effectively contribute to improving the quality and quantity of stormwater runoff in an urbanized watershed and landscape. Furthermore, developing empirical models and producing quantifiable measures enable *a priori* judgements to be made by landscape architects in relation to watershed management and planning. In addition, given the rising concern related to water quality issues in urban environments, it has become crucial for landscape architecture academics and practitioners to adopt a holistic watershed framework approach towards projects in the urban landscape. Landscape architects can assess alternative scenarios in a virtual manner, prior to the design development phase, in order to evaluate various design solutions that produce favorable environmental performance impacts.

Landscape architects can employ tools to address issues related to land-use changes on hydrologic responses in urban watersheds using predictive modeling. Such data can then relate to land use changes to examine varying scenarios of change on urban hydrology. Given the present interest in landscape ecology in urban environments, such applications of GIS and its related software are invaluable.

5.2.3 Research Question 3

Is SWAT an effective tool for landscape architects to learn and adopt in order to assess stormwater quality and quantity?

SWAT can be an instrumental tool for landscape architects for use prior to design development in the site planning process. The strength of the *SWAT* modeling tool lies in its ability to simulate water flow and quality at a given site, under various parameters that can be adjusted by the researcher (amount of tree cover, porous pavement, rain gardens, green roofs). However, *SWAT* has a learning curve which requires an advanced understanding of GIS and a rigorous understanding of the *SWAT* modeling procedure, data requirements, and basic database building skills. Data preparation and set up of the watershed model required a considerable amount of time. Therefore, integrating *SWAT*'s functions with a more user-friendly interface that does not require a significant amount time and billable hours would make it a more appropriate tool for use in landscape architecture practice to assess stormwater runoff quality and quantity with ease prior to design development.

Moreover, *SWAT* was recently updated to model sub-daily hydrologic and water quality processes (Jeong et al. 2011, 2012), whereby LID strategies can be assigned and stormwater is effectively estimated separately from the runoff produced in non-urban areas. These applications and developments in the *SWAT* model are expected to prove valuable in the planning and design of urbanized watersheds (Jeong et. al 2013). Evaluations of the applicability of *SWAT* in a study of a highly urbanized watershed can be valuable for model developers who are continuously upgrading the model to integrate features that better respond to the user's needs.

This study provides insight into the application of the Soil and Water Assessment Tool in landscape architecture practice, and provides input and feedback to the software developers of *SWAT* to possibly integrate features that make the tool an easily applicable platform in practice.

5.3 Discussions: Learning from the Southwestern Medical District

This study evaluated hydrological conditions in a highly urbanized watershed, to assess stormwater runoff quality and quantity under varying land use scenarios. The Headwaters Turtle Creek watershed encompasses the Southwestern Medical District, and was chosen in this study based on its recently proposed development relating to green infrastructure and land use. The study highlights the need for predictive modeling prior to design development in landscape architecture, to better understand the environmental landscape performance and impact of design features prior to construction and implementation.

Stormwater runoff quality and quantity were assessed using Geographic Information System (GIS) and the Soil and Water Assessment Tool (*SWAT*), to evaluate how proposed design features may mitigate the existing site conditions. The results of the analysis suggested that the current state of Southwestern Medical District requires treatment and mitigation practices. Results of the predictive modeling output suggested that the incorporation of stormwater management techniques such as bioswales along road infrastructure can reduce stormwater runoff generated on site and reduce pollutant load. With increased urbanization at the expense of natural landscapes, an alteration of natural hydrological systems occurs, adversely affecting runoff rate and volume, infiltration, and water quality. A decrease in the perviousness of a watershed catchment leads to a decrease in infiltration and an increase in surface runoff (Ahiablame, Engel, & Chaubey, 2012).

Findings suggested that integrating GIS and *SWAT* in the site planning process allows for a more comprehensive approach that responds to the built environment in an urban context. Assessing various scenarios using GIS and *SWAT* prior to design development presents landscape architects and with the tools to model and assess alternatives for development that inform the decision-making process. This predictive modeling process can provide landscape architects with a quantitative analysis approach that forecasts and reduces environmental stresses by proactively designing landscapes that minimize unfavorable environmental impacts. Landscape architects can use predictive modeling to estimate the improvements needed to retrofit existing conditions through restorative tree planting, road consolidation, and pavement removal.

5.4 Significance of the Study

SWAT is a predictive modeling tool that presents opportunities for hydrological modeling in landscape architecture practice and research. Predictive modeling is a method that utilizes computer simulation and monitoring data collected over time and space to visualize various land use changes before implementation. A significant amount of literature has been published relating to the applicability and limitations of the tool, however few research studies have highlighted and evaluated the application of *SWAT* on a site-scale, specifically in urbanized landscapes. Since its development, the Soil and Water Assessment Tool has undergone extensive upgrades and improvements to enhance its performance and to better suit the needs of its users. Several studies have been published that relate to the applicability and limitations of the tool; however, the application of *SWAT* has not been fully evaluated for use on a site-scale, specifically in urbanized landscapes. This scenario-based evaluation applied in this research suggests that *SWAT* could be an effective predictive modeling tool that can inform landscape architecture planning and practice. Results imply that the quantity and quality of water generated on a complex urban site, such as the Southwestern Medical District, can contribute to the total watershed performance if green infrastructure systems and low impact development strategies are integrated.

5.5 Relevance to Landscape Architecture

This research study attempted to highlight that the use of a predictive modeling tool prior to design development can be an effective approach in the site planning process, as illustrated in Figure 5-1. The study explored the use of *SWAT2012* in landscape architectural research, and documented the replicable procedures and methods adopted in the watershed simulation and analysis. This research highlighted that the use of predictive modeling - whether with *SWAT* or other scenario planning and geodesign tools - can provide landscape architects and allied professions with a more comprehensive and responsive approach that informs the built and natural environment.

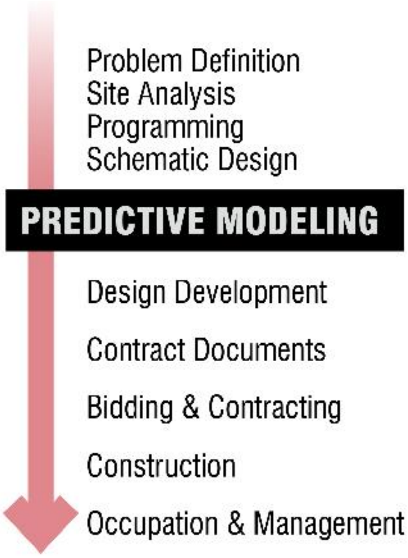


Figure 5-1 Predictive modeling in the site planning process

The research findings highlight the importance of predictive modeling in landscape architecture and planning. Recent developments in Geographic Information System (GIS) have allowed the application of geoanalytical methods that challenge the traditional design and planning processes, and have opened up the inquiry of empirical and scientific knowledge relating to urban environments. This research is an attempt to present a predictive modeling approach using an empirical and quantitative approach, that can be introduced in the earlier stages of the site planning and design process. Integrating GIS and *SWAT* enables researchers and professionals to use geospatial technologies in adaptive and responsive planning and design, and supports decision-making processes with various scenarios for development and alternative design solutions. This can contribute to cost effectiveness and cost-benefit analyses while in the planning and design phase of a project. Furthermore, the research findings suggest that the Soil and Water Assessment Tool could be a valuable skill in the landscape architect’s toolbox, if its functions are simplified for use with ease prior to design development.

5.6 Future Research

This study focused on a predictive modeling approach for assessing environmental landscape performance, specifically stormwater runoff quality and quantity, in a highly urbanized watershed prior to construction and implementation in landscape architecture. The methodology, analysis, and findings revealed insight into the research questions addressed, and raised additional questions that may be valuable for future research investigation. The areas for future research include:

1. Assessing various scenarios for the same study location with *SWAT* prior to construction and implementation, for evaluation of design and planning parameters that focus on factors other than low impact development.
2. Assessing the same study location using other predictive modeling platforms and tools.
3. Applying quantitative comparisons of outputs of different predictive modeling tools to evaluate similarities or discrepancies in results.
4. Assessing environmental landscape performance in post-implementation phases and comparing the results with the predictive modeling outputs.
5. Incorporating climate change projections in predictive modeling studies within *SWAT.*

5.7 Summary

This research study attempted to highlight the relevance and significance of applying a predictive modeling approach in landscape architectural studies and practice, by assessing hydrological conditions and environmental landscape performance of different scenarios in an urban landscape prior to design development. Suggestions for future research within the field of predictive modeling and scenario planning in landscape architecture practice were presented. This research study attempted to highlight that predictive modeling can be introduced as an effective approach in the site planning and design process, to allow landscape architects to respond and adapt to the impending challenges in the built and natural environment.

Appendix A

SWAT: LANDUSE/SOIL/SLOPE DISTRIBUTION

```
LandUseSoilsReport

Detailed LANDUSE/SOIL/SLOPE distribution SWAT model class Date:
11/29/2016
12:00:00 AM Time: 19:45:47.5434824

Area [ha]
Area[acres]
Watershed 1220.0100
3014.7057
Number of Subbasins: 37

Area [ha]
Area[acres] %Wat.Area
LANDUSE:
Residential-High Density --> URHD 94.4700
233.4401 7.74
Residential-Low Density --> URLD 99.8900
246.8332 8.19
Commercial --> UCOM 197.1600
487.1922 16.16
Industrial --> UIDU 22.4100
55.3762 1.84
Transportation --> UTRN 542.4200
1340.3469 44.46
Institutional --> UINS 119.3600
294.9445 9.78
Parks --> PARK 15.6900
38.7708 1.29
Vacant --> VCNT 48.4100
119.6235 3.97
Residential --> URBN 80.2000
198.1782 6.57
SOILS:
TX235 721.1200
1781.9236 59.11
TX574 498.8900
1232.7821 40.89
SLOPE:
0-2 1119.6400
2766.6864 91.77
10-9999 0.4300
```

```
LandUseSoilsReport
1.0626 0.04
2-5 89.1900
220.3929 7.31
5-10 10.7500
26.5638 0.88
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 1 52.7200
130.2738 4.32
LANDUSE:
Residential-High Density --> URHD 0.0700
0.1730 0.01 0.13
Residential-Low Density --> URLD 11.5400
28.5159 0.95 21.89
Commercial --> UCOM 2.3100
5.7081 0.19 4.38
Transportation --> UTRN 15.1100
37.3376 1.24 28.66
Vacant --> VCNT 0.9800
2.4216 0.08 1.86
Residential --> URBN 22.7100
56.1175 1.86 43.08
SOILS:
TX235 52.7200
130.2738 4.32 100.00
SLOPE:
0-2 52.0000
128.4946 4.26 98.63
2-5 0.6900
1.7050 0.06 1.31
5-10 0.0300
0.0741 0.00 0.06
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 2 89.8400
221.9991 7.36
LANDUSE:
Commercial --> UCOM 8.2400
20.3615 0.68 9.17
Industrial --> UIDU 1.6600
4.1019 0.14 1.85
```

```
Transportation --> UTRN 35.5900
87.9447 2.92 39.61
Vacant --> VCNT 1.9900
4.9174 0.16 2.22
Residential --> URBN 42.3600
104.6737 3.47 47.15
SOILS:
TX235 89.8400
221.9991 7.36 100.00
SLOPE:
0-2 88.8500
219.5528 7.28 98.90
2-5 0.9900
2.4463 0.08 1.10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 3 21.5400
53.2264 1.77
LANDUSE:
Residential-High Density --> URHD 2.2400
5.5352 0.18 10.40
Residential-Low Density --> URLD 1.4500
3.5830 0.12 6.73
Commercial --> UCOM 6.9900
17.2726 0.57 32.45
Transportation --> UTRN 7.2500
17.9151 0.59 33.66
Institutional --> UINS 0.0300
0.0741 0.00 0.14
Vacant --> VCNT 1.7100
4.2255 0.14 7.94
Residential --> URBN 1.8700
4.6209 0.15 8.68
LandUseSoilsReport
SOILS:
TX235 21.5400
53.2264 1.77 100.00
SLOPE:
0-2 19.6100
48.4573 1.61 91.04
2-5 1.9300
4.7691 0.16 8.96
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 4 22.4800
55.5492 1.84
LANDUSE:
Residential-High Density --> URHD 1.3400
3.3112 0.11 5.96
Residential-Low Density --> URLD 0.2100
0.5189 0.02 0.93
Commercial --> UCOM 8.3300
20.5838 0.68 37.06
Industrial --> UIDU 1.6900
4.1761 0.14 7.52
Transportation --> UTRN 9.5600
23.6232 0.78 42.53
Institutional --> UINS 0.2800
0.6919 0.02 1.25
Vacant --> VCNT 1.0700
2.6440 0.09 4.76
SOILS:
TX235 22.0100
54.3878 1.80 97.91
TX574 0.4700
1.1614 0.04 2.09
SLOPE:
0-2 21.3800
52.8310 1.75 95.11
2-5 1.1000
2.7182 0.09 4.89
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 5 5.6100
13.8626 0.46
LANDUSE:
Residential-High Density --> URHD 0.5200
1.2849 0.04 9.27
Commercial --> UCOM 1.0700
2.6440 0.09 19.07
Transportation --> UTRN 3.6200
8.9452 0.30 64.53
Vacant --> VCNT 0.4000
0.9884 0.03 7.13
SOILS:
TX235 5.6100
```

```
13.8626 0.46 100.00
SLOPE:
0-2 5.2900
13.0719 0.43 94.30
2-5 0.3200
0.7907 0.03 5.70
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 6 58.9600
145.6931 4.83
LANDUSE:
Residential-Low Density --> URLD 0.1400
0.3459 0.01 0.24
Commercial --> UCOM 23.2600
57.4766 1.91 39.45
Industrial --> UIDU 2.7400
6.7707 0.22 4.65
Transportation --> UTRN 30.1600
74.5269 2.47 51.15
Vacant --> VCNT 1.6000
3.9537 0.13 2.71
Residential --> URBN 1.0600
2.6193 0.09 1.80
SOILS:
TX235 58.9600
145.6931 4.83 100.00
SLOPE:
0-2 57.6900
142.5549 4.73 97.85
2-5 0.9800
2.4216 0.08 1.66
5-10 0.2900
0.7166 0.02 0.49
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 7 10.1300
25.0317 0.83
LANDUSE:
Residential-High Density --> URHD 5.9400
14.6780 0.49 58.64
Commercial --> UCOM 0.7700
1.9027 0.06 7.60
```

```
Transportation --> UTRN 2.7900
6.8942 0.23 27.54
Institutional --> UINS 0.4500
1.1120 0.04 4.44
Vacant --> VCNT 0.1800
0.4448 0.01 1.78
SOILS:
TX235 10.1300
25.0317 0.83 100.00
SLOPE:
0-2 8.8900
21.9676 0.73 87.76
2-5 1.2400
3.0641 0.10 12.24
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 8 3.8200
9.4394 0.31
LANDUSE:
Residential-High Density --> URHD 2.8400
7.0178 0.23 74.35
Commercial --> UCOM 0.0500
0.1236 0.00 1.31
Transportation --> UTRN 0.8800
2.1745 0.07 23.04
Vacant --> VCNT 0.0500
0.1236 0.00 1.31
SOILS:
TX235 3.8200
9.4394 0.31 100.00
SLOPE:
0-2 2.7700
6.8448 0.23 72.51
2-5 1.0500
2.5946 0.09 27.49
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 9 106.8200
263.9576 8.76
LANDUSE:
Residential-High Density --> URHD 0.0300
0.0741 0.00 0.03
```

```
Residential-Low Density --> URLD 4.1900
10.3537 0.34 3.92
Commercial --> UCOM 25.7700
63.6790 2.11 24.12
Industrial --> UIDU 4.8000
11.8610 0.39 4.49
Transportation --> UTRN 51.0800
126.2212 4.19 47.82
Institutional --> UINS 10.1800
25.1553 0.83 9.53
Parks --> PARK 4.9200
12.1576 0.40 4.61
Vacant --> VCNT 4.2400
10.4773 0.35 3.97
Residential --> URBN 1.6100
3.9784 0.13 1.51
SOILS:
TX235 106.8200
263.9576 8.76 100.00
SLOPE:
0-2 99.7300
246.4378 8.17 93.36
2-5 6.4000
15.8147 0.52 5.99
5-10 0.6900
1.7050 0.06 0.65
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 10 19.3000
47.6913 1.58
LANDUSE:
Residential-High Density --> URHD 0.6900
1.7050 0.06 3.58
Residential-Low Density --> URLD 6.1000
15.0734 0.50 31.61
Commercial --> UCOM 2.4000
5.9305 0.20 12.44
Transportation --> UTRN 10.0900
24.9329 0.83 52.28
Vacant --> VCNT 0.0200
0.0494 0.00 0.10
SOILS:
TX235 19.3000
```

```
47.6913 1.58 100.00
SLOPE:
0-2 19.3000
Page 8
LandUseSoilsReport
47.6913 1.58 100.00
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 11 17.9900
44.4542 1.47
LANDUSE:
Residential-High Density --> URHD 5.1200
12.6518 0.42 28.46
Residential-Low Density --> URLD 3.3400
8.2533 0.27 18.57
Commercial --> UCOM 0.7700
1.9027 0.06 4.28
Transportation --> UTRN 7.3800
18.2363 0.60 41.02
Vacant --> VCNT 1.3800
3.4100 0.11 7.67
SOILS:
TX235 17.9900
44.4542 1.47 100.00
SLOPE:
0-2 17.9900
44.4542 1.47 100.00
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 12 18.3600
45.3685 1.50
LANDUSE:
Residential-High Density --> URHD 1.2100
2.9900 0.10 6.59
Residential-Low Density --> URLD 7.0500
17.4209 0.58 38.40
Commercial --> UCOM 1.2200
3.0147 0.10 6.64
Transportation --> UTRN 7.5600
18.6811 0.62 41.18
Institutional --> UINS 1.3200
3.2618 0.11 7.19
SOILS:
```

```
TX235 18.3600
45.3685 1.50 100.00
SLOPE:
0-2 18.3600
45.3685 1.50 100.00
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 13 10.4800
25.8966 0.86
LANDUSE:
Residential-High Density --> URHD 1.5600
3.8548 0.13 14.89
Commercial --> UCOM 2.1600
5.3375 0.18 20.61
Transportation --> UTRN 4.6800
11.5645 0.38 44.66
Institutional --> UINS 1.0000
2.4711 0.08 9.54
Vacant --> VCNT 1.0800
2.6687 0.09 10.31
SOILS:
TX235 10.4800
25.8966 0.86 100.00
SLOPE:
0-2 6.5300
16.1360 0.54 62.31
2-5 3.3200
8.2039 0.27 31.68
5-10 0.6300
1.5568 0.05 6.01
```

```
LandUseSoilsReport
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 14 24.5800
60.7384 2.01
LANDUSE:
Residential-High Density --> URHD 0.2000
0.4942 0.02 0.81
Residential-Low Density --> URLD 0.3200
0.7907 0.03 1.30
Commercial --> UCOM 6.5200
16.1112 0.53 26.53
```

```
Transportation --> UTRN 11.3400
28.0217 0.93 46.14
Institutional --> UINS 5.9900
14.8016 0.49 24.37
Vacant --> VCNT 0.2100
0.5189 0.02 0.85
SOILS:
TX235 19.0700
47.1229 1.56 77.58
TX574 5.5100
13.6155 0.45 22.42
SLOPE:
0-2 21.9500
54.2395 1.80 89.30
2-5 2.5800
6.3753 0.21 10.50
5-10 0.0500
0.1236 0.00 0.20
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 15 37.3300
92.2443 3.06
LANDUSE:
Residential-High Density --> URHD 11.9600
29.5538 0.98 32.04
Residential-Low Density --> URLD 5.8000
14.3321 0.48 15.54
Commercial --> UCOM 1.9900
4.9174 0.16 5.33
Transportation --> UTRN 14.5900
36.0526 1.20 39.08
Vacant --> VCNT 2.9700
7.3390 0.24 7.96
Residential --> URBN 0.0200
0.0494 0.00 0.05
SOILS:
TX235 37.3300
92.2443 3.06 100.00
SLOPE:
0-2 35.4700
87.6481 2.91 95.02
2-5 1.7600
4.3490 0.14 4.71
```

```
5-10 0.1000
0.2471 0.01 0.27
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 16 25.2800
62.4681 2.07
LANDUSE:
Commercial --> UCOM 0.6800
1.6803 0.06 2.69
Industrial --> UIDU 0.5700
1.4085 0.05 2.25
Transportation --> UTRN 8.3600
20.6580 0.69 33.07
Institutional --> UINS 15.6700
38.7214 1.28 61.99
SOILS:
TX235 12.4300
30.7152 1.02 49.17
TX574 12.8500
31.7530 1.05 50.83
SLOPE:
0-2 21.3400
LandUseSoilsReport
52.7322 1.75 84.41
2-5 3.8400
9.4888 0.31 15.19
5-10 0.1000
0.2471 0.01 0.40
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 17 20.0800
49.6187 1.65
LANDUSE:
Residential-High Density --> URHD 2.5000
6.1776 0.20 12.45
Commercial --> UCOM 2.1000
5.1892 0.17 10.46
Industrial --> UIDU 3.7200
9.1923 0.30 18.53
Transportation --> UTRN 7.5900
18.7553 0.62 37.80
Institutional --> UINS 3.6500
```

```
9.0193 0.30 18.18
Vacant --> VCNT 0.5000
1.2355 0.04 2.49
Residential --> URBN 0.0200
0.0494 0.00 0.10
SOILS:
TX235 18.7700
46.3816 1.54 93.48
TX574 1.3100
3.2371 0.11 6.52
SLOPE:
0-2 16.7200
41.3160 1.37 83.27
2-5 3.3400
8.2533 0.27 16.63
5-10 0.0200
0.0494 0.00 0.10
```

```
LandUseSoilsReport
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 18 54.9400
135.7595 4.50
LANDUSE:
Residential-High Density --> URHD 16.9400
41.8596 1.39 30.83
Residential-Low Density --> URLD 4.7900
11.8363 0.39 8.72
Commercial --> UCOM 4.0600
10.0325 0.33 7.39
Transportation --> UTRN 26.1700
64.6674 2.15 47.63
Institutional --> UINS 0.1500
0.3707 0.01 0.27
Vacant --> VCNT 2.7400
6.7707 0.22 4.99
Residential --> URBN 0.0900
0.2224 0.01 0.16
SOILS:
TX235 54.9400
135.7595 4.50 100.00
SLOPE:
0-2 51.7200
127.8027 4.24 94.14
```

```
2-5 2.5900
6.4000 0.21 4.71
5-10 0.6300
1.5568 0.05 1.15
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 19 32.4700
80.2350 2.66
LANDUSE:
Residential-High Density --> URHD 1.1300
2.7923 0.09 3.48
Commercial --> UCOM 4.4600
11.0209 0.37 13.74
Transportation --> UTRN 13.5100
33.3839 1.11 41.61
Institutional --> UINS 12.2000
30.1468 1.00 37.57
Vacant --> VCNT 1.1700
2.8911 0.10 3.60
SOILS:
TX235 12.3200
30.4433 1.01 37.94
TX574 20.1500
49.7917 1.65 62.06
SLOPE:
0-2 25.6900
63.4813 2.11 79.12
2-5 6.7100
16.5807 0.55 20.67
5-10 0.0700
0.1730 0.01 0.22
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 20 26.4800
65.4334 2.17
LANDUSE:
Residential-Low Density --> URLD 1.6800
4.1514 0.14 6.34
Commercial --> UCOM 1.5300
3.7807 0.13 5.78
Transportation --> UTRN 10.5100
25.9707 0.86 39.69
```

```
Institutional --> UINS 12.0100
29.6773 0.98 45.35
Vacant --> VCNT 0.7500
1.8533 0.06 2.83
SOILS:
TX574 26.4800
65.4334 2.17 100.00
SLOPE:
0-2 24.0900
59.5276 1.97 90.97
2-5 2.3900
5.9058 0.20 9.03
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 21 25.9600
64.1485 2.13
LANDUSE:
Residential-High Density --> URHD 1.8800
4.6456 0.15 7.24
Residential-Low Density --> URLD 3.3800
8.3521 0.28 13.02
Commercial --> UCOM 3.9500
9.7606 0.32 15.22
Transportation --> UTRN 11.3200
27.9723 0.93 43.61
Institutional --> UINS 3.7400
9.2417 0.31 14.41
Vacant --> VCNT 1.6900
4.1761 0.14 6.51
SOILS:
TX574 25.9600
64.1485 2.13 100.00
SLOPE:
0-2 24.5200
60.5901 2.01 94.45
2-5 1.4400
3.5583 0.12 5.55
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 22 6.9200
17.0997 0.57
LANDUSE:
```

```
Residential-High Density --> URHD 0.1500
LandUseSoilsReport
0.3707 0.01 2.17
Residential-Low Density --> URLD 1.6400
4.0525 0.13 23.70
Commercial --> UCOM 0.2000
0.4942 0.02 2.89
Transportation --> UTRN 3.5900
8.8711 0.29 51.88
Institutional --> UINS 0.6900
1.7050 0.06 9.97
Vacant --> VCNT 0.6500
1.6062 0.05 9.39
SOILS:
TX574 6.9200
17.0997 0.57 100.00
SLOPE:
0-2 6.3900
15.7900 0.52 92.34
2-5 0.5300
1.3097 0.04 7.66
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 23 28.8800
71.3639 2.37
LANDUSE:
Residential-High Density --> URHD 10.7000
26.4402 0.88 37.05
Residential-Low Density --> URLD 1.8700
4.6209 0.15 6.48
Commercial --> UCOM 2.0300
5.0162 0.17 7.03
Transportation --> UTRN 14.1300
34.9159 1.16 48.93
Institutional --> UINS 0.0600
0.1483 0.00 0.21
Vacant --> VCNT 0.0400
0.0988 0.00 0.14
Residential --> URBN 0.0500
0.1236 0.00 0.17
SOILS:
TX235 27.8200
68.7446 2.28 96.33
TX574 1.0600
```

```
2.6193 0.09 3.67
SLOPE:
0-2 28.1600
69.5848 2.31 97.51
2-5 0.6800
1.6803 0.06 2.35
5-10 0.0400
0.0988 0.00 0.14
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 24 36.7000
90.6875 3.01
LANDUSE:
Residential-High Density --> URHD 6.7100
16.5807 0.55 18.28
Residential-Low Density --> URLD 4.0200
9.9336 0.33 10.95
Commercial --> UCOM 3.8200
9.4394 0.31 10.41
Transportation --> UTRN 19.3200
47.7407 1.58 52.64
Institutional --> UINS 0.2600
0.6425 0.02 0.71
Vacant --> VCNT 2.4800
6.1282 0.20 6.76
Residential --> URBN 0.0900
0.2224 0.01 0.25
SOILS:
TX235 34.6700
85.6713 2.84 94.47
TX574 2.0300
5.0162 0.17 5.53
SLOPE:
0-2 34.8300
86.0667 2.85 94.90
2-5 1.8700
LandUseSoilsReport
4.6209 0.15 5.10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 25 54.5900
134.8946 4.47
LANDUSE:
```

```
Commercial --> UCOM 7.8800
19.4719 0.65 14.43
Industrial --> UIDU 0.9200
2.2734 0.08 1.69
Transportation --> UTRN 22.3500
55.2280 1.83 40.94
Institutional --> UINS 22.0200
54.4125 1.80 40.34
Vacant --> VCNT 1.3900
3.4348 0.11 2.55
Residential --> URBN 0.0300
0.0741 0.00 0.05
SOILS:
TX235 0.0900
0.2224 0.01 0.16
TX574 54.5000
134.6722 4.47 99.84
SLOPE:
0-2 46.4100
114.6814 3.80 85.02
2-5 8.1700
20.1885 0.67 14.97
5-10 0.0100
0.0247 0.00 0.02
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 26 0.1700
0.4201 0.01
LandUseSoilsReport
LANDUSE:
Commercial --> UCOM 0.0700
0.1730 0.01 41.18
Transportation --> UTRN 0.1000
0.2471 0.01 58.82
SOILS:
TX574 0.1700
0.4201 0.01 100.00
SLOPE:
0-2 0.1700
0.4201 0.01 100.00
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
```

```
SUBBASIN # 27 81.0300
200.2292 6.64
LANDUSE:
Residential-High Density --> URHD 11.1600
27.5769 0.91 13.77
Residential-Low Density --> URLD 21.1800
52.3368 1.74 26.14
Commercial --> UCOM 12.5000
30.8881 1.02 15.43
Transportation --> UTRN 24.9700
61.7021 2.05 30.82
Institutional --> UINS 0.0400
0.0988 0.00 0.05
Vacant --> VCNT 10.1900
25.1800 0.84 12.58
Residential --> URBN 0.9900
2.4463 0.08 1.22
SOILS:
TX235 48.3200
119.4011 3.96 59.63
TX574 32.7100
80.8280 2.68 40.37
SLOPE:
0-2 65.2100
161.1372 5.35 80.48
10-9999 0.0700
0.1730 0.01 0.09
2-5 11.9900
29.6279 0.98 14.80
5-10 3.7600
9.2911 0.31 4.64
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 28 41.7300
103.1169 3.42
LANDUSE:
Residential-High Density --> URHD 5.6900
14.0603 0.47 13.64
Residential-Low Density --> URLD 2.8300
6.9931 0.23 6.78
Commercial --> UCOM 5.6300
13.9120 0.46 13.49
Industrial --> UIDU 1.1900
```

```
2.9405 0.10 2.85
Transportation --> UTRN 15.9000
39.2897 1.30 38.10
Institutional --> UINS 2.0100
4.9668 0.16 4.82
Vacant --> VCNT 0.0100
0.0247 0.00 0.02
Residential --> URBN 8.4700
20.9298 0.69 20.30
SOILS:
TX235 14.1900
35.0642 1.16 34.00
TX574 27.5400
68.0527 2.26 66.00
SLOPE:
0-2 40.5300
100.1517 3.32 97.12
2-5 1.2000
2.9653 0.10 2.88
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 29 15.9700
39.4627 1.31
LANDUSE:
Residential-Low Density --> URLD 2.6200
6.4742 0.21 16.41
Commercial --> UCOM 2.0300
5.0162 0.17 12.71
Transportation --> UTRN 6.7400
16.6549 0.55 42.20
Institutional --> UINS 3.2200
7.9568 0.26 20.16
Vacant --> VCNT 1.3600
3.3606 0.11 8.52
SOILS:
TX574 15.9700
39.4627 1.31 100.00
SLOPE:
0-2 12.4100
30.6657 1.02 77.71
2-5 3.5600
8.7969 0.29 22.29
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 30 20.9700
51.8179 1.72
LANDUSE:
Commercial --> UCOM 1.1400
2.8170 0.09 5.44
Industrial --> UIDU 0.8200
2.0263 0.07 3.91
Transportation --> UTRN 10.7600
26.5885 0.88 51.31
Institutional --> UINS 8.2200
20.3120 0.67 39.20
Vacant --> VCNT 0.0300
0.0741 0.00 0.14
SOILS:
TX235 0.3800
0.9390 0.03 1.81
TX574 20.5900
50.8789 1.69 98.19
SLOPE:
0-2 17.1700
42.4279 1.41 81.88
10-9999 0.0700
0.1730 0.01 0.33
2-5 2.9500
7.2896 0.24 14.07
5-10 0.7800
1.9274 0.06 3.72
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 31 50.4600
124.6892 4.14
LANDUSE:
Residential-High Density --> URHD 3.8900
9.6124 0.32 7.71
Residential-Low Density --> URLD 15.6900
38.7708 1.29 31.09
Commercial --> UCOM 2.4200
5.9799 0.20 4.80
Transportation --> UTRN 22.6900
56.0681 1.86 44.97
Institutional --> UINS 0.4700
```

```
1.1614 0.04 0.93
Parks --> PARK 0.6200
1.5321 0.05 1.23
Vacant --> VCNT 3.8500
9.5135 0.32 7.63
Residential --> URBN 0.8300
2.0510 0.07 1.64
SOILS:
TX235 3.2100
7.9321 0.26 6.36
TX574 47.2500
116.7571 3.87 93.64
SLOPE:
0-2 42.1300
104.1053 3.45 83.49
2-5 8.3300
20.5838 0.68 16.51
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 32 14.2400
35.1878 1.17
LANDUSE:
Commercial --> UCOM 3.3000
8.1545 0.27 23.17
Transportation --> UTRN 6.6800
16.5066 0.55 46.91
Institutional --> UINS 4.1700
10.3043 0.34 29.28
Vacant --> VCNT 0.0900
0.2224 0.01 0.63
SOILS:
TX574 14.2400
35.1878 1.17 100.00
SLOPE:
0-2 12.6900
31.3576 1.04 89.12
2-5 1.3200
3.2618 0.11 9.27
5-10 0.2300
0.5683 0.02 1.62
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
```

```
SUBBASIN # 33 1.8600
4.5962 0.15
LANDUSE:
Commercial --> UCOM 0.4900
1.2108 0.04 26.34
Transportation --> UTRN 1.3300
3.2865 0.11 71.51
Institutional --> UINS 0.0400
0.0988 0.00 2.15
SOILS:
TX574 1.8600
4.5962 0.15 100.00
SLOPE:
0-2 1.8600
4.5962 0.15 100.00
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 34 22.7800
56.2905 1.87
LANDUSE:
Commercial --> UCOM 4.3800
10.8232 0.36 19.23
Transportation --> UTRN 15.5800
38.4990 1.28 68.39
Institutional --> UINS 2.5700
6.3506 0.21 11.28
Vacant --> VCNT 0.2500
0.6178 0.02 1.10
SOILS:
TX574 22.7800
56.2905 1.87 100.00
SLOPE:
0-2 20.0600
49.5693 1.64 88.06
2-5 2.5500
6.3012 0.21 11.19
5-10 0.1700
0.4201 0.01 0.75
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 35 88.9000
219.6763 7.29
```

```
LANDUSE:
Residential-Low Density --> URLD 0.0500
0.1236 0.00 0.06
Commercial --> UCOM 24.7300
61.1091 2.03 27.82
Industrial --> UIDU 2.5100
6.2023 0.21 2.82
Transportation --> UTRN 51.1900
126.4930 4.20 57.58
Institutional --> UINS 3.2700
8.0803 0.27 3.68
Parks --> PARK 4.9400
12.2070 0.40 5.56
Vacant --> VCNT 2.2100
5.4610 0.18 2.49
SOILS:
TX574 88.9000
219.6763 7.29 100.00
SLOPE:
0-2 86.8300
214.5613 7.12 97.67
10-9999 0.0600
0.1483 0.00 0.07
2-5 0.6700
1.6556 0.05 0.75
5-10 1.3400
3.3112 0.11 1.51
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 36 46.7900
115.6204 3.84
LANDUSE:
Commercial --> UCOM 12.2000
30.1468 1.00 26.07
Industrial --> UIDU 0.2000
0.4942 0.02 0.43
Transportation --> UTRN 28.5800
70.6226 2.34 61.08
Institutional --> UINS 5.6200
13.8873 0.46 12.01
Vacant --> VCNT 0.1900
0.4695 0.02 0.41
SOILS:
TX574 46.7900
```

```
115.6204 3.84 100.00
SLOPE:
0-2 44.3300
109.5416 3.63 94.74
2-5 2.0800
5.1398 0.17 4.45
5-10 0.3800
0.9390 0.03 0.81
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 37 22.8500
56.4635 1.87
LANDUSE:
Commercial --> UCOM 5.7100
14.1097 0.47 24.99
Industrial --> UIDU 1.5900
3.9290 0.13 6.96
Transportation --> UTRN 9.3700
23.1537 0.77 41.01
Institutional --> UINS 0.0300
0.0741 0.00 0.13
Parks --> PARK 5.2100
12.8742 0.43 22.80
Vacant --> VCNT 0.9400
2.3228 0.08 4.11
SOILS:
TX574 22.8500
56.4635 1.87 100.00
SLOPE:
0-2 20.5700
50.8295 1.69 90.02
10-9999 0.2300
0.5683 0.02 1.01
2-5 0.6200
1.5321 0.05 2.71
5-10 1.4300
3.5336 0.12 6.26
Page 28
```

Appendix B

SWAT: HRU REPORT

```
HRULandUseSoilsReport

SWAT model simulation Date: 11/29/2016 12:00:00 AM Time: 00:00:00
MULTIPLE HRUs LandUse/Soil/Slope OPTION THRESHOLDS : 0 / 3 / 3
[%]
Number of HRUs: 373
Number of Subbasins: 37

Area [ha]
Area[acres]
Watershed 1220.0100
3014.7057

Area [ha]
Area[acres] %Wat.Area
LANDUSE:
Residential-High Density --> URHD 94.4700
233.4401 7.74
Residential-Low Density --> URLD 99.8900
246.8332 8.19
Commercial --> UCOM 197.1600
487.1922 16.16
Transportation --> UTRN 542.4200
1340.3469 44.46
Vacant --> VCNT 48.4100
119.6235 3.97
Residential --> URBN 80.2000
198.1782 6.57
Industrial --> UIDU 22.4100
55.3762 1.84
Institutional --> UINS 119.3600
294.9445 9.78
Parks --> PARK 15.6900
38.7708 1.29
SOILS:
TX235 720.8700
1781.3058 59.09
TX574 499.1400
1233.3999 40.91
SLOPE:
0-2 1123.4217
2776.0313 92.08
```

```
2-5 87.5523
216.3460 7.18
5-10 8.8060
21.7601 0.72
10-9999 0.2300
0.5683 0.02
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 1 52.7200
130.2738 4.32
LANDUSE:
Residential-High Density --> URHD 0.0700
0.1730 0.01 0.13
Residential-Low Density --> URLD 11.5400
28.5159 0.95 21.89
Commercial --> UCOM 2.3100
5.7081 0.19 4.38
Transportation --> UTRN 15.1100
37.3376 1.24 28.66
Vacant --> VCNT 0.9800
2.4216 0.08 1.86
Residential --> URBN 22.7100
56.1175 1.86 43.08
SOILS:
TX235 52.7200
130.2738 4.32 100.00
SLOPE:
0-2 52.2337
129.0720 4.28 99.08
2-5 0.4863
1.2017 0.04 0.92
HRUs
1 Residential-High Density --> URHD/TX235/0-2 0.0700
0.1730 0.01 0.13 1
2 Residential-Low Density --> URLD/TX235/0-2 11.5400
28.5159 0.95 21.89 2
3 Commercial --> UCOM/TX235/2-5 0.4863
1.2017 0.04 0.92 3
4 Commercial --> UCOM/TX235/0-2 1.8237
4.5064 0.15 3.46 4
5 Transportation --> UTRN/TX235/0-2 15.1100
37.3376 1.24 28.66 5
6 Vacant --> VCNT/TX235/0-2 0.9800
```

```
2.4216 0.08 1.86 6
7 Residential --> URBN/TX235/0-2 22.7100
56.1175 1.86 43.08 7
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 2 89.8400
221.9991 7.36
LANDUSE:
Commercial --> UCOM 8.2400
20.3615 0.68 9.17
Industrial --> UIDU 1.6600
4.1019 0.14 1.85
Transportation --> UTRN 35.5900
87.9447 2.92 39.61
Vacant --> VCNT 1.9900
4.9174 0.16 2.22
Residential --> URBN 42.3600
104.6737 3.47 47.15
SOILS:
TX235 89.8400
221.9991 7.36 100.00
SLOPE:
2-5 0.5400
1.3344 0.04 0.60
0-2 89.3000
220.6648 7.32 99.40
HRUs
8 Commercial --> UCOM/TX235/2-5 0.3200
0.7907 0.03 0.36 1
9 Commercial --> UCOM/TX235/0-2 7.9200
19.5707 0.65 8.82 2
10 Industrial --> UIDU/TX235/0-2 1.6600
4.1019 0.14 1.85 3
11 Transportation --> UTRN/TX235/0-2 35.5900
87.9447 2.92 39.61 4
12 Vacant --> VCNT/TX235/2-5 0.2200
0.5436 0.02 0.24 5
13 Vacant --> VCNT/TX235/0-2 1.7700
4.3738 0.15 1.97 6
14 Residential --> URBN/TX235/0-2 42.3600
104.6737 3.47 47.15 7
```

```
Area [ha]
```

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 3 21.5400
53.2264 1.77
LANDUSE:
Residential-High Density --> URHD 2.2400
5.5352 0.18 10.40
Residential-Low Density --> URLD 1.4500
3.5830 0.12 6.73
Commercial --> UCOM 6.9900
17.2726 0.57 32.45
Transportation --> UTRN 7.2500
17.9151 0.59 33.66
Institutional --> UINS 0.0300
0.0741 0.00 0.14
Vacant --> VCNT 1.7100
4.2255 0.14 7.94
Residential --> URBN 1.8700
4.6209 0.15 8.68
SOILS:
TX235 21.5400
53.2264 1.77 100.00
SLOPE:
2-5 1.7600
4.3490 0.14 8.17
0-2 19.7800
48.8774 1.62 91.83
HRUs
15 Residential-High Density --> URHD/TX235/2-5 0.1800
0.4448 0.01 0.84 1
16 Residential-High Density --> URHD/TX235/0-2 2.0600
5.0904 0.17 9.56 2
17 Residential-Low Density --> URLD/TX235/0-2 1.3800
3.4100 0.11 6.41 3
18 Residential-Low Density --> URLD/TX235/2-5 0.0700
0.1730 0.01 0.32 4
19 Commercial --> UCOM/TX235/2-5 1.1200
2.7676 0.09 5.20 5
20 Commercial --> UCOM/TX235/0-2 5.8700
14.5051 0.48 27.25 6
21 Transportation --> UTRN/TX235/0-2 7.2500
17.9151 0.59 33.66 7
22 Institutional --> UINS/TX235/0-2 0.0300
0.0741 0.00 0.14 8
23 Vacant --> VCNT/TX235/0-2 1.3200
```

```
3.2618 0.11 6.13 9
24 Vacant --> VCNT/TX235/2-5 0.3900
0.9637 0.03 1.81 10
25 Residential --> URBN/TX235/0-2 1.8700
4.6209 0.15 8.68 11
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 4 22.4800
55.5492 1.84
LANDUSE:
Residential-High Density --> URHD 1.3400
3.3112 0.11 5.96
Residential-Low Density --> URLD 0.2100
0.5189 0.02 0.93
Commercial --> UCOM 8.3300
20.5838 0.68 37.06
Industrial --> UIDU 1.6900
4.1761 0.14 7.52
Transportation --> UTRN 9.5600
23.6232 0.78 42.53
Institutional --> UINS 0.2800
0.6919 0.02 1.25
Vacant --> VCNT 1.0700
2.6440 0.09 4.76
SOILS:
TX235 22.3100
55.1291 1.83 99.24
TX574 0.1700
0.4201 0.01 0.76
SLOPE:
2-5 1.0943
2.7041 0.09 4.87
0-2 21.3857
52.8451 1.75 95.13
HRUs
26 Residential-High Density --> URHD/TX235/2-5 0.3300
0.8154 0.03 1.47 1
27 Residential-High Density --> URHD/TX235/0-2 1.0100
2.4958 0.08 4.49 2
28 Residential-Low Density --> URLD/TX235/0-2 0.2100
0.5189 0.02 0.93 3
29 Commercial --> UCOM/TX235/0-2 7.8786
19.4685 0.65 35.05 4
```

```
30 Commercial --> UCOM/TX235/2-5 0.4514
1.1154 0.04 2.01 5
31 Industrial --> UIDU/TX235/0-2 1.6900
4.1761 0.14 7.52 6
32 Transportation --> UTRN/TX235/2-5 0.3129
0.7733 0.03 1.39 7
33 Transportation --> UTRN/TX235/0-2 9.2471
22.8499 0.76 41.13 8
34 Institutional --> UINS/TX235/0-2 0.2800
0.6919 0.02 1.25 9
35 Vacant --> VCNT/TX235/0-2 0.9000
2.2239 0.07 4.00 10
36 Vacant --> VCNT/TX574/0-2 0.1700
0.4201 0.01 0.76 11
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 5 5.6100
13.8626 0.46
LANDUSE:
Residential-High Density --> URHD 0.5200
1.2849 0.04 9.27
Commercial --> UCOM 1.0700
2.6440 0.09 19.07
Transportation --> UTRN 3.6200
8.9452 0.30 64.53
Vacant --> VCNT 0.4000
0.9884 0.03 7.13
SOILS:
TX235 5.6100
13.8626 0.46 100.00
SLOPE:
0-2 5.2900
13.0719 0.43 94.30
2-5 0.3200
0.7907 0.03 5.70
HRUs
37 Residential-High Density --> URHD/TX235/0-2 0.4800
1.1861 0.04 8.56 1
38 Residential-High Density --> URHD/TX235/2-5 0.0400
0.0988 0.00 0.71 2
39 Commercial --> UCOM/TX235/0-2 1.0700
2.6440 0.09 19.07 3
40 Transportation --> UTRN/TX235/2-5 0.2000
```

```
0.4942 0.02 3.57 4
41 Transportation --> UTRN/TX235/0-2 3.4200
8.4510 0.28 60.96 5
42 Vacant --> VCNT/TX235/2-5 0.0800
0.1977 0.01 1.43 6
43 Vacant --> VCNT/TX235/0-2 0.3200
0.7907 0.03 5.70 7
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 6 58.9600
145.6931 4.83
LANDUSE:
Residential-Low Density --> URLD 0.1400
0.3459 0.01 0.24
Commercial --> UCOM 23.2600
57.4766 1.91 39.45
Industrial --> UIDU 2.7400
6.7707 0.22 4.65
Transportation --> UTRN 30.1600
74.5269 2.47 51.15
Vacant --> VCNT 1.6000
3.9537 0.13 2.71
Residential --> URBN 1.0600
2.6193 0.09 1.80
SOILS:
TX235 58.9600
145.6931 4.83 100.00
SLOPE:
0-2 58.2028
143.8221 4.77 98.72
2-5 0.7572
1.8710 0.06 1.28
HRUs
44 Residential-Low Density --> URLD/TX235/0-2 0.1400
0.3459 0.01 0.24 1
45 Commercial --> UCOM/TX235/2-5 0.7572
1.8710 0.06 1.28 2
46 Commercial --> UCOM/TX235/0-2 22.5028
55.6056 1.84 38.17 3
47 Industrial --> UIDU/TX235/0-2 2.7400
6.7707 0.22 4.65 4
48 Transportation --> UTRN/TX235/0-2 30.1600
74.5269 2.47 51.15 5
```

```
49 Vacant --> VCNT/TX235/0-2 1.6000
3.9537 0.13 2.71 6
50 Residential --> URBN/TX235/0-2 1.0600
2.6193 0.09 1.80 7
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 7 10.1300
25.0317 0.83
LANDUSE:
Residential-High Density --> URHD 5.9400
14.6780 0.49 58.64
Commercial --> UCOM 0.7700
1.9027 0.06 7.60
Transportation --> UTRN 2.7900
6.8942 0.23 27.54
Institutional --> UINS 0.4500
1.1120 0.04 4.44
Vacant --> VCNT 0.1800
0.4448 0.01 1.78
SOILS:
TX235 10.1300
25.0317 0.83 100.00
SLOPE:
0-2 8.8900
21.9676 0.73 87.76
2-5 1.2400
3.0641 0.10 12.24
HRUs
51 Residential-High Density --> URHD/TX235/0-2 5.1300
12.6765 0.42 50.64 1
52 Residential-High Density --> URHD/TX235/2-5 0.8100
2.0016 0.07 8.00 2
53 Commercial --> UCOM/TX235/2-5 0.1000
0.2471 0.01 0.99 3
54 Commercial --> UCOM/TX235/0-2 0.6700
1.6556 0.05 6.61 4
55 Transportation --> UTRN/TX235/0-2 2.4600
6.0788 0.20 24.28 5
56 Transportation --> UTRN/TX235/2-5 0.3300
0.8154 0.03 3.26 6
57 Institutional --> UINS/TX235/0-2 0.4500
1.1120 0.04 4.44 7
58 Vacant --> VCNT/TX235/0-2 0.1800
```

```
0.4448 0.01 1.78 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 8 3.8200
9.4394 0.31
LANDUSE:
Residential-High Density --> URHD 2.8400
7.0178 0.23 74.35
Commercial --> UCOM 0.0500
0.1236 0.00 1.31
Transportation --> UTRN 0.8800
2.1745 0.07 23.04
Vacant --> VCNT 0.0500
0.1236 0.00 1.31
SOILS:
TX235 3.8200
9.4394 0.31 100.00
SLOPE:
0-2 2.7700
6.8448 0.23 72.51
2-5 1.0500
2.5946 0.09 27.49
HRUs
59 Residential-High Density --> URHD/TX235/0-2 1.9100
4.7197 0.16 50.00 1
60 Residential-High Density --> URHD/TX235/2-5 0.9300
2.2981 0.08 24.35 2
61 Commercial --> UCOM/TX235/0-2 0.0400
0.0988 0.00 1.05 3
62 Commercial --> UCOM/TX235/2-5 0.0100
0.0247 0.00 0.26 4
63 Transportation --> UTRN/TX235/2-5 0.1100
0.2718 0.01 2.88 5
64 Transportation --> UTRN/TX235/0-2 0.7700
1.9027 0.06 20.16 6
65 Vacant --> VCNT/TX235/0-2 0.0500
0.1236 0.00 1.31 7
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 9 106.8200
263.9576 8.76
LANDUSE:
```

```
Residential-High Density --> URHD 0.0300
0.0741 0.00 0.03
Residential-Low Density --> URLD 4.1900
10.3537 0.34 3.92
Commercial --> UCOM 25.7700
63.6790 2.11 24.12
Industrial --> UIDU 4.8000
11.8610 0.39 4.49
Transportation --> UTRN 51.0800
126.2212 4.19 47.82
Institutional --> UINS 10.1800
25.1553 0.83 9.53
Parks --> PARK 4.9200
12.1576 0.40 4.61
Vacant --> VCNT 4.2400
10.4773 0.35 3.97
Residential --> URBN 1.6100
3.9784 0.13 1.51
SOILS:
TX235 106.8200
263.9576 8.76 100.00
SLOPE:
0-2 100.2494
247.7212 8.22 93.85
2-5 6.4306
15.8904 0.53 6.02
5-10 0.1400
0.3459 0.01 0.13
HRUs
66 Residential-High Density --> URHD/TX235/0-2 0.0300
0.0741 0.00 0.03 1
67 Residential-Low Density --> URLD/TX235/2-5 0.3617
0.8938 0.03 0.34 2
68 Residential-Low Density --> URLD/TX235/0-2 3.8283
9.4599 0.31 3.58 3
69 Commercial --> UCOM/TX235/2-5 1.4780
3.6523 0.12 1.38 4
70 Commercial --> UCOM/TX235/0-2 24.2920
60.0267 1.99 22.74 5
71 Industrial --> UIDU/TX235/0-2 4.8000
11.8610 0.39 4.49 6
72 Transportation --> UTRN/TX235/0-2 49.0585
121.2261 4.02 45.93 7
73 Transportation --> UTRN/TX235/2-5 2.0215
```

```
4.9952 0.17 1.89 8
74 Institutional --> UINS/TX235/2-5 0.7243
1.7897 0.06 0.68 9
75 Institutional --> UINS/TX235/0-2 9.4557
23.3656 0.78 8.85 10
76 Parks --> PARK/TX235/2-5 0.5611
1.3866 0.05 0.53 11
77 Parks --> PARK/TX235/0-2 4.3589
10.7710 0.36 4.08 12
78 Vacant --> VCNT/TX235/2-5 0.5640
1.3936 0.05 0.53 13
79 Vacant --> VCNT/TX235/0-2 3.6760
9.0836 0.30 3.44 14
80 Residential --> URBN/TX235/5-10 0.1400
0.3459 0.01 0.13 15
81 Residential --> URBN/TX235/2-5 0.7200
1.7792 0.06 0.67 16
82 Residential --> URBN/TX235/0-2 0.7500
1.8533 0.06 0.70 17
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 10 19.3000
47.6913 1.58
LANDUSE:
Residential-High Density --> URHD 0.6900
1.7050 0.06 3.58
Residential-Low Density --> URLD 6.1000
15.0734 0.50 31.61
Commercial --> UCOM 2.4000
5.9305 0.20 12.44
Transportation --> UTRN 10.0900
24.9329 0.83 52.28
Vacant --> VCNT 0.0200
0.0494 0.00 0.10
SOILS:
TX235 19.3000
47.6913 1.58 100.00
SLOPE:
0-2 19.3000
47.6913 1.58 100.00
HRUs
83 Residential-High Density --> URHD/TX235/0-2 0.6900
1.7050 0.06 3.58 1
```

```
84 Residential-Low Density --> URLD/TX235/0-2 6.1000
15.0734 0.50 31.61 2
85 Commercial --> UCOM/TX235/0-2 2.4000
5.9305 0.20 12.44 3
86 Transportation --> UTRN/TX235/0-2 10.0900
24.9329 0.83 52.28 4
87 Vacant --> VCNT/TX235/0-2 0.0200
0.0494 0.00 0.10 5
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 11 17.9900
44.4542 1.47
Page 12
HRULandUseSoilsReport
LANDUSE:
Residential-High Density --> URHD 5.1200
12.6518 0.42 28.46
Residential-Low Density --> URLD 3.3400
8.2533 0.27 18.57
Commercial --> UCOM 0.7700
1.9027 0.06 4.28
Transportation --> UTRN 7.3800
18.2363 0.60 41.02
Vacant --> VCNT 1.3800
3.4100 0.11 7.67
SOILS:
TX235 17.9900
44.4542 1.47 100.00
SLOPE:
0-2 17.9900
44.4542 1.47 100.00
HRUs
88 Residential-High Density --> URHD/TX235/0-2 5.1200
12.6518 0.42 28.46 1
89 Residential-Low Density --> URLD/TX235/0-2 3.3400
8.2533 0.27 18.57 2
90 Commercial --> UCOM/TX235/0-2 0.7700
1.9027 0.06 4.28 3
91 Transportation --> UTRN/TX235/0-2 7.3800
18.2363 0.60 41.02 4
92 Vacant --> VCNT/TX235/0-2 1.3800
3.4100 0.11 7.67 5
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 12 18.3600
45.3685 1.50
LANDUSE:
Residential-High Density --> URHD 1.2100
2.9900 0.10 6.59
Residential-Low Density --> URLD 7.0500
17.4209 0.58 38.40
Commercial --> UCOM 1.2200
3.0147 0.10 6.64
Transportation --> UTRN 7.5600
18.6811 0.62 41.18
Institutional --> UINS 1.3200
3.2618 0.11 7.19
SOILS:
TX235 18.3600
45.3685 1.50 100.00
SLOPE:
0-2 18.3600
45.3685 1.50 100.00
HRUs
93 Residential-High Density --> URHD/TX235/0-2 1.2100
2.9900 0.10 6.59 1
94 Residential-Low Density --> URLD/TX235/0-2 7.0500
17.4209 0.58 38.40 2
95 Commercial --> UCOM/TX235/0-2 1.2200
3.0147 0.10 6.64 3
96 Transportation --> UTRN/TX235/0-2 7.5600
18.6811 0.62 41.18 4
97 Institutional --> UINS/TX235/0-2 1.3200
3.2618 0.11 7.19 5
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 13 10.4800
25.8966 0.86
LANDUSE:
Residential-High Density --> URHD 1.5600
3.8548 0.13 14.89
Commercial --> UCOM 2.1600
5.3375 0.18 20.61
Transportation --> UTRN 4.6800
11.5645 0.38 44.66
```

```
Institutional --> UINS 1.0000
2.4711 0.08 9.54
Vacant --> VCNT 1.0800
2.6687 0.09 10.31
SOILS:
TX235 10.4800
25.8966 0.86 100.00
SLOPE:
2-5 3.3246
8.2152 0.27 31.72
0-2 6.5354
16.1493 0.54 62.36
5-10 0.6200
1.5321 0.05 5.92
HRUs
98 Residential-High Density --> URHD/TX235/2-5 0.7146
1.7658 0.06 6.82 1
99 Residential-High Density --> URHD/TX235/0-2 0.8454
2.0891 0.07 8.07 2
100 Commercial --> UCOM/TX235/2-5 0.8900
2.1992 0.07 8.49 3
101 Commercial --> UCOM/TX235/5-10 0.1700
0.4201 0.01 1.62 4
102 Commercial --> UCOM/TX235/0-2 1.1000
2.7182 0.09 10.50 5
103 Transportation --> UTRN/TX235/2-5 1.0400
2.5699 0.09 9.92 6
104 Transportation --> UTRN/TX235/0-2 3.4300
8.4757 0.28 32.73 7
105 Transportation --> UTRN/TX235/5-10 0.2100
0.5189 0.02 2.00 8
106 Institutional --> UINS/TX235/5-10 0.0600
0.1483 0.00 0.57 9
107 Institutional --> UINS/TX235/2-5 0.1900
0.4695 0.02 1.81 10
108 Institutional --> UINS/TX235/0-2 0.7500
1.8533 0.06 7.16 11
109 Vacant --> VCNT/TX235/5-10 0.1800
0.4448 0.01 1.72 12
110 Vacant --> VCNT/TX235/2-5 0.4900
1.2108 0.04 4.68 13
111 Vacant --> VCNT/TX235/0-2 0.4100
1.0131 0.03 3.91 14
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 14 24.5800
60.7384 2.01
LANDUSE:
Page 15
HRULandUseSoilsReport
Residential-High Density --> URHD 0.2000
0.4942 0.02 0.81
Residential-Low Density --> URLD 0.3200
0.7907 0.03 1.30
Commercial --> UCOM 6.5200
16.1112 0.53 26.53
Transportation --> UTRN 11.3400
28.0217 0.93 46.14
Institutional --> UINS 5.9900
14.8016 0.49 24.37
Vacant --> VCNT 0.2100
0.5189 0.02 0.85
SOILS:
TX235 19.0700
47.1229 1.56 77.58
TX574 5.5100
13.6155 0.45 22.42
SLOPE:
0-2 21.9922
54.3439 1.80 89.47
2-5 2.5878
6.3945 0.21 10.53
HRUs
112 Residential-High Density --> URHD/TX235/0-2 0.1600
0.3954 0.01 0.65 1
113 Residential-High Density --> URHD/TX235/2-5 0.0400
0.0988 0.00 0.16 2
114 Residential-Low Density --> URLD/TX235/0-2 0.3200
0.7907 0.03 1.30 3
115 Commercial --> UCOM/TX235/0-2 3.8500
9.5135 0.32 15.66 4
116 Commercial --> UCOM/TX235/2-5 0.4800
1.1861 0.04 1.95 5
117 Commercial --> UCOM/TX574/0-2 2.1900
5.4116 0.18 8.91 6
118 Transportation --> UTRN/TX235/2-5 0.9230
2.2808 0.08 3.76 7
```

```
119 Transportation --> UTRN/TX235/0-2 8.2970
20.5023 0.68 33.76 8
120 Transportation --> UTRN/TX574/0-2 2.1200
5.2386 0.17 8.62 9
121 Institutional --> UINS/TX235/0-2 3.6452
9.0075 0.30 14.83 10
122 Institutional --> UINS/TX235/2-5 1.1448
2.8288 0.09 4.66 11
123 Institutional --> UINS/TX574/0-2 1.2000
2.9653 0.10 4.88 12
124 Vacant --> VCNT/TX235/0-2 0.2100
0.5189 0.02 0.85 13
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 15 37.3300
92.2443 3.06
LANDUSE:
Residential-High Density --> URHD 11.9600
29.5538 0.98 32.04
Residential-Low Density --> URLD 5.8000
14.3321 0.48 15.54
Commercial --> UCOM 1.9900
4.9174 0.16 5.33
Transportation --> UTRN 14.5900
36.0526 1.20 39.08
Vacant --> VCNT 2.9700
7.3390 0.24 7.96
Residential --> URBN 0.0200
0.0494 0.00 0.05
SOILS:
TX235 37.3300
92.2443 3.06 100.00
SLOPE:
0-2 35.8325
88.5438 2.94 95.99
2-5 1.4975
3.7005 0.12 4.01
HRUs
125 Residential-High Density --> URHD/TX235/0-2 10.8325
26.7675 0.89 29.02 1
126 Residential-High Density --> URHD/TX235/2-5 1.1275
2.7862 0.09 3.02 2
127 Residential-Low Density --> URLD/TX235/2-5 0.3700
```

```
0.9143 0.03 0.99 3
128 Residential-Low Density --> URLD/TX235/0-2 5.4300
13.4178 0.45 14.55 4
129 Commercial --> UCOM/TX235/0-2 1.9900
4.9174 0.16 5.33 5
130 Transportation --> UTRN/TX235/0-2 14.5900
36.0526 1.20 39.08 6
131 Vacant --> VCNT/TX235/0-2 2.9700
7.3390 0.24 7.96 7
132 Residential --> URBN/TX235/0-2 0.0200
0.0494 0.00 0.05 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 16 25.2800
62.4681 2.07
LANDUSE:
Commercial --> UCOM 0.6800
1.6803 0.06 2.69
Industrial --> UIDU 0.5700
1.4085 0.05 2.25
Transportation --> UTRN 8.3600
20.6580 0.69 33.07
Institutional --> UINS 15.6700
38.7214 1.28 61.99
SOILS:
TX235 12.4300
30.7152 1.02 49.17
TX574 12.8500
31.7530 1.05 50.83
SLOPE:
0-2 21.4998
53.1271 1.76 85.05
2-5 3.7802
9.3411 0.31 14.95
HRUs
133 Commercial --> UCOM/TX235/0-2 0.6800
1.6803 0.06 2.69 1
134 Industrial --> UIDU/TX235/0-2 0.4100
1.0131 0.03 1.62 2
135 Industrial --> UIDU/TX235/2-5 0.1600
0.3954 0.01 0.63 3
136 Transportation --> UTRN/TX235/2-5 0.2110
0.5214 0.02 0.83 4
```

```
137 Transportation --> UTRN/TX235/0-2 4.0190
9.9312 0.33 15.90 5
138 Transportation --> UTRN/TX574/0-2 4.1300
10.2054 0.34 16.34 6
139 Institutional --> UINS/TX235/0-2 5.2808
13.0491 0.43 20.89 7
140 Institutional --> UINS/TX235/2-5 1.6692
4.1247 0.14 6.60 8
141 Institutional --> UINS/TX574/2-5 1.7400
4.2996 0.14 6.88 9
142 Institutional --> UINS/TX574/0-2 6.9800
17.2479 0.57 27.61 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 17 20.0800
49.6187 1.65
LANDUSE:
Residential-High Density --> URHD 2.5000
6.1776 0.20 12.45
Commercial --> UCOM 2.1000
5.1892 0.17 10.46
Industrial --> UIDU 3.7200
9.1923 0.30 18.53
Transportation --> UTRN 7.5900
18.7553 0.62 37.80
Institutional --> UINS 3.6500
9.0193 0.30 18.18
Vacant --> VCNT 0.5000
1.2355 0.04 2.49
Residential --> URBN 0.0200
0.0494 0.00 0.10
SOILS:
TX235 18.7700
46.3816 1.54 93.48
TX574 1.3100
3.2371 0.11 6.52
SLOPE:
2-5 3.3429
8.2605 0.27 16.65
0-2 16.7371
41.3582 1.37 83.35
HRUs
143 Residential-High Density --> URHD/TX235/2-5 0.1400
```

```
0.3459 0.01 0.70 1
144 Residential-High Density --> URHD/TX235/0-2 2.3600
5.8317 0.19 11.75 2
145 Commercial --> UCOM/TX235/0-2 2.1000
5.1892 0.17 10.46 3
146 Industrial --> UIDU/TX235/2-5 0.5314
1.3132 0.04 2.65 4
147 Industrial --> UIDU/TX235/0-2 3.1886
7.8791 0.26 15.88 5
148 Transportation --> UTRN/TX235/2-5 1.1315
2.7960 0.09 5.63 6
149 Transportation --> UTRN/TX235/0-2 6.4585
15.9593 0.53 32.16 7
150 Institutional --> UINS/TX235/2-5 1.3600
3.3606 0.11 6.77 8
151 Institutional --> UINS/TX235/0-2 0.9800
2.4216 0.08 4.88 9
152 Institutional --> UINS/TX574/0-2 1.1300
2.7923 0.09 5.63 10
153 Institutional --> UINS/TX574/2-5 0.1800
0.4448 0.01 0.90 11
154 Vacant --> VCNT/TX235/0-2 0.5000
1.2355 0.04 2.49 12
155 Residential --> URBN/TX235/0-2 0.0200
0.0494 0.00 0.10 13
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 18 54.9400
135.7595 4.50
LANDUSE:
Residential-High Density --> URHD 16.9400
41.8596 1.39 30.83
Residential-Low Density --> URLD 4.7900
11.8363 0.39 8.72
Commercial --> UCOM 4.0600
10.0325 0.33 7.39
Transportation --> UTRN 26.1700
64.6674 2.15 47.63
Institutional --> UINS 0.1500
0.3707 0.01 0.27
Vacant --> VCNT 2.7400
6.7707 0.22 4.99
Residential --> URBN 0.0900
```

```
0.2224 0.01 0.16
SOILS:
TX235 54.9400
135.7595 4.50 100.00
SLOPE:
2-5 2.5449
6.2886 0.21 4.63
0-2 51.8751
128.1860 4.25 94.42
5-10 0.5200
1.2849 0.04 0.95
HRUs
156 Residential-High Density --> URHD/TX235/2-5 1.3800
3.4100 0.11 2.51 1
157 Residential-High Density --> URHD/TX235/0-2 15.0400
37.1646 1.23 27.38 2
158 Residential-High Density --> URHD/TX235/5-10 0.5200
1.2849 0.04 0.95 3
159 Residential-Low Density --> URLD/TX235/0-2 4.7900
11.8363 0.39 8.72 4
160 Commercial --> UCOM/TX235/0-2 4.0600
10.0325 0.33 7.39 5
161 Transportation --> UTRN/TX235/2-5 1.1649
2.8785 0.10 2.12 6
162 Transportation --> UTRN/TX235/0-2 25.0051
61.7889 2.05 45.51 7
163 Institutional --> UINS/TX235/0-2 0.1500
0.3707 0.01 0.27 8
164 Vacant --> VCNT/TX235/0-2 2.7400
6.7707 0.22 4.99 9
165 Residential --> URBN/TX235/0-2 0.0900
0.2224 0.01 0.16 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 19 32.4700
80.2350 2.66
LANDUSE:
Residential-High Density --> URHD 1.1300
2.7923 0.09 3.48
Page 21
HRULandUseSoilsReport
Commercial --> UCOM 4.4600
11.0209 0.37 13.74
```

```
Transportation --> UTRN 13.5100
33.3839 1.11 41.61
Institutional --> UINS 12.2000
30.1468 1.00 37.57
Vacant --> VCNT 1.1700
2.8911 0.10 3.60
SOILS:
TX235 12.3200
30.4433 1.01 37.94
TX574 20.1500
49.7917 1.65 62.06
SLOPE:
0-2 25.7283
63.5760 2.11 79.24
2-5 6.7417
16.6590 0.55 20.76
HRUs
166 Residential-High Density --> URHD/TX235/0-2 0.6300
1.5568 0.05 1.94 1
167 Residential-High Density --> URHD/TX235/2-5 0.5000
1.2355 0.04 1.54 2
168 Commercial --> UCOM/TX235/0-2 1.4700
3.6324 0.12 4.53 3
169 Commercial --> UCOM/TX235/2-5 0.1400
0.3459 0.01 0.43 4
170 Commercial --> UCOM/TX574/2-5 0.1800
0.4448 0.01 0.55 5
171 Commercial --> UCOM/TX574/0-2 2.6700
6.5977 0.22 8.22 6
172 Transportation --> UTRN/TX235/0-2 2.6782
6.6179 0.22 8.25 7
173 Transportation --> UTRN/TX235/2-5 0.6018
1.4872 0.05 1.85 8
174 Transportation --> UTRN/TX574/2-5 1.1800
2.9158 0.10 3.63 9
175 Transportation --> UTRN/TX574/0-2 9.0500
22.3630 0.74 27.87 10
176 Institutional --> UINS/TX235/2-5 2.5498
6.3007 0.21 7.85 11
177 Institutional --> UINS/TX235/0-2 2.5802
6.3757 0.21 7.95 12
178 Institutional --> UINS/TX574/2-5 1.5400
3.8054 0.13 4.74 13
179 Institutional --> UINS/TX574/0-2 5.5300
```

```
13.6649 0.45 17.03 14
180 Vacant --> VCNT/TX235/0-2 1.1200
2.7676 0.09 3.45 15
181 Vacant --> VCNT/TX235/2-5 0.0500
0.1236 0.00 0.15 16
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 20 26.4800
65.4334 2.17
LANDUSE:
Residential-Low Density --> URLD 1.6800
4.1514 0.14 6.34
Commercial --> UCOM 1.5300
3.7807 0.13 5.78
Transportation --> UTRN 10.5100
25.9707 0.86 39.69
Institutional --> UINS 12.0100
29.6773 0.98 45.35
Vacant --> VCNT 0.7500
1.8533 0.06 2.83
SOILS:
TX574 26.4800
65.4334 2.17 100.00
SLOPE:
0-2 24.0900
59.5276 1.97 90.97
2-5 2.3900
5.9058 0.20 9.03
HRUs
182 Residential-Low Density --> URLD/TX574/0-2 1.6800
4.1514 0.14 6.34 1
183 Commercial --> UCOM/TX574/0-2 1.3700
3.3853 0.11 5.17 2
184 Commercial --> UCOM/TX574/2-5 0.1600
0.3954 0.01 0.60 3
185 Transportation --> UTRN/TX574/0-2 9.8600
24.3646 0.81 37.24 4
186 Transportation --> UTRN/TX574/2-5 0.6500
1.6062 0.05 2.45 5
187 Institutional --> UINS/TX574/0-2 10.4300
Page 23
HRULandUseSoilsReport
25.7731 0.85 39.39 6
```

```
188 Institutional --> UINS/TX574/2-5 1.5800
3.9043 0.13 5.97 7
189 Vacant --> VCNT/TX574/0-2 0.7500
1.8533 0.06 2.83 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 21 25.9600
64.1485 2.13
LANDUSE:
Residential-High Density --> URHD 1.8800
4.6456 0.15 7.24
Residential-Low Density --> URLD 3.3800
8.3521 0.28 13.02
Commercial --> UCOM 3.9500
9.7606 0.32 15.22
Transportation --> UTRN 11.3200
27.9723 0.93 43.61
Institutional --> UINS 3.7400
9.2417 0.31 14.41
Vacant --> VCNT 1.6900
4.1761 0.14 6.51
SOILS:
TX574 25.9600
64.1485 2.13 100.00
SLOPE:
2-5 1.3700
3.3853 0.11 5.28
0-2 24.5900
60.7631 2.02 94.72
HRUs
190 Residential-High Density --> URHD/TX574/2-5 0.3900
0.9637 0.03 1.50 1
191 Residential-High Density --> URHD/TX574/0-2 1.4900
3.6819 0.12 5.74 2
192 Residential-Low Density --> URLD/TX574/0-2 3.3800
8.3521 0.28 13.02 3
193 Commercial --> UCOM/TX574/0-2 3.9500
9.7606 0.32 15.22 4
194 Transportation --> UTRN/TX574/2-5 0.5000
1.2355 0.04 1.93 5
195 Transportation --> UTRN/TX574/0-2 10.8200
26.7368 0.89 41.68 6
196 Institutional --> UINS/TX574/0-2 3.5200
```

```
8.6981 0.29 13.56 7
197 Institutional --> UINS/TX574/2-5 0.2200
0.5436 0.02 0.85 8
198 Vacant --> VCNT/TX574/0-2 1.4300
3.5336 0.12 5.51 9
199 Vacant --> VCNT/TX574/2-5 0.2600
0.6425 0.02 1.00 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 22 6.9200
17.0997 0.57
LANDUSE:
Residential-High Density --> URHD 0.1500
0.3707 0.01 2.17
Residential-Low Density --> URLD 1.6400
4.0525 0.13 23.70
Commercial --> UCOM 0.2000
0.4942 0.02 2.89
Transportation --> UTRN 3.5900
8.8711 0.29 51.88
Institutional --> UINS 0.6900
1.7050 0.06 9.97
Vacant --> VCNT 0.6500
1.6062 0.05 9.39
SOILS:
TX574 6.9200
17.0997 0.57 100.00
SLOPE:
0-2 6.3900
15.7900 0.52 92.34
2-5 0.5300
1.3097 0.04 7.66
HRUs
200 Residential-High Density --> URHD/TX574/0-2 0.0500
0.1236 0.00 0.72 1
201 Residential-High Density --> URHD/TX574/2-5 0.1000
Page 25
HRULandUseSoilsReport
0.2471 0.01 1.45 2
202 Residential-Low Density --> URLD/TX574/2-5 0.0500
0.1236 0.00 0.72 3
203 Residential-Low Density --> URLD/TX574/0-2 1.5900
3.9290 0.13 22.98 4
```

```
204 Commercial --> UCOM/TX574/0-2 0.2000
0.4942 0.02 2.89 5
205 Transportation --> UTRN/TX574/2-5 0.1400
0.3459 0.01 2.02 6
206 Transportation --> UTRN/TX574/0-2 3.4500
8.5251 0.28 49.86 7
207 Institutional --> UINS/TX574/0-2 0.6900
1.7050 0.06 9.97 8
208 Vacant --> VCNT/TX574/0-2 0.4100
1.0131 0.03 5.92 9
209 Vacant --> VCNT/TX574/2-5 0.2400
0.5931 0.02 3.47 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 23 28.8800
71.3639 2.37
LANDUSE:
Residential-High Density --> URHD 10.7000
26.4402 0.88 37.05
Residential-Low Density --> URLD 1.8700
4.6209 0.15 6.48
Commercial --> UCOM 2.0300
5.0162 0.17 7.03
Transportation --> UTRN 14.1300
34.9159 1.16 48.93
Institutional --> UINS 0.0600
0.1483 0.00 0.21
Vacant --> VCNT 0.0400
0.0988 0.00 0.14
Residential --> URBN 0.0500
0.1236 0.00 0.17
SOILS:
TX235 27.9500
69.0658 2.29 96.78
TX574 0.9300
2.2981 0.08 3.22
SLOPE:
0-2 28.2287
69.7544 2.31 97.74
2-5 0.6513
1.6095 0.05 2.26
HRUs
210 Residential-High Density --> URHD/TX235/0-2 10.7000
```

```
26.4402 0.88 37.05 1
211 Residential-Low Density --> URLD/TX235/0-2 1.8700
4.6209 0.15 6.48 2
212 Commercial --> UCOM/TX235/0-2 1.8100
4.4726 0.15 6.27 3
213 Commercial --> UCOM/TX574/2-5 0.0800
0.1977 0.01 0.28 4
214 Commercial --> UCOM/TX574/0-2 0.1400
0.3459 0.01 0.48 5
215 Transportation --> UTRN/TX235/2-5 0.4513
1.1153 0.04 1.56 6
216 Transportation --> UTRN/TX235/0-2 12.9887
32.0956 1.06 44.97 7
217 Transportation --> UTRN/TX574/2-5 0.1200
0.2965 0.01 0.42 8
218 Transportation --> UTRN/TX574/0-2 0.5700
1.4085 0.05 1.97 9
219 Institutional --> UINS/TX235/0-2 0.0600
0.1483 0.00 0.21 10
220 Vacant --> VCNT/TX235/0-2 0.0400
0.0988 0.00 0.14 11
221 Residential --> URBN/TX235/0-2 0.0300
0.0741 0.00 0.10 12
222 Residential --> URBN/TX574/0-2 0.0200
0.0494 0.00 0.07 13
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 24 36.7000
90.6875 3.01
LANDUSE:
Residential-High Density --> URHD 6.7100
16.5807 0.55 18.28
Residential-Low Density --> URLD 4.0200
9.9336 0.33 10.95
Commercial --> UCOM 3.8200
9.4394 0.31 10.41
Transportation --> UTRN 19.3200
47.7407 1.58 52.64
Institutional --> UINS 0.2600
0.6425 0.02 0.71
Vacant --> VCNT 2.4800
6.1282 0.20 6.76
Residential --> URBN 0.0900
```

```
0.2224 0.01 0.25
SOILS:
TX235 34.7400
85.8443 2.85 94.66
TX574 1.9600
4.8433 0.16 5.34
SLOPE:
0-2 34.8471
86.1088 2.86 94.95
2-5 1.8529
4.5787 0.15 5.05
HRUs
223 Residential-High Density --> URHD/TX235/0-2 6.4883
16.0330 0.53 17.68 1
224 Residential-High Density --> URHD/TX235/2-5 0.2217
0.5477 0.02 0.60 2
225 Residential-Low Density --> URLD/TX235/0-2 4.0200
9.9336 0.33 10.95 3
226 Commercial --> UCOM/TX235/2-5 0.1200
0.2965 0.01 0.33 4
227 Commercial --> UCOM/TX235/0-2 3.1200
7.7097 0.26 8.50 5
228 Commercial --> UCOM/TX574/0-2 0.5800
1.4332 0.05 1.58 6
229 Transportation --> UTRN/TX235/0-2 16.8000
41.5136 1.38 45.78 7
230 Transportation --> UTRN/TX235/2-5 1.1900
2.9405 0.10 3.24 8
231 Transportation --> UTRN/TX574/0-2 1.3300
3.2865 0.11 3.62 9
232 Institutional --> UINS/TX235/0-2 0.2600
0.6425 0.02 0.71 10
233 Vacant --> VCNT/TX235/0-2 2.1587
5.3343 0.18 5.88 11
234 Vacant --> VCNT/TX235/2-5 0.3213
0.7939 0.03 0.88 12
235 Residential --> URBN/TX235/0-2 0.0400
0.0988 0.00 0.11 13
236 Residential --> URBN/TX574/0-2 0.0500
0.1236 0.00 0.14 14
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 25 54.5900
```

```
134.8946 4.47
LANDUSE:
Commercial --> UCOM 7.8800
19.4719 0.65 14.43
Industrial --> UIDU 0.9200
2.2734 0.08 1.69
Transportation --> UTRN 22.3500
55.2280 1.83 40.94
Institutional --> UINS 22.0200
54.4125 1.80 40.34
Vacant --> VCNT 1.3900
3.4348 0.11 2.55
Residential --> URBN 0.0300
0.0741 0.00 0.05
SOILS:
TX574 54.5900
134.8946 4.47 100.00
SLOPE:
0-2 46.4593
114.8033 3.81 85.11
2-5 8.1307
20.0913 0.67 14.89
HRUs
237 Commercial --> UCOM/TX574/0-2 7.8800
19.4719 0.65 14.43 1
238 Industrial --> UIDU/TX574/0-2 0.9200
2.2734 0.08 1.69 2
239 Transportation --> UTRN/TX574/0-2 20.7872
51.3662 1.70 38.08 3
240 Transportation --> UTRN/TX574/2-5 1.5628
3.8617 0.13 2.86 4
241 Institutional --> UINS/TX574/2-5 6.5679
16.2296 0.54 12.03 5
242 Institutional --> UINS/TX574/0-2 15.4521
Page 29
HRULandUseSoilsReport
38.1829 1.27 28.31 6
243 Vacant --> VCNT/TX574/0-2 1.3900
3.4348 0.11 2.55 7
244 Residential --> URBN/TX574/0-2 0.0300
0.0741 0.00 0.05 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
```

```
SUBBASIN # 26 0.1700
0.4201 0.01
LANDUSE:
Commercial --> UCOM 0.0700
0.1730 0.01 41.18
Transportation --> UTRN 0.1000
0.2471 0.01 58.82
SOILS:
TX574 0.1700
0.4201 0.01 100.00
SLOPE:
0-2 0.1700
0.4201 0.01 100.00
HRUs
245 Commercial --> UCOM/TX574/0-2 0.0700
0.1730 0.01 41.18 1
246 Transportation --> UTRN/TX574/0-2 0.1000
0.2471 0.01 58.82 2
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 27 81.0300
200.2292 6.64
LANDUSE:
Residential-High Density --> URHD 11.1600
27.5769 0.91 13.77
Residential-Low Density --> URLD 21.1800
52.3368 1.74 26.14
Commercial --> UCOM 12.5000
30.8881 1.02 15.43
Transportation --> UTRN 24.9700
61.7021 2.05 30.82
Institutional --> UINS 0.0400
0.0988 0.00 0.05
Vacant --> VCNT 10.1900
25.1800 0.84 12.58
Residential --> URBN 0.9900
2.4463 0.08 1.22
SOILS:
TX235 48.3100
119.3764 3.96 59.62
TX574 32.7200
80.8528 2.68 40.38
SLOPE:
```

```
0-2 65.3670
161.5250 5.36 80.67
5-10 3.6944
9.1291 0.30 4.56
2-5 11.9686
29.5750 0.98 14.77
HRUs
247 Residential-High Density --> URHD/TX235/0-2 8.6900
21.4734 0.71 10.72 1
248 Residential-High Density --> URHD/TX235/5-10 0.3500
0.8649 0.03 0.43 2
249 Residential-High Density --> URHD/TX235/2-5 0.5900
1.4579 0.05 0.73 3
250 Residential-High Density --> URHD/TX574/0-2 1.5300
3.7807 0.13 1.89 4
251 Residential-Low Density --> URLD/TX235/0-2 15.1239
37.3720 1.24 18.66 5
252 Residential-Low Density --> URLD/TX235/2-5 1.2536
3.0978 0.10 1.55 6
253 Residential-Low Density --> URLD/TX235/5-10 0.8324
2.0569 0.07 1.03 7
254 Residential-Low Density --> URLD/TX574/2-5 1.5800
3.9043 0.13 1.95 8
255 Residential-Low Density --> URLD/TX574/5-10 0.3700
0.9143 0.03 0.46 9
256 Residential-Low Density --> URLD/TX574/0-2 2.0200
4.9915 0.17 2.49 10
257 Commercial --> UCOM/TX235/0-2 0.8400
2.0757 0.07 1.04 11
258 Commercial --> UCOM/TX235/2-5 0.0600
Page 31
HRULandUseSoilsReport
0.1483 0.00 0.07 12
259 Commercial --> UCOM/TX574/0-2 8.0800
19.9661 0.66 9.97 13
260 Commercial --> UCOM/TX574/2-5 2.8700
7.0919 0.24 3.54 14
261 Commercial --> UCOM/TX574/5-10 0.6500
1.6062 0.05 0.80 15
262 Transportation --> UTRN/TX235/0-2 13.0878
32.3406 1.07 16.15 16
263 Transportation --> UTRN/TX235/2-5 0.4222
1.0432 0.03 0.52 17
264 Transportation --> UTRN/TX574/5-10 0.5100
```

```
1.2602 0.04 0.63 18
265 Transportation --> UTRN/TX574/0-2 8.1500
20.1391 0.67 10.06 19
266 Transportation --> UTRN/TX574/2-5 2.8000
6.9189 0.23 3.46 20
267 Institutional --> UINS/TX574/0-2 0.0400
0.0988 0.00 0.05 21
268 Vacant --> VCNT/TX235/0-2 5.3652
13.2577 0.44 6.62 22
269 Vacant --> VCNT/TX235/5-10 0.7120
1.7594 0.06 0.88 23
270 Vacant --> VCNT/TX235/2-5 0.9828
2.4285 0.08 1.21 24
271 Vacant --> VCNT/TX574/2-5 1.4100
3.4842 0.12 1.74 25
272 Vacant --> VCNT/TX574/5-10 0.2700
0.6672 0.02 0.33 26
273 Vacant --> VCNT/TX574/0-2 1.4500
3.5830 0.12 1.79 27
274 Residential --> URBN/TX574/0-2 0.9900
2.4463 0.08 1.22 28
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 28 41.7300
103.1169 3.42
LANDUSE:
Residential-High Density --> URHD 5.6900
14.0603 0.47 13.64
Residential-Low Density --> URLD 2.8300
6.9931 0.23 6.78
Commercial --> UCOM 5.6300
13.9120 0.46 13.49
Industrial --> UIDU 1.1900
2.9405 0.10 2.85
Transportation --> UTRN 15.9000
39.2897 1.30 38.10
Institutional --> UINS 2.0100
4.9668 0.16 4.82
Vacant --> VCNT 0.0100
0.0247 0.00 0.02
Residential --> URBN 8.4700
20.9298 0.69 20.30
SOILS:
```

```
TX235 14.1900
35.0642 1.16 34.00
TX574 27.5400
68.0527 2.26 66.00
SLOPE:
0-2 40.5500
100.2011 3.32 97.17
2-5 1.1800
2.9158 0.10 2.83
HRUs
275 Residential-High Density --> URHD/TX235/0-2 4.1700
10.3043 0.34 9.99 1
276 Residential-High Density --> URHD/TX574/0-2 1.5200
3.7560 0.12 3.64 2
277 Residential-Low Density --> URLD/TX235/0-2 2.8300
6.9931 0.23 6.78 3
278 Commercial --> UCOM/TX235/0-2 0.8300
2.0510 0.07 1.99 4
279 Commercial --> UCOM/TX574/2-5 0.3400
0.8402 0.03 0.81 5
280 Commercial --> UCOM/TX574/0-2 4.4600
11.0209 0.37 10.69 6
281 Industrial --> UIDU/TX574/0-2 1.1900
2.9405 0.10 2.85 7
282 Transportation --> UTRN/TX235/0-2 5.2100
12.8742 0.43 12.49 8
283 Transportation --> UTRN/TX574/2-5 0.6300
1.5568 0.05 1.51 9
284 Transportation --> UTRN/TX574/0-2 10.0600
24.8588 0.82 24.11 10
285 Institutional --> UINS/TX235/0-2 0.1400
0.3459 0.01 0.34 11
286 Institutional --> UINS/TX574/2-5 0.2100
0.5189 0.02 0.50 12
287 Institutional --> UINS/TX574/0-2 1.6600
4.1019 0.14 3.98 13
288 Vacant --> VCNT/TX235/0-2 0.0100
0.0247 0.00 0.02 14
289 Residential --> URBN/TX235/0-2 1.0000
2.4711 0.08 2.40 15
290 Residential --> URBN/TX574/0-2 7.4700
18.4587 0.61 17.90 16
```

Area [ha]

```
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 29 15.9700
39.4627 1.31
LANDUSE:
Residential-Low Density --> URLD 2.6200
6.4742 0.21 16.41
Commercial --> UCOM 2.0300
5.0162 0.17 12.71
Transportation --> UTRN 6.7400
16.6549 0.55 42.20
Institutional --> UINS 3.2200
7.9568 0.26 20.16
Vacant --> VCNT 1.3600
3.3606 0.11 8.52
SOILS:
TX574 15.9700
39.4627 1.31 100.00
SLOPE:
0-2 12.4100
30.6657 1.02 77.71
2-5 3.5600
8.7969 0.29 22.29
HRUs
291 Residential-Low Density --> URLD/TX574/0-2 1.9400
4.7938 0.16 12.15 1
292 Residential-Low Density --> URLD/TX574/2-5 0.6800
1.6803 0.06 4.26 2
293 Commercial --> UCOM/TX574/0-2 1.8400
4.5467 0.15 11.52 3
294 Commercial --> UCOM/TX574/2-5 0.1900
0.4695 0.02 1.19 4
295 Transportation --> UTRN/TX574/0-2 5.4200
13.3931 0.44 33.94 5
296 Transportation --> UTRN/TX574/2-5 1.3200
3.2618 0.11 8.27 6
297 Institutional --> UINS/TX574/2-5 1.2700
3.1382 0.10 7.95 7
298 Institutional --> UINS/TX574/0-2 1.9500
4.8185 0.16 12.21 8
299 Vacant --> VCNT/TX574/0-2 1.2600
3.1135 0.10 7.89 9
300 Vacant --> VCNT/TX574/2-5 0.1000
0.2471 0.01 0.63 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 30 20.9700
51.8179 1.72
LANDUSE:
Commercial --> UCOM 1.1400
2.8170 0.09 5.44
Industrial --> UIDU 0.8200
2.0263 0.07 3.91
Transportation --> UTRN 10.7600
26.5885 0.88 51.31
Institutional --> UINS 8.2200
20.3120 0.67 39.20
Vacant --> VCNT 0.0300
0.0741 0.00 0.14
SOILS:
TX235 0.0700
0.1730 0.01 0.33
TX574 20.9000
51.6449 1.71 99.67
SLOPE:
0-2 17.1714
42.4314 1.41 81.89
2-5 3.0035
7.4219 0.25 14.32
5-10 0.7951
1.9647 0.07 3.79
HRUs
301 Commercial --> UCOM/TX235/0-2 0.0700
0.1730 0.01 0.33 1
302 Commercial --> UCOM/TX574/0-2 1.0700
2.6440 0.09 5.10 2
303 Industrial --> UIDU/TX574/0-2 0.8200
2.0263 0.07 3.91 3
304 Transportation --> UTRN/TX574/0-2 9.2419
22.8372 0.76 44.07 4
305 Transportation --> UTRN/TX574/2-5 1.1386
2.8135 0.09 5.43 5
306 Transportation --> UTRN/TX574/5-10 0.3795
0.9378 0.03 1.81 6
307 Institutional --> UINS/TX574/2-5 1.8650
4.6084 0.15 8.89 7
308 Institutional --> UINS/TX574/5-10 0.4156
1.0269 0.03 1.98 8
```

```
309 Institutional --> UINS/TX574/0-2 5.9395
14.6768 0.49 28.32 9
310 Vacant --> VCNT/TX574/0-2 0.0300
0.0741 0.00 0.14 10
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 31 50.4600
124.6892 4.14
LANDUSE:
Residential-High Density --> URHD 3.8900
9.6124 0.32 7.71
Residential-Low Density --> URLD 15.6900
38.7708 1.29 31.09
Commercial --> UCOM 2.4200
5.9799 0.20 4.80
Transportation --> UTRN 22.6900
56.0681 1.86 44.97
Institutional --> UINS 0.4700
1.1614 0.04 0.93
Parks --> PARK 0.6200
1.5321 0.05 1.23
Vacant --> VCNT 3.8500
9.5135 0.32 7.63
Residential --> URBN 0.8300
2.0510 0.07 1.64
SOILS:
TX235 2.8700
7.0919 0.24 5.69
TX574 47.5900
117.5973 3.90 94.31
SLOPE:
0-2 42.0786
103.9782 3.45 83.39
2-5 8.3814
20.7110 0.69 16.61
HRUs
311 Residential-High Density --> URHD/TX235/0-2 1.3700
3.3853 0.11 2.72 1
312 Residential-High Density --> URHD/TX574/0-2 2.2900
5.6587 0.19 4.54 2
313 Residential-High Density --> URHD/TX574/2-5 0.2300
0.5683 0.02 0.46 3
314 Residential-Low Density --> URLD/TX574/0-2 12.9038
```

```
31.8860 1.06 25.57 4
315 Residential-Low Density --> URLD/TX574/2-5 2.7862
6.8848 0.23 5.52 5
316 Commercial --> UCOM/TX235/0-2 0.1100
0.2718 0.01 0.22 6
317 Commercial --> UCOM/TX574/0-2 1.5300
3.7807 0.13 3.03 7
318 Commercial --> UCOM/TX574/2-5 0.7800
1.9274 0.06 1.55 8
319 Transportation --> UTRN/TX235/0-2 0.9700
2.3969 0.08 1.92 9
320 Transportation --> UTRN/TX574/0-2 17.9700
44.4048 1.47 35.61 10
321 Transportation --> UTRN/TX574/2-5 3.7500
9.2664 0.31 7.43 11
322 Institutional --> UINS/TX235/0-2 0.4200
1.0378 0.03 0.83 12
323 Institutional --> UINS/TX574/0-2 0.0500
0.1236 0.00 0.10 13
324 Parks --> PARK/TX574/2-5 0.1000
0.2471 0.01 0.20 14
325 Parks --> PARK/TX574/0-2 0.5200
1.2849 0.04 1.03 15
326 Vacant --> VCNT/TX574/2-5 0.7353
1.8169 0.06 1.46 16
327 Vacant --> VCNT/TX574/0-2 3.1147
7.6966 0.26 6.17 17
328 Residential --> URBN/TX574/0-2 0.8300
2.0510 0.07 1.64 18
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 32 14.2400
35.1878 1.17
LANDUSE:
Commercial --> UCOM 3.3000
8.1545 0.27 23.17
Transportation --> UTRN 6.6800
16.5066 0.55 46.91
Institutional --> UINS 4.1700
10.3043 0.34 29.28
Vacant --> VCNT 0.0900
0.2224 0.01 0.63
SOILS:
```

```
TX574 14.2400
35.1878 1.17 100.00
SLOPE:
0-2 12.8658
31.7921 1.05 90.35
2-5 1.3442
3.3215 0.11 9.44
5-10 0.0300
0.0741 0.00 0.21
HRUs
329 Commercial --> UCOM/TX574/0-2 3.3000
8.1545 0.27 23.17 1
330 Transportation --> UTRN/TX574/0-2 5.9876
14.7956 0.49 42.05 2
331 Transportation --> UTRN/TX574/2-5 0.6924
1.7111 0.06 4.86 3
332 Institutional --> UINS/TX574/2-5 0.6117
1.5116 0.05 4.30 4
333 Institutional --> UINS/TX574/0-2 3.5583
8.7926 0.29 24.99 5
334 Vacant --> VCNT/TX574/5-10 0.0300
0.0741 0.00 0.21 6
335 Vacant --> VCNT/TX574/0-2 0.0200
0.0494 0.00 0.14 7
336 Vacant --> VCNT/TX574/2-5 0.0400
Page 38
HRULandUseSoilsReport
0.0988 0.00 0.28 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 33 1.8600
4.5962 0.15
LANDUSE:
Commercial --> UCOM 0.4900
1.2108 0.04 26.34
Transportation --> UTRN 1.3300
3.2865 0.11 71.51
Institutional --> UINS 0.0400
0.0988 0.00 2.15
SOILS:
TX574 1.8600
4.5962 0.15 100.00
SLOPE:
```

```
0-2 1.8600
4.5962 0.15 100.00
HRUs
337 Commercial --> UCOM/TX574/0-2 0.4900
1.2108 0.04 26.34 1
338 Transportation --> UTRN/TX574/0-2 1.3300
3.2865 0.11 71.51 2
339 Institutional --> UINS/TX574/0-2 0.0400
0.0988 0.00 2.15 3
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 34 22.7800
56.2905 1.87
LANDUSE:
Commercial --> UCOM 4.3800
10.8232 0.36 19.23
Transportation --> UTRN 15.5800
38.4990 1.28 68.39
Institutional --> UINS 2.5700
6.3506 0.21 11.28
Vacant --> VCNT 0.2500
0.6178 0.02 1.10
SOILS:
TX574 22.7800
56.2905 1.87 100.00
SLOPE:
2-5 2.5787
6.3720 0.21 11.32
0-2 20.2013
49.9185 1.66 88.68
HRUs
340 Commercial --> UCOM/TX574/2-5 0.4800
1.1861 0.04 2.11 1
341 Commercial --> UCOM/TX574/0-2 3.9000
9.6371 0.32 17.12 2
342 Transportation --> UTRN/TX574/2-5 1.2379
3.0590 0.10 5.43 3
343 Transportation --> UTRN/TX574/0-2 14.3421
35.4399 1.18 62.96 4
344 Institutional --> UINS/TX574/2-5 0.7607
1.8798 0.06 3.34 5
345 Institutional --> UINS/TX574/0-2 1.8093
4.4708 0.15 7.94 6
```

```
346 Vacant --> VCNT/TX574/2-5 0.1000
0.2471 0.01 0.44 7
347 Vacant --> VCNT/TX574/0-2 0.1500
0.3707 0.01 0.66 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 35 88.9000
219.6763 7.29
LANDUSE:
Residential-Low Density --> URLD 0.0500
0.1236 0.00 0.06
Commercial --> UCOM 24.7300
61.1091 2.03 27.82
Industrial --> UIDU 2.5100
6.2023 0.21 2.82
Transportation --> UTRN 51.1900
126.4930 4.20 57.58
Institutional --> UINS 3.2700
8.0803 0.27 3.68
Parks --> PARK 4.9400
12.2070 0.40 5.56
Vacant --> VCNT 2.2100
5.4610 0.18 2.49
SOILS:
TX574 88.9000
219.6763 7.29 100.00
SLOPE:
0-2 86.8855
214.6985 7.12 97.73
2-5 0.6580
1.6259 0.05 0.74
5-10 1.3565
3.3519 0.11 1.53
HRUs
348 Residential-Low Density --> URLD/TX574/0-2 0.0500
0.1236 0.00 0.06 1
349 Commercial --> UCOM/TX574/0-2 24.7300
61.1091 2.03 27.82 2
350 Industrial --> UIDU/TX574/0-2 2.5100
6.2023 0.21 2.82 3
351 Transportation --> UTRN/TX574/0-2 51.1900
126.4930 4.20 57.58 4
352 Institutional --> UINS/TX574/0-2 3.2700
```

```
8.0803 0.27 3.68 5
353 Parks --> PARK/TX574/2-5 0.6580
1.6259 0.05 0.74 6
354 Parks --> PARK/TX574/5-10 1.3565
3.3519 0.11 1.53 7
355 Parks --> PARK/TX574/0-2 2.9255
7.2291 0.24 3.29 8
356 Vacant --> VCNT/TX574/0-2 2.2100
5.4610 0.18 2.49 9
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 36 46.7900
115.6204 3.84
LANDUSE:
Commercial --> UCOM 12.2000
30.1468 1.00 26.07
Industrial --> UIDU 0.2000
0.4942 0.02 0.43
Transportation --> UTRN 28.5800
70.6226 2.34 61.08
Institutional --> UINS 5.6200
13.8873 0.46 12.01
Vacant --> VCNT 0.1900
0.4695 0.02 0.41
SOILS:
TX574 46.7900
115.6204 3.84 100.00
SLOPE:
0-2 44.7352
110.5429 3.67 95.61
2-5 1.8348
4.5339 0.15 3.92
5-10 0.2200
0.5436 0.02 0.47
HRUs
357 Commercial --> UCOM/TX574/0-2 12.2000
30.1468 1.00 26.07 1
358 Industrial --> UIDU/TX574/0-2 0.2000
0.4942 0.02 0.43 2
359 Transportation --> UTRN/TX574/2-5 0.9848
2.4335 0.08 2.10 3
360 Transportation --> UTRN/TX574/0-2 27.5952
68.1891 2.26 58.98 4
```

```
361 Institutional --> UINS/TX574/5-10 0.2200
0.5436 0.02 0.47 5
362 Institutional --> UINS/TX574/2-5 0.8500
2.1004 0.07 1.82 6
363 Institutional --> UINS/TX574/0-2 4.5500
11.2433 0.37 9.72 7
364 Vacant --> VCNT/TX574/0-2 0.1900
0.4695 0.02 0.41 8
```

```
Area [ha]
Area[acres] %Wat.Area %Sub.Area
SUBBASIN # 37 22.8500
56.4635 1.87
LANDUSE:
Commercial --> UCOM 5.7100
14.1097 0.47 24.99
Industrial --> UIDU 1.5900
3.9290 0.13 6.96
Transportation --> UTRN 9.3700
23.1537 0.77 41.01
Institutional --> UINS 0.0300
0.0741 0.00 0.13
Parks --> PARK 5.2100
12.8742 0.43 22.80
Vacant --> VCNT 0.9400
2.3228 0.08 4.11
SOILS:
TX574 22.8500
56.4635 1.87 100.00
SLOPE:
0-2 20.5700
50.8295 1.69 90.02
10-9999 0.2300
0.5683 0.02 1.01
2-5 0.6200
1.5321 0.05 2.71
5-10 1.4300
3.5336 0.12 6.26
HRUs
365 Commercial --> UCOM/TX574/0-2 5.7100
14.1097 0.47 24.99 1
366 Industrial --> UIDU/TX574/0-2 1.5900
3.9290 0.13 6.96 2
367 Transportation --> UTRN/TX574/0-2 9.3700
```

```
23.1537 0.77 41.01 3
368 Institutional --> UINS/TX574/0-2 0.0300
0.0741 0.00 0.13 4
369 Parks --> PARK/TX574/10-9999 0.2300
0.5683 0.02 1.01 5
370 Parks --> PARK/TX574/0-2 2.9300
7.2402 0.24 12.82 6
371 Parks --> PARK/TX574/2-5 0.6200
1.5321 0.05 2.71 7
372 Parks --> PARK/TX574/5-10 1.4300
3.5336 0.12 6.26 8
373 Vacant --> VCNT/TX574/0-2 0.9400
2.3228 0.08 4.11 9
```

Appendix C

SWAT: OUTPUT FILE

1

```
                SWAT May 20 2015    VER 2015/Rev 637
0/ 0/   0      0: 0: 0
                General Input/Output section (file.cio):
                10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV
                     Number of years in run:    2
                     Area of watershed:       54.544 km2
                SWAT May 20 2015    VER 2015/Rev 637
                General Input/Output section (file.cio):
                10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV
            Annual Summary for Watershed in year    1 of simulation
            UNIT                               PERCO    TILE                         WATER     SED
NO3     NO3     NO3     NO3       N       P       P
            TIME     PREC    SURQ    LATQ     GWQ    LATE      Q     SW       ET     PET
YIELD   YIELD    SURQ    LATQ    PERC    CROP  ORGANIC SOLUBLE ORGANIC
TILENO3
                     (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)
(mm)   ------------------(kg nutrient/ha)-------------------- (kg/ha)
                1   29.20   10.92    0.00    0.00    0.00    0.00  101.97   13.73   49.43   10.84
0.02    0.07    0.00    0.00    0.00     0.23    0.01    0.03    0.00
                2   45.70   20.67    0.00    0.00    0.00    0.00  104.00   22.99   77.91   19.98
0.07    0.10    0.00    0.00    0.00     0.44    0.01    0.05    0.00
                3   51.80   26.15    0.00    0.00    0.00    0.00   95.63   34.02  140.98   26.86
0.09    0.14    0.00    0.00    0.00     0.53    0.01    0.07    0.00
                4  107.70   60.49    0.01    0.00    0.00    0.00  100.89   41.94  142.97   60.48
0.23    0.22    0.00    0.00   21.81     1.28    0.02    0.16    0.00
```

```
            5  197.10  125.89    0.02    0.00    1.97    0.00   75.95   94.15  181.62  106.66
0.09    0.84    0.00    0.23  101.45     0.85    0.03    0.12    0.00
            6   11.60    1.44    0.01    0.02    0.87    0.00    3.71   81.53  222.26   20.81
0.00    0.07    0.00    0.00    0.72     0.16    0.01    0.02    0.00
            7  103.90   53.39    0.01    0.08    0.00    0.00    0.26   53.96  211.69   53.49
0.03    0.18    0.00    0.00    0.36     0.41    0.02    0.05    0.00
            8   28.00    9.92    0.00    0.00    0.00    0.00    5.39   12.94  231.44    9.94
0.01    0.05    0.00    0.00    0.01     0.12    0.00    0.01    0.00
            9  152.60   83.90    0.01    0.00    0.00    0.00   32.99   41.09  167.09   83.81
0.05    0.31    0.00    0.00    0.00     0.67    0.03    0.09    0.00
           10  255.50  197.34    0.01    0.00    1.44    0.00   60.35   29.30  138.23  180.27
0.20    0.43    0.00    0.15    0.00     1.33    0.05    0.19    0.00
           11   56.40   20.85    0.04    0.17    6.33    0.00   61.95   27.58   84.88   37.70
0.02    0.16    0.00    0.52    0.00     0.40    0.01    0.05    0.00
           12  121.30   61.98    0.04    2.19    8.01    0.00   89.30   23.91   36.07   61.85
0.07    0.21    0.00    0.58    0.00     0.73    0.02    0.09    0.00

         1977 1160.80  672.93    0.15    2.45   18.62    0.00   89.30  477.15 1684.58
672.70    0.88    2.77    0.00    1.47  124.35     7.15    0.22    0.94    0.00
         1
            SWAT May 20 2015    VER 2015/Rev 637
            General Input/Output section (file.cio):
            10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV
         Annual Summary for Watershed in year    2 of simulation
```

```
          UNIT                         PERCO    TILE                    WATER    SED
NO3     NO3     NO3     NO3       N      P      P
          TIME    PREC    SURQ    LATQ    GWQ    LATE      Q    SW      ET     PET
YIELD   YIELD    SURQ    LATQ    PERC    CROP  ORGANIC SOLUBLE ORGANIC
TILENO3
                  (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)    (mm)
(mm)   ------------------(kg nutrient/ha)-------------------- (kg/ha)
             1   89.80   38.83    0.04    5.39    8.31    0.00  110.85   21.06   29.78   42.90
0.08    0.17    0.00    0.44    0.00     0.64    0.02    0.08    0.00
             2   66.80   27.35    0.04    6.14    7.99    0.00  114.85   27.42   43.35   35.68
0.05    0.13    0.00    0.38    0.00     0.48    0.01    0.06    0.00
             3  103.90   57.29    0.03    7.06    7.05    0.00   95.03   59.34  131.67   67.26
0.13    0.19    0.00    0.32    0.00     1.01    0.02    0.13    0.00
             4  155.50   90.90    0.02    6.30    3.48    0.00  108.42   47.72  137.97   93.01
0.29    0.26    0.00    0.14    1.86     1.54    0.03    0.20    0.00
             5  257.40  181.89    0.07    6.82   14.31    0.00   81.15   88.33  141.60  193.21
0.29    5.95    0.01    5.78  129.29     2.06    0.05    0.27    0.00
             6  128.70   60.62    0.01    7.29    0.33    0.00   51.05   97.85  172.68   68.14
0.03    0.26    0.00    0.00    3.45     0.53    0.02    0.07    0.00
             7   70.40   31.55    0.01    1.97    0.00    0.00    8.74   81.15  221.77   32.92
0.02    0.11    0.00    0.00    0.54     0.27    0.01    0.03    0.00
             8    8.20    2.34    0.00    0.09    0.00    0.00    0.00   14.60  245.89    4.07
0.00    0.02    0.00    0.00    0.05     0.05    0.00    0.01    0.00
             9  159.80   89.84    0.01    0.00    0.00    0.00   29.04   40.90  165.26   90.03
0.04    0.32    0.00    0.00    0.00     0.65    0.03    0.09    0.00
```

```
          10   61.00   32.53    0.01    0.00    0.00    0.00   30.06   27.44  132.43   32.68
0.02    0.14    0.00    0.00    0.00    0.26    0.01    0.03    0.00
          11  135.70   71.71    0.01    0.00    0.02    0.00   65.29   28.72   89.82   68.28
0.04    0.28    0.00    0.00    0.00    0.59    0.02    0.08    0.00
          12   85.80   44.66    0.04    0.44    7.31    0.00   72.75   26.31   52.91   48.72
0.03    0.18    0.00    1.32    0.00    0.43    0.02    0.06    0.00

        1978 1323.00  729.53    0.28   41.50   48.81    0.00   72.75  560.84 1565.13
776.89    1.02    8.02    0.01    8.38  135.20    8.50    0.25    1.10    0.00
       1
          SWAT May 20 2015    VER 2015/Rev 637

          General Input/Output section (file.cio):
          10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV

          FINAL VALUES
          SWAT May 20 2015    VER 2015/Rev 637

          General Input/Output section (file.cio):
          10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV

                                  Average Plant Values (kg/ha)

         HRU       1 SUB   1 BERM  Yld = 11565.0 BIOM =  16559.3
         HRU       2 SUB   1 BERM  Yld = 11565.1 BIOM =  16559.4
```

```
HRU      3 SUB   1 BERM  Yld =  5115.8 BIOM =   7128.7

HRU      4 SUB   1 BERM  Yld =  5115.8 BIOM =   7128.7

HRU      5 SUB   1 BERM  Yld =  5410.3 BIOM =   7540.1

HRU      6 SUB   2 BERM  Yld = 11565.0 BIOM =  16559.3

HRU      7 SUB   2 BERM  Yld =  5115.8 BIOM =   7128.7

HRU      8 SUB   3 BERM  Yld =  8164.0 BIOM =  11518.0

HRU      9 SUB   3 BERM  Yld =  9577.0 BIOM =  13592.5

HRU     10 SUB   3 BERM  Yld =  9572.1 BIOM =  13585.4

HRU     11 SUB   3 BERM  Yld =  5410.4 BIOM =   7540.2

HRU     12 SUB   3 BERM  Yld =  5531.5 BIOM =   7707.4

HRU     13 SUB   3 BERM  Yld =  5529.8 BIOM =   7705.0

HRU     14 SUB   4 BERM  Yld = 12865.6 BIOM =  18451.2

HRU     15 SUB   4 BERM  Yld =  5410.4 BIOM =   7540.2

HRU     16 SUB   4 BERM  Yld = 13055.0 BIOM =  18724.5

HRU     17 SUB   4 BERM  Yld = 13167.1 BIOM =  18884.9

HRU     18 SUB   4 BERM  Yld = 13168.0 BIOM =  18886.2

HRU     19 SUB   5 BERM  Yld =  8164.0 BIOM =  11517.9

HRU     20 SUB   5 BERM  Yld =  5410.4 BIOM =   7540.2

HRU     21 SUB   6 BERM  Yld = 11565.0 BIOM =  16559.3

HRU     22 SUB   6 BERM  Yld =  5115.8 BIOM =   7128.7

HRU     23 SUB   6 BERM  Yld = 11720.0 BIOM =  16787.1

HRU     24 SUB   7 BERM  Yld = 11565.0 BIOM =  16559.3

HRU     25 SUB   7 BERM  Yld =  5115.8 BIOM =   7128.7

HRU     26 SUB   8 BERM  Yld = 11565.1 BIOM =  16559.4

HRU     27 SUB   8 BERM  Yld =  8163.9 BIOM =  11517.8
```

```
HRU      28 SUB   8 BERM  Yld =  5115.9 BIOM =   7128.7
HRU      29 SUB   8 BERM  Yld =  5410.3 BIOM =   7540.1
HRU      30 SUB   9 BERM  Yld =  9964.2 BIOM =  14159.7
HRU      31 SUB   9 BERM  Yld =  9963.2 BIOM =  14158.2
HRU      32 SUB   9 BERM  Yld =  8163.9 BIOM =  11517.9
HRU      33 SUB   9 BERM  Yld =  5410.4 BIOM =   7540.2
HRU      34 SUB  10 BERM  Yld = 11565.2 BIOM =  16559.5
HRU      35 SUB  10 BERM  Yld = 12865.7 BIOM =  18451.3
HRU      36 SUB  10 BERM  Yld =  8163.9 BIOM =  11517.8
HRU      37 SUB  10 BERM  Yld =  8163.5 BIOM =  11517.2
HRU      38 SUB  10 BERM  Yld =  9577.2 BIOM =  13592.7
HRU      39 SUB  10 BERM  Yld =  5115.9 BIOM =   7128.8
HRU      40 SUB  10 BERM  Yld =  5410.4 BIOM =   7540.2
HRU      41 SUB  10 BERM  Yld =  5531.4 BIOM =   7707.2
HRU      42 SUB  10 BERM  Yld = 10296.3 BIOM =  14647.4
HRU      43 SUB  10 BERM  Yld = 10294.2 BIOM =  14644.4
HRU      44 SUB  10 BERM  Yld = 11206.0 BIOM =  15973.4
HRU      45 SUB  10 BERM  Yld = 11208.5 BIOM =  15977.2
HRU      46 SUB  11 BERM  Yld =  5410.4 BIOM =   7540.2
HRU      47 SUB  11 BERM  Yld =  5531.9 BIOM =   7707.9
HRU      48 SUB  11 BERM  Yld = 10294.4 BIOM =  14644.7
HRU      49 SUB  11 BERM  Yld = 10296.5 BIOM =  14647.7
HRU      50 SUB  11 BERM  Yld = 11206.2 BIOM =  15973.7
HRU      51 SUB  11 BERM  Yld = 11208.7 BIOM =  15977.4
HRU      52 SUB  12 BERM  Yld =  9578.0 BIOM =  13593.9
```

```
HRU      53 SUB  12 BERM  Yld =  5532.6 BIOM =   7709.0

HRU      54 SUB  12 BERM  Yld = 13168.2 BIOM =  18886.5

HRU      55 SUB  12 BERM  Yld = 13166.8 BIOM =  18884.6

HRU      56 SUB  12 BERM  Yld = 13164.7 BIOM =  18881.5

HRU      57 SUB  13 BERM  Yld =  9578.0 BIOM =  13593.9

HRU      58 SUB  13 BERM  Yld =  5532.8 BIOM =   7709.1

HRU      59 SUB  14 BERM  Yld =  9578.0 BIOM =  13593.9

HRU      60 SUB  14 BERM  Yld =  5532.7 BIOM =   7709.0

HRU      61 SUB  15 BERM  Yld =  9577.6 BIOM =  13593.4

HRU      62 SUB  15 BERM  Yld =  5532.4 BIOM =   7708.6

HRU      63 SUB  15 BERM  Yld = 13168.1 BIOM =  18886.4

HRU      64 SUB  15 BERM  Yld = 13167.1 BIOM =  18885.0

HRU      65 SUB  16 BERM  Yld =  9577.6 BIOM =  13593.3

HRU      66 SUB  16 BERM  Yld =  5532.2 BIOM =   7708.4

HRU      67 SUB  16 BERM  Yld = 11208.7 BIOM =  15977.5

HRU      68 SUB  16 BERM  Yld = 11205.9 BIOM =  15973.3

HRU      69 SUB  17 BERM  Yld =  9964.0 BIOM =  14159.5

HRU      70 SUB  17 BERM  Yld = 11565.1 BIOM =  16559.5

HRU      71 SUB  17 BERM  Yld = 12865.6 BIOM =  18451.2

HRU      72 SUB  17 BERM  Yld =  5115.9 BIOM =   7128.8

HRU      73 SUB  17 BERM  Yld =  5410.4 BIOM =   7540.1

HRU      74 SUB  17 BERM  Yld =  5529.4 BIOM =   7704.5

HRU      75 SUB  17 BERM  Yld =  5531.2 BIOM =   7707.0

HRU      76 SUB  18 BERM  Yld =  9577.8 BIOM =  13593.7

HRU      77 SUB  18 BERM  Yld =  5532.7 BIOM =   7709.0
```

```
HRU      78 SUB  19 BERM  Yld =  9578.2 BIOM =  13594.2
HRU      79 SUB  19 BERM  Yld =  5532.8 BIOM =   7709.2
HRU      80 SUB  20 BERM  Yld = 13127.6 BIOM =  18828.3
HRU      81 SUB  20 BERM  Yld = 13128.5 BIOM =  18829.6
HRU      82 SUB  20 BERM  Yld =  5530.7 BIOM =   7706.3
HRU      83 SUB  20 BERM  Yld =  5532.1 BIOM =   7708.2
HRU      84 SUB  20 BERM  Yld =  7269.1 BIOM =  10187.3
HRU      85 SUB  21 BERM  Yld =  9964.3 BIOM =  14159.8
HRU      86 SUB  21 BERM  Yld = 11580.1 BIOM =  16537.5
HRU      87 SUB  21 BERM  Yld = 11565.2 BIOM =  16559.5
HRU      88 SUB  21 BERM  Yld = 12865.6 BIOM =  18451.3
HRU      89 SUB  21 BERM  Yld = 13127.3 BIOM =  18827.9
HRU      90 SUB  21 BERM  Yld = 13128.6 BIOM =  18829.7
HRU      91 SUB  21 BERM  Yld =  5410.4 BIOM =   7540.2
HRU      92 SUB  21 BERM  Yld =  5529.8 BIOM =   7705.0
HRU      93 SUB  21 BERM  Yld =  5531.4 BIOM =   7707.2
HRU      94 SUB  22 BERM  Yld =  9577.5 BIOM =  13593.2
HRU      95 SUB  22 BERM  Yld =  5410.4 BIOM =   7540.2
HRU      96 SUB  22 BERM  Yld =  5530.0 BIOM =   7705.3
HRU      97 SUB  22 BERM  Yld =  5532.0 BIOM =   7708.1
HRU      98 SUB  23 BERM  Yld =  9120.7 BIOM =  12929.5
HRU      99 SUB  23 BERM  Yld =  9964.2 BIOM =  14159.7
HRU     100 SUB  23 BERM  Yld = 11574.8 BIOM =  16529.6
HRU     101 SUB  23 BERM  Yld = 11558.7 BIOM =  16505.0
HRU     102 SUB  23 BERM  Yld = 11564.9 BIOM =  16559.1
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HRU     103 SUB  23 BERM  Yld = 11565.1 BIOM =  16559.4
HRU     104 SUB  23 BERM  Yld = 12967.5 BIOM =  18598.8
HRU     105 SUB  23 BERM  Yld = 12967.1 BIOM =  18598.3
HRU     106 SUB  23 BERM  Yld =  7657.6 BIOM =  10788.3
HRU     107 SUB  23 BERM  Yld =  8163.8 BIOM =  11517.7
HRU     108 SUB  23 BERM  Yld =  9662.0 BIOM =  13707.4
HRU     109 SUB  23 BERM  Yld =  9747.9 BIOM =  13831.8
HRU     110 SUB  23 BERM  Yld =  5115.9 BIOM =   7128.7
HRU     111 SUB  23 BERM  Yld =  5410.4 BIOM =   7540.2
HRU     112 SUB  23 BERM  Yld =  5836.5 BIOM =   8133.2
HRU     113 SUB  23 BERM  Yld =  5828.8 BIOM =   8122.3
HRU     114 SUB  24 BERM  Yld =  9577.9 BIOM =  13593.8
HRU     115 SUB  24 BERM  Yld =  5532.7 BIOM =   7709.0
HRU     116 SUB  25 BERM  Yld =  9577.9 BIOM =  13593.8
HRU     117 SUB  25 BERM  Yld =  5532.7 BIOM =   7709.1
HRU     118 SUB  26 BERM  Yld =  9964.4 BIOM =  14160.0
HRU     119 SUB  26 BERM  Yld = 11577.9 BIOM =  16534.2
HRU     120 SUB  26 BERM  Yld = 11217.2 BIOM =  15988.5
HRU     121 SUB  26 BERM  Yld =  8163.7 BIOM =  11517.6
HRU     122 SUB  26 BERM  Yld =  9750.4 BIOM =  13835.4
HRU     123 SUB  26 BERM  Yld =  9577.2 BIOM =  13592.8
HRU     124 SUB  26 BERM  Yld =  5410.4 BIOM =   7540.2
HRU     125 SUB  26 BERM  Yld =  5837.0 BIOM =   8133.9
HRU     126 SUB  26 BERM  Yld =  5531.7 BIOM =   7707.7
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              HRU STATISTICS

                         AVE ANNUAL VALUES

              HRU  SUB  SOIL      AREAkm2    CN     AWCmm   USLE_LS  IRRmm

AUTONkh AUTOPkh  MIXEF PRECmm SURQGENmm   GWQmm    ETmm   SEDth

NO3kgh  ORGNkgh BIOMth   YLDth  SURQmm

                1   1   AUSTIN     .708E+00   74.86  137.16    0.11    0.00  143.25    0.00

0.20 1241.90  259.15  108.16  786.40    0.85   10.11    4.37   16.56   11.57  259.15

                2   1   AUSTIN     .239E+00   74.86  137.16    0.10    0.00  143.25    0.00

0.20 1241.90  259.16  108.05  786.40    0.73   10.07    3.64   16.56   11.57  259.16

                3   1   AUSTIN     .382E+00   97.48  137.16    0.10    0.00   98.87    0.00

0.20 1241.90  916.44    0.00  339.58    0.82    4.10    9.15    7.13    5.12  916.43

                4   1   AUSTIN     .792E-01   97.48  137.16    0.10    0.00   98.84    0.00

0.20 1241.90  916.44    0.00  339.58    1.80    4.48    9.97    7.13    5.12  916.43

                5   1   HOUSTON    .188E+00   97.62  228.60    0.09    0.00   99.75    0.00

0.20 1241.90  915.70    0.00  369.70    1.14    4.32    9.69    7.54    5.41  915.69

                6   2   AUSTIN     .123E+01   74.86  137.16    0.10    0.00  143.25    0.00

0.20 1241.90  259.15  108.14  786.40    0.67   10.10    3.87   16.56   11.57  259.15

                7   2   AUSTIN     .759E+00   97.48  137.16    0.09    0.00   98.85    0.00

0.20 1241.90  916.44    0.00  339.58    0.54    3.95    8.75    7.13    5.12  916.42

                8   3   HOUSTON    .181E+00   91.73  228.60    0.12    0.00   96.80    0.00

0.20 1241.90  702.04    0.00  564.29    2.69    5.37   13.19   11.52    8.16  702.04

                9   3   TRINITY    .943E-01   91.73  206.76    0.13    0.00   90.25    0.00

0.20 1241.90  659.39    0.00  594.79    2.63    3.36   10.39   13.59    9.58  659.39

               10   3   TRINITY    .241E-01   91.73  206.76    0.50    0.00   90.55    0.00

0.20 1241.90  659.33    0.02  594.50   10.41    3.49   19.92   13.59    9.57  659.33
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          11   3   HOUSTON    .132E+01   97.62  228.60    0.08    0.00   99.74    0.00
0.20 1241.90  915.70    0.00  369.70    0.40    3.88    8.63    7.54    5.41  915.67
          12   3   TRINITY    .152E+00   97.62  206.76    0.14    0.00   84.21    0.00
0.20 1241.90  920.12    0.00  354.90    1.49    4.10    9.90    7.71    5.53  920.11
          13   3   TRINITY    .408E-01   97.62  206.76    0.42    0.00   84.56    0.00
0.20 1241.90  920.12    0.01  354.77    3.85    4.43   11.18    7.71    5.53  920.12
          14   4   HOUSTON    .620E+00   81.09  228.60    0.10    0.00  128.57    0.00
0.20 1241.90  329.25   31.78  802.51    1.18   11.11    7.27   18.45   12.87  329.25
          15   4   HOUSTON    .207E+01   97.62  228.60    0.08    0.00   99.74    0.00
0.20 1241.90  915.70    0.00  369.70    0.34    3.78    8.42    7.54    5.41  915.67
          16   4   HOUSTON    .531E-01   79.95  228.60    0.09    0.00  129.38    0.00
0.20 1241.90  293.37   44.07  818.80    0.79   11.11    4.86   18.72   13.05  293.37
          17   4   TRINITY    .348E-01   79.95  206.76    0.44    0.00  146.83    0.00
0.20 1241.90  251.23   93.22  793.20    4.87   14.56   16.17   18.88   13.17  251.23
          18   4   TRINITY    .240E+00   79.95  206.76    0.13    0.00  146.79    0.00
0.20 1241.90  251.52   93.45  793.33    1.24   14.57    6.16   18.89   13.17  251.52
          19   5   HOUSTON    .365E+00   91.73  228.60    0.11    0.00   96.79    0.00
0.20 1241.90  702.04    0.00  564.29    2.38    5.31   12.83   11.52    8.16  702.03
          20   5   HOUSTON    .225E+01   97.62  228.60    0.09    0.00   99.78    0.00
0.20 1241.90  915.70    0.00  369.70    0.37    3.77    8.47    7.54    5.41  915.68
          21   6   AUSTIN     .260E+01   74.86  137.16    0.10    0.00  143.25    0.00
0.20 1241.90  259.15  108.13  786.40    0.69   10.09    4.08   16.56   11.57  259.15
          22   6   AUSTIN     .103E+01   97.48  137.16    0.10    0.00   98.88    0.00
0.20 1241.90  916.44    0.00  339.58    0.53    3.88    8.67    7.13    5.12  916.43
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          23   6   AUSTIN     .588E+00   73.30  137.16    0.13    0.00  151.69    0.00

0.20 1241.90  214.82  135.47  798.49    0.94    9.43    4.62   16.79   11.72  214.82

          24   7   AUSTIN     .103E+01   74.86  137.16    0.13    0.00  143.26    0.00

0.20 1241.90  259.14  108.22  786.41    0.99   10.12    5.19   16.56   11.57  259.14

          25   7   AUSTIN     .444E+00   97.48  137.16    0.13    0.00   98.94    0.00

0.20 1241.90  916.44    0.00  339.58    0.85    4.07    9.21    7.13    5.12  916.43

          26   8   AUSTIN     .915E+00   74.86  137.16    0.10    0.00  143.25    0.00

0.20 1241.90  259.15  108.13  786.42    0.72   10.10    3.94   16.56   11.57  259.14

          27   8   HOUSTON    .429E+00   91.73  228.60    0.10    0.00   96.78    0.00

0.20 1241.90  702.04    0.00  564.29    2.06    5.29   12.07   11.52    8.16  702.03

          28   8   AUSTIN     .511E+00   97.48  137.16    0.10    0.00   98.87    0.00

0.20 1241.90  916.44    0.00  339.58    0.71    4.04    9.00    7.13    5.12  916.43

          29   8   HOUSTON    .708E+00   97.62  228.60    0.10    0.00   99.80    0.00

0.20 1241.90  915.70    0.00  369.70    0.65    4.01    9.10    7.54    5.41  915.69

          30   9   HOUSTON    .107E+00   90.40  228.60    0.13    0.00  100.79    0.00

0.20 1241.90  603.48    0.00  644.63    2.55    5.29   11.67   14.16    9.96  603.48

          31   9   HOUSTON    .214E-01   90.40  228.60    0.42    0.00  100.99    0.00

0.20 1241.90  603.47    0.01  644.59    9.19    5.40   22.40   14.16    9.96  603.47

          32   9   HOUSTON    .389E+00   91.73  228.60    0.10    0.00   96.77    0.00

0.20 1241.90  702.03    0.00  564.30    1.92    5.30   11.75   11.52    8.16  702.03

          33   9   HOUSTON    .565E+00   97.62  228.60    0.10    0.00   99.78    0.00

0.20 1241.90  915.70    0.00  369.70    0.67    4.06    9.17    7.54    5.41  915.69

          34  10   AUSTIN     .149E+00   74.86  137.16    0.09    0.00  143.25    0.00

0.20 1241.90  259.14  108.09  786.43    0.59   10.09    3.04   16.56   11.57  259.14
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           35  10   HOUSTON    .231E+00   81.09  228.60    0.08    0.00  128.56    0.00
0.20 1241.90  329.25   31.78  802.53    0.78   11.11    5.17   18.45   12.87  329.24
           36  10   HOUSTON    .122E+00   91.73  228.60    0.12    0.00   96.79    0.00
0.20 1241.90  702.03    0.00  564.30    2.76    5.40   12.98   11.52    8.16  702.03
           37  10   HOUSTON    .170E-01   91.73  228.60    0.48    0.00   97.09    0.00
0.20 1241.90  702.04    0.01  564.24   12.22    5.59   24.69   11.52    8.16  702.04
           38  10   TRINITY    .560E-01   91.73  206.76    0.11    0.00   90.22    0.00
0.20 1241.90  659.39    0.00  594.82    2.44    3.41    9.23   13.59    9.58  659.39
           39  10   AUSTIN     .756E-01   97.48  137.16    0.10    0.00   98.84    0.00
0.20 1241.90  916.44    0.00  339.59    1.83    4.50    9.99    7.13    5.12  916.43
           40  10   HOUSTON    .501E+00   97.62  228.60    0.10    0.00   99.79    0.00
0.20 1241.90  915.70    0.00  369.70    0.73    4.09    9.25    7.54    5.41  915.69
           41  10   TRINITY    .137E+00   97.62  206.76    0.14    0.00   84.21    0.00
0.20 1241.90  920.12    0.00  354.90    1.56    4.12    9.95    7.71    5.53  920.11
           42  10   HOUSTON    .449E-01   88.69  228.60    0.44    0.00  102.13    0.00
0.20 1241.90  590.02    0.01  656.67   10.33    5.94   26.18   14.65   10.30  590.02
           43  10   HOUSTON    .103E+00   88.69  228.60    0.16    0.00   97.04    0.00
0.20 1241.90  590.05    0.00  656.71    3.46    3.51   14.47   14.64   10.29  590.05
           44  10   TRINITY    .177E-01   88.69  206.76    0.38    0.00   98.73    0.00
0.20 1241.90  557.63    0.02  664.65    7.83    2.99   17.90   15.97   11.21  557.63
           45  10   TRINITY    .774E-01   88.69  206.76    0.15    0.00   98.66    0.00
0.20 1241.90  557.70    0.00  664.80    2.82    2.92   10.30   15.98   11.21  557.70
           46  11   HOUSTON    .472E-01   97.62  228.60    0.11    0.00   99.78    0.00
0.20 1241.90  915.70    0.00  369.70    2.46    4.66   10.54    7.54    5.41  915.69
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                47  11   TRINITY    .146E+00   97.62  206.76    0.14    0.00   84.21    0.00
0.20 1241.90  920.12    0.00  354.90    1.50    4.11    9.92    7.71    5.53  920.11
                48  11   HOUSTON    .590E-01   88.69  228.60    0.14    0.00   97.01    0.00
0.20 1241.90  590.05    0.00  656.72    2.99    3.54   12.46   14.64   10.29  590.04
                49  11   HOUSTON    .186E-01   88.69  228.60    0.42    0.00  102.10    0.00
0.20 1241.90  590.02    0.01  656.68    9.69    5.98   24.41   14.65   10.30  590.02
                50  11   TRINITY    .371E-01   88.69  206.76    0.36    0.00   98.74    0.00
0.20 1241.90  557.63    0.02  664.67    7.44    2.95   18.14   15.97   11.21  557.63
                51  11   TRINITY    .190E+00   88.69  206.76    0.15    0.00   98.66    0.00
0.20 1241.90  557.70    0.00  664.80    2.66    2.88   10.71   15.98   11.21  557.70
                52  12   TRINITY    .141E+01   91.73  206.76    0.07    0.00   90.17    0.00
0.20 1241.90  659.40    0.00  594.85    0.59    3.14    6.06   13.59    9.58  659.28
                53  12   TRINITY    .853E+00   97.62  206.76    0.08    0.00   83.91    0.00
0.20 1241.90  920.12    0.00  354.93    0.40    3.69    8.62    7.71    5.53  920.05
                54  12   TRINITY    .195E+00   79.95  206.76    0.09    0.00  146.79    0.00
0.20 1241.90  251.55   93.47  793.37    0.63   14.57    3.66   18.89   13.17  251.55
                55  12   TRINITY    .501E-01   79.95  206.76    0.54    0.00  146.84    0.00
0.20 1241.90  251.16   93.17  793.19    6.04   14.56   19.03   18.88   13.17  251.16
                56  12   TRINITY    .962E-01   79.95  206.76    1.31    0.00  146.95    0.00
0.20 1241.90  250.26   92.49  792.77   16.85   14.53   35.48   18.88   13.16  250.26
                57  13   TRINITY    .104E+01   91.73  206.76    0.07    0.00   90.18    0.00
0.20 1241.90  659.40    0.00  594.85    0.69    3.16    6.61   13.59    9.58  659.35
                58  13   TRINITY    .932E+00   97.62  206.76    0.07    0.00   83.90    0.00
0.20 1241.90  920.12    0.00  354.93    0.38    3.68    8.54    7.71    5.53  920.05
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              59  14   TRINITY    .129E+00   91.73  206.76    0.07    0.00   90.17    0.00
0.20 1241.90  659.40    0.00  594.85    0.98    3.34    6.53   13.59    9.58  659.37
              60  14   TRINITY    .287E+00   97.62  206.76    0.09    0.00   83.91    0.00
0.20 1241.90  920.12    0.00  354.92    0.67    3.94    9.19    7.71    5.53  920.06
              61  15   TRINITY    .112E+01   91.73  206.76    0.09    0.00   90.22    0.00
0.20 1241.90  659.40    0.00  594.83    1.24    3.16    8.52   13.59    9.58  659.39
              62  15   TRINITY    .246E+01   97.62  206.76    0.09    0.00   84.12    0.00
0.20 1241.90  920.12    0.00  354.92    0.31    3.47    8.23    7.71    5.53  920.08
              63  15   TRINITY    .433E+00   79.95  206.76    0.11    0.00  146.79    0.00
0.20 1241.90  251.53   93.46  793.35    0.98   14.57    5.25   18.89   13.17  251.53
              64  15   TRINITY    .103E+00   79.95  206.76    0.38    0.00  146.82    0.00
0.20 1241.90  251.26   93.24  793.23    4.67   14.56   15.90   18.89   13.17  251.26
              65  16   TRINITY    .185E+00   91.73  206.76    0.09    0.00   90.21    0.00
0.20 1241.90  659.40    0.00  594.84    1.58    3.31    8.41   13.59    9.58  659.39
              66  16   TRINITY    .650E+00   97.62  206.76    0.10    0.00   84.14    0.00
0.20 1241.90  920.12    0.00  354.92    0.62    3.76    8.95    7.71    5.53  920.11
              67  16   TRINITY    .228E+00   88.69  206.76    0.15    0.00   98.66    0.00
0.20 1241.90  557.70    0.00  664.81    2.67    2.87   10.83   15.98   11.21  557.69
              68  16   TRINITY    .763E-01   88.69  206.76    0.40    0.00   98.77    0.00
0.20 1241.90  557.62    0.02  664.65    8.30    2.92   19.87   15.97   11.21  557.62
              69  17   HOUSTON    .669E+00   90.40  228.60    0.11    0.00  100.78    0.00
0.20 1241.90  603.48    0.00  644.63    1.89    5.17   11.13   14.16    9.96  603.48
              70  17   AUSTIN     .116E+01   74.86  137.16    0.09    0.00  143.25    0.00
0.20 1241.90  259.14  108.09  786.43    0.60   10.09    3.50   16.56   11.57  259.14
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           71  17   HOUSTON    .702E+00   81.09  228.60    0.10    0.00  128.57    0.00
0.20 1241.90  329.24   31.78  802.52    1.18   11.11    7.33   18.45   12.87  329.24
           72  17   AUSTIN     .592E+00   97.48  137.16    0.09    0.00   98.85    0.00
0.20 1241.90  916.44    0.00  339.59    0.62    4.00    8.87    7.13    5.12  916.43
           73  17   HOUSTON    .956E+00   97.62  228.60    0.10    0.00   99.80    0.00
0.20 1241.90  915.70    0.00  369.70    0.57    3.95    8.95    7.54    5.41  915.69
           74  17   TRINITY    .480E-01   97.62  206.76    0.42    0.00   84.56    0.00
0.20 1241.90  920.12    0.01  354.77    3.62    4.38   11.08    7.70    5.53  920.12
           75  17   TRINITY    .349E+00   97.62  206.76    0.12    0.00   84.18    0.00
0.20 1241.90  920.12    0.00  354.91    0.96    3.90    9.39    7.71    5.53  920.11
           76  18   TRINITY    .223E+00   91.73  206.76    0.08    0.00   90.19    0.00
0.20 1241.90  659.40    0.00  594.85    1.05    3.29    7.24   13.59    9.58  659.38
           77  18   TRINITY    .573E+00   97.62  206.76    0.08    0.00   83.89    0.00
0.20 1241.90  920.12    0.00  354.93    0.47    3.78    8.78    7.71    5.53  920.02
           78  19   TRINITY    .330E-02   91.73  206.76    0.07    0.00   90.14    0.00
0.20 1241.90  659.40    0.00  594.87    4.05    3.71    5.67   13.59    9.58  659.29
           79  19   TRINITY    .139E-01   97.62  206.76    0.07    0.00   83.83    0.00
0.20 1241.90  920.12    0.00  354.94    3.24    4.72   10.74    7.71    5.53  919.93
           80  20   TRINITY    .749E-02   81.09  206.76    0.36    0.00  142.87    0.00
0.20 1241.90  285.75   74.99  786.09    3.86   14.94   12.78   18.83   13.13  285.75
           81  20   TRINITY    .198E-01   81.09  206.76    0.23    0.00  142.85    0.00
0.20 1241.90  285.87   75.17  786.17    2.31   14.94    9.10   18.83   13.13  285.87
           82  20   TRINITY    .749E-02   97.62  206.76    0.35    0.00   84.42    0.00
0.20 1241.90  920.12    0.01  354.80    8.20    4.90   12.12    7.71    5.53  920.12
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                  83  20   TRINITY    .283E-01   97.62  206.76    0.14    0.00   84.18    0.00
0.20 1241.90  920.12    0.00  354.90    3.42    4.53   10.82    7.71    5.53  920.12
                  84  20   TRINITY    .892E-02   94.96  206.76    0.10    0.00   85.40    0.00
0.20 1241.90  804.22    0.00  462.90    5.19    4.32   10.40   10.19    7.27  804.21
                  85  21   HOUSTON    .433E+00   90.40  228.60    0.10    0.00  100.77    0.00
0.20 1241.90  603.48    0.00  644.64    1.64    5.20   10.10   14.16    9.96  603.48
                  86  21   BASTSIL    .729E-01   82.40  243.84    0.08    0.00  106.20    0.00
0.20 1241.90  543.43    0.22  690.51    1.19    3.37    3.64   16.54   11.58  543.43
                  87  21   AUSTIN     .128E+00   74.86  137.16    0.10    0.00  143.25    0.00
0.20 1241.90  259.14  108.12  786.44    0.69   10.10    3.39   16.56   11.57  259.14
                  88  21   HOUSTON    .203E+00   81.09  228.60    0.10    0.00  128.57    0.00
0.20 1241.90  329.24   31.77  802.53    1.12   11.11    6.64   18.45   12.87  329.24
                  89  21   TRINITY    .341E-01   81.09  206.76    0.38    0.00  142.87    0.00
0.20 1241.90  285.75   74.98  786.08    4.64   14.93   15.12   18.83   13.13  285.75
                  90  21   TRINITY    .158E+00   81.09  206.76    0.17    0.00  142.85    0.00
0.20 1241.90  285.90   75.22  786.17    1.94   14.94    8.50   18.83   13.13  285.90
                  91  21   HOUSTON    .781E+00   97.62  228.60    0.10    0.00   99.79    0.00
0.20 1241.90  915.70    0.00  369.70    0.59    3.99    9.02    7.54    5.41  915.68
                  92  21   TRINITY    .497E-01   97.62  206.76    0.38    0.00   84.53    0.00
0.20 1241.90  920.12    0.01  354.78    3.46    4.38   11.03    7.71    5.53  920.12
                  93  21   TRINITY    .265E+00   97.62  206.76    0.14    0.00   84.22    0.00
0.20 1241.90  920.12    0.00  354.90    1.15    3.96    9.61    7.71    5.53  920.11
                  94  22   TRINITY    .258E+00   91.73  206.76    0.09    0.00   90.21    0.00
0.20 1241.90  659.39    0.00  594.84    1.52    3.28    8.48   13.59    9.58  659.39
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                95  22   HOUSTON    .172E+00   97.62  228.60    0.10    0.00   99.78    0.00
0.20 1241.90  915.70    0.00  369.70    1.23    4.34    9.79    7.54    5.41  915.69
                96  22   TRINITY    .554E-01   97.62  206.76    0.46    0.00   84.61    0.00
0.20 1241.90  920.12    0.01  354.76    3.51    4.35   11.03    7.71    5.53  920.12
                97  22   TRINITY    .480E+00   97.62  206.76    0.11    0.00   84.17    0.00
0.20 1241.90  920.12    0.00  354.91    0.78    3.83    9.17    7.71    5.53  920.11
                98  23   AUSTIN     .179E+00   87.60  137.16    0.12    0.00  111.74    0.00
0.20 1241.90  581.11    0.11  626.78    1.97    7.50    8.87   12.93    9.12  581.10
                99  23   HOUSTON    .205E+00   90.40  228.60    0.12    0.00  100.79    0.00
0.20 1241.90  603.48    0.00  644.64    2.30    5.25   11.47   14.16    9.96  603.48
               100  23   BASTSIL    .588E+00   82.40  243.84    0.15    0.00  110.87    0.00
0.20 1241.90  543.24    0.98  690.25    1.73    5.02    4.81   16.53   11.57  543.24
               101  23   BASTSIL    .157E+00   82.40  243.84    0.44    0.00  110.94    0.00
0.20 1241.90  542.44    4.21  689.10    5.85    5.15    8.03   16.51   11.56  542.44
               102  23   AUSTIN     .330E-01   74.86  137.16    0.40    0.00  143.30    0.00
0.20 1241.90  259.09  108.99  786.41    3.74   10.38   12.14   16.56   11.56  259.09
               103  23   AUSTIN     .195E+00   74.86  137.16    0.14    0.00  143.26    0.00
0.20 1241.90  259.13  108.24  786.44    1.17   10.13    5.26   16.56   11.57  259.13
               104  23   BASTSIL    .145E+00   63.29  243.84    0.17    0.00  134.74    0.00
0.20 1241.90  165.10  154.49  824.46    0.87    2.81    1.48   18.60   12.97  165.10
               105  23   BASTSIL    .103E+00   63.29  243.84    0.46    0.00  134.80    0.00
0.20 1241.90  164.46  157.92  822.85    2.70    2.96    3.49   18.60   12.97  164.46
               106  23   AUSTIN     .672E-01   89.42  137.16    0.11    0.00   94.49    0.00
0.20 1241.90  696.77    0.01  537.97    2.48    4.31    9.83   10.79    7.66  696.77
```

```
           107  23   HOUSTON    .128E+00   91.73  228.60    0.10    0.00   96.77    0.00
0.20 1241.90  702.03    0.00  564.31    2.29    5.40   11.64   11.52    8.16  702.03
           108  23   BASTSIL    .464E-01   85.13  243.84    0.48    0.00  105.04    0.00
0.20 1241.90  659.19    3.38  598.53    7.56    5.55    9.47   13.71    9.66  659.19
           109  23   BASTSIL    .322E+00   85.13  243.84    0.13    0.00  104.84    0.00
0.20 1241.90  659.70    0.57  600.57    1.84    5.33    5.60   13.83    9.75  659.70
           110  23   AUSTIN     .209E+00   97.48  137.16    0.13    0.00   98.93    0.00
0.20 1241.90  916.44    0.00  339.58    1.23    4.24    9.60    7.13    5.12  916.43
           111  23   HOUSTON    .355E+00   97.62  228.60    0.11    0.00   99.82    0.00
0.20 1241.90  915.70    0.00  369.70    0.94    4.17    9.50    7.54    5.41  915.69
           112  23   BASTSIL    .102E+01   97.22  243.84    0.14    0.00  105.19    0.00
0.20 1241.90  912.38    0.28  370.02    0.60    3.92    8.31    8.13    5.84  912.38
           113  23   BASTSIL    .245E+00   97.22  243.84    0.46    0.00  105.63    0.00
0.20 1241.90  912.35    1.42  368.96    1.89    4.26    9.33    8.12    5.83  912.35
           114  24   TRINITY    .222E+00   91.73  206.76    0.07    0.00   90.18    0.00
0.20 1241.90  659.39    0.00  594.86    1.00    3.29    6.94   13.59    9.58  659.38
           115  24   TRINITY    .570E+00   97.62  206.76    0.08    0.00   83.92    0.00
0.20 1241.90  920.12    0.00  354.93    0.53    3.78    8.86    7.71    5.53  920.09
           116  25   TRINITY    .185E+01   91.73  206.76    0.07    0.00   90.18    0.00
0.20 1241.90  659.40    0.00  594.86    0.63    3.12    6.37   13.59    9.58  659.32
           117  25   TRINITY    .300E+01   97.62  206.76    0.07    0.00   83.88    0.00
0.20 1241.90  920.12    0.00  354.93    0.22    3.43    7.91    7.71    5.53  919.85
           118  26   HOUSTON    .632E-01   90.40  228.60    0.11    0.00  100.77    0.00
0.20 1241.90  603.47    0.00  644.65    2.32    5.33   10.14   14.16    9.96  603.47
```

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          119  26   BASTSIL    .310E+00   82.40  243.84    0.12    0.00  106.22    0.00
0.20 1241.90  543.32    0.65  690.37    1.37    3.28    4.26   16.53   11.58  543.31
          120  26   TRINITY    .149E+00   90.40  206.76    0.13    0.00   97.58    0.00
0.20 1241.90  561.27    0.00  665.21    2.12    2.80    8.97   15.99   11.22  561.27
          121  26   HOUSTON    .202E+00   91.73  228.60    0.09    0.00   96.76    0.00
0.20 1241.90  702.03    0.00  564.31    1.91    5.36   11.00   11.52    8.16  702.02
          122  26   BASTSIL    .533E+00   85.13  243.84    0.12    0.00  104.84    0.00
0.20 1241.90  659.71    0.49  600.64    1.55    5.28    5.36   13.84    9.75  659.71
          123  26   TRINITY    .162E+00   91.73  206.76    0.10    0.00   90.22    0.00
0.20 1241.90  659.39    0.00  594.83    1.87    3.32    9.01   13.59    9.58  659.39
          124  26   HOUSTON    .554E+00   97.62  228.60    0.10    0.00   99.80    0.00
0.20 1241.90  915.70    0.00  369.70    0.72    4.07    9.21    7.54    5.41  915.69
          125  26   BASTSIL    .118E+01   97.22  243.84    0.12    0.00  105.15    0.00
0.20 1241.90  912.38    0.21  370.09    0.49    3.89    8.19    8.13    5.84  912.37
          126  26   TRINITY    .653E+00   97.62  206.76    0.10    0.00   84.15    0.00
0.20 1241.90  920.12    0.00  354.92    0.66    3.76    8.97    7.71    5.53  920.11

                  AVE MONTHLY BASIN VALUES
                    SNOW              WATER         SED
         MON    RAIN    FALL  SURF Q   LAT Q   YIELD     ET   YIELD     PET
               (MM)    (MM)    (MM)    (MM)    (MM)    (MM)  (T/HA)    (MM)
          1    59.50   25.65   24.88    0.02   26.87   17.39    0.05   39.60
          2    56.25   20.85   24.01    0.02   27.83   25.21    0.06   60.63
          3    77.85    0.00   41.72    0.02   47.06   46.68    0.11  136.33
          4   131.60    0.00   75.69    0.01   76.75   44.83    0.26  140.47
```

```
5   227.25     0.00   153.89     0.04   149.94    91.24     0.19   161.61
6    70.15     0.00    31.03     0.01    44.47    89.69     0.02   197.47
7    87.15     0.00    42.47     0.01    43.21    67.55     0.02   216.73
8    18.10     0.00     6.13     0.00     7.00    13.77     0.00   238.67
9   156.20     0.00    86.87     0.01    86.92    41.00     0.05   166.17
10   158.25     0.00   114.94     0.01   106.48    28.37     0.11   135.33
11    96.05     0.00    46.28     0.02    52.99    28.15     0.03    87.35
12   103.55     1.65    53.32     0.04    55.28    25.11     0.05    44.49

 AVE ANNUAL BASIN STRESS DAYS
           WATER STRESS DAYS =    28.93
           TEMPERATURE STRESS DAYS =     5.08
           NITROGEN STRESS DAYS =    23.04
           PHOSPHORUS STRESS DAYS =     0.00
           AERATION STRESS DAYS =     0.01
SWAT May 20 2015    VER 2015/Rev 637
General Input/Output section (file.cio):
10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV

     AVE ANNUAL BASIN VALUES

          PRECIP =   1241.9 MM
          SNOW FALL =   48.15 MM
          SNOW MELT =    47.63 MM
          SUBLIMATION =     0.52 MM
```

```
          SURFACE RUNOFF Q =   701.23 MM
          LATERAL SOIL Q =    0.21 MM
          TILE Q =     0.00 MM
          GROUNDWATER (SHAL AQ) Q =    21.98 MM
          GROUNDWATER (DEEP AQ) Q =     1.41 MM
          REVAP (SHAL AQ => SOIL/PLANTS) =   32.50 MM
          DEEP AQ RECHARGE =     1.58 MM
          TOTAL AQ RECHARGE =   31.60 MM
          TOTAL WATER YLD =   724.79 MM
          PERCOLATION OUT OF SOIL =   33.72 MM
          ET =    519.0 MM
          PET =   1624.9MM
          TRANSMISSION LOSSES =     0.00 MM
          SEPTIC INFLOW =       0.00 MM
          TOTAL SEDIMENT LOADING =     0.952 T/HA
          TILE FROM IMPOUNDED WATER =     0.000 (MM)
          EVAPORATION FROM IMPOUNDED WATER =     0.000 (MM)
          SEEPAGE INTO SOIL FROM IMPOUNDED WATER =    0.000 (MM)
          OVERFLOW FROM IMPOUNDED WATER =    0.000 (MM)
1
     SWAT May 20 2015    VER 2015/Rev 637


     General Input/Output section (file.cio):
     10/30/2016 12:00:00 AM ARCGIS-SWAT interface AV
```

```
AVE ANNUAL BASIN VALUES


NUTRIENTS
    ORGANIC N =     7.825 (KG/HA)
    ORGANIC P =     1.017 (KG/HA)
    NO3 YIELD (SQ) =     5.396 (KG/HA)
    NO3 YIELD (LAT) =    0.008 (KG/HA)
    NO3 YIELD (TILE) =    0.000 (KG/HA)
    SOLP YIELD (TILE) =    0.000(KG/HA)
    SOLP YIELD (SURF INLET RISER) =    0.000 (KG/HA)
    SOL P YIELD =    0.238 (KG/HA)
    NO3 LEACHED =     4.927 (KG/HA)
    P LEACHED =     0.019 (KG/HA)
    N UPTAKE =   129.776 (KG/HA)
    P UPTAKE =   29.775 (KG/HA)
    NO3 YIELD (GWQ) =     0.028 (KG/HA)
    ACTIVE TO SOLUTION P FLOW =       -32.256 (KG/HA)
    ACTIVE TO STABLE P FLOW =       -44.405 (KG/HA)
    N FERTILIZER APPLIED =   105.103 (KG/HA)
    P FERTILIZER APPLIED =     0.000 (KG/HA)
    N FIXATION =     0.000 (KG/HA)
    DENITRIFICATION =     1.778 (KG/HA)
    HUMUS MIN ON ACTIVE ORG N =    10.621 (KG/HA)
    ACTIVE TO STABLE ORG N =    -1.302 (KG/HA)
```

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HUMUS MIN ON ACTIVE ORG P =    1.822 (KG/HA)
MIN FROM FRESH ORG N =   19.464 (KG/HA)
MIN FROM FRESH ORG P =    6.142 (KG/HA)
NO3 IN RAINFALL =     0.000 (KG/HA)
INITIAL NO3 IN SOIL =      53.469 (KG/HA)
FINAL NO3 IN SOIL =        14.867 (KG/HA)
INITIAL ORG N IN SOIL =   14831.633 (KG/HA)
FINAL ORG N IN SOIL =     14786.255 (KG/HA)
INITIAL MIN P IN SOIL =    4306.907 (KG/HA)
FINAL MIN P IN SOIL =      4252.468 (KG/HA)
INITIAL ORG P IN SOIL =    1816.875 (KG/HA)
FINAL ORG P IN SOIL =    1813.948 (KG/HA)
NO3 IN FERT =   105.103 (KG/HA)
AMMONIA IN FERT =     0.000 (KG/HA)
ORG N IN FERT =     0.000 (KG/HA)
MINERAL P IN FERT =     0.000 (KG/HA)
ORG P IN FERT =     0.000 (KG/HA)
N REMOVED IN YIELD =   103.821 (KG/HA)
P REMOVED IN YIELD =    21.647 (KG/HA)
AMMONIA VOLATILIZATION =     0.000 (KG/HA)
AMMONIA NITRIFICATION =      0.000 (KG/HA)
NO3 EVAP-LAYER 2 TO 1 =    7.328

DIE-GRO P Q =       0.0 (No/HA)
DIE-GRO LP Q =       0.0 (No/HA)
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            DIE-GRO P SED =      0.0 (No/HA)

            DIE-GRO LP SED =      0.0 (No/HA)

            BACT P RUNOFF =      0.0 (No/HA)

            BACT LP RUNOFF =      0.0 (No/HA)

            BACT P SEDIMENT =      0.0 (No/HA)

            BACT LP SEDIMENT =      0.0 (No/HA)

            BACT P INCORP =      0.0 (No/HA)

            BACT LP INCORP =      0.0 (No/HA)


            NITRATE SEPTIC =         0.00 (kg/ha)

            AMMONIA SEPTIC =         0.00 (kg/ha)

            ORG N SEPTIC =         0.00 (kg/ha)

            FRESH ORGN SEPTIC =         0.00 (kg/ha)

            ORG P SEPTIC =         0.00 (kg/ha)

            FRESH ORGP SEPTIC =         0.00 (kg/ha)

            SOL P SEPTIC =         0.00 (kg/ha)

      BOD SEPTIC =         0.00 (kg/ha)
```

Appendix D

SWAT: LOW IMPACT DEVELOPMENT INPUT FILE

```
LIDtext
Low Impact Development practices (.lid): for a Green Roof, the
next *** for a Rain
Gargen, the next *** for a CiStern, and the following *** for a
Porous pavement
URHD URMD URML URLD UCOM UIDU UTRN UINS |Urban land use
class codes (from "urban.dat")
0 0 0 0 0 0 0 0 |GR_ONOFF: 0=the green roof is
inactive (no simulation), 1=active
1 1 1 1 1 1 1 1 |GR_IMO: Month the green roof
became operational (1-12)
1987 1987 1987 1987 1987 1987 1987 1987 |GR_IYR: Year the wet
pond
became operational (eg 1980)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |GR_FAREA: Fraction of
impervious areas where the green roofs are installed
1 1 1 1 1 1 1 1 |GR_SOIL: 0=Characteristics
(FC, WP, and Ksat) of the amended soil are identical to those of
the native HRU
soil, 1=read user input
0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 |GR_ETCOEF:
Evapotranspiration
coefficient
0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 |GR_FC: Field
capacity of the amended soil, mm/mm
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 |GR_WP: Wilting
point of the amended soil, mm/mm
7.5 7.5 7.5 7.5 7.5 7.5 7.5 7.5 |GR_KSAT: Saturated hydraulic
conductivity through the amended soil layer, mm/hr
0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 |GR_POR: Porosity the
amended
soil layer
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |GR_HYDEFF: Hydraulic
efficiency factor (considering clogging up and anisotropy ratio)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |GR_DEPTH: Depth of the
amended soil, m
0 0 0 0 0 0 0 0 |GR_DUMMAY1: Spare line for
additional parameters for the green roof
0 0 0 0 0 0 0 0 |GR_DUMMAY2: Spare line for
additional parameters for the green roof
0 0 0 0 0 0 0 0 |GR_DUMMAY3: Spare line for
additional parameters for the green roof
0 0 0 0 0 0 0 0 |GR_DUMMAY4: Spare line for
additional parameters for the green roof
```

```
0 0 0 0 0 0 0 0 |GR_DUMMAY5: Spare line for
additional parameters for the green roof
0 0 0 0 0 0 0 0 |RG_ONOFF: 0=the rain garden
is inactive (no simulation), 1=active
1 1 1 1 1 1 1 1 |RG_IMO: Month the rain garden
became operational (1-12)
1987 1987 1987 1987 1987 1987 1987 1987 |RG_IYR: Year the wet
pond
became operational (eg 1980)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |RG_FAREA: Franction of
impervious areas draining water to the rain garden
1 1 1 1 1 1 1 1 |RG_SOIL: 0=Characteristics
Page 1
LIDtext
(FC, WP, and Ksat) of the amended soil are identical to those of
the native HRU
soil, 1=read user input
0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 |RG_ETCOEF:
Evapotranspiration
coefficient
0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 |RG_FC: Field
capacity of the amended soil, mm/mm
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 |RG_WP: Wilting
point of the amended soil, mm/mm
7.5 7.5 7.5 7.5 7.5 7.5 7.5 7.5 |RG_KSAT: Saturated hydraulic
conductivity through the amended soil layer, mm/hr
0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 |RG_POR: Porosity the
amended
soil layer
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |RG_HYDEFF: Hydraulic
efficiency factor (considering clogging up and anisotropy ratio)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |RG_DEPTH: Depth of the
amended soil, m
0 0 0 0 0 0 0 0 |RG_DIM: Rain garden storage
(for ponding water), 2=determine the storage dimension based on
the volume provided
by a user from drainage areas assuming the depth of the rain
garden storage of 0.5
m, 1=read user input (dimension), 0=determined the storage
dimension based on
required volume estimated from drainage areas assuming the depth
of the rain garden
storage of 0.1 m
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |RG_SAREA: Fractional area of
```

```
the rain garden storage surface to the impervious area of an
urban HRU (faction)
2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 | (not used yet) RG_VOL:
Runoff volume to fill the pool (storage of the rain garden on the
soil surface),
m^3
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |RG_STH: Depth of the rain
garden storage, m
1 1 1 1 1 1 1 1 | (not used yet) RG_SDIA:
Diameter of the surface area of the rain garden, m (frustum of a
circular cone)
1 1 1 1 1 1 1 1 | (not used yet) RG_BDIA:
Diameter of the bottom of the rain garden, m (frustum of a
circular cone)
1 1 1 1 1 1 1 1 | (not used yet) RG_STS:
Slope of a slant of the rain garden storage (surface side
slopes), m (frustum of a
circular cone)
1 1 1 1 1 1 1 1 |RG_ORIFICE: 0=the orifice
drainage is inactive (no simulation), 1=active
0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 |RG_OHEIGHT: the height
of
the orifice from the bottom of the storage (m)
0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 |RG_ODIA: the diameter of
the orifice pipe (m)
0 0 0 0 0 0 0 0 |RG_DUMMAY1: Spare line for
additional parameters for the rain garden
0 0 0 0 0 0 0 0 |RG_DUMMAY2: Spare line for
additional parameters for the rain garden
0 0 0 0 0 0 0 0 |RG_DUMMAY3: Spare line for
additional parameters for the rain garden
Page 2
LIDtext
0 0 0 0 0 0 0 0 |RG_DUMMAY4: Spare line for
additional parameters for the rain garden
0 0 0 0 0 0 0 0 |RG_DUMMAY5: Spare line for
additional parameters for the rain garden
0 0 0 0 0 0 0 0 |CS_ONOFF: 0=the cistern is
inactive (no simulation), 1=active
1 1 1 1 1 1 1 1 |CS_IMO: Month the cistern
became operational (1-12)
1987 1987 1987 1987 1987 1987 1987 1987 |CS_IYR: Year the cistern
became operational (eg 1980)
1 1 1 1 1 1 1 1 |CS_GRCON: 0=the cistern is
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not connected to the corresponding green roof located in the same
land use, 1=the
cistern is connected to the corresponding green roof located in
the same land use
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |CS_FAREA: Fraction of
impervious areas draining water to the cistern
0 0 0 0 0 0 0 0 |CS_VOL: Runoff volume to fill
the cistern (storage of the cistern), m^3; If CS_VOL is zero SWAT
calculates the
cistern capacity with CS_RDEPTH
2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 |CS_RDEPTH: Rainfall depth
generated in treated area to fill the cistern (storage of the
cistern), mm; If
CS_RDEPTH is zero SWAT assumes the cistern capacity as 5 m3
0 0 0 0 0 0 0 0 |CS_DUMMAY1: Spare line for
additional parameters for the cistern
0 0 0 0 0 0 0 0 |CS_DUMMAY2: Spare line for
additional parameters for the cistern
0 0 0 0 0 0 0 0 |CS_DUMMAY3: Spare line for
additional parameters for the cistern
0 0 0 0 0 0 0 0 |CS_DUMMAY4: Spare line for
additional parameters for the cistern
0 0 0 0 0 0 0 0 |CS_DUMMAY5: Spare line for
additional parameters for the cistern
0 0 0 0 0 0 0 0 |PV_ONOFF: 0=the porous
pavement is inactive (no simulation), 1=active
1 1 1 1 1 1 1 1 |PV_IMO: Month the porous
pavement became operational (1-12)
1987 1987 1987 1987 1987 1987 1987 1987 |PV_IYR: Year the porous
pavement became operational (eg 1980)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |PV_FAREA: Fraction of
impervious areas where the porous pavement is installed
130 130 130 130 130 130 130 130 |PV_GRVDEP: Depth of the
gravel bed of porous pavement, mm
0.35 0.35 0.35 0.35 0.35 0.35 0.35 0.35 |PV_GRVPOR: Porosity
of the gravel bed of porous pavement
1 1 1 1 1 1 1 1 |PV_SOIL: 0=Characteristics
(FC, WP, and Ksat) of the amended soil are identical to those of
the native HRU
soil, 1=read user input
0.60 0.60 0.60 0.60 0.60 0.60 0.60 0.60 |PV_DRAIN: Drainage
coefficient
Page 3
LIDtext
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0.40 0.40 0.40 0.40 0.40 0.40 0.40 0.40 |PV_FC: Field
capacity of the amended soil, mm/mm
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 |PV_WP: Wilting
point of the amended soil, mm/mm
7.5 7.5 7.5 7.5 7.5 7.5 7.5 7.5 |PV_KSAT: Saturated hydraulic
conductivity through the amended soil layer, mm/hr
0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 |PV_POR: Porosity the
amended
soil layer
0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |PV_HYDEFF: Hydraulic
efficiency factor (considering clogging up and anisotropy ratio)
0.25 0.25 0.25 0.25 0.25 0.25 0.25 0.25 |PV_DEPTH: Depth of the
amended soil, m
0 0 0 0 0 0 0 0 |PV_DUMMAY1: Spare line for
additional parameters for the porous pavement
0 0 0 0 0 0 0 0 |PV_DUMMAY2: Spare line for
additional parameters for the porous pavement
0 0 0 0 0 0 0 0 |PV_DUMMAY3: Spare line for
additional parameters for the porous pavement
0 0 0 0 0 0 0 0 |PV_DUMMAY4: Spare line for
additional parameters for the porous pavement
0 0 0 0 0 0 0 0 |PV_DUMMAY5: Spare line for
additional parameters for the porous pavement
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