INNOVATIVE STORM WATER BEST MANAGEMENT PRACTICES: THEIR INFLUENCE ON LANDSCAPE ARCHITECTURE IN NORTH TEXAS

by

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ABSTRACT

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The development process is essentially a three step progression consisting of input from developers who envision and fund a project, designers who translate the developer's vision into a buildable project, and the regulators who ensure that the project upholds, to the extent allowable by law, the health and welfare of mankind including the environment.

As an outgrowth of this development model, the modern American city has evolved overtime into a sprawling metropolis, which has had a direct, deleterious impact on watersheds. To address these detrimental impacts, storm water regulations have been authored on federal, state, and local levels, which include the use of post-construction, structural (or built) storm water best management practices (BMPs) to reduce water quantity and improve water quality. However, a majority of these storm water BMPs are used for strictly utilitarian purposes. The metropolitan area collectively referred to as North Texas represents this model.

The objective of this research is to identify the criteria and influences for the selection and use of structural storm water BMPs for developing or re-developing areas by the representatives of the development process. Although the technology is available, innovative, structural storm water BMPs for aesthetic, environmental, or educational purposes are seldom implemented in developments and redevelopments in North Texas. This thesis attempts to answer why these solutions are seldom implemented through qualitative analysis of responses from the aforementioned representatives.

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CHAPTER 1

1.1 Introduction

In the United States, the development process is essentially a three tier progression. The initial leg represents a developer who has a vision and attempts to finance and build that vision. The developer usually hires a designer to put his or her vision on paper, which characterizes the second leg of this process. The remaining leg is reserved for the bureaucrat. A bureaucrat is the enforcer of regulations to ensure that the health and welfare of mankind including the environment is upheld to the maximum extent practicable. All three legs or tiers of the development process are necessary to see a project to fruition.

Since the adoption of the Clean Water Act in 1972, there have been increasing regulations issued to address water quality concerns. The most recent regulation, Phase II of the National Pollutant Discharge Elimination System (NPDES), was issued in 1999 by the U.S. Environmental Protection Agency and went into effect in 2008. Phase II of the NPDES requires that all regulated activities occurring within urbanized municipalities with populations less than 100,000 adhere to diffuse source storm water pollution standards. Municipalities with populations greater than 100,000 already adhere to NPDES regulations. In other words, almost all development activities within a municipality must apply for and obtain a NPDES permit. A component of this permit is the establishment of storm water best management practices (BMPs) to minimize or prevent polluted runoff from entering the receiving water body or storm water system.

This document attempts to identify the factors that influence the selection of structural storm water BMPs within the aforementioned development process by soliciting responses from representatives of the three tiers. Specifically, this document attempts to answer what determines the selection criteria for structural, post-construction storm water BMPs. The document also attempts to discern if innovative, structural storm water BMPs are or are not readily integrated into the landscape for aesthetic and environmental benefits in North Texas.

1.2 Research Objective

The objective of this research was to identify the criteria and influences for the selection and use of structural storm water BMPs for developing or re-developing areas by the key stakeholders. Qualitative analysis of the interviews was used to reveal insights as to what determines the BMPs selection process to comply with the NPDES regulations.

1.3 Definition of Terms

The following terms are found within this document and are defined to fit the context of this study. If the citation is not noted, it was obtained from the Random House Dictionary.

Aesthetic: Combines biological, cultural, and personal bases to define aesthetics in a comprehensive paradigm. This paradigm is based on Vygotsky's developmental approach to understanding the human mind and human behavior. Vygotsky's method leads to the identification of three fundamental processes of development: phylogenesis (biological evolution), sociogenesis (cultural history), and ontogenesis (individual development) (Bourassa, 1990).

American Society of Landscape Architects (ASLA): A national professional society that represents the profession of landscape architecture (Landscape Architecture, 2008).

Anaerobic. Pertaining to or caused by the absence of oxygen.

Biodiversity: Diversity among and within plant and animal species in an environment.

Best Management Practice (BMP): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. (USEPA, 1999a).

Buffer Zone: A strip of land situated between development and an environmentally sensitive area to mitigate damage and pollution to the environmentally sensitive area.

Bureaucrat: An official of bureaucracy.

Code: A systematically arranged collection or compendium of laws, rules, or regulations set forth and enforced by a local government agency for the protection of public safety, health, etc.

Combined Sewer: Co-mingling of sanitary and storm sewer systems.

Clean Water Act of 1972 (CWA): Congressional legislation enacted to clean and protect the waters of the U.S.

Decentralize: To disperse something from an area of concentration.

Develop: To cause (a tract of land) to serve a particular purpose.

Ecosystem: A system formed by the interaction of a community of organisms with their environment.

Environment: The air, water, minerals, organisms, and all other external factors surrounding and affecting a given organism at any time.

Freeboard: The height of the watertight portion of a building or other construction above a given level of water in a lake, river, etc.

Habitat: The arrangement of cover, food, and water that enables some form of wildlife to maintain itself in a given area.

Impair: To make or cause to become worse, diminish in ability, value, excellence, etc.

Integrated Storm Water Management (iSWM): Storm water protocol devised to aid North Texas cities and developers in the design and implementation of beneficial storm water techniques and practices (NCTCOG, 2008).

Key Informant: The most prominent, informed, and influential people in an organization or field of practice (Patton, 1987).

Metropolitan: Of or pertaining to a large city, its surrounding suburbs, and other neighboring communities.

Megalopolis: An urban region, especially one consisting of several large cities and suburbs that adjoin one another.

National Pollutant Discharge Elimination System (NPDES): An individual component of the Clean Water Act that attempts to limit or eliminate pollutants to waters of the U.S.

North Central Texas Council of Governments (NCTCOG): An organization representing municipalities with the council of government's sixteen (16) county area (NCTCOG, 2008).

Non-Point Source Pollution: Pollution from unidentifiable, generalized sources.

Ordinance: A public injunction or regulation.

Perspective: A point of view or the state of one's ideas.

Point Source Pollution: Pollution from a single, identifiable, localized source.

Pollutant: Any substance, as certain chemicals or waste products, that renders the air, soil, water, and other natural resource harmful or unsuitable for a specific purpose.

Polycentric: Having many centers.

Potable: Fit or suitable for drinking.

Qualitative: Involving distinctions based on qualities.

Respondent: Interviewee; See Key Informant

Sewer: An artificial conduit, usually underground, for carrying off wastewater and refuse, as in a town or city.

Sprawl: To spread out, extend, or be distributed in a straggling or irregular manner.

Storm Water: An abnormal amount of surface water due to a heavy rain or snowstorm.

Suburb: A district lying immediately outside a city or town, especially a smaller residential community.

Texas Commission on Environmental Quality (TCEQ): The agency that administers the environmental regulations within the State of Texas.

Urban: Of, pertaining to, or designating a city or town.

United States Environmental Protection Agency (USEPA): The agency that administers the environmental regulations of the U.S.

Wastewater: Water that has been used in washing, flushing, manufacturing, etc.

Zoning: Of or pertaining to the division of an area into zones, as to restrict the number and types of buildings and their uses.

1.4 Limitations

The limitations of this study were conditions beyond the researcher's control. In North Texas, a majority of the cities fall under Phase II of the NPDES and were implementing their storm water programs at the time of this paper. Furthermore, since this study attempts to get the perspectives from different representatives of the development process, the pool of key informants representing each facet of the development process was limited. Also, opinions and experiences may have differed from those who participated in the study. For example, engineers at times have different perspectives than landscape architects. Also, generational and cultural differences may have influenced the opinions of those who participated in the study. These factors may have restricted the generalizations offered in the study's results.

1.5 Delimitations

The scope of the study was delimited in various ways. First, all of the informants who participated in the study do business in or work for entities in North Texas. All of the informants were familiar with the NPDES process, were intimately familiar with the various structural storm water BMPs available, and all had specific knowledge and experience pertaining storm water controls. Lastly, by participating in this study, the respondents did not benefit financially or professionally in any way; therefore, their opinions remained completely objective.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This research provides a cursory overview of the past and current development trends in the United States (U.S.) and North Texas with respect to how this expansion has impacted watersheds. A watershed diminishes flood events, serves as a repository for sediment accumulation, and protects water quality and aquatic health (Field, et. al., 2006). Over time and in reaction to water quality issues and flooding, laws and regulations have been enacted to address storm water concerns. In response to the regulatory procedures and processes, storm water best management practices (BMPs) have been developed to mitigate for the loss of aquatic functions. The U.S. Environmental Protection Agency (USEPA) defines storm water BMPs as "schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S." (USEPA, 1999a). Both structural and non-structural storm water BMPs exist; however, this research will only address structural storm water BMPs, their design elements and performance. Since structural storm water BMPs can be integrated into the landscape, these systems have the potential to benefit the health, welfare, and aesthetic value not only for mankind but for the flora and fauna that rely on these systems.

2.2 Spatial and Temporal Change

Urban land uses have changed dramatically since the 1900’s transitioning from a compact, centralized city structure to sprawling, “polycentric” metropolitan areas (USEPA, 2001). During this timeframe, urban land uses have quadrupled. In 1945, urbanized areas within the contiguous 48 states represented approximately 15 million acres (USDA, 2006). By 2002, urbanization engulfed 59 million acres (USDA, 2006). The primary factor contributing to urbanization was city expansion at the end of World War II. The federal government authorized the Federal Housing Administration and the Veterans Administration to offer low interest loan programs and mortgages following World War II (Fishman, 2000). In doing so, these loan programs persuaded citizens to move to the suburbs as opposed to renting or rehabilitating existing structures within the central city (Duany, Plater-Zyberk, and Speck, 2000). These new developments created growth rings surrounding the older, central city core.

In order to connect the burgeoning growth after World War II, a network of roads and highways were requisite to provide an avenue for vehicular access to the central city where employment was typically located. On June 29, 1956, President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956. One of the primary features of the act was the provision for a 41,000-mile network of limited access roads linking 90 percent of the cities with populations greater than 50,000 (Weingroff, 2006). During this same timeframe, states were authorizing monies to construct or expand farm to market roads and state highways. From 1945 to 2002, the mileage of paved road surfaces tripled (USEPA, 2001). From 1980 to 1997, vehicular miles traveled outpaced population growth by two percent (Figure 2.1). These road networks provided additional access to lands that were previously considered rural and as shown in Figure 2.2, this trend is not anticipated to abate. From the data, one can readily surmise that people are living further away from cultural and/or work centers.

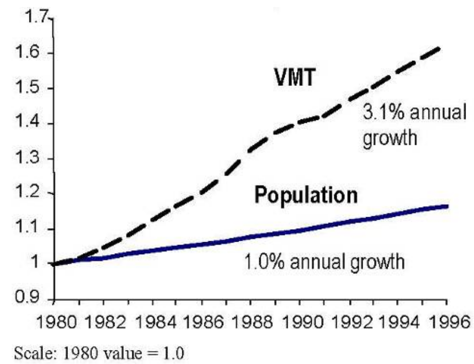


Figure 2.1: Growth in vehicular miles traveled versus population from 1980-1997 (USEPA, 2001)

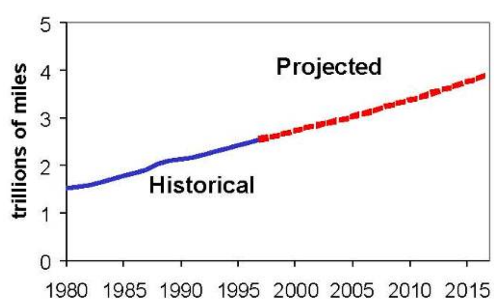


Figure 2.2: Projected growth in vehicular miles traveled (USEPA, 2001)

Low interest home loan programs and expanded road infrastructure were not the only influencing factors contributing to the rapid expansion of cities after World War II. Land planners and influential citizens during this era were encouraging residents to move away from the ills of the central city. Henry Ford, founder of the Ford Motor Company, is quoted as saying “we shall solve the city problem by leaving the city”

(Fischer, 1984). During this era, the central city was considered as a haven for persons of low-income, minority families, decrypted buildings, crime, and undesirables (Downs, 1973).

Ebenezer Howard, a land planner and considered the father of the "New Town" despised everything there was about the city. In response to his city aversion, he developed the concept of the "three magnets" (Figure 2.3). Howard's three magnets ideology details the pros and cons of living in the inner city versus the country, and the merits of the combination of the two into a new town.

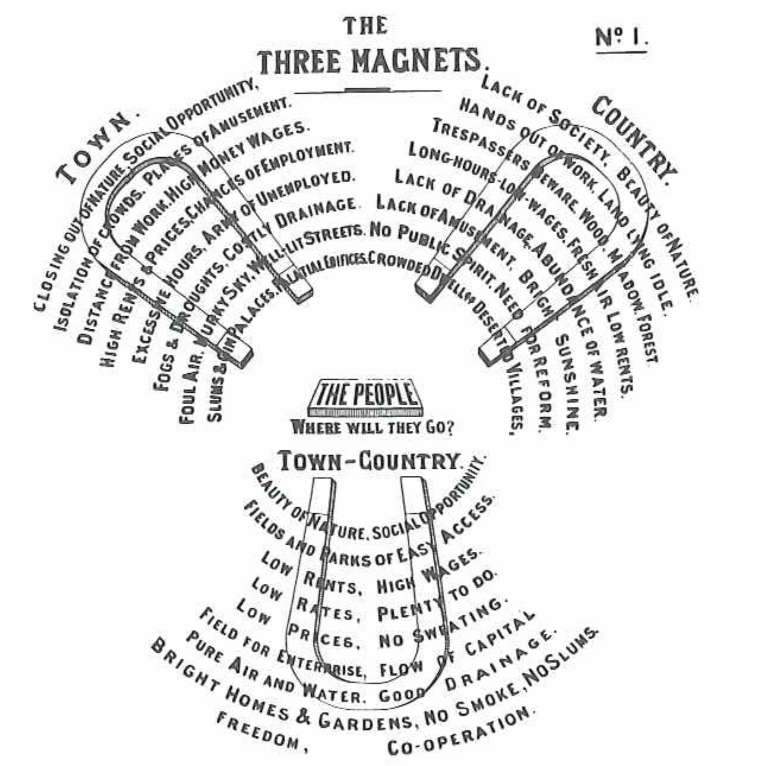


Figure 2.3: Ebenezer Howard's three magnets concept (Howard, 1989)

Howard is quoted as saying, "town and country must be married, and out of the joyous union will spring a new hope, a new life, a new civilization" (Howard, 2003).

From these concepts, Howard coined the term "the Garden City" to describe his new town (Ward, 1992). The Garden City is to be encircled by a green belt dedicated to agriculture. Within the green belt, each aspect of a city, whether it be industry, schools, housing, or open space, is to be compartmentalized into its own section of the city. The city core would house the commercial, club, and cultural places (Ward, 1992). Even if contemporary land planners do not subscribe to Howard's philosophies, his influence on American planning still governs its underlying principles (Jacobs, 1961).

Another planner of the era, Sir Patrick Geddes, proffered Howard's concepts to regional planning. Geddes envisioned not planning individual Garden Cities but placing individual cities within a region (Jacobs, 1961). This regional planning effort would situate new towns in areas to best utilize the natural resources available. Geddes' ideas, as illustrated by the "valley section" in his book *Cities in Evolution* (Geddes, 1949), are arguably the precursor to McHargian ecological planning (Spirn, 2000).

In America, city planners diverged from the American town planning concept, which consisted of an intermixture of commercial, institutional, and residential uses. Around 1920, notable authors, scholars, and planners Lewis Mumford, Clarence Stein, Henry Wright, and Catherine Bauer adopted the movement that championed decentralization (Jacobs, 1961). Mumford, perhaps the most influential of the four, in his book *The Culture of Cities*, personifies decentralization. He is quoted as saying, "Instead of clinging to the sardonic funeral towers of metropolitan finance, ours to march out to newly plowed fields, to create fresh patterns of political action, to alter for human purposes the perverse mechanisms of our economic regime, to conceive and to germinate fresh forms of human culture" (Mumford, 1938). This example of Mumford's writing embodies a push to the un-indoctrinated countryside to rekindle human culture and diverge from the ailments of the central city.

Overall, the focus of Mumford, Stein, Wright, and Bauer's philosophy was to disperse city enterprises and populations to smaller cities or towns. Their primary objective was not to see their theories implemented but to influence city planning and legislation (Jacobs, 1961). Influential land planning notions exemplified by the faction included streets are dire, segregation of land uses, and Howard's concept of new town independence and isolation (Jacobs, 1961).

Other land planning philosophies of the early 20th century included the City Beautiful Movement, Frank Lloyd Wright's Broadacre City, and Le Corbusier's Radiant City. Each of these philosophies either advocated the segregation of land uses or promoted decentralization.

The City Beautiful Movement was an offshoot of Olmstedian thought and was brought to the fore after the World's Columbian Exposition by Daniel Burnham. This school of thought dealt with city beautification through urban design and the use of grandiose, ornate buildings (Wilson, 1989). These buildings were isolated cultural or civic centers further promoting the premise of segregation of uses.

Frank Lloyd Wright's Broadacre City was in the model of Ebenezer Howard's Garden City; a model for decentralization (Fishman, 1988). However, in comparing Wright's concept to Howard's, Broadacre took decentralization to the extreme. Wright's ultimate goal of Broadacre was to distribute the man-made environment to the countryside so that it organically became conjoined to the landscape (Figure 2.4) (Fishman, 1988). Wright considered the current establishment of cities as a barrier to progress. He regarded the big city as a "monstrous aberration, built by greed, destructive both to efficient production and to human values" (Fishman, 1988). Perceptibly, Wright was promoting megalopolis decentralization and the migration to the countryside to rekindle humanistic and moralistic values, much like Howard.

Figure 2.4: Frank Lloyd Wright's concept for Broadacre City (Fishman, 1988)

For Le Corbusier, the concept for the Radiant City spawned from his disdain for the disorder of the great city, a visual chaos (Figure 2.5). The Radiant City concept consists of a conglomeration of uniform skyscrapers set in parks, which would provide visual harmony (Figure 2.6).

Figure 2.5: Visual chaos of New York City as proclaimed by Le Corbusier (Le Corbusier, 1964)

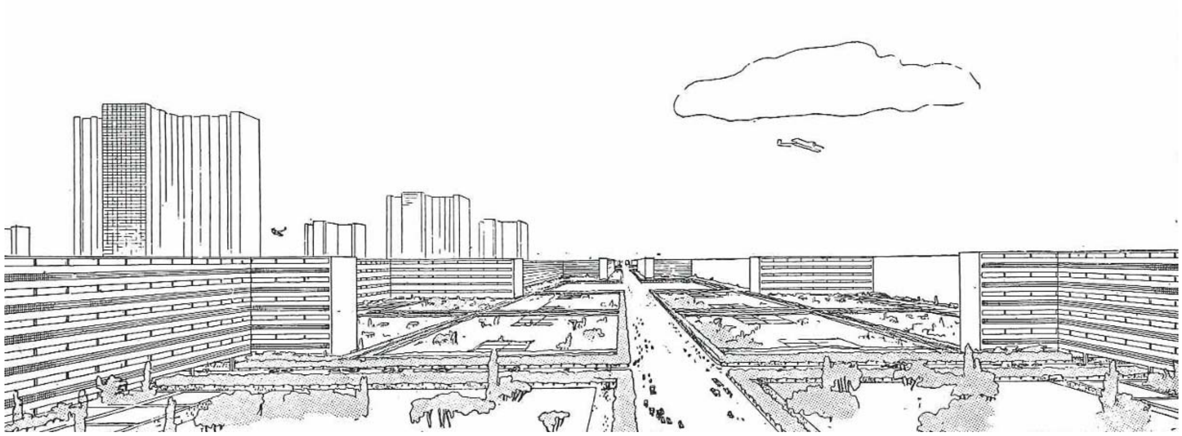


Figure 2.6: Le Corbusier's Radiant City concept (Le Corbusier, 1964)

Le Corbusier knew that cities were unavoidable. He thought cities should be structured and orderly while maintaining a person's individual liberty (Fishman, 1988). In that vain, his guiding principle for the "contemporary city," according to Robert Fishman, was "the juxtaposition of a collective realm of order and administration with an individualistic realm of family life and participation" (Fishman, 1988). Consistent with the theme of segregation of uses, Le Corbusier's concept was aimed at alleviating street and sidewalk congestion including the removal of bustling public squares, untidy neighborhoods, and the patchwork of existing skyscrapers. The Radiant City would provide its inhabitants with clean high-rise towers set in a regimented pattern with sufficient distance between one another offering a park-like or pastoral landscape (Figure 2.7). The new city would be separated into discrete zones for working, living, and leisure (Le Corbusier, 1964).

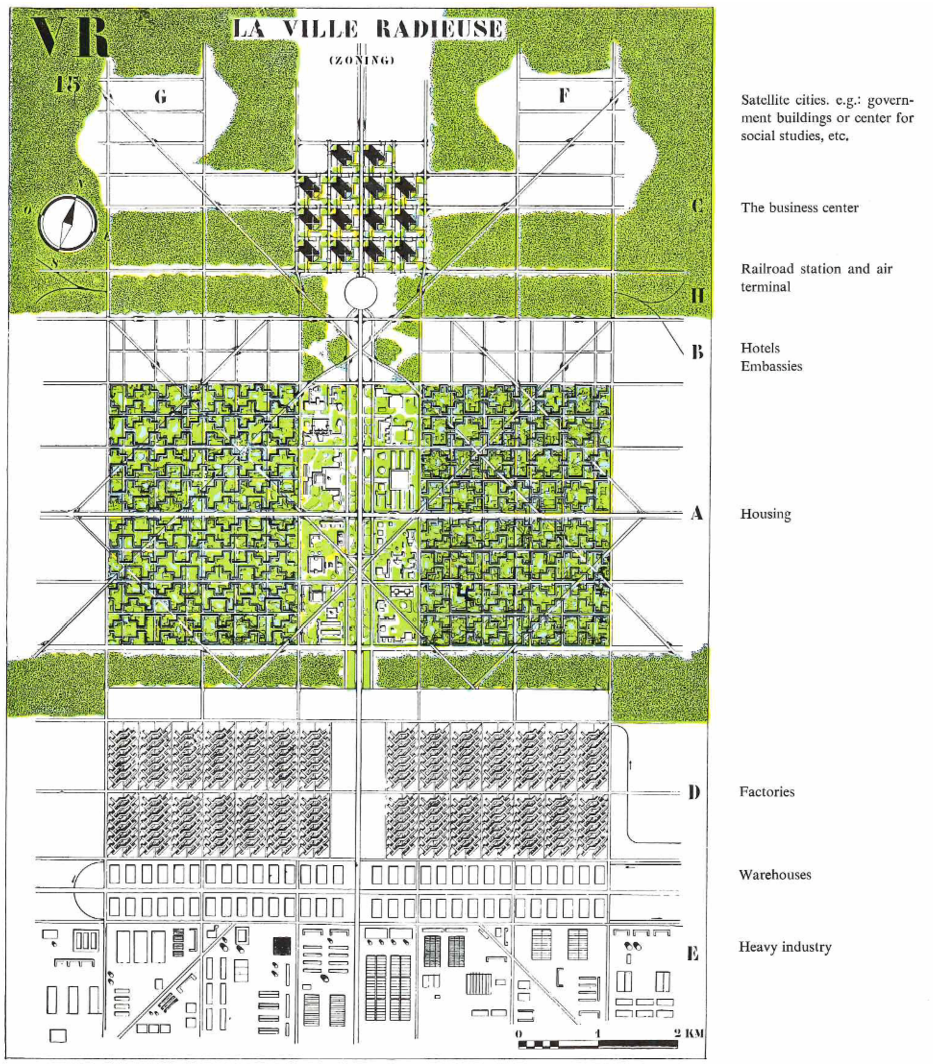


Figure 2.7: Plan view of the conceptual Radiant City showing the discrete zones of infrastructure (LeCorbusier, 1964)

In the United States, the Radiant City took the form of urban-renewal concepts. One such concept offered by Victor Gruen of Victor Gruen Associates – Architects and Planners, provided a pedestrian scheme for the City of Fort Worth, Texas, which offered a zero-automobile downtown concept (Jacobs, 1961). Gruen's concept was to provide a road encircling downtown Fort Worth with six garages strategically located along the road to house 10,000 vehicles each. Obviously by visiting Fort Worth, this plan was never implemented but still represents an example for the separation of land uses.

As an outgrowth of these early land planning movements, zoning ordinances and codes were authored to provide rules for separating land uses as well as instructions for appurtenances within developments. Zoning is defined as a means for controlling and directing the use and development of property in any given area by dividing it into districts according to present and potential uses of the property (MacCorkle, 1955). Zoning is designed to:

- Lessen congestion in the streets,
- Secure safety from fire, panic, and other dangers,
- Promote health, morals, and general welfare,
- Provide adequate light and air,
- Prevent overcrowding of land and buildings, and
- Avoid undue concentration of population (Rody, 1960).

A typical contemporary zoning ordinance has several dozen land use designations. Housing is separated from industry. Housing itself is diversified into zones of single-family and multi-family complexes. Medical offices are separated from general offices. Restaurants and shops are separated from the aforementioned. Typical code and zoning ordinance regulations underutilize space or use space inefficiently (Duany, Plater-Zyberk, and Speck, 2000); thereby, fostering continued conurbation.

Historically, separation of land uses was indeed a noble concept. In the late 1800's to early 1900's, separating factories from residential areas was a necessity to facilitate citizen's health and welfare especially in populous cities such as Paris, Barcelona, and London (Duany, Plater-Zyberk, and Speck, 2000). Separation of these land uses at the time was genius because the quality of life for these citizens improved dramatically thereafter (Duany, Plater-Zyberk, and Speck, 2000). However, today, due to regulations and technological advances, factories, for example, are typically good neighbors and do not need to be separated from residential nodes.

In development projects, municipal codes and other ordinances deal with site specific pieces of the improvements. They typically determine a building's explicit set-back, offer design specifications such as parking lot size, offer landscape specifications such as green space and plant material, and the list continues. The majority of these codes and ordinances are use specific and generic. These regulations coerce the continued homogeneity of modern day suburbia including inefficient use of space.

All of the aforementioned established the groundwork for the sprawling nature of the modern city. Today, citizens of these vast metropolitan areas must rely on automobiles to commute to and from work and to reach their various everyday commercial goods and services such as the grocery store. Since the automobile is the driving factor in today’s milieu, developments and land planning have had to adjust to accommodate vehicles. New subdivisions are typically located away from the older, central city core and separated from nodes of commercial services and business parks. As such, vast freeways, roads, and parking lots are necessary to accommodate the influx of vehicles.

Consumer mindsets have also changed. Today’s suburbanite is more pragmatic, choosing to migrate to the new towns located on the fringe of the city because homes are typically more spacious and more affordable (Fisher, 1984). In Texas, school districts and public schools located in the suburbs on average are considered exemplary to those of the inner city (TEA, 2008). Crime on average is lower in the suburbs (TDPS, 2007). Because of all of the aforementioned, the suburbs will continue to be a magnet attracting a continuous pool of localized immigrants.

2.3 Population Trends

The United States (U.S.) is one of the most populous of today's developed countries and continues to grow about one percent annually, which equates to the addition of approximately 2.5 million people annually (Census, 2008). To put this in perspective, this increase is equivalent to a new city approximately the size of Dallas County, Texas in terms of population (not spatial coverage). The current U.S. population estimate is over 305 million people, up from 203 million in 1970 (Census, 2008). Immigration contributes roughly a third of the annual increase; however, natural increases (births minus deaths) remain substantial at about 1.7 million annually

(Census, 2008). Figure 2.8 displays the growth rate of states from 1990 to 2000, which represents a data comparison between the 1990 and 2000 census. During this ten year period, Texas is shown to have a growth rate between 14.4 to 23.5 percent. All states are shown to have an increase in population during this timeframe with Nevada having the highest growth rate.

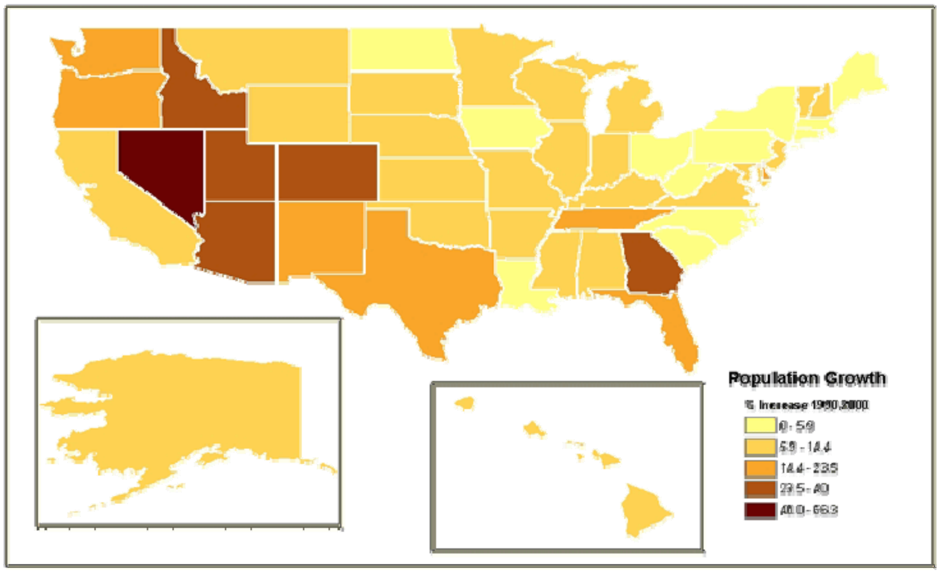


Figure 2.8: Comparison of 1990 to 2000 census data showing nationwide population increases and decreases by state (Population State, 2008)

According to the North Central Texas Council of Governments (NCTCOG), the sixteen counties representing North Texas (Figure 2.9) established itself as one of the fastest growing areas in the country between 1990 and 2000.

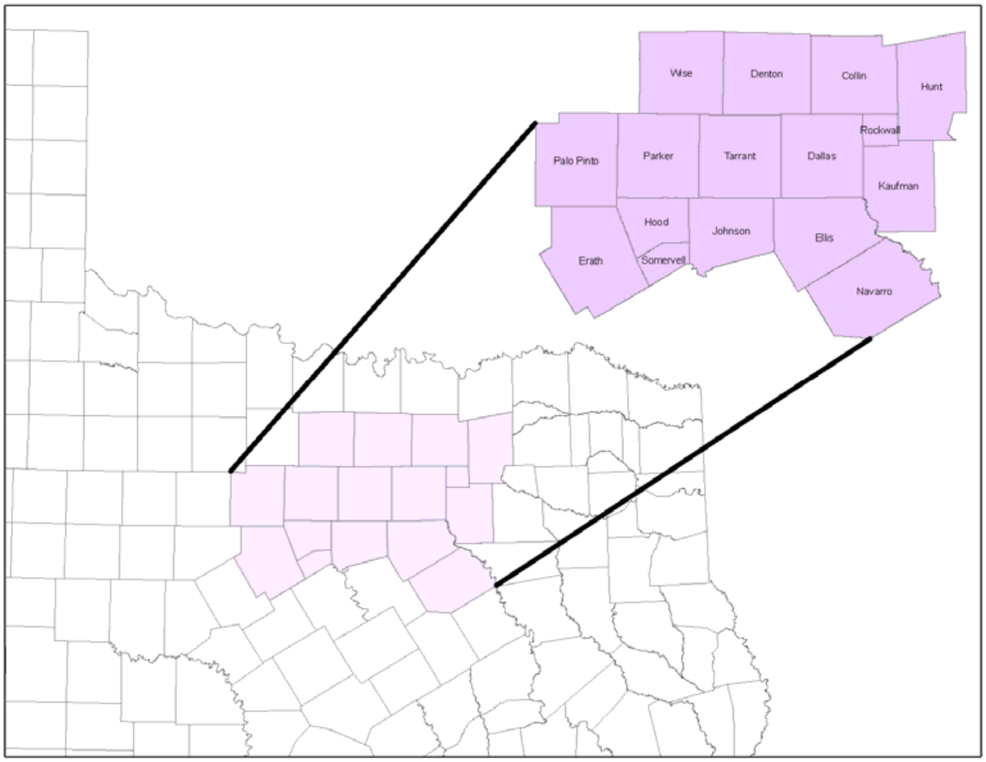


Figure 2.9: North Central Texas Council of Government's 16 County Area (Voight, 2008)

As of April 1, 2000, the region gained 1,197,527 residents brining the areas population to 5,309,277 (NCTCOG, 2000). The region's growth rate of 30 percent claims one third of the growth in Texas since 1990. During this timeframe, the region's growth added more people than Arkansas, Oklahoma, and New Mexico and the area's population is now greater than 36 states' populations (NCTCOG, 2000). According to a 2006 American Community Survey, Dallas County maintains the largest population in the region at 2,345,815 followed by Tarrant, Collin, and Denton Counties with populations of 1,671,295, 698,851, and 584,238, respectively (Census, 2008). These four counties account for 86 percent of the region's growth (NCTCOG, 2008).

Indicators suggest that these trends will continue through 2010, which represents the next decennial census. Figure 2.10 illustrates the increase and decrease of population per county (parish) within the U.S. from 1990 to 2000. The counties representing North Texas have all increased in population and this trend is not anticipated to lessen (Figure 2.11).

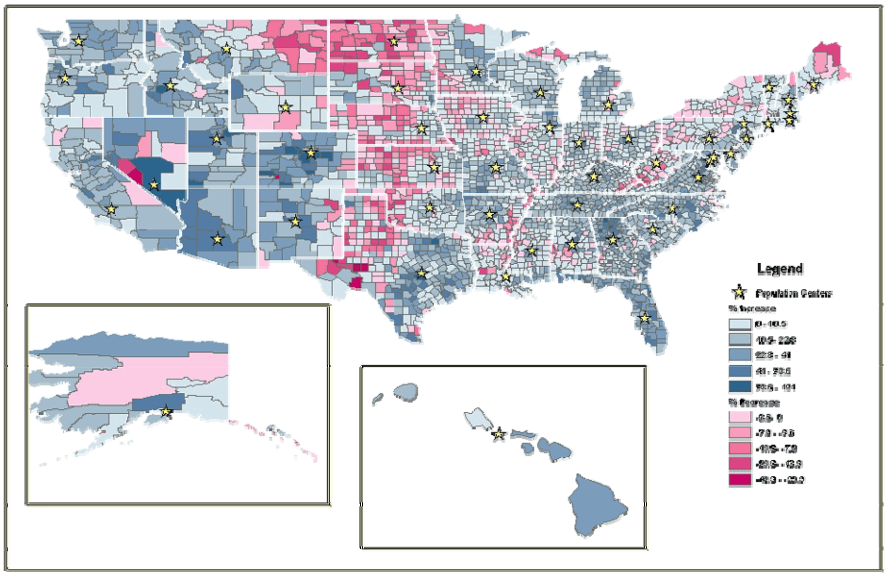


Figure 2.10: Comparison of 1990 Census Data to 2000 Census Data Showing Nationwide Population Increases and Decreases by County (Parish) (Population County, 2008)

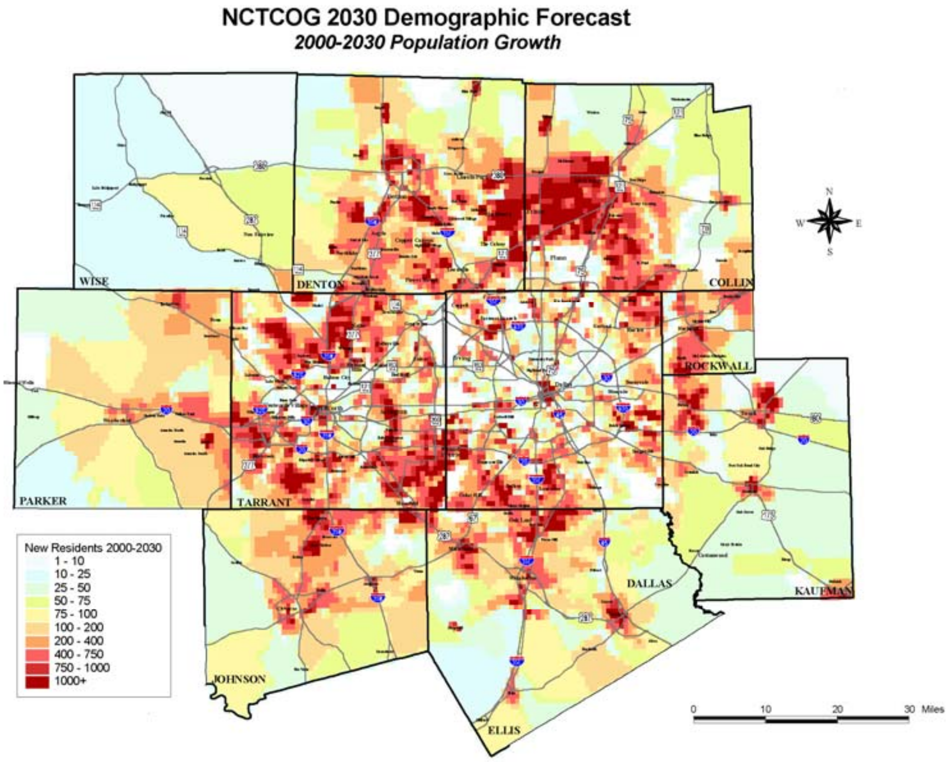


Figure 2.11: Projected population increases in the North Texas area (NCTCOG, 2003)

2.4 Water Quality

Since populations are increasing and land uses are converting from agricultural in nature to urban, watersheds are being altered at an alarming rate. Urbanization with its associated impervious surfaces typically decreases a watershed's ability to mitigate floods, facilitate sediment replenishment, and protect water quality and aquatic health. A watershed has the ability to promote water quality by removing excess nutrients and other chemical contaminants before runoff enters receiving waters. Urban development also changes the hydrological regime (Figure 2.12), which usually results in habitat loss and other ecological impairments due to more frequent and longer bank full events, lower base flows, and increased stream channel erosion (Figure 2.13) (Roesner, et. al., 2001).

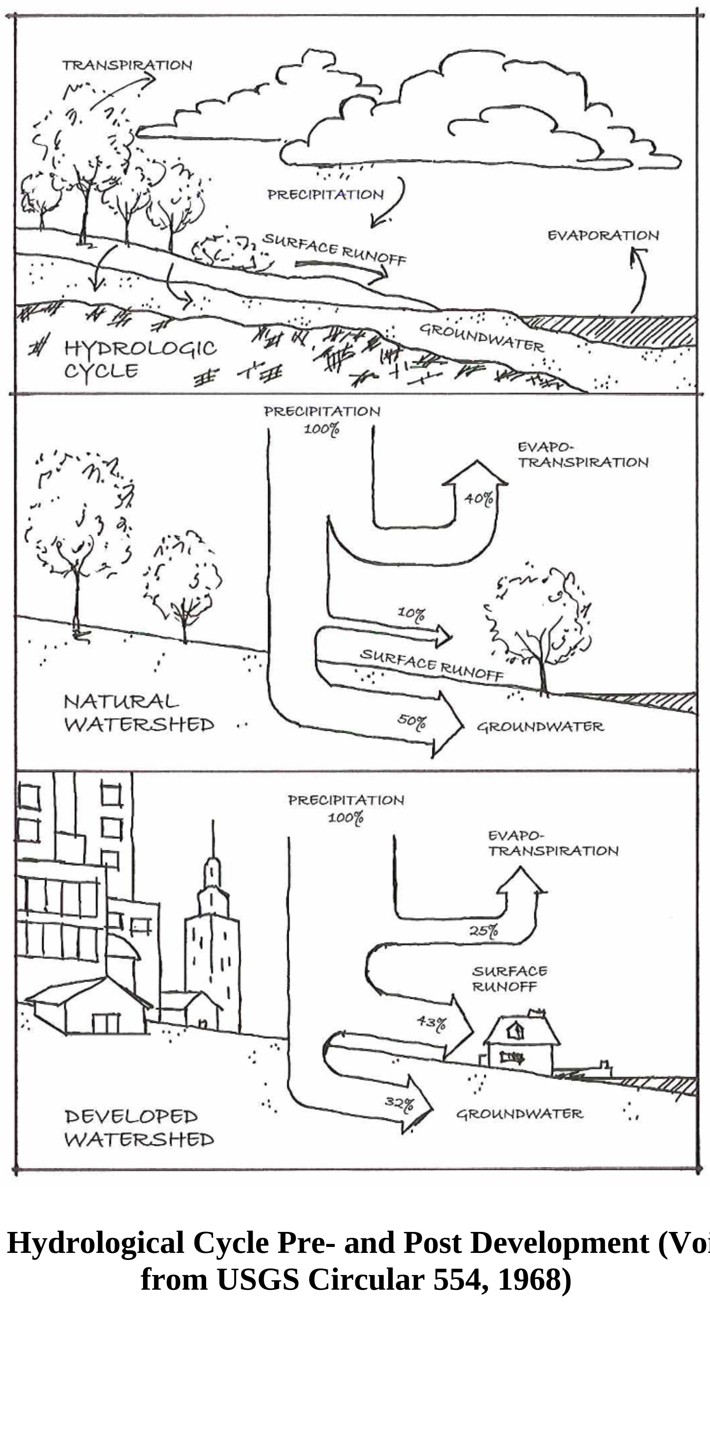


Figure 2.12: Hydrological Cycle Pre- and Post Development (Voight, adapted from USGS Circular 554, 1968)

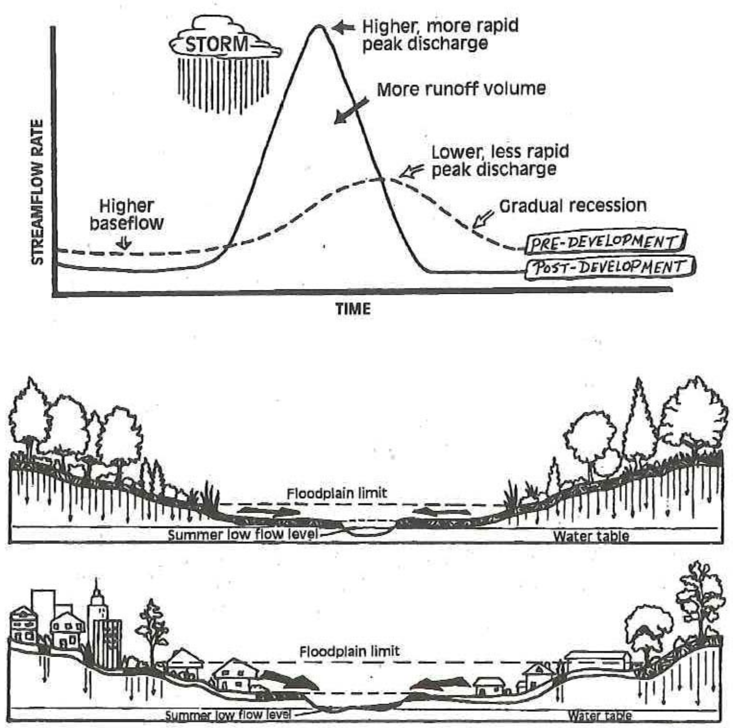


Figure 2.13: Alterations to hydrology from development (USEPA, 1995)

Typical pollutants associated with urbanization include the following:

- nutrients (nitrogen and phosphorus),
- sediment (total suspended solids),
- pathogens (bacteria, viruses, and others),
- metals (lead, mercury, cadmium, and others),
- hydrocarbons (oil, napthalenes, pyrenes, and others),
- organics (pesticides, synthetic chemicals, and others), and
- inorganic acids and salts (sulphuric acid, sodium chloride, and others) (USEPA, 2004).

Of the aforementioned pollutants, the percentages of the most frequent water pollutants derived from storm water runoff, excluding sediment or total suspended solids, are shown on Table 2.1.

Table 2.1: Most Frequent Water Pollutants Derived from Runoff (Terrene, 1995)

Pollutant	Runoff Contribution
Iron	95%
Total Nitrogen	90%
Fecal Coliform Bacteria	90%
Chemical Oxygen Demand	70%
Oil	70%
Zinc	70%
Phosphorus	66%
Lead	57%
Chromium	50%

These pollutants impact water quality through the promotion of algal growth; the reduction of dissolved oxygen available to biological species; the bioaccumulation of toxins (heavy metals) in aquatic species; toxicity to the overall water column; the coating of gills and/or impact to the respiration of aquatic species; the release other pollutants in the water column; the reduction of water clarity; an increase in water temperature; and others (USEPA, 2004). If these pollutants are in excess, it can impair the visual aesthetics of a water body, impair the recreational usage of the water body, and/or impair the available raw water supply. Most have visualized a posted sign's aphorism "possession of fish from this lake strictly prohibited" (Figure 2.14) or "beach is closed until further notice." Barring any shark encounters, these signs are typically posted due to the water source being contaminated from one or more of the aforementioned pollutants.

Figure 2.14: Warning Sign Positioned Along Lake Como in the City of Fort Worth, Texas (Warning Sign, 2008)

In the *National Water Quality Inventory: Report to Congress – 2002 Reporting Cycle*, impacts due to urbanization within watersheds attributed to the following:

- Of the assessed estuaries, 32 percent are reported as impaired, with the impairment attributable to urban runoff, industrial sources, municipal discharges, and unspecified sources,
- Of the assessed river miles, 45 percent are reported as impaired or not clean enough to support their designated uses, with the top sources of impairment attributed to agricultural activities, urban runoff, hydrological modifications, and unspecified sources,

- Of the assessed lakes, ponds, reservoirs, 47 percent were reported as impaired, with urban runoff, agricultural activities, and atmospheric deposition as the sources of impairment (USEPA, 2007).

Within Texas, the Texas Commission on Environmental Quality (TCEQ) is charged with protecting the state's natural resources. A component of this mission is monitoring the condition of the state's surface waters and assessing water quality. Every two years, the TCEQ prepares the *Texas Water Quality Inventory and 303(d) List*, which is the statewide report of the status of the state's waters. This document is prepared in accordance with Sections 303(d) and 305(b) of the Clean Water Act (CWA). In 2008, 925 water bodies were surveyed for potential impairments. Out of the 925 water bodies surveyed, 386 are listed on the 303(d) list and the survey found 516 impairments (some water bodies had multiple impairments) (TCEQ, 2008). Impairments consist of bacteria, dissolved oxygen, toxicity, organics, metals, dissolved solids, temperature, pH, nutrients, and biologicals (TCEQ, 2008). The good news is 2008 represents a three percent decrease in 303(d) listed water bodies and a five percent decrease in impairments compared to 2006 for the state (TCEQ, 2008).

2.5 Regulatory History and Process Regarding Storm Water

Prior to the passage of the CWA in 1972, water pollution control laws or regulations were virtually nonexistent (Field, et. al., 2006). The health of the nation's waters was in peril. It was not until the publication of Rachel Carson's milestone literary work, *Silent Spring*, in 1962 that legislators began to take impacts to the nation's waters seriously. *Silent Spring* spawned changes in government policy toward the environment, one of which included the passage of the CWA and the establishment of the USEPA. Once the CWA passed, water pollution control efforts, of which the USEPA is the agency with regulatory authority, focused primarily on wastewater discharges from point sources consisting of municipal treatment plants, industrial plants, and combined sewer overflows. Point source pollution is pollution from a single, identifiable, localized source (USEPA, 2004).

The initial iteration of the CWA fell short on addressing or emphasizing non-point source pollution or pollution from unidentifiable, generalized sources. In 1987, the CWA was amended to address this pollution source. From the amended CWA, the National Pollutant Discharge Elimination System (NPDES) was established and provided requirements to address storm water discharges. On November 16, 1990, the USEPA published in the Federal Register the Phase I Storm Water Permit Program to address the requirements promulgated by the amended CWA. This program targeted storm water discharges associated with industrial activities and large storm sewer systems of municipalities with populations greater than or equal to 100,000 (Federal Register, 1990). On December 8, 1999, the USEPA issued Phase II storm water regulations expanding the list to include smaller municipal systems (populations less than 100,000) in Bureau of Census defined urbanized areas (Federal Register, 1999). With the Phase II regulations, the regulated entity must obtain a NPDES permit and utilize storm water discharge controls such as storm water BMPs. In Texas, the USEPA has delegated the administration of the NPDES program to the TCEQ. Texas' program is referred to as the TPDES program.

2.6 Storm Water Best Management Practices

Best management practices for water quality improvement include operational activities, physical controls, or educational measures that are applied to reduce the discharge of pollutants and to minimize potential impacts to receiving waters. Within the BMP umbrella, non-structural and structural storm water management techniques are the two types of storm water management tools used to reduce pollutants from developing or redeveloping areas. According to the USEPA, storm water management tools, at a minimum, should attempt:

- to maintain the natural hydrological cycle prior to site development,
- to remove pollutants for water quality improvement,
- to be site appropriate,
- to be cost effective with limited long-term maintenance, and
- to maintain a neutral impact upon the environment (USEPA, 2004).

As mentioned, there are two types of storm water BMPs: non-structural and structural. Non-structural storm water BMPs are typically management techniques such as regulations, economic instruments, and/or behavioral changes used to reduce pollution levels. Structural storm water BMPs, which is the emphasis of this paper, are designed and/or engineered systems used to provide temporary storage and treatment of storm water runoff to improve water quality and to control the quantity of storm water runoff to receiving systems. It should be noted that any combination of non-structural and structural storm water BMPs will likely provide a greater desired result. Further, sub-regional and regional placement of large-scale storm water BMPs would provide additional regional water quality benefits (USEPA, 2004).

2.7 Structural Storm Water Best Management Practices

The location of structural (or built) storm water BMPs can be either at the point of generation or at the point of discharge to the storm sewer system or receiving water. The selection and successful design of selected structural BMPs for storm water quality enhancement is the cornerstone of storm water management systems in developing or redeveloping systems. Storm water systems are typically grouped by category pertaining to their function. Within the structural storm water BMP parasol, six categories of BMPs exist (USEPA, 2004) and include:

1. Storm Water Ponds
2. Wetlands
3. Vegetative Biofilters
4. Infiltration Practices
5. Green Roofs, Rainwater Harvesting, and Rain Gardens
6. Other Technology Options.

When planning structural storm water BMPs for use in a development, design considerations must include defining the mass loading in terms of flow rate, pollutant concentrations, and type of pollutant constituents (USEPA, 2004). This will ensure proper selection and design of the BMP for the desired outcome. For improved water quality, the design should also focus on the smaller more frequent storm events rather than the 50- or 100-year storm (USEPA, 2004). With any design or system, the selected BMP should be equipped to handle the initial runoff or "first flush," which is a term to describe the initial volume of rain that mobilizes pollutants.

2.7.1 Storm Water Ponds

Storm water ponds either detain or retain water within the storm water system. Detainment systems typically capture a volume of runoff and temporarily retain that volume for subsequent release (usually up to 72 hours). These systems are characteristically dry between storm events. On the other hand, retainment systems normally capture a volume of runoff and hold that volume until it is displaced in part or in total by the next runoff event (USEPA, 2004). In other words, a permanent pool of water remains within the system. Detention ponds, extended detention ponds, and wet (retention) ponds are three common systems categorized under storm water ponds.

2.7.1.1 Detention Ponds

Detention ponds are storm water basins designed to intercept a volume of runoff and temporarily impound the water for gradual release to the receiving water body or storm water system. These systems are typically designed to reduce the peak flow resulting from a storm event to the property's pre-development condition. In doing this, the chance for downstream flooding and channel erosion is reduced. Since these systems remain dry between storm events, they are not effective at removing pollutants due to their short detention times. For example, pollutants, such as total suspended solids, usually do not have sufficient time to settle from the water column with detention systems. Consequently, these systems are primarily used to reduce the peak discharge; thereby, preventing downstream flooding and channel scouring.

In North Texas, anecdotally speaking (based on interviews of the key respondents for this study), these systems appear to be the predominant choice for fulfilling storm water requirements within developments. The following are examples of detention systems located within North Texas (Figures 2.15 and 2.16).

Figure 2.15: Detention basin system for a large box retail development in Fort Worth, Texas (Voight, 2008)

Figure 2.16: Detention system for a retail strip center in Fort Worth, Texas (Voight, 2008)

These systems are usually designed for a singular purpose; however, some detention basins double as recreational playing fields (Figure 2.17).

Figure 2.17: Detention basin doubling as a recreational playing field in Fort Worth, Texas (Voight, 2008)

2.7.1.2 Extended-detention Ponds

Extended-detention ponds are akin to detention ponds with one subtle difference. The difference is that the release outlet is sized to slowly discharge the storm water runoff, which in turn allows for suspended solids and other pollutants to settle out of the water column. Like detention ponds, extended-detention ponds are usually dry between rain events and as such do not have areas with permanent standing water. Most systems are comprised of two stages to handle small, more frequent rain events and the infrequent, larger storm event (USEPA, 2004).

2.7.1.3 Wet Ponds

Wet ponds or better known as retention ponds are systems that retain a permanent pool of water year round. These systems are sized with sufficient freeboard to allow for storage of storm water runoff. During rain events, water retained in the permanent pool mixes with the storm water. Like the aforementioned systems, retention ponds have an outlet that slowly releases the mixture of storm water combined with the water retained in the permanent pool to the receiving water body or system. This process leaves a renewed mixture of water at permanent pool. These systems serve a dual purpose by improving water quality and by controlling the release of water to the receiving water body or storm water system. Most wet ponds are integrated into the overall design of the development providing an aesthetic amenity, if properly maintained (Figure 2.18).

Figure 2.18: A wet pond integrated into the landscape. This system is located within Central Park in Austin, Texas (photograph courtesy of Corey May, 2008)

2.7.2 Storm Water Wetlands

The federal government defines wetlands as lands that are typically inundated or saturated by surface or ground water at a frequency and duration that supports vegetation adapted for anaerobic conditions (Federal Register, 2006). Wetlands, often referred to as the sponges of the earth, characteristically include swamps, marshes, fens, quagmires, bogs, and other similar areas. Wetlands can be natural or man-made. Man-made or constructed wetlands usually serve a purpose for treating municipal wastewater and storm water, or the polishing of raw water for eventual water supply (Figure 2.19). These systems, either natural or man-made, are highly productive systems.

Figure 2.19: Aerial perspective of Tarrant Regional Water District's George W. Shannon Wetlands Water Recycling Facility (field scale phase) along Richland-Chambers Reservoir near Corsicana, Texas (photograph courtesy of Alan Plummer Associates, Inc., 2005)

2.7.2.1 Constructed Wetlands for Storm Water

Constructed wetlands are engineered systems designed to mimic the functions of natural wetland systems. Notable wetland functions include flood attenuation, settlement of particulates, and the uptake of nutrients (Moshiri, 1993). Specifically for storm water, constructed wetlands contain and treat surface water pollutants; thereby, decreasing the pollutant load to downstream receiving waters or storm water system (Strecker, et. al., 1992). Table 2.2 illustrates a wetlands ability to remove pollutants.

Table 2.2: Pollutant Removal Rates with Wetlands (Martin, 1995)

Pollutant	Removal Rate
Inorganic Solids	96%
Organic Solids	94%
Total Nitrogen	76%
Ammonia	37%
Nitrate	70%
Nitrite	75%
Total Phosphorus	90%
Unfiltered Phosphorus	53%
Filtered Phosphorus	78%

What separates wetlands from detention/retention systems is vegetation adapted to anaerobic conditions occupying the majority of the basin's surface area. Wetlands for the most part are shallow water systems with depths averaging less than two feet. Once water depths become greater than two feet, vegetative growth begins to retard. Deep water, which typically lacks vegetation, commences at depths greater than 6 ½ feet (Marble, 1992).

Storm water wetlands are characteristically classified into five designs: shallow marsh systems, pond/wetland systems, extended detention systems, pocket wetland systems, and fringe wetland systems (Schueler, 1992). The shallow marsh system is a land intensive (often in excess of 25 acres) system, which requires a reliable baseflow or groundwater supply to maintain the desired water elevation to support wetland vegetation year round (Schueler, 1992). The pond/wetland system is a two part system consisting of a wet pond to trap sediments and to reduce the inflow runoff velocity. This is initial pond system removes pollutants through settlement. The second part of the system is the shallow marsh, which further provides polishing of the storm water for improved water quality. This system is less land intensive than the shallow marsh system. The third system, the extended detention system, provides temporary vertical storage of storm water above the shallow marsh. This system is also a less land intensive system. The forth system, pocket wetlands, are designed for smaller sites. These systems typically receive infrequent rainfall which results in low vegetative diversity. Lastly, fringe wetland systems are found along the land/water interface of permanent bodies of water. The zone immediately adjacent to the land/water interface provides conditions suitable for vegetation adapted to anaerobic conditions (wetland vegetation). Comparisons of the five wetland systems for storm water are illustrated on Figure 2.20.

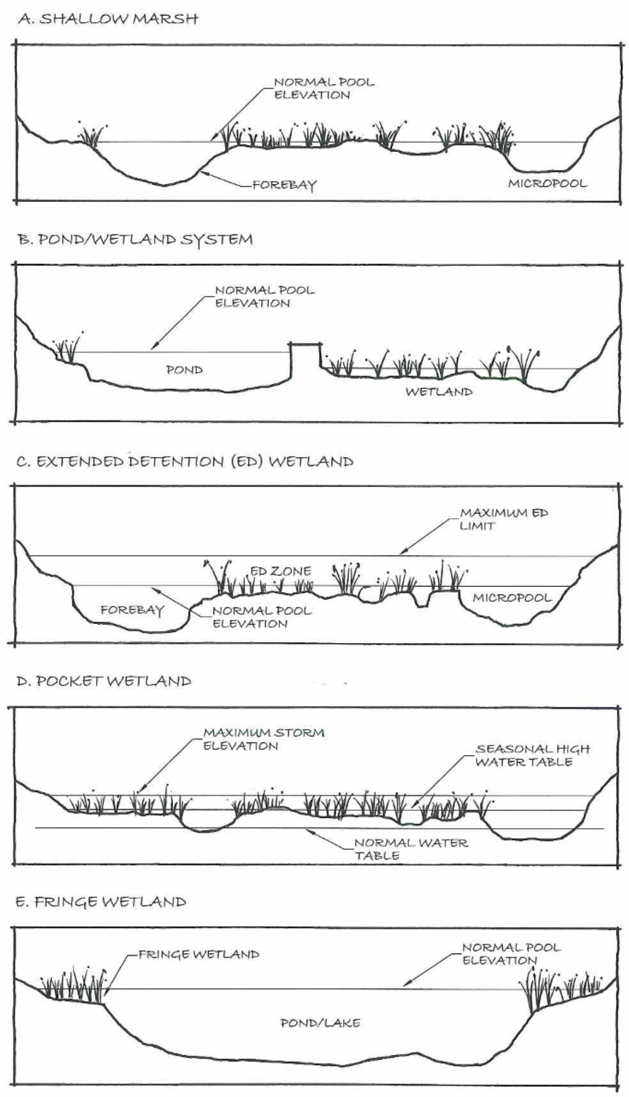


Figure 2.20: Cross-sectional profiles of the five storm water wetland systems (not drawn to scale) (Voight, adapted from Schueler, 1992)

2.7.3 Vegetative Biofilters

Vegetative biofilters are systems designed to collect storm water within defined areas and allow the vegetation within the structure to treat the runoff through vegetative filtration or soil infiltration (Field and Sullivan, 2003). These systems are also designed to detain the volume of storm water reducing the peak discharge to receiving waters. Typical vegetative biofilters include wet and dry grass swales, vegetated buffers or filter strips, and bioretention systems.

2.7.3.1 Grass Swales (wet and dry)

Grass swales are usually man-made, linear systems vegetated with grasses and specifically designed to filter storm water while conveying the excess storm water to its desired location (USEPA, 2004). These systems are usually constructed above the water table and lined with loamy to sandy type soils to allow for maximum infiltration. Grassed swales are often lined with rock check dams (Figure 2.21) to decrease the velocity of runoff allowing for increased infiltration (USEPA, 2004).

Figure 2.21: Roadside dry grass swale containing rock check dams within a residential area (Lake Superior Streams, 2005)

In residential or commercial areas where standing water is not usually desired, these swales are vegetated with turf grasses and remain dry during periods of no rainfall. Conversely, these systems can be designed for intermittently wet conditions. Systems allowing for intermittently inundated or saturated conditions are usually vegetated with wetland-type vegetation allowing for water quality benefits similar to constructed wetlands provided the retention time is sufficient (USEPA, 1999a). These solutions are usually situated along state or federal highways or large arterial streets (Figure 2.22).

Figure 2.22: Vegetated swale with wetland type vegetation (*Eleocharis spp.*) (Voight, 2008)

For dry grass swales, the predominant water quality benefit is the removal of suspended solids or sediments from the storm water. Dry grass swales do allow for rapid infiltration of storm water into the ground. Wet swales on the other hand are usually constructed with the native soils, which do not allow for rapid infiltration of water. Wet swales are generally broader than dry swales and may come in contact with the water table. Water quality improvement is usually achieved from the detaining of water for sufficient duration to settle pollutants and allow for those pollutants to be removed through microbial processes or uptake from the wetland-type vegetation (USEPA, 2004).

2.7.3.2 Vegetated Buffers (Filter Strip)

Vegetated buffers, according to the USEPA, are a “permanent, maintained strip of planted or indigenous vegetation located between non-point sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of diffuse source pollutants such as nutrients, pesticides, sediments, and suspended solids” (USEPA, 1993). In other words, these buffers receive the storm water from upstream areas and polish it before it reaches the downstream receiving water body or storm sewer system. These systems only handle surface flow and thus cannot handle concentrated pollutants. In general, these systems are integrated into the landscape of a development such as in conjunction with a riparian corridor along a stream or river. These systems characteristically serve as storm water pretreatment prior to its discharge into the receiving water body or the storm water system. Oftentimes, these systems are additional components of the overall storm water BMP design.

2.7.3.3 Bioretention Systems

Bioretention systems are dedicated areas that receive storm water runoff from parking lots, small commercial areas, or residential areas. These systems are usually areas occupied by a shallow depression where storm water is allowed to enter and collect on the surface. Over time, the collected storm water infiltrates into the ground (Figure 2.23). Water quality is improved with these systems through pollutant adsorption, filtration, volatilization, ion exchange, and decomposition (USEPA, 2004). Bioretention systems usually contain grass buffers, organic mulch and compost layers, planting soil, loam, and sand beds, check dams, and plants (Arvidson, 2006).

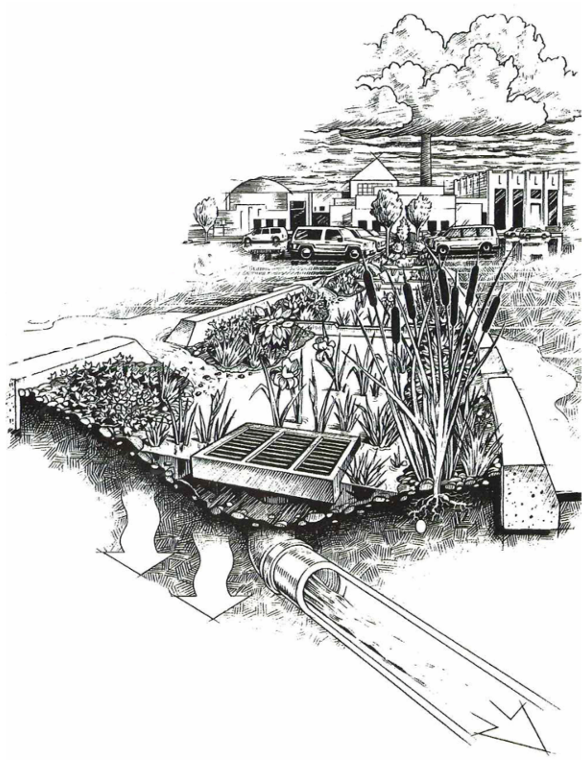


Figure 2.23: Conceptual bioretention system in a parking lot setting (Thompson, 1996)

2.7.4 Infiltration Practices

The primary function of infiltration systems is to capture a volume of storm water and infiltrate it into the ground over a period of hours or days. These systems have the potential to control the quantity and quality of storm water through the capture and containment of water, which lowers the pollutant concentration of the storm water runoff. A potential problem associated with this type of system is the contamination of groundwater. Water continuously infiltrated to the ground water could accumulate pollutants through contaminant migration (USEPA, 2004). Infiltration systems consist of trenches, basins, or porous pavements.

2.7.4.1 Infiltration Trenches and Basins

Infiltration trenches and basins are typically excavated areas designed for a specific size storm event. Infiltration trenches differ from basins in that they are generally shallower, sized for the smaller storm event, and are usually used in conjunction with other storm water BMPs. These systems are regularly lined with a filter fabric and filled with rock to create an underground reservoir. Infiltration basins, much like infiltration trenches, are systems used to divert a volume of storm water into an excavated basin that typically holds more volume than an infiltration trench. These basins may be open or filled with rock or geo-membrane and may or may not contain vegetation at the surface. The main purpose for either infiltration trenches or basins is to transform the surface water flow into a groundwater flow; thereby, removing pollutants through filtration, adsorption, and biological absorption. An additional component of trenches and basins is the reduction of the quantity of storm water to the receiving water body or storm water system. Much like dry detention basins, infiltration trenches and basins drain themselves within 72 hours to be readied for the next rain event (Field and Sullivan, 2003). In an installation at the Washington National Cathedral's Olmsted Woods (Figure 2.24), landscape architects spaced infiltration basins every 50 feet to facilitate water infiltration and to minimize the erosive forces of storm water to receiving water bodies (McIntyre, 2006a).

Figure 2.24: Infiltration basin at Olmsted Woods at the Washington National Cathedral during construction (McIntyre, 2006a)

2.7.4.2 Porous Pavement

Porous pavement is permeable paving surfaces that allow for storm water to percolate into the ground. Permeable paving surfaces include asphalt, porous concrete, modular perforated concrete blocks, cobble pavers with porous joints, crushed stone or gravel, or reinforced stabilized turf. Porous pavement reduces the need or size of on-site storm water treatment. These solutions work well in areas not frequently used such as overflow parking areas or fire lanes. The conversion of overflow parking areas

(Figures 2.25 and 2.26) are feasible solutions because studies suggest that the vast majority of retail parking is only used during peak periods (Thompson, 1996).

Figure 2.25: Reinforced stabilized turf in an overflow parking area (Thompson, 1996)

Figure 2.26: Overflow parking lot at a school stadium in Fort Worth, Texas (Voight, 2008)

2.7.5 Green Roofs, Rainwater Harvesting, and Rain Gardens

Green roofs, rainwater harvesting, and rain gardens are currently en vogue solutions for addressing storm water meanwhile adding a landscape or architectural element to the overall design. A number of these solutions are technically offshoots of the aforementioned storm water BMPs (e.g. rain gardens are essentially bioretention systems). Since these specific storm water BMPs integrate suitably into the landscape, they have been classified into an independent category.

2.7.5.1 Green Roofs

Green roofs, also known as roof gardens, vegetated roof covers, eco-roofs, and nature roofs, are landscaped roofs of commercial, institutional, or residential buildings to help mitigate the effects of urbanization by filtering, absorbing, or detaining rainfall (Liptan and Strecker, 2003). They are intricate, light weight solutions to soften a rooftop, which in turn provides a visual amenity to the structure's utilitarian use. Although the visual amenity is most likely the economic driver for the installation of these gardens, they do have the potential to provide environmental benefits such as reducing heat (Eisenman, 2004) and the sequestration of storm water (McIntyre, 2007a). Joe Fry in *Landscape Architecture* is quoted as saying "…a roof garden can have sustainable aspects while still being a social, comfortable, and symbolic space like any garden either on a roof or on grade" (McIntyre, 2007a).

Roof gardens can range from elaborate to the less flamboyant. In Chicago, Illinois, the City Hall building was equipped with a roof garden that cost an estimated

$45 per square foot, which included some roof repairs (Eisenmen, 2004). Conversely, a roof garden installation on a residential condominium in Washington D.C. ran an estimated $12 dollars per square foot (McIntyre, 2007b). Roof gardens appear, at first glance, to be costly solutions, but in actuality they can be quite affordable solutions.

As far as improving the quality of storm water, the jury is still out on the benefits roof gardens provide (McIntyre, 2007b). These solutions do curb and filter the initial rain event. However, it is recommended that roof gardens be used in conjunction with other storm water BMPs. In April 2008, Professor David Hopman in association with the University of Texas at Arlington installed the University's first green roof and is the only green roof installation in North Texas. This testing facility consists of two, 500 square feet plots to discern what types of vegetation would be best suited for the climate of North Texas and what types of water quality benefits these systems will provide. Upon successful completion of the project, a full scale design is scheduled for the University's new engineering research building scheduled to be online by 2010 (Greenroof, 2008).

2.7.5.2 Rainwater Harvesting

The collection of rainwater is an ancient practice. In Texas and in other arid to semi-arid areas, the gathering of rainwater is enjoying a renaissance. According to the TCEQ, rainwater harvesting is "the practice of collecting water that falls as rain before it has a chance to collect into the ground and become groundwater or run off into a watercourse and become surface water" (TCEQ, 2007). The predominant type of rainwater harvesting is from the collection of rain that falls on a roof or other impervious surface and is ultimately collected in some form of vessel (Figure 2.27). Typical uses of collected rainwater include non-potable and potable uses. Non-potable uses include but are not limited to landscape irrigation, laundry, and toilet flushing. Potable uses include drinking water, dish washing, food preparation, bathing, etc. Potable uses of harvested rainwater do require a considerable amount of treatment prior to usage (TWDB, 2005).

Figure 2.27: Typical residential usage of a rainwater harvesting system in an urban setting (Pioneer, 2008)

Rainwater harvesting is considered a storm water BMP since it can mitigate or eliminate the increased volume and velocity of runoff from impervious surfaces, which in turn reduces or eliminates the need for additional storm water BMPs. To quantify the potential benefits of rainwater harvesting, the volume of rainwater a 2,000 square feet impervious surface can capture from one-inch of rain is over 1,000 gallons. The Lady

Bird Johnson Wildflower Research Center in Austin, Texas harvests 300,000 gallons of water annually to irrigate its native landscape (TWDB, 2005).

2.7.5.3 Rain gardens

Rain gardens, which are essentially bioretention systems, are structures to treat storm water runoff from parking lots, roadways, driveways, or other impervious surfaces through the temporary collection of water and subsequent infiltration. Rain gardens are landscape elements that consist of a well planted area that is slightly depressed from the surrounding topography or infrastructure (Arvidson, 2006). Storm water is channeled to the area via pipes, curb openings, or gravity. Pollutants typically removed or reduced by rain gardens include nutrients, sediments, metals, and pathogens (Arvidson, 2006). Rain gardens do have their limitations. They cannot handle large volumes of storm water runoff. Rain gardens are usually sized to be three (3) to eight (8) percent of the size of the drainage area (Arvidson, 2006).

What separates rain gardens from bioretention systems are their ability to be integrated into the landscape for aesthetic purposes (Winogradoff, 2002). Echols and Pennypacker have coined the term “artful rainwater design” to describe rain gardens that evoke curiosity and discovery (Figure 2.28) (Pennypacker and Echols, 2008). Some rain garden installations “…exploit the placemaking potential” of storm water management systems (Figure 2.29) (Echols and Pennypacker, 2006). Rain gardens embrace storm water as a resource and are typically designed with the human in mind.

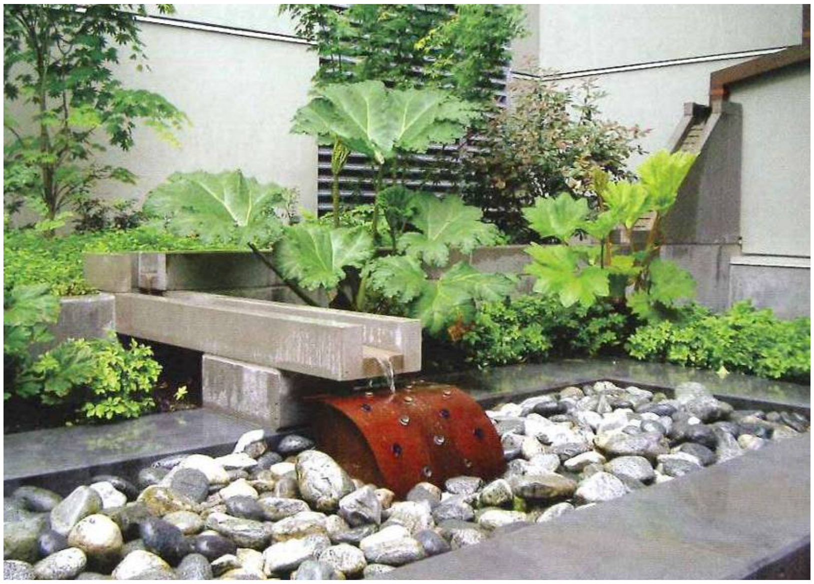


Figure 2.28: An artful rain garden that invokes curiosity at an apartment courtyard (Echols and Pennypacker, 2006)

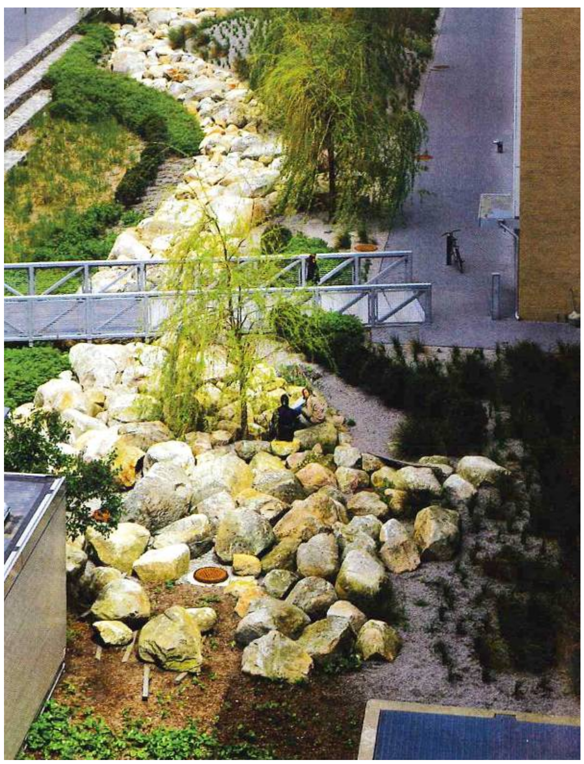


Figure 2.29: A rain garden installation at the MIT campus creating a sense of place (Echols and Pennypacker, 2006)

2.7.6 Other Technology Options

Other structural storm water options exist that are more mechanical, proprietary, or engineered in nature. These systems typically pinpoint certain pollutants for removal. The following include a generalized list of technological options for storm water BMPs:

- Surface Sand Filters
- Perimeter Filters
- Media Filter
- Underground Filter
- Water Quality Inlets
- Multichambered Treatment Trains
- Vortex Separation/Continuous Deflection Systems (USEPA, 2004).

Of the aforementioned technological options, surface sand filters are essentially the only surface storm water BMP that would offer any value for landscape design purposes. The City of Austin, Texas has implemented numerous of these devices throughout the city (Figure 2.30).

Figure 2.30: City of Austin, Texas' Gillis Park Sedimentation/Filtration Pond (City of Austin, 2008)

These systems are typically two chambered systems consisting of a sedimentation basin followed with a sand filtration basin (Figure 2.31) (USEPA, 1999b). Although these systems can be integrated into the landscape, they are still highly engineered structures.

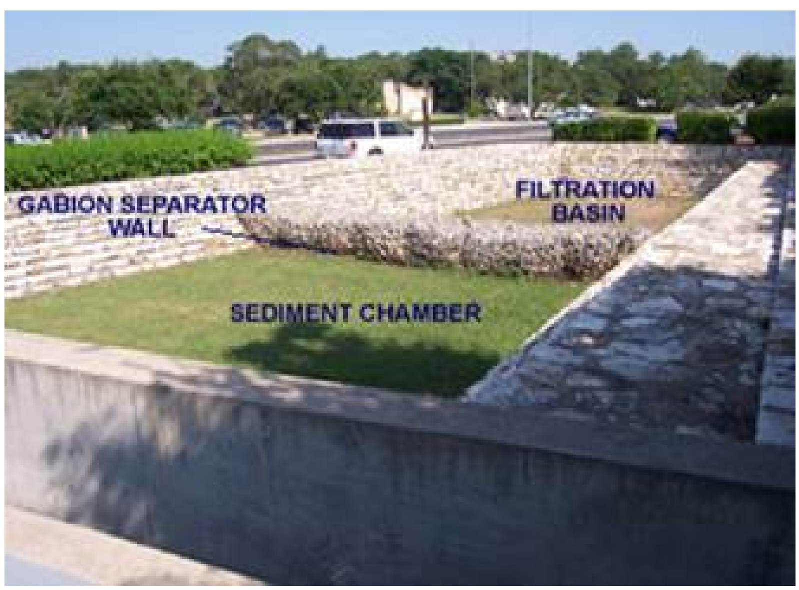


Figure 2.31: City of Austin sand filter design (City of Austin, 2008)

2.8 Current Trends for the Treatment of Storm Water in North Texas

2.8.1 North Central Texas Council of Governments

The NCTCOG, established in 1966 and the first of its kind in Texas, is an association of local governments established to assist in intergovernmental planning, cooperation, and coordination for sound regional development within its 16 county jurisdiction. Although the NCTCOG has no regulatory power or authority over its members, its informational clearinghouse and its ability to provide and recommend various regional planning programs are invaluable to its members.

A department within the NCTCOG organization addresses environmental and developmental issues. One of the duties of this department is developing strategies for tackling storm water concerns. It is through this department that a manual entitled *Integrated Storm Water Management* or *ISWM* was authored to assist NCTCOG members in addressing storm water concerns within their jurisdiction. *ISWM* is actually divided into two manuals: one for construction and one for site development. The manual for site development is applicable to post-construction storm water management.

2.8.1.1 Integrated Storm Water Management for Site Development

At its January 26, 2006 meeting, NCTCOG's Executive Board released *ISWM for Site Development* to participating local governments. The document is a detailed instructional guide for developers and government agencies to aide in the control and management of storm water quality and quantity within developing and redeveloping areas. Specifically, the manual suggests that developers or governmental agencies address storm water issues at the conceptual stages of projects. As such, the manual provides tools to achieve the goals of water quality and stream bank protection, and flood control. The primary aim for authoring the manual is regional adoption of its concepts. Regionalized adoption of the document will simplify engineering designs, minimize local government plan review efforts, facilitate multi-jurisdictional drainage analysis, and enable regional training opportunities (ISWM, 2006). The ultimate goal of this project is regional water quality improvement. Although the benefits of storm water management techniques as illustrated in the *ISWM* manual are significant, the manual fails to emphasize the importance of incorporating storm water BMPs into the design for aesthetic and/or wildlife habitat purposes. The manual only mentions the multi-purpose benefits of storm water management while discussing the five principles of storm water site planning in the first chapter of the document.

2.8.1.2 Integrated Storm Water Management Case Study

In February 2005, the NCTCOG through its sub-consultant AMEC prepared a report on the potential benefits of *ISWM* on the Big Fossil Creek watershed located in northern Tarrant County, Texas. The purpose of the report was to discern the benefits of incorporating the guidelines tendered by *ISWM* on a watershed basis compared to current storm water practices. The result of the project overwhelmingly supports the incorporation of *ISWM* guidelines on a watershed basis. Based on the findings in the report, Big Fossil Creek actually agraded using *ISWM* guidelines. A copy of the Big Fossil Creek report is included in Appendix A.

2.8.2 Municipal Storm Water Ordinances

Numerous municipalities within North Texas are upgrading their ordinances to address storm water concerns primarily to comply with current NPDES regulations. However, in randomly selecting cities in North Texas to review their ordinances, none suggest integrating structural storm water BMPs for multiple benefits. Of the reviewed ordinances, the requirements for placing specific structural BMPs into use were vague and poorly defined if defined at all. Of the ordinances that did specify the use of structural storm water BMPs, they were weak in their coverage of all possible land development activities. In North Texas, storm water ordinances, as currently written, will continue to promote strictly utilitarian storm water controls.

2.9 Economic Benefits of Aesthetic Storm Water Controls

Humanity over time has had a strong connection to water. Since people gravitate towards water, waterfront properties tend to increase in value compared to that of non-waterfront properties. To prove this point, the National Association of Home Builders conducted a study which concluded that similar homes in close proximity (within 300 feet) to a beach, pond, or stream had a 28 percent increase in value (NAHB, 1993). Commercial properties also benefit from being located adjacent to water. These properties tend to demand higher rent, have lower vacancies, and have lower tenant turnover (USEPA, 1995).

Within North Texas, there are a limited number of waterfront sites along lakes, ponds, rivers, or streams. There is, however, an opportunity to increase waterfront property through the use of innovative, structural storm water BMPs. There are two proven structural storm water BMPs that afford economic benefits: urban wet ponds and constructed wetlands (USEPA, 1995). It can be tested, in recent years, rain gardens and green roofs should be added to the list. If designed and maintained properly, wet ponds, wetlands, rain gardens, and green roofs can reduce the negative environmental impacts associated with development and subsequently increase a property's value.

Many consumers today prefer products and services that are environmentally friendly or "green" (USEPA, 1995). Most "green" goods and services sell at a premium compared to similar, conventionally crafted items. For the sake of storm water, developers who incorporate the use of natural drainage design features could meet federal, state, and local mandates for environmental quality while simultaneously promoting their development as "green" through increased habitat, a more diverse landscape, and its passive recreational opportunities.

Storm water management for water quality presents developers and designers with an opportunity to design more attractive projects that will have an advantage over the conventionally designed competition. Naturalistic urban runoff systems, especially when recreational and environmental areas are included, demand a premium. These items become the development's feature attraction and marketing signpost. Not to mention, these solutions generally cost less than sub-surface, highly engineered drainage systems (Boubli and Kassim, 2003) provided the space is available. As these areas mature over time, the current and future property owners can charge premiums for land with views of water, wetlands, green roofs, rain gardens, streams, and rivers.

2.10 Projects Utilizing Innovative Storm Water Best Management Tools

Numerous innovative storm water BMP projects have been implemented nationwide. These projects range from the most mundane storm water system, such as porous paving materials, to systems that invoke curiosity and exploration. The following are examples of innovative solutions to address storm water while still providing a visual aesthetic, creating a sense of place, enhancing wildlife habitat potential, and/or providing an educational opportunity.

Perhaps the most well-known and influential project addressing ecological design is Ian McHarg's work at the Woodlands, Texas. McHarg, in his book *Design with Nature*, developed a process for analysis of environmental conditions in layers or overlays and matrices to unearth locations that would provide sound development choices and complement the environment (McHarg, 1992). McHarg, in conjunction with his firm Wallace, McHarg, Roberts, and Todd (now Wallace, Roberts, and Todd), put the *Design with Nature* concepts to use and developed a plan for the Woodlands that addressed soil permeability related to storm water infiltration, surface water management of storm water, and provided a master plan devoted to open space and storm water management (Campbell and Ogden, 1999). This project was a holistic view of ecological development with storm water management as its cornerstone.

Developing with McHarg's *Design with Nature* processes actually saved (made) the owner, George Mitchell, millions of dollars (Spirn, 2000).

At Wellesley College in Massachusetts, Michael Van Valkenburgh Associates created a unique, sub-regional storm water design that turned a parking lot into a multifunctional ecological system. The project, which was situated on a former 13.5-acre parking lot and industrial site, created an events lawn, amphitheater, and a multifaceted storm water system (Figure 2.32). The storm water system consists of marsh feeder ponds, forebays, infiltration basins, and a cattail marsh to cleanse rainwater from the area prior to its discharge to Lake Waban (Freeman, 2006).

Figure 2.32: Aerial perspective of the storm water system and overall design at Wellesley College (Freeman, 2006)

The current guru of innovative storm water BMP solutions is landscape architect Tom Liptan (Figure 2.33) with the City of Portland, Oregon. Since 1990, Liptan has been promoting innovative, structural storm water BMPs throughout the city, which range from green roofs to rain gardens (Figure 2.34) to curb extensions (Figure 2.35).

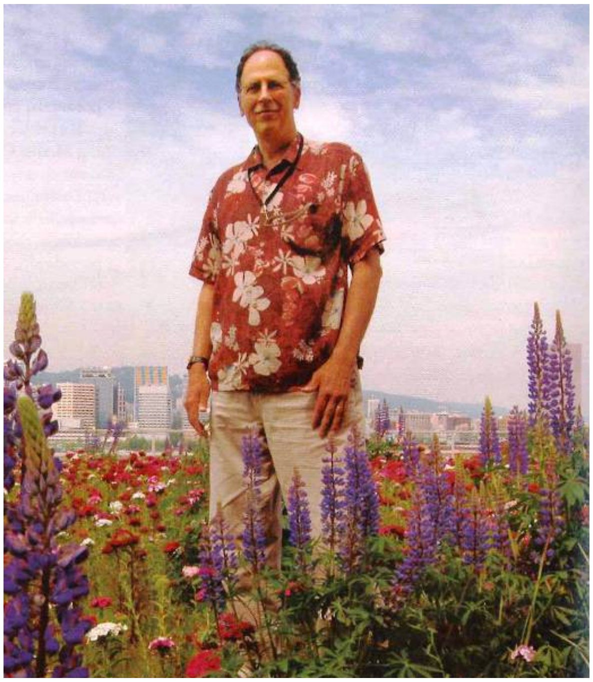


Figure 2.33: Tom Liptan atop Portland's Multnomah County Building Green Roof (Viani, 2005)

Figure 2.34: Rain garden at Glencoe Elementary in Portland, Oregon (Kays, 2006)

Figure 2.35: Curb extension located on Northeast Siskiyou Street in Portland, Oregon (Kays, 2006)

Currently, Portland has a database of over 2,000 permitted projects that manage storm water onsite, 400 storm water planters, and 30 green roofs (Vivani, 2005).

Lately, many landscape architects, architects, and engineers enjoy the advantages of marketing and the notoriety associated with obtaining a U.S. Green Building Council's Leadership in Energy Efficient Design (LEED) certification. LEED is a certification program and an accepted benchmark for the design, construction, and operation of energy efficient, sustainable buildings. For landscape architects, storm water BMP solutions offer the opportunity to obtain LEED points toward a design's certification. One such example is the Desert Botanical Garden project in Phoenix, Arizona, which obtained LEED points through low impact development, rainwater harvesting, and storm water reuse. Components of the design included pervious materials, rain gardens for infiltration (Figure 2.36), cisterns for rain harvesting, and multifunctional detention/retention areas (Kinkade-Levario, 2004).

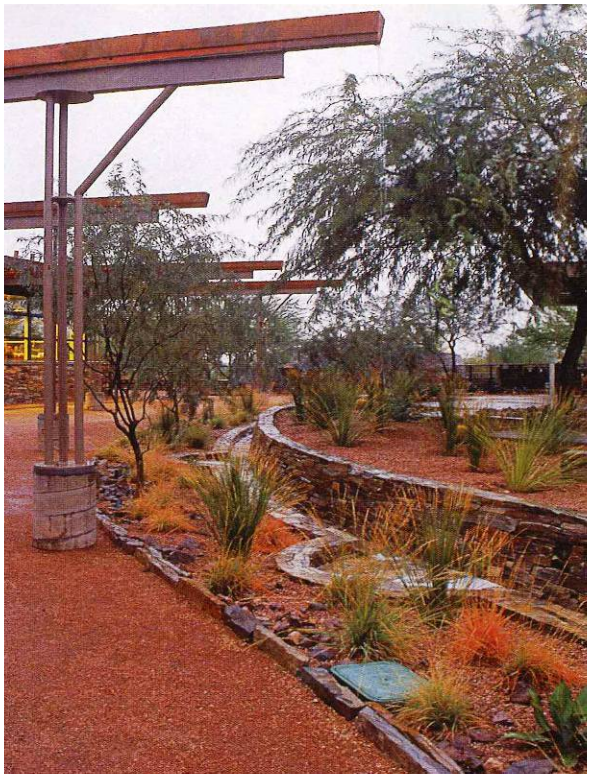


Figure 2.36: Rain garden at the Desert Botanical Garden in Phoenix, Arizona (Kinkade-Levario, 2004)

At the Shangri La Botanical Garden in Orange, Texas, the landscape architecture firms of Mesa Design Group and Jeff Carbo Landscape Architects in conjunction with the architecture firm of Lake Flato obtained the platinum LEED certification for new construction. Shangri La achieved LEED certification for energy use, lighting, water and material use as well as for incorporating a variety of other sustainable strategies (Shangri La, 2008). At the gardens, storm water is captured and harvested in storage tanks for reuse (Figure 2.37). Storm water not captured is either infiltrated into the soils through the use of pervious materials or directed through an educational wetland for polishing thereby enhancing water quality (Figure 2.38).

Figure 2.37: Rainwater collection storage tank at the Shangri La Botanical Gardens (Voight. 2008)

Figure 2.38: Educational wetlands at the Shangri La Botanical Gardens (Voight, 2008)

Projects around the country have designed storm water BMPs with people in mind. These solutions embrace storm water as an asset and therefore incorporate storm water elements into the overall design for the benefit of people. At the University of Virginia, the Dell incorporates an aesthetically pleasing comprehensive storm water solution into a once muddy, seldom used area. The overall design integrates storm water management BMPs such as bioretention meadows, a restored stream, and a wet pond into this once seldom used area (Figure 2.39). The Dell is now bustling with both wildlife and people (McIntyre, 2008a).

Figure 2.39: View of the Dell's restored stream and wet pond (photograph by Nelson Byrd Woltz Landscape Architects) (Scup, 2008)

In Portland, Oregon, a rain garden project was designed to "celebrate the bounty of rainfall in the Pacific Northwest" (Thompson, 2004). At the Oregon Convention Center, landscape architects Mayer/Reed with others conceived the idea of collecting and commemorating rainwater from the center's 5.5-acre impervious roof. The rainwater is directed to a rain garden designed with people in mind for the purposes of education (Figure 2.40).

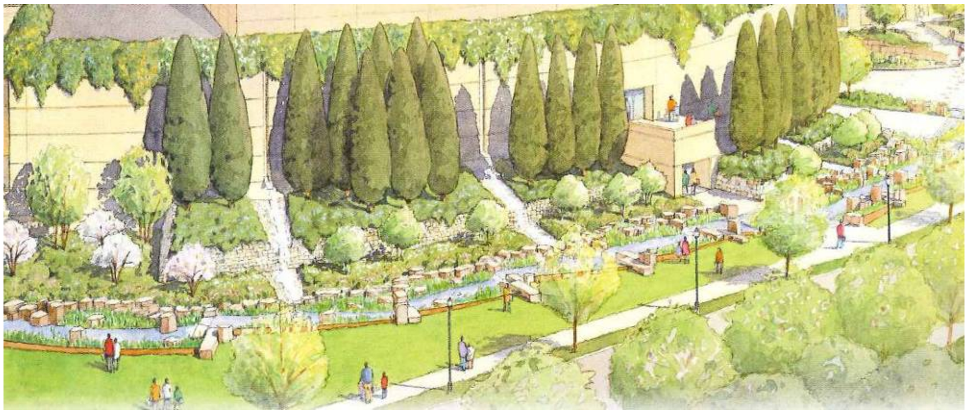


Figure 2.40: Conceptual rendering of the Oregon Convention Center's rain garden (Thompson, 2004)

In Seattle, Washington, an artistic roof garden installation at Washington Mutual's (now Chase Bank) headquarters is another instance where artful rainwater design was incorporated into a completely utilitarian space (Figure 2.41) for the benefit of people (McIntyre, 2007a). Not only do patrons of the building have the ability to admire the landscape, neighboring buildings have views of the roof garden as well.

Figure 2.41: Roof garden atop Washington Mutual's (Chase Bank) headquarters in Seattle, Washington (McIntyre, 2007a)

Lastly, a Monroe, Michigan convent developed a master plan centered on sustainability. The Sisters of the Immaculate Heart of Mary embarked on an ecological approach to revamp the convent for the 21st century. In doing so, the Sisters developed a less pervious concept that restored the native prairie to the area, constructed wet meadows, and installed a constructed wetland (Figure 2.42) (McIntyre, 2006b). By converting the landscape back to a more naturalistic environment, millions of gallons of water are retained onsite and thereby never reach the municipal storm sewer (McIntyre, 2006b). The wet meadows, restored native prairie, and constructed wetland have all enhanced the visual aesthetic of the grounds.

Figure 2.42: Constructed wetland and adjacent native prairie at the Sisters of the Immaculate Heart of Mary convent (McIntyre, 2006b)

All in all, these projects embody storm water as an asset. In doing so, these projects benefit the visual aesthetic of the area and in some instances increase habitat for wildlife. There are many other projects around the country realizing the benefits of incorporating innovative, structural storm water solutions for the benefit of human use and enjoyment, ecology, and the environment. Prior to this paradigm, the common practice of designers was focused on providing highly efficient drainage systems to rapidly collect and remove runoff through underground pipes, linear concrete streams, and engineered rectangular basins, which were often located at the back of the property, away from the public. Designers were driven by an attitude that storm water had no value as a useful resource and added little to the amenity of the urban environment (Wong, 2006).

However, as more and more people realize the benefits of incorporating innovative storm water solutions into the built environment, this new paradigm will continue to spread (Wong, 2006). In order for this model to be successful, it must embody a more holistic and multi-disciplinary approach to storm water design and management to ensure planning and design decisions are made with a reliable understanding of environmental, social, and economic consequences (Wong, 2006).

2.11 Conclusion

The use of strictly utilitarian storm water management tools has become common place in urban areas. This is due in part to regulations authored by the federal government, local governments, and/or local municipalities. These regulations dictate the type and use of both structural and non-structural storm water BMPs. As pithily articulated in an article in *Landscape Architecture*, “Rarely are storm water facilities conceived as places for people” (Echols and Pennypacker, 2006). To add to that, rarely are storm water systems designed to benefit the flora and fauna that are displaced by development. Storm water is considered a problem to solve rather than an asset to embrace.

Landscape architects and the profession in general have the opportunity to capitalize on the use of integrated and progressive storm water design solutions that can benefit both man and the environment. As a reminder, Landscape Architecture as defined by the American Society of Landscape Architects (ASLA) “…encompasses the analysis, planning, design, management, and stewardship of the natural and built environment” (Landscape Architecture, 2008). Echols and Pennypacker state “…this growing necessity to manage storm water onsite poses an intriguing opportunity to transform storm water management into an onsite design feature” (Echols and Pennypacker, 2006). They go on to say, “Some creative landscape architects are seizing this opportunity to create better storm water management systems while exploiting the placemaking potential of rainwater” (Echols and Pennypacker, 2006).

In closing, developing and redeveloping areas within the U.S. have to adhere to the storm water regulations promulgated by the CWA. Echols and Pennypacker in the aforementioned article summarize what storm water decision makers should attempt to accomplish with their development, “…rainwater design can…provide utility and amenity to effectively unite two critical facets of landscape architecture: stewardship of water and land and the creation of engaging, meaningful places for people to experience" (Echols and Pennypacker, 2006). Some cities, such as Seattle, Washington, Portland, Oregon, Austin, Texas, and others, are realizing the benefits of integrating innovative storm water management systems into developing or redeveloping areas. These innovative solutions thus far have been led by landscape architects (Thompson, 1996).

CHAPTER 3

RESEARCH METHODS

3.1 Introduction

Qualitative methods of research allow for the in depth study of selected issues without the constraint of predetermined categories of analysis (Patton, 1987). Therefore, qualitative approaches to research are uniquely suited for uncovering the unexpected and exploring new avenues (Marshall and Rossman, 1995). There have been numerous published studies detailing the merits and effectiveness of storm water best management practices (BMPs); however, no studies were identified as to why one solution was chosen over the other. Aside from a lifetime cost analysis, no studies were identified that provided insights into what drives the BMP selection process.

3.2 Research Design

A standardized, open-ended interview with qualified individuals is the qualitative data collection process utilized for this research. This format allows for the accumulation of large amounts of data within a limited timeframe (Marshall and Rossman, 1999). The standardized, open-ended interview consists of a series of questions carefully worded and arranged for the purpose of taking each respondent through the same sequence. Each respondent is asked the same questions with essentially the same words (Patton, 1987). This approach ensures that the fundamental issues are exposed meanwhile allowing for new data specific to each interviewee to materialize. According to Marshall and Rossman, the assumption critical to qualitative research is that the "…perspective on the phenomenon of interest should unfold as the participant views it, not as the researcher views it" (Marshall and Rossman, 1999). Consequently, the interviewer actively participates in the interview process by providing questions specific to the research content while maintaining the interview's focus. However, the interviewer must allow the interviewee to express his or her own views openly and respect how he or she frames their response.

To maintain the interview's content and focus, a series of interview questions are formulated in advance. During the interview process, these questions are asked exactly as they were written. The questions are designed to be as open-ended as feasible, allowing for as much depth and detail as possible in the interviewee's response (Patton, 1987). Open-ended questions provide a forum for elaborations, explanations, meanings, and new ideas (Patton, 1987) as opposed to the yes or no answers associated with closed-ended questions.

3.3 Research Questions

The questions explored in this research include:

1. What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or other similar "green" storm water BMPs in North Texas?
2. What is your perception with storm water BMPs in general?
3. What methods do you employ in the BMP selection process?
4. What drives the final selection of specific storm water BMPs?
5. What advantages do you see with the implementation of storm water BMPs?

6. What disadvantages do you see with the implementation of storm water BMPs?
7. What insights can you provide regarding storm water codes or ordinances?
8. What advice would you like to offer regarding the selection of storm water BMPs?

3.4 Qualified Respondents

A qualified respondent or key informant is an individual who displays the following characteristics:

- Knowledgeable on the subject,
- Ability to understand the questions presented,
- Ability to articulate an answer, and
- Possesses time and ability to participate in the interview process (Northcutt and McCoy, 2004).

Key informants often contribute insight, meaning, and understanding to the setting (Taylor and Bogdan, 1998) because they are intelligent and quick thinking people, at home in the realm of ideas, policies, and generalizations (Marshall and Rossman, 1999). For this study, key informants were selected from three categories of individuals within the storm water BMP assessment leg of the development process. The desired makeup of the key informant pool consists of equal numbers of bureaucrats, designers, and developers since they represent a different discipline within the decision making process. The desired respondents for this study are prominent individuals within the public sector specializing in water quality issues and regulations (bureaucrats), prominent individuals within the private practices of landscape architecture, architecture, and/or engineering (designers), and prominent individuals either self employed or employed by a known firm in the development community (developers). The names of individuals were obtained from personal sources, the North Central Texas Council of Governments, and from initial, informal conversations with other identified key informants.

Sixty nine key informants (47 bureaucrats, 13 designers, and 9 developers) were contacted via e-mail, by letter, or by telephone and asked to participate in this study. A minimum goal of three informants per category was elected to provide sufficient depth and detail into the idiosyncrasies of the BMP selection process. Ten key informants (four bureaucrats, three designers, and three developers) chose to participate by agreeing to be interviewed. These informants were assured anonymity through the consent form with anonymity as an explicit condition of their acceptance to participate in the interview process. Anonymity typically allows for the interviewee to be open and objective with their responses. All interviews were tape recorded to ensure that their responses were not misconstrued or misrepresented. The transcribed interview script and responses are included in Appendices B and C, respectively.

3.5 Data Analysis

The overall goals of the interview process are

- to identify if the use of innovative storm water BMPs are or are not widely used in the North Texas,

- to identify complexities in the selection process for storm water management tools,
- to identify opinions about storm water BMPs in general from each of the three categories of respondents, and
- to capture the complexities of their individual perceptions (Patton, 1987).

In order to identify common themes in and to corroborate the key informant's responses, triangulation of qualitative data sources is used. Triangulation of qualitative data sources compares the perspectives of people from different points of view (Patton, 1990). Triangulation validates information obtained through interviews by checking, categorizing, and coding what interview respondent's report (Patton, 1990). The point of triangulation is to identify and study when and why there are differences in the data (Patton, 1990). Patton suggests that triangulation provides consistency in overall patterns of data from different sources and reasonable explanations for differences in data from divergent sources, which contributes significantly to the overall credibility of findings (Patton, 1990). Triangulation, in this case, provides additional credibility to the research by comparing three different points of view from three different decision makers during the storm water BMP selection process. In comparing the individual responses, common themes are unearthed to further understand the fundamental issues with the storm water BMP selection process.

The interviews were conducted in person and telephonically during the months of October and November of 2008. The recorded interviews were transcribed immediately to ensure accuracy. In addition to recording the dialogue, detailed notes were taken during the course of the interviews to help formulate new questions, to facilitate analysis of the transcribed interviews (Patton, 1990), and to capture the body language of the interviewee when applicable (Taylor and Bogdan, 1998). Interviewee body language allows the interviewer to further comprehend what the respondent was reporting through non-verbal expressions (Taylor and Bogdan, 1998).

The transcribed interviews were then reviewed to identify common themes, typologies, and relations (Taylor and Bogdan, 1998). By analyzing the data for common themes, typologies, and relations, interpretations of the data begin to materialize. The initial interpretations of the data obtained from the interviews were then coded into distinct groups of meaning (key words or phrases) to further develop and refine the data (Northcutt and McCoy, 2004). The coding scheme or commonalities unearthed during the interview process allowed for relevant concepts or propositions to surface. These propositions can both validate or rebuke the initial thesis or take the thesis "…to a higher level of conceptualization" (Taylor and Bogdan, 1998).

3.6 Interview Subjects

Descriptions of the interview subjects are listed by the category of the decision process that they represent and in chronological order as the interviews were conducted. The interview subjects are as follows:

3.5.1 Bureaucrats

Bureaucrat #1 is a registered professional engineer in the State of Texas with over 30 years of experience as a project manager with extensive environmental engineering experience. He is currently employed by a large municipality in the North Texas area. His duties include conducting industrial storm water inspections, review of storm water pollution prevention plans, and assists with all aspects of the city's storm water program. He also provides regulatory compliance guidance to industries and the city. He actively participates in long term planning and provides interface with other local regulated entities and groups such as the NCTCOG and the Trinity River Authority of Texas. He is also involved in the city's emergency response planning and safety evaluations of emergency responses.

Bureaucrat #2 is a professional in the field of storm water and is currently employed by a large municipality in North Texas. He has had over eight years of experience dealing with storm water issues and concerns while working for two municipalities in North Texas. He has a bachelor's degree in chemistry and a master's degree in public administration. He is soon to complete a master's degree in environmental science. He also serves in the naval reserves as an oceanographer and meteorologist.

Bureaucrat #3 has eight years of experience in the storm water field. She is currently the storm water administrator for a mid-sized city in North Texas. Prior to being employed by the city, she worked for the Texas Department of Transportation as a storm water inspector for their projects. She has a bachelor's degree in environmental science.

Bureaucrat #4 has a bachelor's degree in mechanical engineering and is a registered professional engineer in the State of Texas. He has over 35 years of professional experience working for both large and mid-sized municipalities. Currently, he is a public works operations engineer for a mid-sized city in North Texas. His duties, among others, include the authoring of the city's storm water ordinance and the administration of the city's storm water program.

3.5.2 Designers

Designer #1 has a master's degree in landscape architecture and is a registered landscape architect in the State of Texas. He has over four years of experience as a park planner for municipalities in North Texas. Prior to becoming a landscape architect, he owned and operated his own landscape contracting business for 14 years. Duties associated with the contracting business included the installation and maintenance of storm water systems.

Designer #2 is a registered professional engineer in the State of Texas with over nine years of experience in design. He has a degree in agricultural engineering with an emphasis on environmental and natural systems. He currently works for a well-regarded environmental engineering firm in North Texas. Prior to his current position, he was employed by a well-respected North Texas landscape architecture firm for seven years. He has had the privilege of working in Washington State and is familiar with the state's storm water policies.

Designer #3 is a registered professional engineer in the State of Texas with over 25 years of experience. He has had the distinct privilege of working both as a city engineer and as a consulting engineer. He has a Ph.D. in civil engineering with an emphasis on environmental engineering. In his current position, he serves as a consulting engineer for a firm in the North Texas area. One of his clients is a small municipality in North Texas. Therefore, he has the ability to both design storm water facilities as well as review proposed storm water facilities on behalf of the municipality.

3.5.3 Developers

Developer #1 has been in the business for over eight years working for both mid-sized and boutique development companies. During his eight years, he has worked in both the construction and development spectrums of the business including the management of a portfolio of properties. He has done business in several North Texas cities as well as Texas in general, which included both infill and green field developments. His typical product line includes suburban and mid-rise office buildings and structured parking, industrial facilities, retail, and single and multi-family developments.

Developer #2 has over 38 years of development experience and currently owns his own commercial real estate firm in the Dallas, Texas area. Prior to becoming a developer, he was a registered architect. During his 38 years of development experience, he has worked for some of the largest developers in the nation. With those firms, he primarily worked on new developments and assisted in construction management. His current portfolio of developments include 53,000 square feet of retail space in Frisco, Texas, 140,000 square feet of office and warehouse space in Denison, Texas, and 56,000 square feet of office space in San Antonio, Texas.

Developer #3 is a registered professional engineer in the State of Texas with over 15 years of experience. She is currently employed by one of the more progressive residential development companies in North Texas. One of her current projects that recently commenced earthwork is incorporating numerous “green” storm water technologies in a proposed multi-use development. Prior to her current employer, she was employed by a national engineering firm for eight years and then by a national home builder and developer.

CHAPTER 4

INTERVIEW RESULTS

4.1 Introduction

The purpose of open-ended interview questions is to allow the respondent the opportunity to elaborate on topics of interest, as well as, to open new avenues of discussion, which facilitates a deeper understanding of the underlying thesis. As mentioned previously, the practice of triangulation was selected to provide credibility to the research by comparing three different points of view from three different decision makers in the development process. Triangulation validates information obtained through interviews by checking, categorizing, and coding what interview respondent's report. In comparing the individual responses, common themes, typologies, and relations are unearthed to further understand the fundamental issues with the structural storm water BMP selection process.

Eight interview questions were presented to the categories of respondents. The initial interpretations of the data obtained from the interviews were then coded into distinct groups of meaning (key words or phrases) and applied to a matrix to further develop and refine the data. The coding scheme or commonalities unearthed during the interview process allowed for relevant propositions to surface. These propositions can both validate or rebuke the initial thesis. Accordingly, the initial thesis presumed designer experience or lack thereof as the leading driver for the selection of structural storm water BMPs in North Texas. Upon analysis of the responses, the data actually disclosed a different proposition for the selection of storm water BMPs.

This chapter is organized in accordance with the eight interview questions offered to the key informants in the order presented. There were no attempts to lead informants toward particular answers. All quoted references are responses from the key informants during the interview process.

4.2 What Is Your Perception of Storm Water Wetlands, Green Roofs, Bio-Swales, Rain Gardens, and/or Other Similar "Green" Storm Water Best Management Practices in North Texas?

4.2.1 Bureaucrat Discussion

The predominant perception revealed in interviewing bureaucrats was that designers, developers, and the general public were not readily familiar with storm water controls and specifically "green" storm water controls. By way of example, one respondent stated, "…right now, they're ["green" storm water BMPs] not being utilized anywhere close to their full extent." He also stated, "From a policy standpoint, they're almost an unknown…" and "…I don't think the general public has really any idea of what it means."

A secondary perception of "green" storm water BMPs from bureaucratic points of view was one of appropriateness. One individual suggested that these solutions are just one tool in the entire toolbox of BMPs, "We have put some of these kinds of things into place as a part of some previous developments, but not very many…and they have not really been done in a fashion to try and optimize their benefit to improvements in water quality. These are just one element of a whole collection of elements that have to be implemented to benefit and improve water quality." Another bureaucrat stated, "Here's what's available [in our storm water manual]. Use and choose what would be applicable."

4.2.2 Designer Discussion

In discussions with designers, the predominant theme revealed coincided with the bureaucratic response; designers, developers, and the public are ignorant towards "green" storm water BMP solutions. For example, one respondent stated, "The knowledge is out there but a lot of people are not aware of it….or it's just not something they think of when they're planning their projects." Designers also implied that people get accustomed to what they are use to designing. "I think people need to quit doing what they've always done. I think more people are aware of it ["green" storm water BMPs], sort of in the back of their minds but not to the extent where they say, oh, we can solve this problem that way." Another designer stated, "I think we're just ignoring some of these issues ["green" storm water BMPs] and they're bound to be coming our way eventually."

Cost is another factor associated with the perception of "green" solutions. One respondent stated, "What ends up happening though is budgets are a factor…Because sometimes trying to employ these BMPs can get expensive."

4.2.3 Developer Discussion

Not surprisingly, the perception developers had with "green" storm water BMPs was that they are both inappropriate and costly. One developer stated, "From a developer's standpoint, it's expensive. We always have to be conscious of the cost and the impact and how that plays into the return of the project." Another developer said that "green" solutions are "inappropriate."

4.3 What Is Your Perception with Storm Water Best Management Practices in General?

4.3.1 Bureaucrat Discussion

The bureaucratic perception with storm water BMPs in general is that people are ignorant towards understanding storm water BMPs. One respondent states, "Storm water BMPs are very misunderstood…all the way down from the engineers, designers, architects, to the site operators, construction people, and even a lot of the city and regulatory staff." Another respondent stated, "We've got a long way to go...it's not an easy process to get implemented, and part of the reason it's not an easy process to get implemented is that to do these things requires changes in how you approach doing things around your operations." Another respondent states that as a Phase II city "We've only been under the requirements for a year now."

Cost is another concern offered by a bureaucratic respondent. He states that "All these things [storm water BMPs] that we're talking about have an increased cost." "It takes land. It takes cost and money for construction, and it takes cost and money to maintain it."

4.3.2 Designer Discussion

The designer's perception of storm water BMPs in general is one of ignorance as well as it being an ordinance requirement. One designer states, "…there is plenty of literature out there, it's [storm water BMPs} just not practiced. But a lot of the solutions that could be used, could be used in such a way that they actually become an amenity for a park or a site and not just an ugly piece of infrastructure." Another designer said, "There's a lot of detention ponds, a lot of retention ponds. There's really nothing about treatment, it's all about trying to maintain floodways and those types of things to keep people from being flooded. Those seem to be the primary BMPs."

One designer also feels that a lot of these storm water BMPs are strictly ordinance driven. For example, he states, "Most cities around here …are being a little short-sighted, and they're trying to make everybody detain and retain."

4.3.3 Developer Discussion

The developer's viewpoint of storm water BMPs was one of appropriateness and cost. By appropriate, one developer responded that some of the ordinances are promoters of inefficient use of space. For example, "I think innovative solutions on storm water management are appropriate. That being said some of the things fight against each other, large detention basins work against urban sprawl." Referring to cost, another developer said, "Land is not cheap and when BMPs are used, they consume land, which drives up the cost."

4.4 What Methods Do You Employ in the Best Management Practice Selection Process?

4.4.1 Bureaucrat Discussion

Bureaucrats considered ordinances, cost, and a holistic look at the system as the methods they employ in the BMP selection process. Since they are in the business of enforcing ordinances, this was the predominant answer for the BMP selection process. "…the vast majority of developments don't have a driver that let's them do it voluntarily. There is not some increase economic advantage by providing most of these permanent BMPs. You need to have a regulatory mechanism that requires these things."

Bureaucrats also considered, in a near tie with ordinances, cost as a factor in the BMP selection process. One bureaucrat reported by way of providing an example, "I'm [developer] going to go with the cheaper way to do it, the way that makes the most money for me in developing the property." Another respondent stated, "We're having to do this [storm water BMPs] along with the other things that we're doing water and wastewater wise with the resources that we have in place right now." He goes on to say, "We are in the process of developing a storm water utility fee…these fees will be used to support the cost associated with our storm water management plan and the best management practices for doing for each of those."

The regulators also considered looking at the development holistically. One respondent stated "…I think we're going to look at the specification of the BMP and whether or not it's correct for the site." He continues, "What we will be looking from a

BMP selection standpoint is to know we're looking at a stand back, big picture look at the site and how best a BMP is going to address the runoff coming from the site."

4.4.2 Designer Discussion

The designer response for the selection of BMPs addressed appropriateness and cost. For example, one designer simply stated, "We ask the questions, Can we do it practically and what's it going to cost?" Another designer stated that the selection of BMPs is determined on designer experience including ordinance guidelines. "When I think of BMPs, I think of probably in this vicinity, I think mainly of detention and retention ponds. Most of the methods are usually dictated by the cities and what they want or they require."

4.4.3 Developer Discussion

Again, developers considered cost as the primary driver for the employment of BMPs in developments. One developer declares, "It [BMP selection] has a lot to do with land costs." However, developers do look at the big picture and discern which BMP is best for the development. One is quoted as saying, "A lot of times, it [BMP] is dictated project to project. Another developer states, "I rely on the experience of the engineers and architects I employ." Competition by way of cost also plays into the developer's mindset, "If I want to be a responsible developer and develop this in an energy-efficient manor, but my competitor doesn't do that so my cost is higher, why I can't compete with him."

4.5 What Drives the Final Selection of Specific Storm Water Best Management Practices?

4.5.1 Bureaucrat Discussion

The bureaucrats almost unanimously considered cost as the driver for the final selection of storm water BMPs. One bureaucrat said succinctly, “probably cost.” When prodded further, he said, “At this point, I would say it’s going to be short-term upfront cost.” He goes on to say, “I think our biggest problem is cost and understanding the difference between a short-term cost and a long-term cost.” Another bureaucrat states, “From a regulatory standpoint, you’re always faced with the developer wants to do the minimum. What’s the cheapest I can do?”

4.5.2 Designer Discussion

The designers agreed with the bureaucrats by saying cost drives the final selection of storm water BMPs. One designer stated, “I know you’ve probably heard this before but budget has a lot to do with it, and everyone is going to tell you that because typically that’s it.” Another designer stated, “Unfortunately, it’s usually the cost.”

4.5.3 Developer Discussion

Developers enjoy maximizing the bottom line and therefore cost is the primary driver for the selection of storm water BMPs. One developer said, “I leave the specific selection of storm water BMPs to the engineers and architects I employ for the design. Cost, of course, is the final selector.” Another developer considered cost as a primary factor but he did at least have concerns for how the storm water BMP integrates into the development. He stated, "From a developer's standpoint, I think that a lot of times it does get down to cost, and how does that work, and how does it fit within the project."

4.6 What Advantages Do You See with the Implementation of Storm Water Best Management Practices?

4.6.1 Bureaucrat Discussion

The ability of storm water BMPs to holistically enhance water quality was the primary response from the bureaucrats. One respondent said, "The main advantages are that I should get some improvement in the water quality." He goes on to say, "It [storm water BMP] should have an environment that makes it more desirable to visit, more accessible, more usable." Another respondent stated, "…storm water quality is the plus." Yet another respondent stated, "Water quality is going to be better for sure in our streams. Just all around, it's going to help one of the most valuable resources that we have and that's our water." The following statement, offered by one of the respondents, summarizes the bureaucrat's primary focus, "I'm just looking at the overall benefit to the environment in general."

4.6.2 Designer Discussion

The designers also feel that the holistic improvement to the environment is the primary advantage offered by storm water BMPs. One designer stated, "I think the advantages help the environment. Instead of passing our storm water problems to the next county or the next city, we're going to take that water and try to hold it on our site longer so that we can allow it to recharge back into the ground where it really needs to be – water quality."

4.6.3 Developer Discussion

The developer's responses were divided on the advantages tendered by storm water BMPs. One developer was concerned with the holistic impacts to infrastructure whereas another developer did not see any benefits with the implementation of storm water BMPs. The developer commenting on infrastructure stated, "It is definitely something we're all going to have to pay a lot of attention to because the repercussion to our cities and our roads and infrastructure could just be almost catastrophic." The developer that did not see any advantages from the implementation of storm water BMPs is quoted as saying, "There are none. Cities only make us install these." Strangely, none of the developers commented on the implementation of storm water BMPs offering protections or improvements to the environment.

4.7 What Disadvantages Do You See with the Implementation of Storm Water Best Management Practices?

4.7.1 Bureaucrat Discussion

The bureaucratic response to the disadvantages associated with storm water BMPs was the upfront cost with implementation and the associated long-term maintenance cost. One respondent stated, "The biggest disadvantage is that these things cost money. They're going to make for more cost. The first cost of including them in or dedicating the land to them, and there is the secondary cost of maintaining them whatever they are." Another respondent said, "It's going to be cost. Maintenance cost, I guess, would be my best [guess], and that's a hidden cost because you put it [storm water BMP] in and nobody thinks about how much it's going to cost over the next year." Another respondent mentioned cost but he also mentioned appropriateness, "There's some [storm water BMPs] out there that, as far as I'm concerned, that are to me unreasonable, very costly, and aren't for a particular area or city."

4.7.2 Designer Discussion

The designer's perspective on the disadvantages associated with the implementation of storm water BMPs were the general lack of knowledge and the cost associated with implementation. One designer is quoted, "One disadvantage is that there's not enough education about it [storm water BMPs]. More people need to know about some of the other possibilities or some of the other practices that can be used for storm water management."

In referring to cost, one designer stated, "At this point to a certain extent maybe upfront cost. If you really think about it that should not be a disadvantage but it is. Budget drives things." Another designer said, "Cost is a huge disadvantage."

4.7.3 Developer Discussion

The developer consensus associated with the disadvantages of storm water BMPs was appropriateness and cost. One developer stated, "The smell, the cost, the attractiveness. You've just got to cover all those different things and the use of the land." Another developer stated, "The bottom line is dollars and cents."

4.8 What Insights Can You Provide Regarding Storm Water Codes or Ordinances?

4.8.1 Bureaucrat Discussion

Strikingly, the bureaucratic response to providing insights on codes and ordinances that address storm water was one of ignorance on both defining and developing codes and ordinances as well as interpretations of the codes and ordinances. For example, one regulator stated, "Frequently the intent of the ordinances as was written and the implementation of the ordinances are two different things." Another respondent said, "Writing good coherent, strong ordinances to begin with that express the desires and the intents of what you're trying to do with the ordinance." Another bureaucrat declared, "I don't think they're [codes and ordinances] where they need to be as aligning with either the federal or state codes or Phase II permit." He continues, "I think there needs to be a lot more alignment of those things [codes and ordinances] so that the development community is aware that they need to do these things and what role they're going to play and what role the city will play."

4.8.2 Designer Discussion

The designer perspective on codes and ordinances was one of inappropriateness. For example, one designer stated, "I think it's still in a lot of city's codes and ordinances [that] don't allow designer and builders to do things that we really shouldn't be doing." He goes on to say, "I think the codes and ordinances still need to be changed further in order to try to encourage more use of green roofs, bio-swales, and rain gardens and other methods of storm water practices." Another designer said, "…storm water codes sometimes can be short sided."

4.8.3 Developer Discussion

Developers insist that codes and ordinances increase cost. One developer said, "From a developer's standpoint, it gets pretty expensive and this goes beyond storm water stuff." He goes on to say, "City mandates and codes have almost made it where you practically have to halfway develop the site plan before you can even get a zoning change or do anything to see if you can use the property for how you want to use it." Another developer said, "Their [designer] responsibility is to abide by the codes and the legislation and the management practices, and then just tell the developer this is what it is, and then we make the decisions if that cost is affordable or we need to go to the next site."

4.9 What Advice Would You Like to Offer Regarding the Selection of Storm Water Best Management Practices?

4.9.1 Bureaucrat Discussion

The bureaucrats offered three main points of advice: be mindful of the cost, educate the uninformed, and look at storm water holistically. With regard to cost and looking at the project wholly, one regulator stated, "Make this a holistic approach to the evaluation of the BMP then include what the long-term cost is and make the provisions necessary to maintain the system. Unfortunately, that makes a more expensive job." Another respondent commented on educating the uninformed, "I think there's going to have to be a public education process. Really, a philosophy change, a paradigm shift, as for the selection of storm water BMPs." Anther respondent reported on appropriateness and cost, "They [storm water BMPs] should be reasonable. They should be flexible to fit realistic needs. They should be common-sense based, and be cost-effective."

4.9.2 Designer Discussion

The advice offered by the designers was across the board and included cost, educating the uninformed, appropriateness, ordinance, and looking at the common good. For example, one designer said referring to cost, "I think the advice for developers would be to ask then to consider spending a little more money and try to do something the right way instead of always going for the cheapest fix, which is typically what they do." Another designer combined cost with appropriateness, "The best think is that you're trying to work with your client to save them money, but you also want to make sure that it's aesthetic and it's not just a hole in the ground just to get them through development."

With regard to education and ordinance, one designer said succinctly, "More education. I want the developers to consider, research, look into other possibilities, to search beyond the status quo." In referring to cities, one designer said, "There are other cities that know their ordinance has not really been reviewed, it's just a blanket deal."

As far as altruism, one designer said, "Occasionally you will see developments where a lot of consideration has gone into the project." He goes on to say, "I just ask them to please spend a little more time and money and try to do something better for all of us."

4.9.3 Developer Discussion

The developer response was looking at the development holistically. They would like to see the requirements mandated by cities serve multiple purposes. For example, a developer said by way of example, "If you can get dual credit for the landscaping requirements through the use of storm water BMPs, I like that." Also, looking at storm water regionally was another suggestion offered by developers. One developer said, "If there is a way to do a fund where they would go in and start, instead of requiring a bunch of stuff [storm water BMPs], they can increase the capacity of their storm system instead of having a bunch of best management practices onsite."

4.10 Analysis

The responses to the eight interview questions presented to the categories of respondents revealed six recurring themes, which were grouped into keys words or combination of words. The six key words or combination of words, placed in alphabetical order, are as follows:

- Altruism,
- Appropriateness,
- Cost/Expense,
- Holistic,
- Ignorance/Experience, and

- Ordinance.

Altruism was a recurring theme due to the respondents stating that selection criteria are either for the good of the development or for the good for the environment. Appropriateness was elected as a recurring theme due to respondents stating that criteria may or may not be suitable for a desired solution. Cost/Expense was a recurring theme evident in all responses to the questions provided by the respondents. The respondents reported that thinking holistically had the ability to improve water quality or improve the overall design of their development. Ignorance/Experience was chosen since respondents reported that the selection criteria may be predicated on individual experiences and/or the lack of knowledge with an equitable solution. Lastly, a concern with ordinances was a recurring theme in replies from the respondents.

To further analyze the data obtained from the key informants, the six words or combinations of words were applied to a matrix. Each time a recurring theme relevant to one of the key words was mentioned by a key informant, it was recorded on the matrix. As shown on Table 4.1, the overwhelming driver for the selection of structural, storm water BMPs is cost, followed by in a tie appropriateness and ignorance/experience. The remaining three in order of responses were ordinance, holistic, and altruism. The fully populated matrix is included in Appendix D.

Table 4.1: Frequency of Responses to Common Themes during the Interview Process for all Questions

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	5	9	63	33	17	17
Designer	3	31	29	16	12	4
Developer	1	15	24	6	2	7
Total	**9**	**55**	**116**	**55**	**31**	**28**

The following tables address the findings from each individual questions presented to the qualified respondents.

Table 4.2: Frequency of Responses to Common Themes Recorded from Question 1

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	1	2	0	6	1	3
Designer	0	3	2	5	0	0
Developer	0	2	5	1	0	0
Total	**1**	**7**	**7**	**12**	**1**	**3**

Table 4.3: Frequency of Responses to Common Themes Recorded from Question 2

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	1	1	6	8	0	2
Designer	0	7	0	3	2	0
Developer	1	5	4	1	1	1
Total	**2**	**13**	**10**	**12**	**3**	**3**

Table 4.4: Frequency of Responses to Common Themes Recorded from Question 3

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	2	1	11	3	11	2
Designer	0	4	3	1	3	0
Developer	0	1	1	2	0	2
Total	**2**	**6**	**15**	**6**	**14**	**4**

Table 4.5: Frequency of Responses to Common Themes Recorded from Question 4

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	0	3	11	2	1	1
Designer	0	3	10	0	1	0
Developer	0	1	4	0	1	2
Total	**0**	**7**	**25**	**2**	**3**	**3**

Table 4.6: Frequency of Responses to Common Themes Recorded from Question 5

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	1	0	1	0	0	6
Designer	0	2	0	0	0	4
Developer	0	0	2	0	0	1
Total	**1**	**2**	**3**	**0**	**0**	**11**

Table 4.7: Frequency of Responses to Common Themes Recorded from Question 6

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	0	1	28	0	0	0
Designer	0	3	7	1	2	0
Developer	0	2	3	0	0	0
Total	**0**	**6**	**38**	**1**	**2**	**0**

Table 4.8: Frequency of Responses to Common Themes Recorded from Question 7

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	0	0	0	8	4	0
Designer	1	4	3	1	1	0
Developer	0	2	3	2	0	1
Total	**1**	**6**	**6**	**11**	**5**	**1**

Table 4.9: Frequency of Responses to Common Themes Recorded from Question 8

	Altruism	Appropriateness	Cost/Expense	Ignorance/Experience	Ordinance	Holistic
Bureaucrat	0	1	6	6	0	3
Designer	2	5	4	5	3	0
Developer	0	2	3	0	0	0
Total	**2**	**8**	**13**	**11**	**3**	**3**

4.11 Conclusion

When looking at the big picture, the overwhelming number of responses indicates that cost is the reason for the selection of storm water management tools in North Texas with appropriateness and ignorance/experience as the secondary drivers (tie). But, when you look at the data individually, bureaucrats and developers say cost or expense impels the selection of storm water management tools in North Texas. Whereas, designers suggest that appropriateness should be the leading principle. Beyond cost and appropriateness, the drivers for the selection of storm water management tools begin to blur.

Bureaucrats indicate that storm water management tools are selected based on the past experience or ignorance towards other equitable solutions. In other words, what has worked in the past will suffice. This was followed with looking at the management tool holistically and of course what the ordinance says as the tertiary drivers (tie).

Designers suggest that the secondary selector for storm water management tools is cost followed with ignorance/experience. One can understand this perspective. A designer's thought process is lets one study what is appropriate first, then how much is this going to cost, and lastly what has worked in the past.

Developers, once they get past the sticker shock, indicate that appropriateness of the selected BMP is the next standard followed with looking at the big picture or holistically. Developers produce a product and as such prefer that the appropriate solution is applied to that product. Once a solution is selected, developers ask, "How does that solution fit into the overall scheme of the development?"

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

5.1 Introduction

Based on the literature review, this is the first study that used a qualitative approach in researching the factors that influence the selection of storm water management tools through the solicitation of responses from representatives of the development process. The data obtained through the interviews revealed insights to further understand what drives a representative of the development process to select a particular management technique. If an individual understands what a bureaucrat, designer, or developer considers important, they can gear their discussion to overcome those barriers to at least allow for the consideration of an alternative, more aesthetically pleasing solution or a solution that benefits the environment.

During the interview process, respondents indicated that the predominant storm water management tool being used in developments are detention ponds. For example, a bureaucratic respondent stated, “By in large, the two things you are going to see are silt fencing and detention ponds.” A developer responded, “A lot of what is being done now is detention ponds.” A designer affirmed, “There’s a lot of detention ponds [and] a lot of retention ponds.” In North Texas, these solutions are commonplace. Their function is predominantly for flood control. They are not designed for aesthetic purposes such as defining a sense of place or for environmental purposes such as establishing habitat. They are purely utilitarian solutions to satisfy NPDES regulations and municipal ordinances.

The following discussion defines the factors that influence representatives of the development process in the selection of storm water management practices.

5.2 Discussion

Overall, the data indicated that cost or expense of the BMP was the primary factor influencing the selection of a specific management technique to address storm water. Developers make the ultimate decision for the implementation of a particular storm water management tool. Since maximizing the return on investment is the main reason for being in the development business, developers typically do the minimum to satisfy the storm water ordinance requirements. There are not many altruistic developers that choose a more aesthetic or environmentally friendly solution. Therefore, it is up to either designers and/or bureaucrats to educate or become educated, to promote, and to be familiar with innovative storm water management techniques; techniques that provide both amenity as well as utility.

Although the data pointed to upfront cost as the primary issue, other factors do influence the decision process for the selection of storm water management practices. The data indicated that representatives of the three tiers of the development process do look at what is appropriate or conversely what is inappropriate for the site. The data also suggests that ignorance with a particular solution or experience with a particular solution facilitates the selection of a specific storm water management tool. Landscape architects and engineers are licensed in the State of Texas. Their livelihood hinges on maintaining that license. Therefore, these individuals usually err on conservatism and stay with known, proven solutions. To overcome this, education and becoming familiar with these innovative storm water management tools is paramount for increased implementation. Pilot projects demonstrating the ability to design for both amenity and utility can ease designer and bureaucrat apprehensions.

Although the data indicates cost, appropriateness, and ignorance/experience are the overall factors for the selection of storm water management tools, the data disclosed individual themes for the selection of storm water management tools from each of the three representatives.

5.2.1 Bureaucrat

Bureaucrats responded that cost is the primary factor that drives the selection of specific storm water management techniques. Bureaucrats are actually concerned with long-term maintenance costs. One bureaucrat stated, "I've got the cost as a regulator of monitoring that structure over its life to make sure that it is maintained." If landscape architects can prove that these innovative storm water solutions are comparable if not less costly in terms of long-term maintenance, then bureaucratic apprehension is lessoned.

Beyond cost, bureaucrats considered experience as the secondary factor in the selection process. They tend to stick with what they know. They know how the system works and how to maintain that system. To overcome this aspect, landscape architects must educate bureaucrats on how these innovative systems work. Lastly, bureaucrats said that both what is in the ordinance and looking at maintaining water quality over the entire system gets the final approval of specific BMPs. Landscape architects must be familiar with municipal storm water ordinances and codes. If the code or ordinance is outdated, landscape architects must be prepared to address this through previous proven projects. Lastly, bureaucrats want to improve water quality holistically throughout their jurisdiction. Landscape architects must embrace that concern and prove how these innovative solutions can achieve that goal.

5.2.2 Designer

Designers consider what is appropriate for the site foremost. However, cost and experience do play important roles in their selection process. As mentioned, engineers, architects, and landscape architects are licensed in the State of Texas. Their primary purpose is maintaining the health and welfare of mankind. Therefore, they design solutions to promote this mantra. To overcome this, landscape architects must provide prudent quantifiable data on how these solutions can be appropriate for a particular project, be cost effective, and provide education to overcome the experiential bias.

5.2.3 Developer

Developers are concerned with the bottom line. Landscape architects need to prove that these solutions will increase the bottom line through increased revenues, longer rental agreements, faster sales at a premium, etc. If this can be done, developer apprehension will lesson. Lastly, developers hire designers to suggest what is appropriate and to incorporate that solution into the overall scheme of the development.

For example, one developer stated, “I tend to leave the selection of specific storm water BMPs to the engineers or architects I employ.” Developers are not the technically savvy designers and as such depend on the team they hire to suggest the best solutions to accomplish the overall goals of the development. Therefore, the selection and suggestion of specific storm water BMPs falls back to the designer.

5.3 Implications for the Profession of Landscape Architecture

Over time, landscape architects have played an important role in design, restoration, wetland mitigation, remediation, policy, and construction of environmentally related projects. Storm water is another avenue where landscape architects can play an important environmental role and follow their creed of “…analysis, planning, design, management, and stewardship of the natural and built environment” (Landscape Architecture, 2008). In other areas of the United States, landscape architects are providing utility and amenity through the use of artful storm water design. However, in North Texas and in other areas of the country, storm water management techniques are either nonexistent or they are purely used for utilitarian purposes. If landscape architects can learn to overcome objections to cost, appropriateness, and ignorance towards these innovative management techniques, they can be at the forefront of providing more meaningful designs utilizing storm water as a corner piece.

In North Texas, bureaucrats and landscape architects can work symbiotically to facilitate education of these innovative storm water BMPs. Through the implementation pilot storm water management projects, these can demonstrate the effectiveness of designing storm water facilities that satisfy both amenity and utility. If a developer can be persuaded through landscape ordinance credits or other beneficial means, pilot projects can be installed within private developments to demonstrate the effectiveness of designing for both amenity and utility.

Education is another important factor in promoting storm water management techniques for multiple uses. Landscape architects, especially in North Texas, must be advocates for implementing innovative storm water management tools. They have to educate their clients including hard-line representatives of municipalities. Grass roots education programs, such as brown bag seminars to engineering firms, could garner increased interest in designing storm water facilities for amenity and utility.

Landscape architects at times are on the project team solely to provide a planting plan at the tail end of design. In order to overcome this, landscape architects must be proactive in design solutions and demand to be on the team at the fore of design. Landscape architects need to take a proactive role in storm water design.

Public awareness of successful projects incorporating storm water techniques for amenity and utility can increase the usage of these innovative solutions. The use of news media, periodicals, journals, news print, and others can promote increased public awareness of these projects and thereby potentially increase demand for these projects. However, the public awareness campaign must reach other media outlets outside of the landscape architecture parasol. For example, engineers design a majority of storm water solutions in North Texas. Engineering firms and their related media outlets should be targeted for publishing articles about innovative storm water solutions that provide multiple benefits.

5.4 Suggestions for Future Research

This study provided cursory details for the sprawling nature of today's modern city and its resulting impact on watersheds in urban and urbanizing areas. To mitigate for those impacts to watersheds, this study provided examples of tools for addressing impacts to watersheds. This study also provided examples of innovative storm water management solutions that are being implemented throughout cities in the United States that provide an amenity as well as provide a specific utility. But as this study progressed, many new questions surfaced. Questions for future research include:

1. Are innovative storm water management tools such as rain gardens more costly than detention ponds or basins?
2. Are innovative, multi-use storm water management tools appropriate?
3. What is aesthetic storm water design?
4. Is designer experience with storm water management tools quantifiable? If so, how?
5. Provide a comparison of conventional storm water management tools to low impact development tools for creating a sense of place.
6. What are the advantages and disadvantages of large-scale regional storm water parks versus the small-scale individual development storm water management techniques?

7. If cost was not a factor, would the composition of the common themes provided by the respondents change?

8. Can storm water management tools provide both an amenity and utility in North Texas?

9. Do storm water BMPs or low impact development techniques promote sprawl?

10. Do storm water management tools increase or decrease the carbon footprint?

11. Can storm water management tools, if designed properly, account for both a landscape ordinance and storm water ordinance?

12. Are the storm water ordinances in North Texas proponents of inefficient use of space?

13. What are the environmental consequences of current storm water management techniques versus the more innovative techniques?

14. What types of innovative storm water management techniques are appropriate for North Texas?

15. What types of artful rainwater design pilot projects are appropriate for North Texas?

16. Do landscape architects have a say in storm water management decisions?

17. Do artful rainwater design solutions offer a premium (in terms of return on investment, increased rents, less tenant turnover, etc.) over conventional rainwater designs?

5.5 Conclusion

This study is essentially an overview to discern the decision criteria for the selection of storm water management techniques from the decision makers of the development process. Although the respondents to the interview questions did suggest common themes, the study was limited by the lack of breadth of respondents from each of the three categories. An opportunity for expanded research using the six common themes (cost, appropriateness, ignorance/experience, ordinance, holism, and altruism) is available. Perhaps a survey could be generated using questions geared at testing if cost, appropriateness, ignorance/experience, ordinance, holism, and altruism are truly the factors that drive the selection process of specific storm water management tools. The survey could reach a far greater sample pool compared to individual interviews.

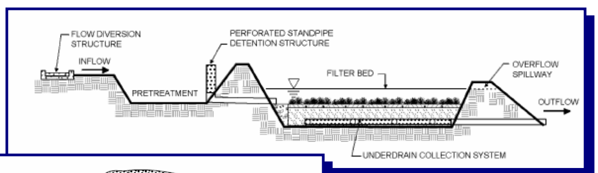
In closing, the factors that influence the selection of storm water management techniques are primarily cost, appropriateness, and ignorance/experience. If landscape architects can develop tools to overcome these objections, more storm water facilities incorporating designs for both amenity and utility should surface in developments throughout North Texas and the remainder of the county.

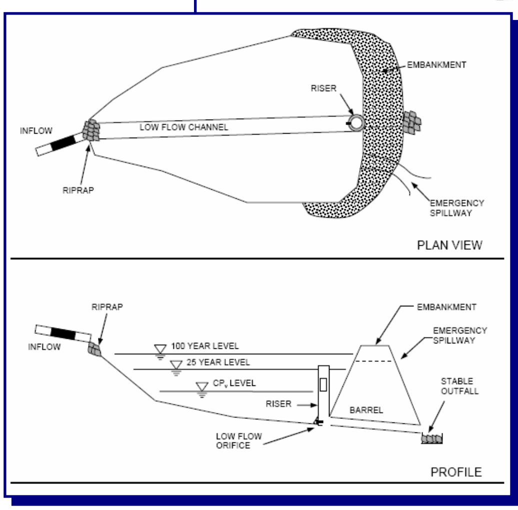
APPENDIX A

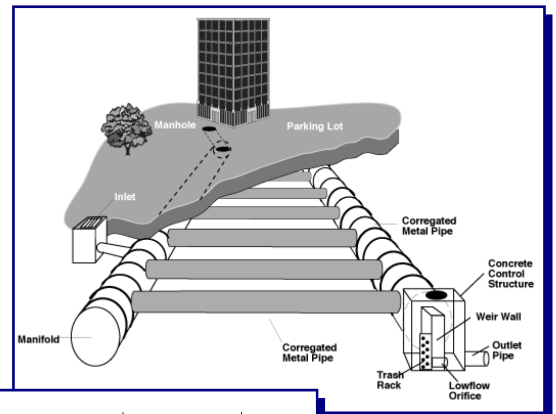
BIG FOSSIL CREEK WATERSHED STUDY

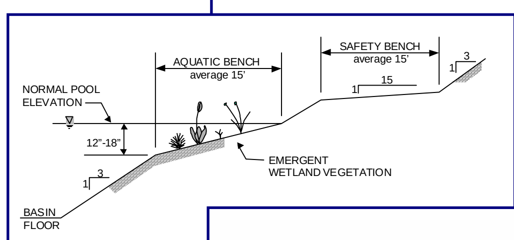
integrated Storm Water Management

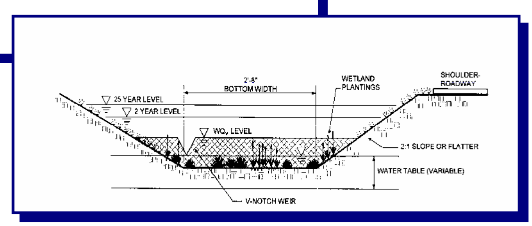
Big Fossil Creek Watershed Study











iSWM

February 2005

This report was prepared by AMEC for the North Central Texas Council of Governments. The purpose of this study is to provide a quantitative analysis to determine the impacts of implementing iSWM for development in North Texas. The report was reviewed by the Technical Review Team as well as the iSWM Steering Committee.

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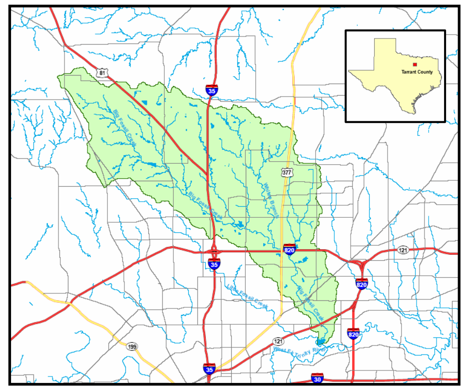
Executive Summary

The benefits of integrated Storm Water Management (iSWM) may be extended beyond the individual site planning level to the watershed level when applied consistently throughout the development of a watershed. The Big Fossil Creek Watershed, located in the northwestern portion of the North Central Texas Council of Governments (NCTCOG) region, was selected to apply simulated development utilizing the iSWM design criteria and watershed models (see figure below). The purpose was to test the potential impacts of iSWM application to the remaining undeveloped portions of Big Fossil Creek compared to development without iSWM practices.

The Big Fossil Creek Watershed covers an area of approximately 56 square miles and encompasses Big Fossil Creek, four un-named tributaries, and Whites Branch. Residential, commercial, and industrial development has primarily occurred in the lower portion of the watershed, leaving the undeveloped upper portion a prime location to simulate iSWM design criteria and verify watershed wide benefits.



Big Fossil Creek Watershed

The iSWM simulation within the Big Fossil Creek Watershed focused on the analysis of the iSWM design criteria in achieving the goals of flood control, water quality, and streambank protection for three watershed scenarios:

- existing watershed conditions;
- future conditions *without* the application of iSWM design criteria; and
- future conditions *with* the application of iSWM design criteria.

Results

The table below compares the results of the three watershed scenarios for each of the four iSWM design criteria goals: (1) runoff quantity flood control; (2) floodplain impact flood control; (3) water quality; and (4) streambank protection. It can be noted the increase from existing conditions to future conditions is consistently reduced with the application of iSWM design practices.

iSWM Design Goals	Watershed Conditions					
	Existing	Future without iSWM	Increase from Existing to Future	Future *with* iSWM	Increase from Existing to Future *with* iSWM	Increase from Future to Future *with* iSWM
Flood Control Analysis – Runoff Quantity						
100-Yr Peak Discharge Upstream of SH 121	34,204 cfs	38,026 cfs	+ 11%	34,639 cfs	+ 1%	- 9%
1-Yr Peak Discharge Upstream of SH 121	5,742 cfs	8,576 cfs	+ 49%	5,054 cfs	- 12%	- 41%
Flood Control Analysis – Floodplain Impact						
Flood Elevation Cross Section # 1	512.66 ft	513.98 ft	1.32 ft	512.81 ft	0.15 ft	- 1.17 ft
Flood Elevation Cross Section # 2	564.77 ft	567.49 ft	2.72 ft	565.47 ft	0.70 ft	- 2.02 ft
Water Quality Analysis						
Total Annual TSS Loading	7,692,556 lbs	11,395,189 lbs	+ 32%	9,714,227 lbs	+18%	-17%
Streambank Protection Analysis (ft)						
Channel Width (ft)	73.00 ft	96.97 ft	+ 33%	63.21 ft	- 13%	- 35%
Channel Depth (ft)	7.60 ft	10.99 ft	+ 45%	7.42 ft	- 2%	- 33%

Value-added Benefits

Developers in North Central Texas can effectively implement storm water management practices to address the impacts of new development and redevelopment, and to prevent and mitigate problems associated with urban storm water runoff. Within the limits of the study approach, the analyses of runoff quantity, floodplain impact, water quality, and streambank protection verified the benefits of iSWM design criteria at the watershed level for future conditions:

- Reduction in future runoff quantities to near existing conditions;
- Reduction in the increase of water surface elevations;
- Reduction in the increase of TSS loadings; and
- Reduction in the increase of erosion to channel depths and widths.

While the water quality analysis primarily focused on the simulated application of structural BMPs to reduce the pollutant loading to the stream, it can also be noted that water quality benefits are achieved through streambank protection. With bed and bank erosion as a primary source of TSS loadings within the North Central Texas region, a reduction in the amount of channel erosion, through streambank protection, will also result in a reduction in TSS loadings.

Summary of Big Fossil Creek Watershed Study

The benefits of iSWM may be extended beyond the individual site planning level to the watershed level when applied consistently throughout the development of a watershed. The Big Fossil Creek Watershed, located in the northwestern portion of the North Central Texas Council of Governments (NCTCOG) region, was selected for conceptual development utilizing the iSWM design criteria and watershed models (See Figure 1). The purpose was to test the potential impacts of iSWM application to the remaining undeveloped portions of Big Fossil Creek compared to development without ISWM practices.

The Big Fossil Creek Watershed covers an area of approximately 56 square miles and encompasses Big Fossil Creek, four un-named tributaries, and Whites Branch. Residential, commercial, and industrial development has primarily occurred in the lower portion of the watershed, leaving the undeveloped upper portion a prime location to simulate iSWM design criteria and verify watershed wide benefits.

The iSWM simulation within the Big Fossil Creek Watershed focused on the analysis of the iSWM design criteria in achieving the goals of flood control, water quality, and streambank protection for three watershed scenarios: existing watershed conditions, future conditions *without* the application of iSWM design criteria, and future conditions *with* the application of iSWM design criteria.

Flood Control Analysis – Runoff Quantity

The analysis of runoff quantity required the development of a hydrologic model. An existing conditions hydrologic model was first created, using the HEC-1 computer program, to reflect the current types of land use, soil conditions, and runoff parameters within the watershed. The Big Fossil Creek Watershed was divided into six basins, representing Big Fossil Creek, the four un-named tributaries, and Whites Branch. Each basin was comprised of varying numbers of sub-basins, ranging in area from 0.25 to 1.0 square miles. Figure 2 presents the computed existing conditions curve numbers for each sub-basin in the watershed. Curve numbers are a numerical description of the impermeability of the land in the watershed. This number varies from 0 (100% rainfall infiltration) to 100 (0% infiltration - i.e., pavement). This gives an indication for the potential for runoff.

The hydrologic model was then modified to reflect future developed conditions. Future developed conditions for the year 2025 were determined from land use projections provided by the NCTCOG and the City of Fort Worth. Increased impervious areas due to projected residential, commercial, and industrial growth are reflected in the increased curve numbers and somewhat reduced lag times computed throughout the watershed. Figure 3 presents the developed future curve numbers for each sub-basin in the watershed.

A second modified model was created to reflect the application of iSWM design criteria in the currently undeveloped areas of the upper portion of the watershed. Figure 4 highlights the undeveloped sub-basins selected for iSWM model application.

The hydrologic model was modified to reflect the iSWM design standard known as the ten percent rule. The ten percent rule recognizes the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone of influence the structural control becomes relatively insignificant compared to the runoff from the total drainage area.

Due to the limited budget and large number of sub-basins within the hydrologic model, a target range of acceptable peak flow reduction from 5 percent less than existing conditions peak flow to

25 percent less than existing conditions peak flow was assumed. This would allow for an average reduction in the 100-year peak flow to achieve the ten percent rule within the selected sub-basins. Table 1 presents the peak runoff values for the three watershed scenarios throughout the lower portion of the watershed, specifically from the stream crossing at Blue Mound Road to the base of the watershed, just upstream of State Highway 121. The application of iSWM design criteria in the upper portion of the watershed would almost maintain the runoff quantity of the existing conditions scenario. A detailed discussion of the hydrologic model development and modifications is presented in Appendix A.

Table 1. Summary of Conceptual Development Analysis – Runoff Quantity

Area of Big Fossil Creek Watershed (sq.mi.)	100 Year Peak Flow (cfs)					
	Existing Watershed Conditions	Future without iSWM Watershed Conditions	Percent Increase from Existing to Future	Future *with* iSWM Watershed Conditions	Percent Increase from Existing to Future *with* iSWM	Percent Increase from Future to Future *with* iSWM
16.64	16955	19259	13.6%	16963	0.0%	-11.9%
17.57	17355	19754	13.8%	17574	1.3%	-11.0%
18.18	17617	20030	13.7%	17967	2.0%	-10.3%
19.31	18603	21150	13.7%	19166	3.0%	-9.4%
19.98	18534	21100	13.8%	19368	4.5%	-8.2%
20.75	18832	21406	13.7%	19783	5.0%	-7.6%
21.76	19089	21683	13.6%	20296	6.3%	-6.4%
22.40	19176	21734	13.3%	20496	6.9%	-5.7%
28.63	24273	27668	14.0%	25724	6.0%	-7.0%
28.74	24132	27438	13.7%	25599	6.1%	-6.7%
31.06	25470	29011	13.9%	26737	5.0%	-7.8%
31.77	25308	28755	13.6%	26512	4.8%	-7.8%
32.32	23788	26648	12.0%	24731	4.0%	-7.2%
42.94	32280	36166	12.0%	33153	2.7%	-8.3%
43.44	31717	35501	11.9%	32668	3.0%	-8.0%
44.35	31756	35507	11.8%	32681	2.9%	-8.0%
49.84	33654	37495	11.4%	34175	1.5%	-8.9%
50.63	33805	37650	11.4%	34294	1.4%	-8.9%
51.17	33587	37420	11.4%	34119	1.6%	-8.8%
51.94	33715	37553	11.4%	34229	1.5%	-8.9%
52.57	33786	37628	11.4%	34313	1.6%	-8.8%
53.60	34016	37880	11.4%	34488	1.4%	-9.0%
54.31	33984	37800	11.2%	34443	1.4%	-8.9%
55.88	34204	38025	11.2%	34639	1.3%	-8.9%
56.63	33934	37678	11.0%	34398	1.4%	-8.7%

Flood Control Analysis - Floodplain Impact

The flood impact analysis applied the computed runoff quantities of the three watershed scenarios to a hydraulic model, previously created by the U.S. Army Corps of Engineers, Fort Worth District, along a defined stream reach, Interstate 35 to State Highway 121. This stream reach, located within the developed lower portion of the watershed, was selected because of identified flooding problems. As development occurs in the upper portion of the watershed, maintaining or lessening the impact of a flood event in the existing lower developed area is important.

Flood elevations were determined at multiple cross sections within the stream reach for the 100-year storm event. A detailed discussion of the hydraulic model and modifications is presented in Appendix B. Table 2 presents 100-year water surface elevations (WSEL) for the same three development scenarios as the hydrologic model discussed above at several locations within the stream reach. It can be seen that the flood elevation increase from existing conditions to future conditions without iSWM is greater than the increase from existing conditions to future conditions *with* iSWM.

Table 2. Summary of Conceptual Development Analysis – Flood Impact

Location	100-Year Water Surface Elevation (ft)				
	Existing Watershed Conditions	Future without iSWM Watershed Conditions	Increase in Future WSEL from Existing Conditions	Future *with* iSWM Watershed Conditions	Increase in Future iSWM WSEL from Existing Conditions
Flood Elevation (ft) Cross Section # 17130 Upstream of Hwy 183	512.66	513.98	1.32	512.81	0.15
Flood Elevation (ft) Cross Section # 35870/36000 Upstream of T&P RR	564.77	567.49	2.72	565.47	0.70
Flood Elevation (ft) Cross Section # 57920 Upstream of Western Ctr Blvd	605.84	607.84	2.00	606.47	0.63

The application of iSWM holds the flow elevation increase to an average increase of 0.27 feet throughout the reach, while uncontrolled development in just the currently undeveloped portion allows the 100-year flow elevation to increase by an average of 1.2 feet throughout the reach, with a maximum increase of 2.72 feet.

While this increase does not create problems in developed areas remote from the flood increases, in currently flooded areas would create increasingly dangerous flood depths and velocities for those homes currently flooded, a further reduction in property values, and would inundate several additional structures in the neighborhood. For example, Exhibits 1 and 2 show two neighborhoods where significant new portions of streetside flooding occurs. New flooding is indicated by the dark blue areas, while the light blue areas indicate existing 100-year floodplain limits. Actual planimetric structure footprint information was not assessed to verify actual structure locations. On a larger scale, figures 5 and 6 present the 100-year floodplain in the upper and lower portions of the watershed, respectively.

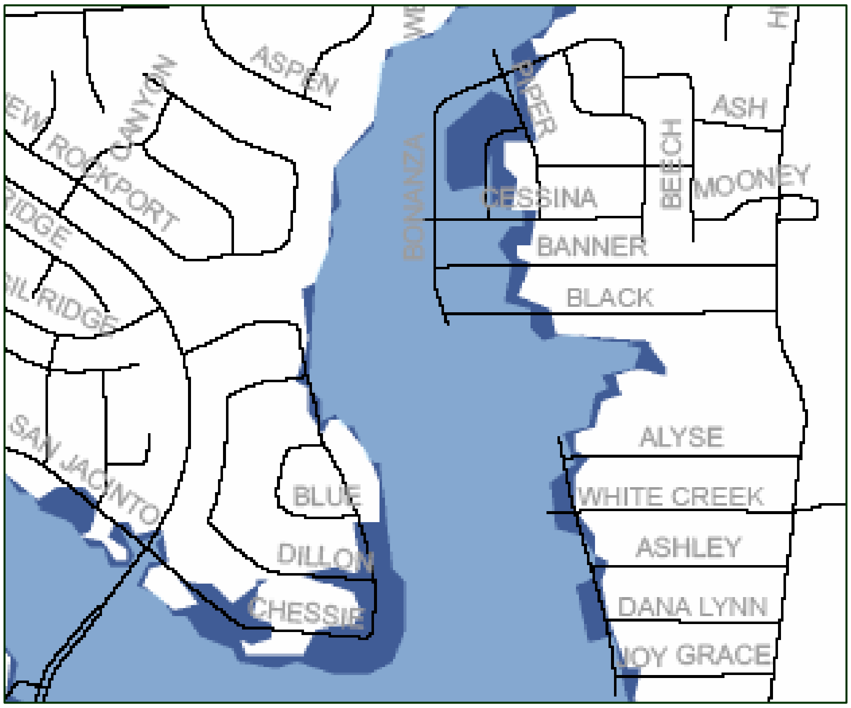


Exhibit 1. Neighborhood Flooding in Study Reach Example 1

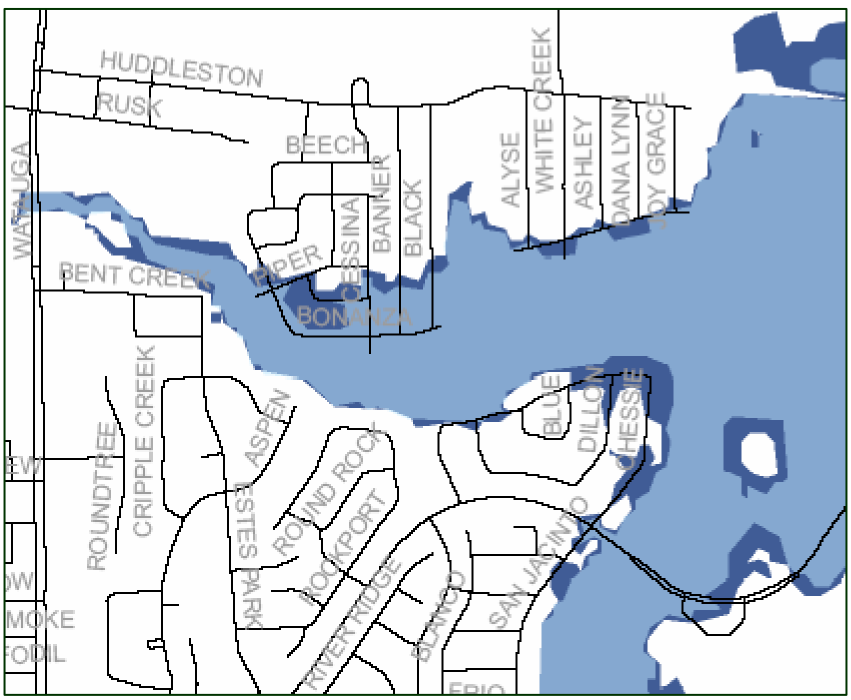


Exhibit 2. Neighborhood Flooding in Study Reach Example 2

Water Quality Analysis

The amount of total suspended solids (TSS) in a stream is a fair indicator of the overall water quality of the stream. But it is not without its problems especially in drier climates. Urban pollutants, such as oils and grease, attach themselves to the suspended solids and are transported downstream. Additionally, sediment in Texas streams is seen as a significant problem. Excess sediment in streams causes the following problems:

- Lost property or conveyance and adjacent structural damage;
- Safety concerns for crossing structures and steep or caving banks;
- Increased flooding due to channel siltation;
- Reservoir filling reducing storage capability;
- Water quality degradation;
- Ecological damage from turbid waters;
- Aesthetics & quality of life; and
- Property value preservation.

For the water quality analysis, TSS was selected as the indicator pollutant used to compare water quality impacts for the watershed scenarios. TSS pollutant loadings were computed for each sub-basin developed within the hydrologic model using a land use approach to estimate the annual and/or seasonal non-point source loads based upon the event mean concentrations (EMCs) and runoff volumes. Event mean concentrations were determined through a qualitative in-stream monitoring program completed by the NCTCOG. Table 3 presents the EMC values for TSS.

Table 3. Event Mean Concentrations, TSS (mg/l)

Type of Land Use	Season 1 (Sep – Oct)	Season 2 (Nov – Feb)	Season 3 (Mar – Jun)	Season 4 (Jul – Aug)
Commercial	41.5	37.5	46	37
Highway	62	142	134	142
Industrial	54	86	135	86
Open	118	332	118	332
Residential	90	73	116	73

"Open Space" has the highest TSS concentration per unit of runoff. But, when coupled with the much greater total volume of runoff per acre from more impervious areas, and the fact that other pollutants that attach to TSS are more highly concentrated in urbanized runoff, it is clear that urban development increases pollution to streams and channels.

Additionally, it can be surmised from data from the monitoring program that often the largest component of TSS loadings downstream are the result of bed and bank erosion within the channel itself (see discussion on stream erosion below). Thus the control of channel erosion through the channel protection criteria would also significantly improve the TSS loading reductions and associated stream water quality, though reduced channel erosion would not reduce other kinds of pollution.

Similar to the hydrologic and hydraulic model scenarios, water quality models were created for existing conditions, future conditions *without* iSWM, and future conditions *with* iSWM design criteria. In order to simulate the future conditions *with* iSWM scenario, a 70 percent reduction in TSS loadings was applied to each of the selected iSWM sub-basins, previously identified in the hydrologic model development. This application was done to reflect the design recommendations of the iSWM structural Best Management Practices (BMPs). The recommended water quality BMPs, if designed and installed properly and maintained, will remove 70-80 percent of the average annual TSS load in typical urban post-development runoff and a proportional removal of other pollutants.

While this assumption of 70-80 percent removal is true for sites with well designed and newly constructed controls, as we saw above, it may not be true for the whole watershed or for individual sub-basins. This is true, in part, because of bed and bank erosion, erosion along unprotected roadways, and general erosion in areas not protected by structural controls. Also, without proper maintenance, controls can lose effectiveness over time. No effort was made in this brief study to quantify these other sources of TSS and other pollutants.

Table 4 presents the TSS loadings determined for the entire watershed for the three watershed scenarios. A detailed discussion of the water quality model and TSS loading results for individual sub-basins is presented in Appendix C.

Table 4. Summary of Conceptual Development Analysis – Water Quality

Season	TSS LOADING (lbs)					
	Existing Watershed Conditions	Future without iSWM Watershed Conditions	Percent Difference from Existing to Future	Future *with* iSWM Watershed Conditions	Percent Difference from Existing to Future *with* iSWM	Percent Difference from Future to Future *with* iSWM
Sep- Oct	935,230	1,536,896	39%	1,311,525	24%	-17%
Nov – Feb	2,504,454	2,916,779	14%	2,515,762	0.4%	-16%
Mar – Jun	3,148,510	5,655,309	44%	4,777,553	29%	-18%
Jul – Aug	1,104,361	1,286,205	14%	1,109,387	0.4%	-16%
TOTAL ANNUAL LOADING	**7,692,556**	**11,395,189**	**32%**	**9,714,227**	**18%**	**-17%**

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The focus of the water quality analysis on TSS loadings reveals that urbanization does not necessarily increase the concentration of TSS from existing to future conditions. The EMC values determined for TSS within open space were significantly high, contributing to high TSS loadings for existing conditions. On a national level, the TSS concentrations for stabilized open space ranges between 150 and 250 mg/l.

Urbanization, however, does increase the volume of runoff, as well as the concentration of urban pollutants, such as oil and grease, attached to the suspended solids. It is the application of structural BMPs, which does reduce the TSS loading for future conditions *with iSWM* from future conditions without iSWM.

Streambank Protection Analysis

For the channel impact analysis, the computed runoff quantities from the three watershed scenarios were applied to a locally derived regression equation for computing channel erosion. Channel erosion and incision have both environmental and physical effects. As listed above, these effects range from undermining bridges, undermining pipeline crossings, lowering local ground water tables, filling reservoirs and detention ponds, loss of property (along with property value), and creating a safety problem with vertical cliffs to loss of wildlife habitats and biodiversity. The equation used in this study of Big Fossil Creek was derived in the technical paper *Erodibility of Urban Bedrock and Alluvial Channels, North Texas* (Allen, Peter M., et.al.). This technical paper identified and quantified the erosion processes and erosion potential of stream channel types specific to North Texas.

According to the technical paper, major erosion of urban stream channels in North Texas is found in smaller basins with contributing drainage areas of less than ten square miles. For these basins, four basic channel types have been identified based on bed and bank lithologies: alluvial banks and bottoms, alluvial banks and gravel bottoms, alluvial banks and rock bottoms, and rock banks and rock bottoms. Most channels, approximately 75 percent, have alluvial banks with gravel or rock bottoms. Channel slopes are steep and rock consists predominantly shale and limestone.

For the study of Big Fossil Creek, representative cross sections were identified in the stream reach from Interstate 35 to State Highway 121. From these cross sections it was possible to categorize the channel type as alluvial banks with rock bottom. For this specific channel type, a channel erosion equation derived in the technical paper was used to estimate the changes in channel shape due to the increased shear forces along channel side slopes and bottom width. A detailed discussion of the channel impact analysis is presented in Appendix D.

To illustrate the impacts of urban development on channel widths and depths, the equation is plotted against C factor. This exhibit was developed by calculating required peak flows for the channel size equation using the Rational Method. It is assumed that the initial undeveloped C Factor is 0.2. The exhibit illustrates what happens to a channel in terms of the ratio of stream width and depth compared to the "natural" width and depth for a C Factor of 0.20.

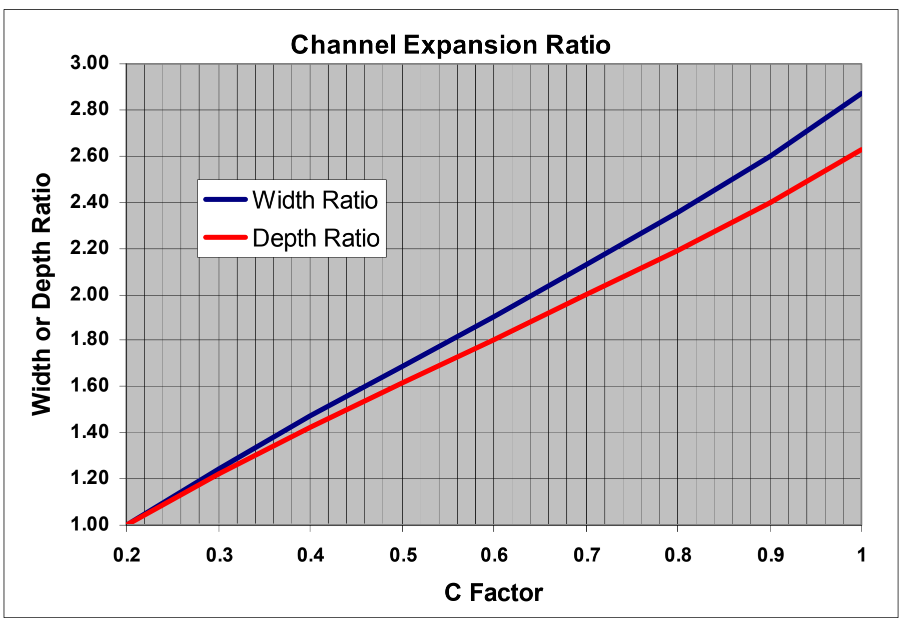


Exhibit 3. Channel Expansion Ratio versus Rational C Factor

When this equation is applied over the 9.5-mile study reach from Interstate 35 to State Highway 121, approximately 20,000,000 ft^3 (460 acre-feet) of sediment are anticipated to be removed from Big Fossil Creek under future conditions without the application of iSWM design criteria. When the watershed as a whole is considered with more than 85 miles of streams the total sediment load and potential for damage is enormous.

Table 5 presents the reduction in channel erosion between the future conditions without and *with* iSWM application for the specific cross section. Notice that the iSWM cross section is actually smaller than the existing condition. This indicates, within the margin of error of the equations, that the channel would have been less than its currently impacted shape had iSWM been used throughout the upstream area from the beginning. Exhibit 4 presents the specific channel cross sections for existing, future, and future *with* iSWM conditions.

Table 5. Summary of Conceptual Development Analysis – Streambank Protection

Type of Analysis	Existing Conditions from HEC-2 Model	Future Conditions without iSWM	Percent Difference from Existing to Future	Future Conditions *with* iSWM	Percent Difference from Existing to Future *with* iSWM	Percent Difference from Future to Future *with* iSWM
Channel Width (ft)	73.00	96.97	32.84%	63.21	-13.41%	-34.8%
Channel Depth (ft)	7.60	10.99	44.61%	7.42	-2.37%	-32.5%
Channel Area (ft^2)	429	824[1]	---	359[1]	---	---

[1]Trapezoidal channels with 2:1 side slopes were assumed for both of the future conditions scenarios.

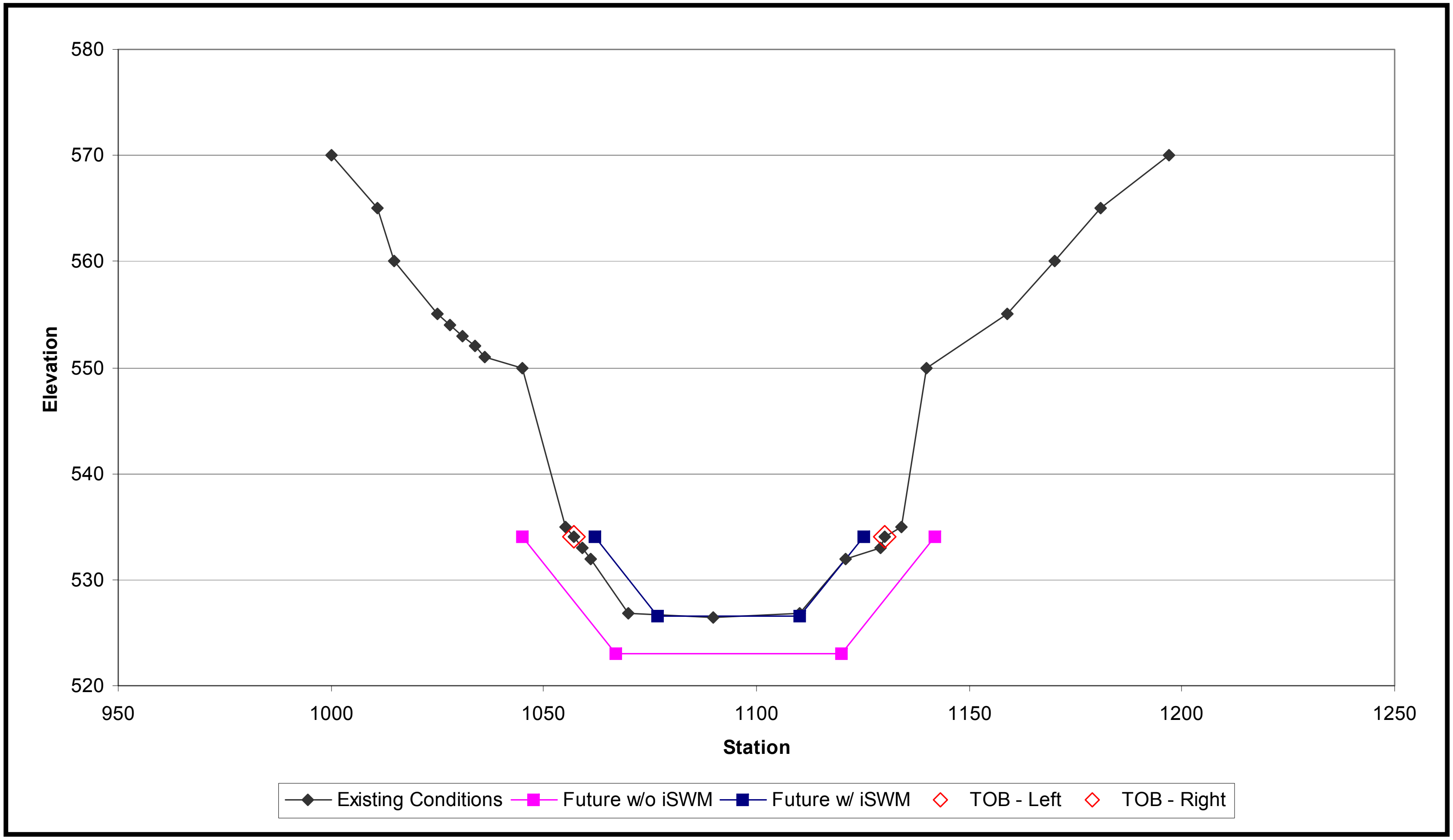


Exhibit 4. Computed Streambank Erosion on Sample Cross Section

Conclusion

Developers in North Central Texas can effectively implement storm water management practices to address the impacts of new development and redevelopment, and to prevent and to mitigate problems associated with urban storm water runoff. Within the limits of the study approach, the analyses of runoff quantity, floodplain impact, water quality, and streambank protection verified the benefits of iSWM design criteria at the watershed level for future conditions:

- Reduction in future runoff quantities to near existing conditions;
- Reduction in the increase of water surface elevations;
- Reduction in the increase of TSS loadings; and
- Reduction in the increase of erosion to channel depths and widths.

While the water quality analysis primarily focused on the simulated application of structural BMPs to reduce the pollutant loading to the stream, it can also be noted that water quality benefits are achieved through streambank protection. With bed and bank erosion as a primary source of TSS loadings within the North Central Texas region, a reduction in the amount of channel erosion, through streambank protection, will also result in a reduction in TSS loadings.

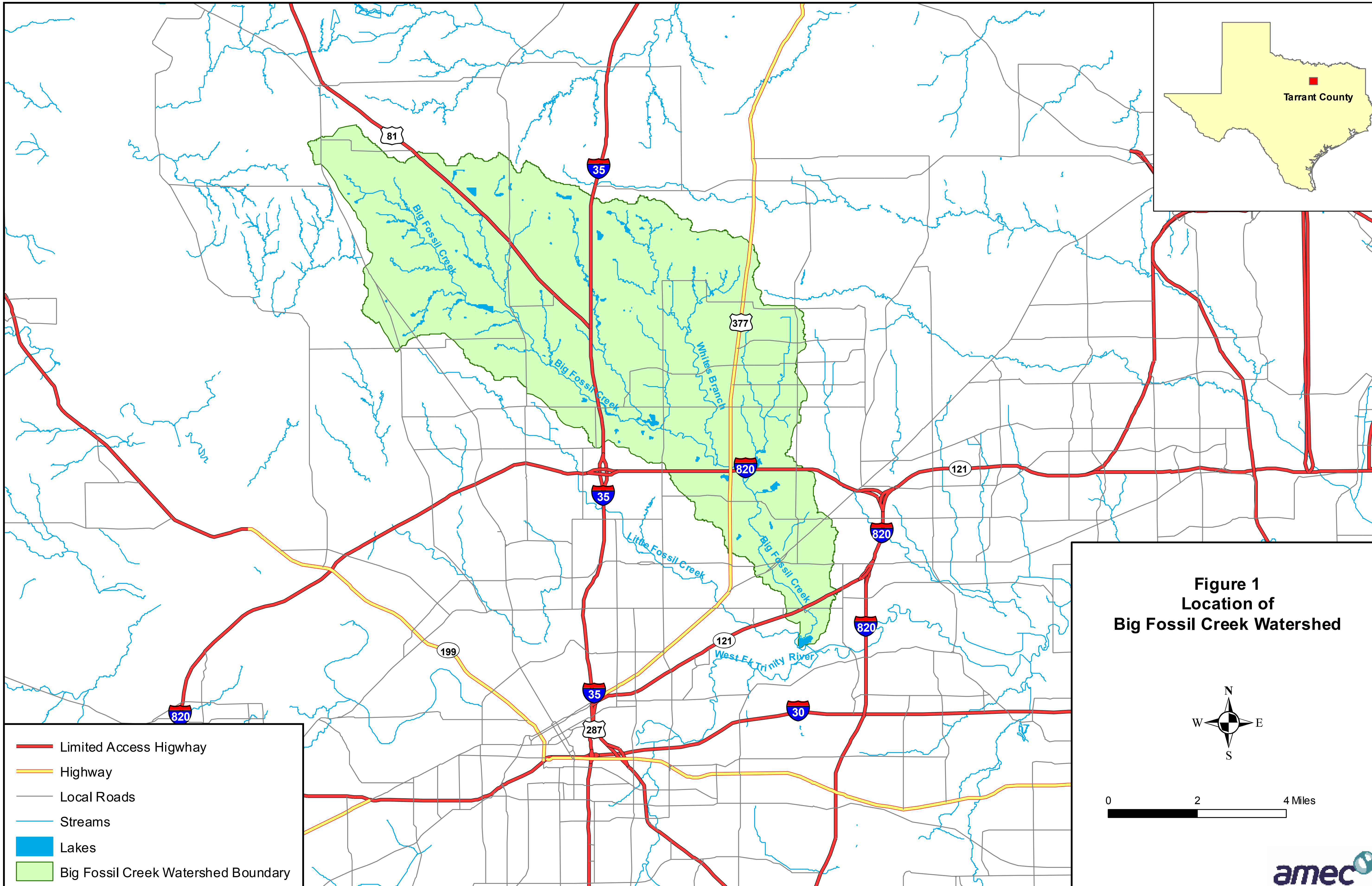


Figure 1
Location of
Big Fossil Creek Watershed

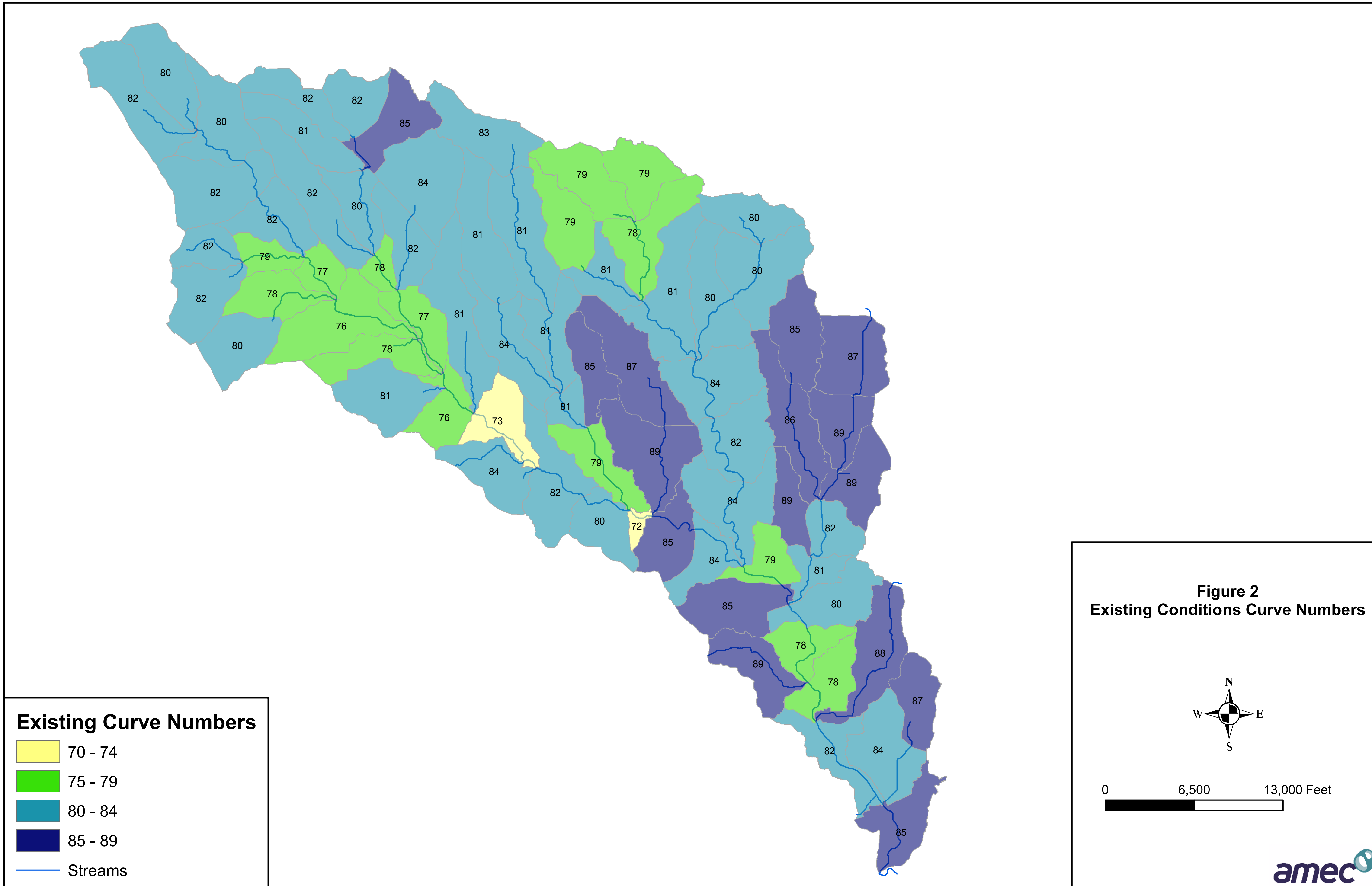


Figure 2
Existing Conditions Curve Numbers

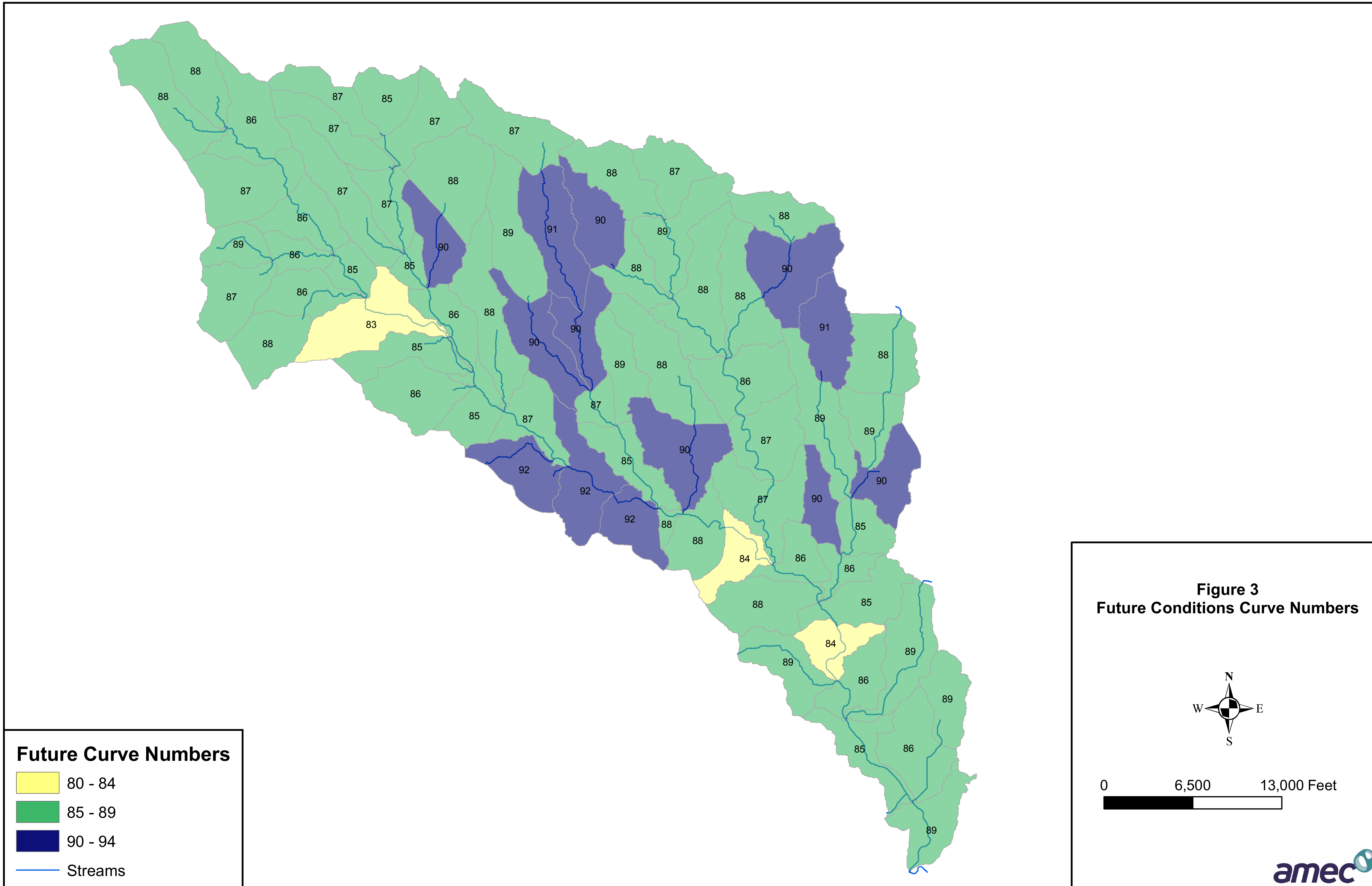


Figure 3
Future Conditions Curve Numbers

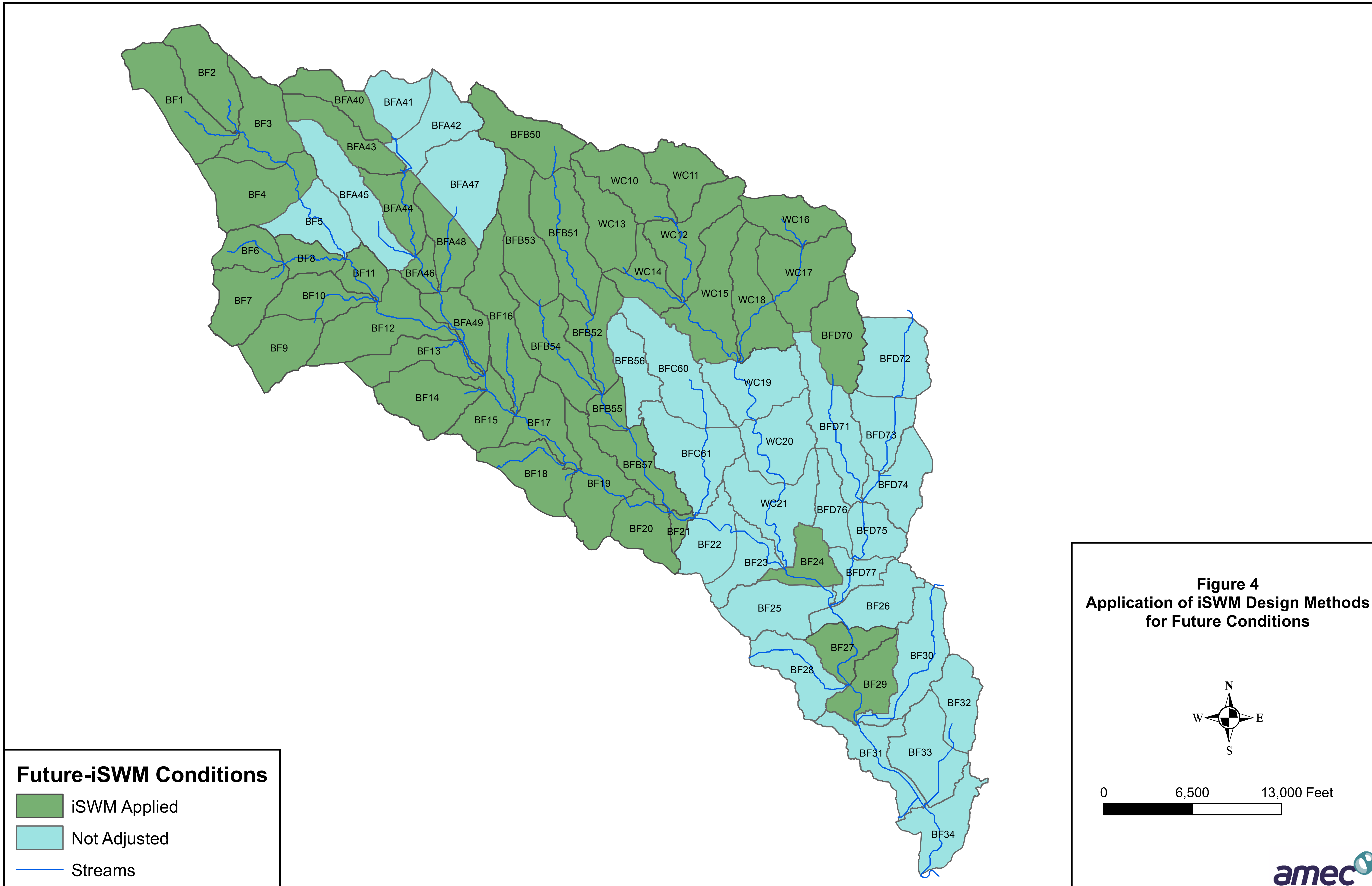


Figure 4
Application of iSWM Design Methods for Future Conditions

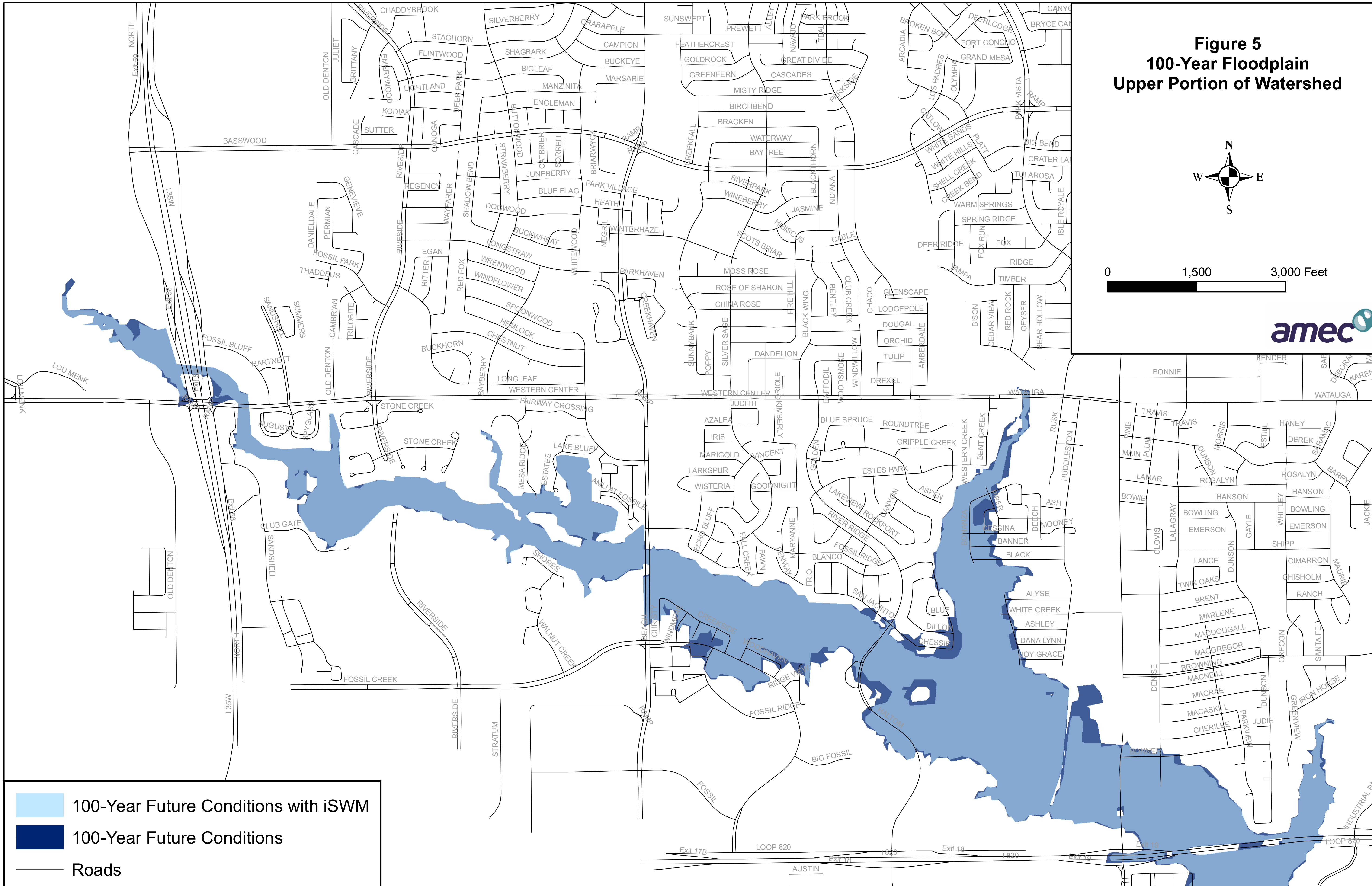
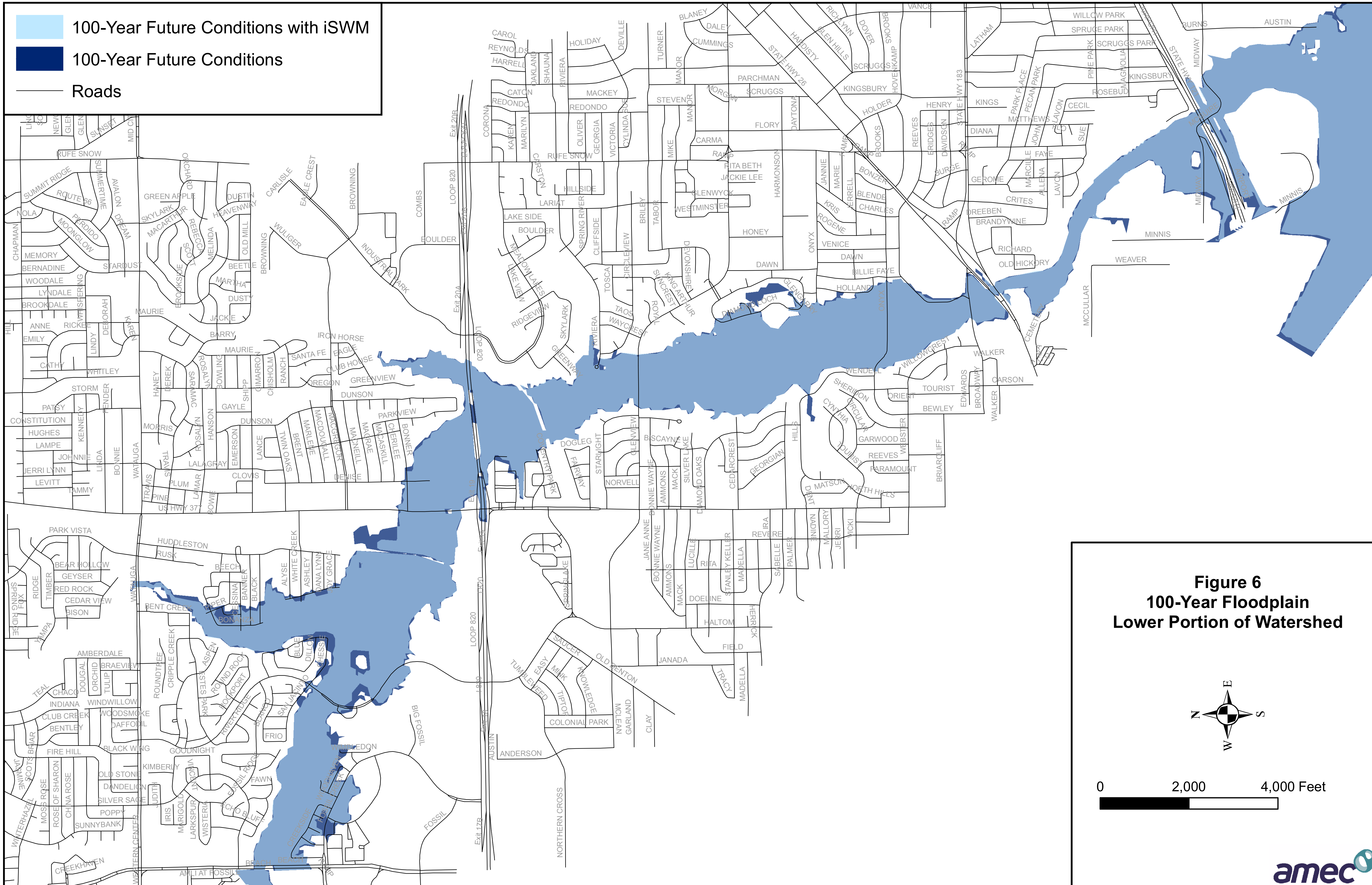


Figure 5
100-Year Floodplain
Upper Portion of Watershed


100-Year Future Conditions with iSWM
100-Year Future Conditions
Roads
Figure 6
100-Year Floodplain
Lower Portion of Watershed
N
E
S
W
0
2,000
4,000 Feet
amec

Appendix A – Runoff Quantity Analysis

A hydrologic model of Big Fossil Creek was created in order to estimate the flow rate of storm water runoff for the watershed. The model was developed from data including precipitation, basin characteristics, and types of soil and land uses. The model produced results that can be used to predict flows from a wide range of storm events.

The primary method of flow rate computation used was the Snyder's Unit Hydrograph. The HEC-1 Flood Hydrograph Package (USACE, 1990) computer model was used to facilitate the calculations. The following sections detail the procedures for developing the model, and present the results of the model.

Model Development
Input for the hydrologic model includes precipitation data, basin characteristic data (area, SCS runoff curve number, lagtime t_p and peaking coefficient C_p), and stream data (channel length, slope, roughness value, and/or storage-elevation/volume-discharge relationship).

Precipitation
A 24-hour balanced storm was used to simulate the design rainfall in the Big Fossil Creek hydrologic model. Table A-1 presents the 1-year and 100-year frequency rainfall depths for various durations used to develop the balanced storm for hydrologic modeling in the Big Fossil Creek Watershed.

Table A-1. Rainfall Depth-Duration-Frequency Data for Tarrant County

Frequency (years)	Rainfall Depths (inches)							
	5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
1	0.44	0.83	1.36	1.62	1.77	2.04	2.28	2.64
100	0.92	2.00	3.84	4.84	5.43	6.54	7.68	9.12

Rainfall depths are presented in Appendix A of the *iSWM Design Manual for Development/Redevelopment.*

Unit Hydrograph
The HEC-1 model supports several unit hydrograph methods to transform rainfall excess into surface runoff. The method selected for this study was the Snyder's unit hydrograph method, which is the method used by the US Army Corps of Engineers, Fort Worth District, for the majority of hydrologic studies in the region. It is similar to the Soil Conservation Service (SCS) method, in that it considers the time distribution of the rainfall, the initial losses to interception and depression storage, and an infiltration rate that decreases during the course of a storm.

Areal Reduction and Computational Interval
The average rainfall depth over a watershed for a given frequency decreases with increasing drainage area. Areal reduction of point rainfall is necessary to reduce rainfall depths applied to a sub-basin by the HEC-1 model. The area of the Big Fossil Creek Watershed is over 56 square miles, therefore areal reduction of point rainfall was performed using the depth-area option in the HEC-1 model. A computation interval of 6 minutes (0.1 hrs) was chosen for the HEC-1 model of the Big Fossil Creek Watershed.

Drainage Boundary Delineation
Sub-basin boundaries in the Big Fossil Creek Watershed were automatically delineated using the digital mapping tool, ArcHydro, and two-foot contour information obtained from the NCTCOG. ArcHydro is an extension tool in the ArcMap digital mapping software program.
Adjustments were made to individual sub-basins in order to limit each sub-basin area to approximately one square mile. ArcHydro was used to estimate the longest flow path (L); to

estimate the length of the flow path from the centroid of sub-basin to the sub-basin's outlet (L_{ca}); and to extract elevations for both the highest and lowest points along the flow path. Table A-2 summarizes the hydraulic data used in the hydrologic analysis of Big Fossil Creek Watershed.

The Big Fossil Creek Watershed was divided into six basins, each comprised of varying numbers of sub-basins, for a total of 74 sub-basins within the watershed. Basins and sub-basin boundaries of the watershed are shown in Figure A-1. Sub-basins located in the Big Fossil Creek Watershed range in size from 150 acres to 770 acres, with an average size of approximately 500 acres. All sub-basin boundaries were utilized, without adjustment, for the existing and future conditions scenarios.

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca} ,ft)	Slope (ft/mi)
BF1	679.1	1.06	13864	94	6555	35.8
BF10	407.9	0.64	9657	107	5625	58.5
BF11	223.0	0.35	6641	52	3032	41.3
BF12	768.5	1.20	16653	122	7822	38.7
BF13	432.4	0.68	13548	116	8111	45.2
BF14	594.0	0.93	10556	112	6475	56.0
BF15	390.7	0.61	7595	85	2595	59.1
BF16	722.7	1.13	17346	129	8490	39.3
BF17	429.2	0.67	10814	89	5260	43.5
BF18	492.7	0.77	8283	83	3404	52.9
BF19	647.6	1.01	10804	109	3332	53.3
BF2	530.7	0.83	10961	70	6187	33.7
BF20	410.4	0.64	7549	88	3200	61.5
BF21	69.7	0.11	3897	87	1909	117.9
BF22	454.4	0.71	6000	100	2597	88.0
BF23	353.7	0.55	7937	113	4002	75.2
BF24	317.7	0.50	5405	80	3645	78.2
BF25	585.1	0.91	10979	122	5286	58.7
BF26	508.7	0.79	9242	106	3983	60.6
BF27	348.2	0.54	8035	88	4000	57.8
BF28	490.6	0.77	9663	107	4956	58.5
BF29	403.2	0.63	10381	128	4025	65.1
BF3	597.5	0.93	10529	72	4316	36.1
BF30	660.9	1.03	14958	116	8828	40.9
BF31	453.2	0.71	12034	113	5576	49.6

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca} ,ft)	Slope (ft/mi)
BF32	386.0	0.60	7618	68	3959	47.1
BF33	618.4	0.97	8946	122	4167	72.0
BF34	482.6	0.75	12039	66	4571	28.9
BF4	722.6	1.13	9301	96	4744	54.5
BF5	466.0	0.73	8735	86	4221	52.0
BF6	285.6	0.45	6868	72	3329	55.4
BF7	496.7	0.78	10529	72	4971	36.1
BF8	222.7	0.35	7189	70	3649	51.4
BF9	485.7	0.76	7306	58	3781	41.9
BFA40	356.7	0.56	10425	66	5424	33.4
BFA41	358.0	0.56	6536	128	3316	103.4
BFA42	484.7	0.76	9685	138	5241	75.2
BFA43	437.1	0.68	12515	81	6245	34.2
BFA44	372.2	0.58	9517	73	5029	40.5
BFA45	659.5	1.03	16563	104	8353	33.2
BFA46	152.3	0.24	5390	44	2313	43.1
BFA47	749.3	1.17	8680	120	4090	73.0
BFA48	405.1	0.63	9088	54	4370	31.4
BFA49	344.3	0.54	9534	78	4881	43.2
BFB50	577.2	0.90	11262	96	4911	45.0
BFB51	732.2	1.14	13153	144	7892	57.8
BFB52	438.2	0.68	10621	93	5524	46.2
BFB53	628.5	0.98	14069	151	6346	56.7
BFB54	621.8	0.97	13122	97	5911	39.0
BFB55	177.7	0.28	4819	58	2440	63.6
BFB56	376.8	0.59	10163	94	4843	48.8
BFB57	441.4	0.69	10377	88	4748	44.8
BFC60	735.6	1.15	13926	96	6037	36.4
BFC61	745.9	1.17	12760	71	6725	29.4
BFD70	526.9	0.82	8944	74	4080	43.7
BFD71	659.1	1.03	15938	136	7410	45.1
BFD72	622.5	0.97	6671	44	4038	34.8
BFD73	408.9	0.64	8623	76	4414	46.5
BFD74	468.0	0.73	6804	52	4284	40.4

Table A-2. Hydrologic Data Summary

Sub-basin	Area (acres)	Area (sq.mi.)	Length of Longest Flow Path (L, ft)	Elevation Difference Along Longest Flow Path (ft)	Length of Flow Path from Sub-basin's Centroid to Outlet (L_{ca} ,ft)	Slope (ft/mi)
BFD75	319.5	0.50	6284	94	3517	79.0
BFD76	303.6	0.47	9944	117	4621	62.1
BFD77	214.3	0.33	6915	135	3766	103.1
WC10	508.5	0.79	11653	120	5865	54.4
WC11	429.3	0.67	8250	96	4330	61.4
WC12	597.4	0.93	14325	176	6688	64.9
WC13	492.8	0.77	11682	123	4737	55.6
WC14	347.7	0.54	8187	104	3934	67.1
WC15	765.7	1.20	15374	192	6855	65.9
WC16	408.9	0.64	4899	42	2855	45.3
WC17	745.9	1.17	10329	96	3630	49.1
WC18	586.9	0.92	12134	203	5775	88.3
WC19	654.9	1.02	9028	94	4173	55.0
WC20	576.0	0.90	10785	119	4944	58.3
WC21	681.9	1.07	12210	97	7286	41.9

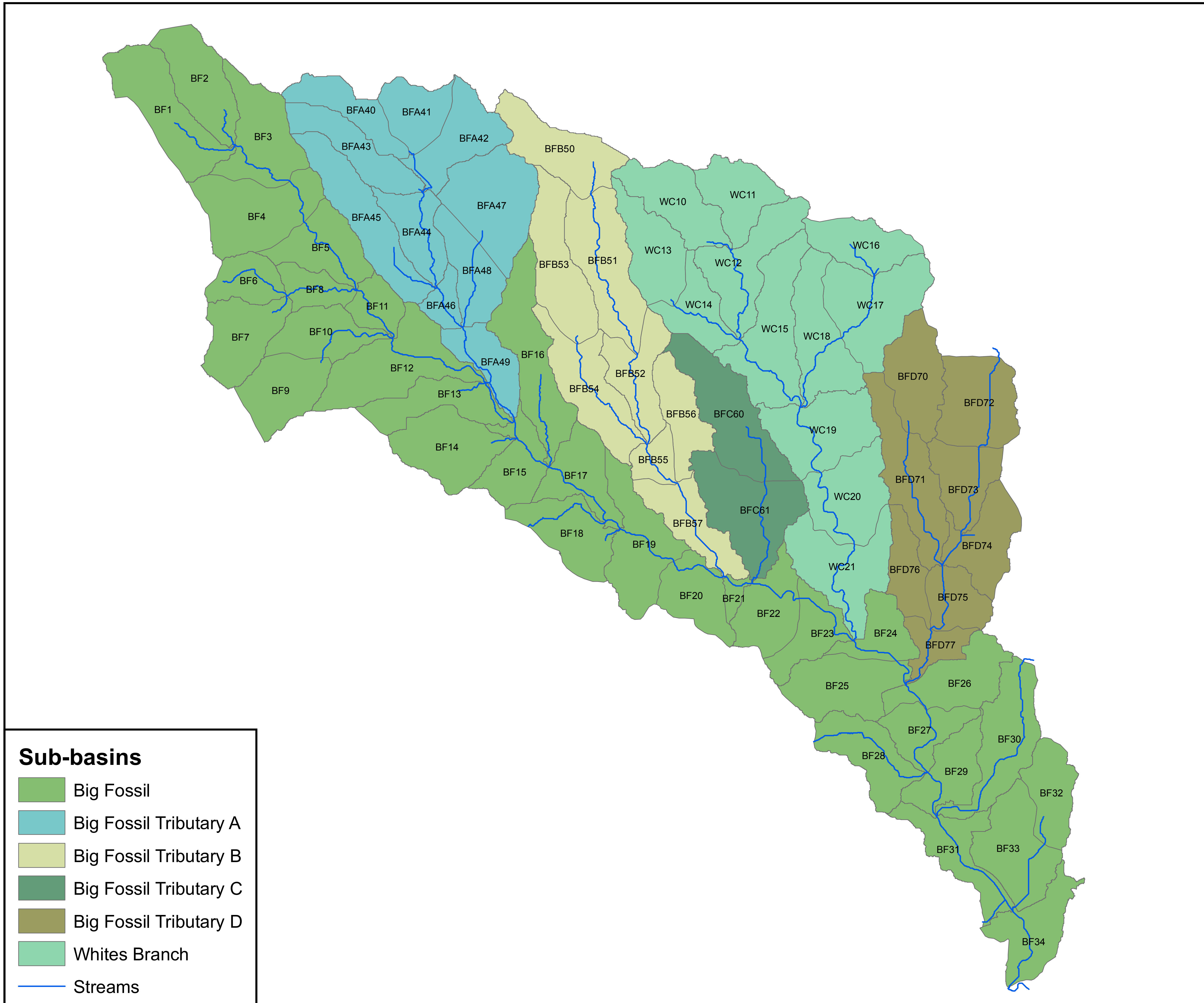


Figure A-1
Schematic of Delineated
Basin and Sub-basin Boundaries

N
W
E
S

0 6,500 13,000 Feet

amec

Soils Data
Soils information was provided by the NCTCOG in an ArcView shape file format. However the associated data table lacked the hydrological soil group definition. In order to populate this field, SURGO data were used to populate the hydrologic soil group. Soils delineation was utilized, without adjustment, for the existing and future conditions scenarios. The type of soil is a major factor in determining the amount of runoff that will occur during the event. Sandy soils will allow significant infiltration while rock formations tend to allow no infiltration. Soil types were matched to a specific hydrologic soil group (A, B, C, D) as used to compute curve numbers in the SCS method. The definition of each hydrologic soil group is given in Table A-3.

Table A-3. Definition of Hydrologic Soil Groups

Hydrologic Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-to-excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impeded downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils have very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Curve Numbers
The SCS runoff curve number (CN) is an index developed to represent the combined hydrologic effect of soil type, land use, and antecedent soil moisture condition. Using this index to determine the amount of available storage (and subsequent precipitation excess) in a drainage basin is a standard hydrologic analysis technique developed by the SCS.

In watersheds that are delineated into numerous sub-basins, such as the Big Fossil Creek Watershed, GIS software is well suited for curve number estimation because it can manipulate the large amounts of spatial data (e.g., soil and land use coverage). Area-weighted curve numbers were determined for each sub-basin by combining the soil, land use, and sub-basin boundary maps in ArcView, through use of a script (i.e., program) developed specifically for curve number generation.

Since future land use designations were developed with the stipulation that runoff potential could not decrease from existing to future conditions, future curve numbers for each sub-basin will be equal to or greater than existing curve numbers.

Land Use
Land use was classified into 25 categories as designated by the *iSWM Design Manual for Development/Redevelopment*. Table A-4 presents these categories and the corresponding curve numbers. The curve numbers shown in Table A-4 are assumed to correspond to antecedent moisture condition II (AMC II).

Land use data for this study was provided by both the NCTCOG and the City of Fort Worth in ArcView shape file formats. Land use data for the year 2000 and 2003 was provided by the

NCTCOG. Future conditions land use data for the year 2025 was provided by the City of Fort Worth. For the existing conditions hydrologic model, the 2000 land use data was used. For future conditions hydrologic modeling, a combination of the NCTCOG and Fort Worth data was used. That is, the 2003 land use data was used to complete the portions of the watershed not included within the Fort Worth 2025 future land use information.

The 2000 and 2003 land use mapping from the NCTCOG defined land use through a numbered code field that ranged from 111 to 500. The future land use information from the City of Fort Worth defined land use through a descriptive code field. Table A-5 assigns a new land use code for both the NCTCOG and Fort Worth data that corresponds to the 25 land use categories designated by iSWM (See Table A-4).

Table A-4. Curve Number Look-Up Table

Cover Description	Land Use Code for Correlation	Curve Number by hydrological soil group				Cp Value
		A	B	C	D	
Cultivated Land w/o conservation treatment	1a	72	81	88	91	0.58
Cultivated Land w/ conservation treatment	1b	62	71	78	81	0.58
Pasture or Range land: Poor Condition	2a	68	79	86	89	0.58
Pasture or Range land: Good Condition	2b	39	61	74	80	0.58
Meadow: Good Condition	3	30	58	71	78	0.58
Wood or Forest Land: Thin Stand; Poor Cover	4a	45	66	77	83	0.58
Wood or Forest Land: Good Cover	4b	25	55	70	77	0.58
Open Space: Poor Condition (<50%)	5a	68	79	86	89	0.58
Open Space: Fair Condition (50% to 75%)	5b	49	69	79	84	0.58
Open Space: Good Condition (<75%)	5c	39	61	74	80	0.58
Impervious Areas	6	98	98	98	98	0.73
Streets and Roads: Paved excluding ROW	7a	98	98	98	98	0.73
Streets and Roads: Paved including ROW	7b	83	89	92	93	0.73
Streets and Roads: Gravel	7c	76	85	89	91	0.73
Streets and Roads: Dirt	7d	72	82	87	89	0.73
Urban Districts: Commercial and Business	8a	89	92	94	95	0.73
Urban Districts: Industrial	8b	81	88	91	93	0.73
Residential: 1/8 acre or less	9a	77	85	90	92	0.73
Residential: 1/4 acre	9b	61	75	83	87	0.66
Residential: 1/3 acre	9c	57	72	81	86	0.66
Residential: 1/2 acre	9d	54	70	80	85	0.66
Residential: 1 acre	9e	51	68	79	84	0.66
Residential: 2 acres	9f	46	65	77	82	0.66
Developing Urban Areas	10	77	86	91	94	0.66
Water	11	100	100	100	100	1.00

Curve Number data presented in the *iSWM Design Manual for Development/Redevelopment.*

Table A-5. Land Use Codes

NCTCOG Land Use Codes (2000 and 2003)	Corresponding Land Use Code		City of Ft. Worth Land Use Codes (2025)	Corresponding Land Use Code
111	9b		AG	1b
112	9a		NC	8b
113	9a		GC	8b
114	9f		HI	8a
121	8a		LI	8b
122	8a		IGC	8a
123	8a		MUGC	8b
131	8b		INFRA	7a
141	6		INST	9f
142	6		PRIPK	5c
143	3		PUBPK	5c
144	6		LDR	9e
171	5c		MDR	9d
171	5c		MH	9a
172	5b		RURAL	9f
173	5a		SF	9b
181	10		SUB	9b
300	5c			
308	7b			
500	11			

Lagtimes and Peaking Coefficient
Snyder's Unit Hydrograph method was used to calculate a runoff hydrograph for the development of the HEC-1 model of the Big Fossil Creek Watershed. This method requires specification of a lagtime (t_p) and peaking coefficient (C_p) for each sub-basin. The lagtime, specified in hours, is defined as the lag (time) between the center of mass of rainfall excess and the peak of the unit hydrograph.

The *iSWM Design Manual for Development/Redevelopment* describes the lagtime and peak flow (q_p) as:

$$t_p = C_t(L\ L_{ca})^{0.33}/S^{1/2}$$
$$q_p = C_p\ 640/t_p$$

The coefficient C_t is a regional coefficient for variations in slopes within the watershed. L is the river mileage from the sub-basin outlet to the upstream limits of the drainage area. L_{ca} is the river mileage from the outlet of the sub-basin into the center of gravity of the drainage area. S is the slope of the longest flow-path (ft/mi).

The coefficient C_p is the peaking coefficient, typically ranges from 0.3 to 1.2 with an average value of 0.8, and is related to the flood wave and storage coefficients of the watershed (See Table A-6). Larger values of C_p are generally associated with smaller values of C_t.

Table A-6. Typical Values of Cp

Typical Drainage Area Characteristics	Value of Cp
Undeveloped Area w/Storm Drains	
Flat Basin Slope <0.5%	0.55
Moderate Basin Slope 0.5% to 0.8%	*0.58*
Steep Basin Slope >0.8%	0.61
Moderately Developed Area	
Flat Basin Slope <0.5%	0.63
Moderate Basin Slope 0.5% to 0.8%	*0.66*
Steep Basin Slope >0.8%	0.69
Highly Developed/Commercial Area	
Flat Basin Slope <0.5%	0.7
Moderate Basin Slope 0.5% to 0.8%	*0.73*
Steep Basin Slope >0.8%	0.77

Cp values are presented in the *iSWM Design Manual for Development/Redevelopment.*

The lagtime for each sub-basins was calculated using the ArcHydro tools in the ArcMap environment. Automated utilities of Arc Hydro expedited the process of determining the parameters of the t_p equation: L , $L_{ca,}$ and slope.

After preliminary analysis, it was determined that the initial slope term in the equation for lagtime causes the lagtime to be too small for the size of watershed under consideration. In addition, the original format of Snyder's equation does not contain the slope (S) term. The addition of the slope S in the iSWM Design Manual refers to the U.S. Army Corps of Engineers Manual (EM 1112-2-1405). However, this reference states that in some instances, other measurable characteristics of basins maybe included in the original Snyder's methodology if regression analysis on the effect of the regressed parameter is developed for a region. Thus, the original format of Snyder's equation was used in this study.

For the determination of C_t, the iSWM Design Manual suggests that average values range from 0.4 to 2.3 with an average value of 1.1. Review of previous hydrologic modeling efforts of Big Fossil Creek by the U.S. Army Corps of Engineers indicated an average value of 0.45 was used for Little and Big Fossil Creek Watersheds. In order to estimate the C_t value, a regression formula was developed between the slope of each basin (ft/mile) and the C_t value used in the previous hydrologic model. The resulting equation:

$$C_t = (-0.0032 * \text{Slope}) + 0.5718$$

was used to estimate the C_t value, then it was increased uniformly by 0.1 for all sub-basins to adjust the t_p value.

In determining the C_p value, the iSWM Design Manual was used as a guide. Three levels of development; undeveloped, moderately developed, and highly developed categories were associated with different levels of land use. Due to the level of detailed delineated land use the median values of 0.58, 0.66, and 0.73 were assigned to C_p for the three respective levels of development. Subsequently, in the curve number lookup table (Table A-4) the appropriate C_p value was assigned to different categories of land use. C_p values within each sub-basin were area weighted and a composite C_p value was calculated for each sub-basin, Table A-7.

Future Conditions without iSWM
New development in the Big Fossil Creek Watershed is anticipated to be primarily residential or commercial. Changes in the curve numbers and subsequently C_p values were the only differences considered between the existing and the future condition models. No further adjustment in the C_t value was made for the future condition, see Table A-7.

Future Conditions with iSWM
A systematic procedure was used to simulate the effectiveness of the proposed best management practices in the iSWM manual. iSWM design criteria were applied only to selected sub-basins in the watershed; the undeveloped areas of the upper portion of the watershed. Sub-basins, for which the future curve number had the potential to increase more that 6 points from the existing conditions land use, were selected for iSWM application. Thus, iSWM design criteria was applied only to those sub-basins that were currently undeveloped but were anticipated to be developed in the future.

It was assumed that the iSWM design criteria would reduce the 100-year peak flow to a level approximately 15 percent below the existing condition's peak. Inferring that this will account for the ten-percent rule as presented in the *iSWM Design Manual for Development/Redevelopment.* Due to the large number of sub-basins within the hydrologic model, a target range of acceptable peak flow reduction from 5 percent less than existing conditions peak flow to 25 percent less than existing conditions peak flow was assumed. This would allow for an average reduction in the 100-year peak flow to achieve the ten-percent rule within the Big Fossil Creek Watershed.

The ten-percent rule recognizes the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone of influence the structural control becomes relatively insignificant compared to the runoff from the total drainage area. Based on studies and master planning results for a large number of sites, that zone of influence is considered to be the point where the drainage area controlled by the detention or storage facility comprises 10 percent of the total drainage area. For example, if the structural control drains 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater.

In order to decrease the iSWM selected sub-basins' outflow by target of 15 percent lower than the existing condition the C_t value was uniformly increased by 0.4. For those sub-basins that did not reach this target value, subsequent further modifications were made to the Ct values.

Table A-7 Hydrologic Variable Parameters for the Three Watershed Scenarios (iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
BF1	82	0.61	0.56	0.82	88	0.68	0.56	0.82	88	0.90	1.33
BF10	78	0.59	0.48	0.60	86	0.67	0.48	0.60	86	0.86	1.07
BF11	77	0.58	0.54	0.48	85	0.66	0.54	0.48	85	0.98	0.88
BF12	76	0.60	0.55	0.91	83	0.66	0.55	0.91	83	0.94	1.56
BF13	78	0.59	0.53	0.83	85	0.64	0.53	0.83	85	0.89	1.40
BF14	81	0.60	0.49	0.66	86	0.63	0.49	0.66	86	0.77	1.04
BF15	76	0.60	0.48	0.43	85	0.67	0.48	0.43	85	0.89	0.79
BF16	81	0.60	0.55	0.95	88	0.68	0.55	0.95	88	0.95	1.64
BF17	73	0.59	0.53	0.67	87	0.69	0.53	0.67	87	1.20	1.52
BF18	84	0.63	0.50	0.50	92	0.72	0.50	0.50	92	0.88	0.88
BF19	82	0.62	0.50	0.55	92	0.72	0.50	0.55	92	0.93	1.01
BF2	80	0.59	0.56	0.76	88	0.68	0.56	0.76	88	0.99	1.33
BF20	80	0.62	0.47	0.45	92	0.73	0.47	0.45	92	0.95	0.91
BF21	72	0.61	0.29	0.19	88	0.73	0.29	0.19	88	0.79	0.51
BF22	85	0.66	0.39	0.32	88	0.68	0.39	0.32	88	0.39	0.32
BF23	84	0.68	0.43	0.45	84	0.65	0.43	0.45	84	0.43	0.45
BF24	79	0.65	0.42	0.38	86	0.67	0.42	0.38	86	0.71	0.63
BF25	85	0.66	0.48	0.62	88	0.67	0.48	0.62	88	0.48	0.62
BF26	80	0.67	0.48	0.52	85	0.69	0.48	0.52	85	0.48	0.52
BF27	78	0.64	0.49	0.51	84	0.66	0.49	0.51	84	0.74	0.78
BF28	89	0.68	0.48	0.58	89	0.68	0.48	0.58	89	0.48	0.58
BF29	78	0.65	0.46	0.53	86	0.68	0.46	0.53	86	0.77	0.88
BF3	80	0.59	0.56	0.65	86	0.66	0.56	0.65	86	0.94	1.10
BF30	88	0.68	0.54	0.90	89	0.68	0.54	0.90	89	0.54	0.90
BF31	82	0.66	0.51	0.69	85	0.66	0.51	0.69	85	0.51	0.69
BF32	87	0.67	0.52	0.53	89	0.68	0.52	0.53	89	0.52	0.53
BF33	84	0.67	0.44	0.49	86	0.68	0.44	0.49	86	0.44	0.49
BF34	85	0.67	0.58	0.72	89	0.69	0.58	0.72	89	0.58	0.72
BF4	82	0.62	0.50	0.58	87	0.67	0.50	0.58	87	0.80	0.93
BF5	82	0.62	0.51	0.55	86	0.66	0.51	0.55	86	0.51	0.55
BF6	82	0.62	0.49	0.46	89	0.68	0.49	0.46	89	0.84	0.79
BF7	82	0.61	0.56	0.68	87	0.67	0.56	0.68	87	0.89	1.10
BF8	79	0.60	0.51	0.50	86	0.66	0.51	0.50	86	0.86	0.84

Table A-7 Hydrologic Variable Parameters
for the Three Watershed Scenarios
(iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
BF9	80	0.60	0.54	0.54	88	0.66	0.54	0.54	88	0.95	0.95
BFA40	82	0.62	0.56	0.71	87	0.67	0.56	0.71	87	0.86	1.09
BFA41	82	0.61	0.34	0.31	85	0.64	0.34	0.31	85	0.34	0.31
BFA42	85	0.64	0.43	0.53	87	0.65	0.43	0.53	87	0.43	0.53
BFA43	81	0.59	0.56	0.79	87	0.66	0.56	0.79	87	0.95	1.33
BFA44	80	0.58	0.54	0.65	87	0.66	0.54	0.65	87	0.94	1.13
BFA45	82	0.59	0.57	0.96	87	0.66	0.57	0.96	87	0.57	0.96
BFA46	78	0.59	0.53	0.41	85	0.66	0.53	0.41	85	0.93	0.72
BFA47	84	0.62	0.44	0.47	88	0.67	0.44	0.47	88	0.44	0.47
BFA48	82	0.62	0.57	0.64	90	0.70	0.57	0.64	90	0.98	1.10
BFA49	77	0.61	0.53	0.63	86	0.68	0.53	0.63	86	0.98	1.16
BFB50	83	0.64	0.53	0.66	87	0.67	0.53	0.66	87	0.78	0.98
BFB51	81	0.60	0.49	0.75	91	0.71	0.49	0.75	91	0.92	1.42
BFB52	81	0.60	0.52	0.67	90	0.70	0.52	0.67	90	0.97	1.24
BFB53	81	0.60	0.49	0.72	89	0.68	0.49	0.72	89	0.86	1.26
BFB54	84	0.62	0.55	0.77	90	0.69	0.55	0.77	90	0.90	1.26
BFB55	81	0.59	0.47	0.35	87	0.67	0.47	0.35	87	0.87	0.65
BFB56	85	0.63	0.52	0.62	89	0.69	0.52	0.62	89	0.52	0.62
BFB57	79	0.65	0.53	0.64	85	0.70	0.53	0.64	85	0.87	1.05
BFC60	87	0.66	0.56	0.80	88	0.68	0.56	0.80	88	0.56	0.80
BFC61	89	0.68	0.58	0.84	90	0.68	0.58	0.84	90	0.58	0.84
BFD70	85	0.63	0.53	0.58	91	0.69	0.53	0.58	91	0.87	0.95
BFD71	86	0.65	0.53	0.85	89	0.68	0.53	0.85	89	0.53	0.85
BFD72	87	0.67	0.56	0.55	88	0.67	0.56	0.55	88	0.56	0.55
BFD73	89	0.67	0.52	0.58	89	0.67	0.52	0.58	89	0.52	0.58
BFD74	89	0.68	0.54	0.55	90	0.69	0.54	0.55	90	0.54	0.55
BFD75	82	0.64	0.42	0.39	85	0.65	0.42	0.39	85	0.42	0.39
BFD76	89	0.67	0.47	0.56	90	0.67	0.47	0.56	90	0.47	0.56
BFD77	81	0.65	0.34	0.33	86	0.67	0.34	0.33	86	0.34	0.33
WC10	79	0.60	0.50	0.67	88	0.69	0.50	0.67	88	0.92	1.24
WC11	79	0.59	0.48	0.52	87	0.67	0.48	0.52	87	0.88	0.95
WC12	78	0.59	0.46	0.70	89	0.67	0.46	0.70	89	0.86	1.30
WC13	79	0.60	0.49	0.62	90	0.72	0.49	0.62	90	0.96	1.20

Table A-7 Hydrologic Variable Parameters for the Three Watershed Scenarios (iSWM application noted as Highlighted Sub-basins)

Sub-basin	Existing Conditions				Future Conditions *without* iSWM				Future Conditions *with* iSWM		
	CN	C_p	C_t	t_p	CN	C_p	C_t	t_p	CN	C_t	t_p
WC14	81	0.59	0.46	0.48	88	0.67	0.46	0.48	88	0.83	0.87
WC15	81	0.60	0.46	0.71	88	0.66	0.46	0.71	88	0.72	1.12
WC16	80	0.63	0.53	0.42	88	0.69	0.53	0.42	88	0.93	0.74
WC17	80	0.60	0.51	0.57	90	0.69	0.51	0.57	90	0.98	1.08
WC18	80	0.61	0.39	0.53	88	0.66	0.39	0.53	88	0.67	0.91
WC19	84	0.65	0.50	0.55	86	0.67	0.50	0.55	86	0.50	0.55
WC20	82	0.63	0.49	0.60	87	0.67	0.49	0.60	87	0.49	0.60
WC21	84	0.66	0.54	0.79	87	0.67	0.54	0.79	87	0.54	0.79

Hydrograph Routing

For those routing reaches where a HEC-2 model had been developed previously by the USACE Ft. Worth and could be located on associated USACE work maps, the Modified Puls Routing methodology was used for storage-routing analysis. Otherwise, Muskingum-Cunge channel routing method was used to represent the reach. An initial outflow equal to initial inflow was used for the initial condition. Table A-8 presents the storage routing reaches information obtained from previous HEC-2 models and used in HEC-1.

The Muskingum-Cunge channel routing method was used for stream reaches located at the upstream limits of the HEC-2 models or where no previous study was available. To perform Muskingum-Cunge routing, the HEC-1 model requires reach length, slope, Manning's n value, channel shape (trapezoidal, rectangular or circular), bottom width, and side slopes. Reach length, slope, Manning's n value and channel geometry parameters were determined using aerial photography and two-foot topographic maps. A sample cross section of flow within the routing reach was digitized in GIS and elevations along this cross section were extracted from the terrain data. HEC-1 requires an eight point cross section representing the routing reach, thus the extracted cross section was simplified to an eight point cross section representing the over banks and the channel geometry.

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards	Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BFC61	K20BFC1	DS - 1150 US - 6940	SV 0 98 121 133 169 SQ 0 3550 4700 5200 6550	5790	8.0	2
WC14	K20WB	DS - 31190 US – 34950	SV 0 76 98 107 130 SQ 0 5150 6900 7600 9550	3760	4.0	3
WC15	K20WB	DS – 24700 US – 31190	SV 0 253 321 346 417 SQ 0 5950 8200 9100 11700	6490	5.5	3
WC19	K20WB	DS - 18140 US – 24700	SV 0 312 394 425 510 SQ 0 9100 12450 13850 17700	6560	8.5	2
WC20	K20WB	DS - 9850 US – 18140	SV 0 296 421 474 587 SQ 0 7200 10100 11500 14700	8290	8.0	3
WC21	K20WB	DS - 2310 US - 9850	SV 0 360 469 520 629 SQ 0 7200 10100 11500 14700	7540	8.0	3
BFD73	X20SINGH	DS - 13730 US – 19800	SV 0 95 118 133 160 SQ 0 3900 5200 5800 7200	6070	7.0	2
BFD74	X20SINGH	DS - 11230 US – 13660	SV 0 48 63 69 84 SQ 0 3900 5200 5800 7200	2430	7.0	1
BFD75	X20SINGH	DS - 6070 US – 10610	SV 0 141 183 200 240 SQ 0 5900 8000 8900 11200	4540	6.0	2
BFD77	X20SINGH	DS - 2310 US – 4850	SV 0 110 133 141 161 SQ 0 5900 8000 8900 11200	2540	7.0	1
BF4	K20BF0S3	DS - 94660 US – 96830	SV 0 41 59 67 83 SQ 0 4550 6150 6900 8600	2170	10.0	1
BF5	K20BF0S3	DS - 87800 US – 94660	SV 0 307 365 390 441 SQ 0 6100 8300 9250 11550	6860	7.0	3
BF11	K20BF0S3	DS - 83550 US – 87800	SV 0 160 209 228 273 SQ 0 5350 8700 9950 12800	4250	7.0	2
BF12	K20BF0S3	DS - 75720 US – 82700	SV 0 753 1031 1110 1293 SQ 0 10400 16200 18600 24450	6980	7.0	3
BFA49X	K20BF0S3	DS - 72900 US – 74650	SV 0 108 153 170 208 SQ 0 10400 16200 18600 24500	1750	7.0	1
BF15	K20BF0S3	DS - 71390 US – 71430	SV 0 2 3 4 5 SQ 0 10850 16700 19350 25350	1500	7.0	1
BF15	K20BF0S3	DS - 67930 US – 71390	SV 0 253 355 397 484 SQ 0 10350 16200 18800 24800	3460	7.0	1
BF17	K20BF0S3	DS - 60540 US – 66890	SV 0 297 472 543 688 SQ 0 10300 16250 18950 25150	6350	8.0	2

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards	Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BF19	K20BF0S3	DS - 57110 US – 59260	SV 0 75 149 180 237 SQ 0 10300 16100 18800 25000	2150	7.5	1
BF20	K20BF0S3	DS - 51410 US – 54410	SV 0 128 202 231 290 SQ 0 14600 22000 25400 33450	3000	10.0	1
BF21	J20BFC	DS - 47270 US – 51410	SV 0 127 223 275 388 SQ 0 14590 22420 26620 34950	4140	10.0	1
BF22	J20BFC	DS - 42430 US – 47100	SV 0 307 422 526 708 SQ 0 13700 20040 23070 29360	4670	6.5	2
BF23	J20BFC	DS - 37340 US – 42020	SV 0 875 1661 2029 2912 SQ 0 20020 28590 32840 41080	4680	6.0	2
BF24	J20BFC	DS - 33400 US – 36970	SV 0 460 763 890 1155 SQ 0 19640 28020 31770 39400	3570	7.0	1
BF25	J20BFC	DS - 31080 US – 33180	SV 0 316 470 544 685 SQ 0 20670 29320 33570 41300	2100	6.0	1
BF26	J20BFC	DS - 29400 US – 30830	SV 0 130 176 197 232 SQ 0 20670 29320 33570 41300	1430	8.0	0
BF27	J20BFC	DS - 20430 US – 28300	SV 0 1299 1766 1978 2350 SQ 0 20300 29230 33820 42080	7870	7.0	3
B29	J20BFC	DS - 19110 US – 20230	SV 0 153 226 258 318 SQ 0 20300 29230 33820 42080	1120	6.0	1
BF31	J20BFC	DS - 10730 US – 18140	SV 0 727 974 1106 1411 SQ 0 19470 28620 33440 42000	7410	7.5	3
BF34	J20BFC	DS - 940 US – 10610	SV 0 2451 3188 3476 4059 SQ 0 26000 36750 41250 51750	9670	7.0	4
BF33	C20BF5	DS - 2170 US – 5470	SV 0 38 46 50 61 SQ 0 2100 2700 2900 3800	3300	7.0	1
BFB52	K20BFC2A	DS - 840 US – 6570	SV 0 138 174 189 223 SQ 0 2500 3400 3800 4750	5730	5.0	3
BFB54	K20BFC2	DS - 12600 US – 20920	SV 0 153 264 286 338 SQ 0 2000 2850 3150 3950	8320	6.5	4
BFB55	K20BFC2	DS - 8220 US – 11630	SV 0 128 164 179 214 SQ 0 5350 7500 8400 10600	3410	7.0	1
BFB57	K20BFC2	DS - 1140 US – 8130	SV 0 237 318 351 426 SQ 0 5350 7500 8400 10600	6990	7.0	3
WC12	K20WB1	DS - 1610 US – 4855	SV 0 69 87 94 115 SQ 0 3400 4550 5050 6550	3245	6.5	1
BFA49R	K20BFC4	DS - 1960 US – 4525	SV 0 120 152 167 203 SQ 0 7100 9900 11200 14200	2565	7.0	1

Table A-8. Routing Reaches developed from previous HEC-2 models

HEC-1 Routing Reach	HEC-2 Model	Downstream and Upstream Stations	SV and SQ cards	Reach Length (ft)	Avg Velocity (ft/s)	Time Steps
BFA46	K20BFC4	DS - 4650 US – 7900	SV 0 100 126 137 163 SQ 0 7150 9800 11000 13850	3250	6.5	1
BFA44	K20BFC4	DS - 9300 US – 16800	SV 0 170 217 236 286 SQ 0 3550 4900 5500 7050	7500	6.0	3
BFC48	K20BFC4A	DS - 730 US – 6960	SV 0 182 214 228 262 SQ 0 2600 3500 3900 4900	6230	7.0	2

Peak Discharge Determination

The HEC-1 models for the three scenarios: existing conditions, future conditions *without* iSWM application and future conditions *with* iSWM application were executed for the 1-year and 100-year storm events to determine the peak discharges. Table A-9 presents the peak discharges of each of the individual sub-basins for three scenarios for each storm event. For the future conditions *with* iSWM application 1-year event it was not feasible to simulate detention by adjusting the unit hydrograph parameters as was performed for the 100-year condition. Therefore the total volume beneath each selected sub-basins hydrograph for future condition 1-year event was taken and a constant rate flow hydrograph was developed in such a way that the sub-basin outlet would discharge the same volume over 24-hour period. Table A-9 also presents the future conditions *with* iSWM peak flows for selected sub-basins where the sub-basin C_t values were changed to accomplish reduction of future flows to produces peak flows approximately 15 percent lower than existing peak flows.

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
BF1	1703	1985	1447	316	488	42	-15%
BF10	1139	1399	978	178	326	23	-14%
BF11	680	847	591	103	191	12	-13%
BF12	1586	1913	1341	212	373	36	-15%
BF13	978	1167	821	147	249	23	-16%
BF14	1636	1826	1383	294	413	33	-15%
BF15	1272	1607	1113	181	370	21	-13%
BF16	1581	1928	1336	275	464	44	-15%
BF17	991	1418	838	114	338	25	-15%
BF18	1753	2100	1498	379	633	37	-15%
BF19	2065	2591	1798	395	774	49	-13%
BF2	1299	1631	1134	219	401	33	-13%
BF20	1424	1853	1234	251	565	31	-13%
BF21	337	474	290	43	137	5	-14%
BF22	2142	2267	2267	509	613	613	
BF23	1405	1350	1350	307	292	292	
BF24	1239	1404	1068	217	337	18	-14%
BF25	1916	2000	2000	424	504	504	
BF26	1738	1905	1905	310	432	432	
BF27	1132	1263	970	182	274	18	-14%
BF28	1789	1789	1789	469	469	469	
BF29	1300	1506	1101	206	354	23	-15%
BF3	1603	1919	1375	273	438	33	-14%
BF30	1807	1827	1827	437	460	460	
BF31	1334	1392	1392	255	304	304	
BF32	1440	1482	1482	353	395	395	
BF33	2309	2404	2404	503	569	569	
BF34	1455	1558	1558	318	404	404	
BF4	2247	2540	1907	433	611	42	-15%
BF5	1495	1674	1674	286	390	390	
BF6	1021	1200	870	199	323	19	-15%
BF7	1386	1602	1180	262	380	29	-15%
BF8	721	846	620	121	201	13	-14%

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
BF9	1486	1797	1271	257	456	30	-14%
BFA40	998	1121	854	189	268	21	-14%
BFA41	1579	1709	1709	325	408	408	
BFA42	1718	1784	1784	383	436	436	
BFA43	1055	1260	894	187	295	26	-15%
BFA44	989	1214	850	168	289	22	-14%
BFA45	1429	1689	1689	259	388	388	
BFA46	536	646	462	87	150	8	-14%
BFA47	2688	2999	2999	575	770	770	
BFA48	1183	1436	1019	223	391	28	-14%
BFA49	935	1164	791	137	269	19	-15%
BFB50	1719	1886	1470	341	450	34	-14%
BFB51	1857	2399	1594	329	669	52	-14%
BFB52	1185	1498	1023	213	405	30	-14%
BFB53	1655	2012	1405	295	521	41	-15%
BFB54	1669	1942	1424	341	517	42	-15%
BFB55	702	834	595	133	213	11	-15%
BFB56	1206	1343	1343	265	354	354	
BFB57	1286	1488	1092	211	329	24	-15%
BFC60	2103	2169	2169	493	531	531	
BFC61	2176	2198	2198	552	581	581	
BFD70	1721	1958	1459	380	556	38	-15%
BFD71	1777	1908	1908	395	484	484	
BFD72	2267	2293	2293	552	582	582	
BFD73	1475	1475	1475	386	386	386	
BFD74	1755	1795	1795	464	495	495	
BFD75	1277	1348	1348	260	314	314	
BFD76	1108	1119	1119	291	306	306	
BFD77	920	1004	1004	180	248	248	
WC10	1330	1690	1148	217	420	31	-14%
WC11	1310	1621	1120	216	399	25	-15%
WC12	1495	1908	1287	229	492	39	-14%
WC13	1388	1823	1207	227	502	34	-13%
WC14	1133	1370	965	212	350	22	-15%

Table A-9. Comparison of Peak Discharges for the Three Watershed Scenarios (iSWM Application noted as Highlighted Sub-Basins)

Sub-basin	Flow 100-year (cfs)			Flow 1-year (cfs)			% Difference Existing Future-iSWM Peak Flow
	Existing	Future	Future iSWM	Existing	Future	Future iSWM	
WC15	2045	2386	1787	366	593	47	-13%
WC16	1511	1801	1297	272	474	26	-14%
WC17	2205	2800	1894	384	767	51	-14%
WC18	1850	2200	1570	322	561	36	-15%
WC19	2243	2356	2356	476	549	549	
WC20	1788	1989	1989	346	482	482	
WC21	1903	1998	1998	393	469	469	

Hydrologic Model Results

The hydrologic model of the Big Fossil Creek Watershed provides peak discharge estimates at numerous locations in the watershed. Table A-9 presents a comparison of the peak discharges of the three proposed scenarios for the two flood events, 1-year and 100-year. The tabulated values are the individual sub-basins' hydrograph peaks. In order to analyze the aggregate effect of best management practices suggested in iSWM manual, a single location was chosen for comparison of peak flow from the three scenarios. The chosen comparison location was just upstream of State Highway 121, the most downstream location of Big Fossil Creek before receiving flow from Little Fossil Creek.

Runoff from the existing conditions scenario (34,204 cfs) as compared to the future conditions *without* iSWM scenario (38,026 cfs) increases by 11.2 percent while the increase to the future conditions *with* iSWM scenario (34,634 cfs) is 1.3 percent. The application of iSWM design criteria in the upper portion of the watershed would almost maintain the runoff quantity of the existing conditions scenario.

For the future conditions with iSWM, the assumption was made that application of best management practices recommended through the iSWM manual at a sub-basin level could potentially reduce peak flow by 15 percent, thus reducing the effect downstream. This assumption was put to test through simulation. Sub-basins for which future curve number had the potential to increase more that 6 points were selected. The time to peak of their corresponding hydrograph were altered in such a way that the peak discharge would be reduced by approximately 15 percent relative to the existing 100-year peak flow. The result of this analysis indicated that the discharge at the junction just upstream of State Highway 121 would equal 34634 cfs. This is equivalent to a 1.26 percent increase in discharge relative to the existing condition.

Although the hydrologic model developed and analyzed for this study was used for comparative runoff quantity purposes only, it is encouraging to note the similarities with an existing USACE Ft. Worth hydrologic model of the Big Fossil Creek Watershed. This previous hydrologic model, SWFHYD, Southwest Fort Worth Hydrology (USACE 1986), was developed for a drainage area of 55.0 square miles. For existing conditions the SWFHYD model produces a flow of 33,813 cfs. For future conditions, or as it is titled in the SWFHYD model "projected urbanization (fully developed) runoff condition", flow is predicted as 37,228 cfs.

The HEC-1 model developed for the Big Fossil Creek Watershed Study was developed for a drainage area of 55.88 square miles. For future conditions the HEC-1 model produces a flow of 34,204 cfs. For future conditions without iSWM design criteria, flow is calculated at 38,026 cfs. The HEC-1 model predicts a 11.2 percent increase in existing versus future flow, whereas SWFHYD predicts an increase of 10.1 percent.

Appendix B – Flood Impact Analysis

The flood impact analysis applied the computed runoff quantities of the three watershed scenarios to a HEC-2 (USACE, 1989) hydraulic model along a defined stream reach between Interstate 35 and State Highway 121. The hydraulic model for this study was developed through the combination of several hydraulic models previously created by the U.S. Army Corps of Engineers, Fort Worth District (USACE, Ft. Worth).

Two USACE Ft. Worth HEC-2 models, identified as J20BFC and K20BFOS3, previously modeled the selected stream reach. The appropriate cross sections from upstream of Interstate Highway 35 to downstream of State Highway 121, including bridge and culvert information, were extracted from the USACE models and combined into a single HEC-2 model. The flows (identified as QT cards) were updated to reflect the three watershed scenarios: existing conditions, future conditions *without* iSWM, and future conditions *with* iSWM, for the 1- and 100-year storm events (see Table B-1).

The combined HEC-2 model was executed to produce the water surface elevations (see Table B-2). The centerline of the study reach of Big Fossil Creek was calibrated by positioning the HEC-2 stations over the digital stream information. The calculated water surface elevations were digitally plotted using a floodplain routine scripted in Visual Basic in the ArcMap environment. Figures 5 and 6, presented in the Summary Portion of this Study, display the floodplains graphically for comparative purposes.

Table B-1. Updated Flow Change Points within HEC-2 Model.

HEC-2 Station	HEC-1 Sub-Basin	Flow 100-year (cfs)			Flow 1-year (cfs)		
		Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
60540	BF18C	18832	21406	19783	2769	4049	1906
57110	BF19C	19089	21683	20296	2821	4109	1948
51410	BF20D	24273	27668	25724	3631	5446	2275
49300	BF21D	25470	29011	26737	3908	5793	2552
47220	BF22C	25308	28753	26512	3916	5798	2564
38200	BF23D	32280	36169	33153	5351	8354	3416
35870	BF24C	31717	35503	32668	5293	8231	3375
31080	BF25D	33654	37496	34175	5738	8744	4924
28980	BF26C	33805	37652	34294	5759	8765	5034
22920	BF28C	33715	37554	34229	5677	8547	4836
20850	BF30C	34016	37881	34488	5727	8598	4992
16340	BF31D	34204	38026	34639	5742	8576	5054
3180	BF31D	34204	38026	34639	5742	8576	5054

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
940	498.75	499.3	498.82	488.6	491.33	487.84
3180	499.70	500.24	499.77	489.76	492.49	489.00
6790	501.55	502.08	501.61	492.76	495.06	492.13
8510	503.48	504.13	503.56	494.01	496.24	493.38
9950	504.99	505.69	505.07	494.57	497.07	493.88
10000	505.00	505.73	505.08	494.41	496.83	493.74
10020	505.15	505.88	505.24	494.51	496.96	493.82
10100	505.49	506.17	505.57	495.04	497.79	494.28
10340	505.75	506.44	505.83	495.19	497.99	494.42
10390	505.44	506.07	505.51	495.19	497.97	494.43
10430	505.68	506.36	505.76	495.21	498.00	494.44
10520	505.90	506.67	505.99	495.22	498.01	494.45
10610	505.91	506.65	505.99	495.23	498.02	494.46
10730	505.97	506.72	506.06	495.23	498.03	494.46
10780	506.08	506.91	506.17	495.24	498.03	494.46
11180	506.51	507.36	506.61	495.28	498.09	494.50.
11910	506.67	507.53	506.77	495.33	498.15	494.55
12380	506.70	507.52	506.79	495.37	498.20	494.58
13120	507.02	507.87	507.12	495.44	498.29	494.65
14120	507.60	508.49	507.70	495.60	498.46	494.81
14780	508.06	508.97	508.16	495.76	498.62	494.96
15660	508.90	509.87	509.02	496.14	498.95	495.36
16000	509.48	510.43	509.59	496.81	499.53	496.08
16340	510.17	511.15	510.29	497.43	500.04	496.74
16680	510.32	511.26	510.43	497.91	500.39	497.24
16920	510.68	511.62	510.79	498.32	500.72	497.68
16960	511.04	512.02	511.16	498.53	500.91	497.88
17000	511.63	512.77	511.77	498.73	501.04	498.11
17030	511.01	511.98	511.12	498.67	500.97	498.04
17080	511.58	512.62	511.70	498.92	501.22	498.29
17130	512.66	513.98	512.81	499.21	501.47	498.59
17700	513.62	514.90	513.77	501.51	503.61	500.91
17750	513.63	514.82	513.66	501.80	503.91	501.19
17790	513.92	514.82	514.01	502.04	504.25	501.40
17840	515.08	515.63	515.15	502.31	504.55	501.65

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
18140	516.71	517.28	516.78	503.5	505.86	502.80
19110	519.00	519.65	519.08	507.22	509.68	506.44
19920	520.44	521.06	520.52	509.54	511.97	508.75
19970	520.45	521.07	520.53	510.00	512.56	509.18
20020	520.49	521.11	520.57	510.04	512.60	509.22
20060	520.51	521.13	520.59	510.07	512.64	509.24
20120	520.65	521.27	520.73	510.10	512.67	509.27
20160	520.65	521.27	520.73	511.94	513.27	510.85
20230	520.69	521.31	520.77	511.96	513.29	510.87
20430	520.71	521.33	520.79	512.06	513.44	510.98
20610	520.83	521.45	520.91	512.14	513.57	511.05
20850	521.14	521.76	521.21	512.32	513.87	511.24
22920	524.03	524.60	524.10	516.39	518.76	515.42
24720	527.70	528.18	527.76	520.95	523.00	520.05
24750	527.91	528.40	527.98	520.40	522.77	520.12
24780	527.91	528.39	527.97	521.83	523.34	521.48
25750	529.61	530.08	529.67	522.84	524.64	522.37
25790	529.68	530.15	529.74	522.98	524.83	522.49
25800	529.71	530.19	529.77	522.90	524.13	522.44
25810	529.77	530.24	529.83	522.87	524.06	522.34
25820	529.83	530.28	529.89	523.46	526.26	522.76
26450	530.68	531.14	530.74	524.75	526.82	524.11
26520	530.84	531.29	530.90	524.88	526.88	524.57
26550	530.88	531.33	530.93	525.59	526.95	525.41
26860	531.27	531.73	531.33	525.84	527.17	525.63
28050	532.94	533.45	533.01	526.94	528.20	526.62
28165	533.23	533.74	533.29	527.01	528.36	526.69
28235	533.47	533.95	533.53	527.10	528.46	526.76
28300	533.61	534.09	533.67	527.26	528.86	526.88
28720	533.67	534.19	533.74	527.68	529.13	527.28
28980	536.46	537.01	536.53	528.33	530.14	527.84
29400	537.35	537.91	537.43	529.04	531.06	528.48
29422	537.76	538.34	537.84	528.95	531.05	528.39
29434	537.83	538.41	537.91	529.16	531.22	528.61
29512	537.88	538.45	537.96	529.68	531.59	529.12
30230	539.05	539.65	539.14	530.35	532.38	529.72

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
30620	538.93	539.47	539.00	530.59	532.60	529.97
30830	540.72	541.34	540.81	531.10	533.21	530.44
30860	540.79	541.40	540.88	531.17	533.29	530.51
30890	540.65	541.22	540.73	531.18	533.28	530.52
30910	541.97	543.25	542.12	531.25	533.39	530.58
30960	546.65	548.31	546.88	531.88	534.36	531.11
31080	547.97	549.72	548.21	531.99	534.49	531.22
31360	548.25	549.98	548.48	532.45	534.92	531.68
32500	548.54	550.24	548.78	533.86	536.28	532.52
32780	548.55	550.24	548.79	534.28	536.56	532.80
32880	548.58	550.26	548.82	534.41	536.72	532.89
32980	548.61	550.28	548.85	534.58	536.92	533.00
33080	548.66	550.29	548.89	534.78	537.15	533.15
33130	548.69	550.29	548.91	534.90	537.27	533.24
33180	548.85	550.68	549.08	535.04	537.49	533.34
33400	549.13	551.22	549.51	535.12	537.60	533.40
33480	550.75	552.61	551.17	535.47	538.06	533.66
33630	550.76	552.62	551.18	535.46	537.88	533.74
33960	550.81	552.66	551.23	536.58	539.14	534.58
34430	551.01	552.82	551.42	537.41	540.11	535.27
34480	551.15	552.91	551.55	537.50	540.21	535.33
34570	551.76	553.11	552.04	537.54	540.27	535.37
34630	551.77	553.12	552.05	537.16	539.79	535.16
35050	551.90	553.20	552.17	539.70	542.33	537.39
35510	552.39	553.60	552.65	540.48	543.11	538.13
35710	552.55	553.71	552.80	540.61	543.27	538.25
35755	552.87	554.07	553.14	540.66	543.34	538.28
35780	552.56	553.71	552.81	540.64	543.30	538.27
35820	561.44	563.75	562.03	540.72	543.44	538.32
35870	563.52	566.24	564.22	540.91	543.76	538.44
36000	564.77	567.49	565.47	540.70	543.78	538.14
36130	565.14	567.83	565.83	542.23	545.13	539.83
36720	565.31	567.99	566.00	543.62	546.28	541.35
36970	565.34	568.02	566.02	544.10	546.59	542.01
37340	565.38	568.05	566.06	544.59	546.92	542.56
37960	565.42	568.09	566.10	545.21	547.40	543.26

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
38200	565.44	568.11	566.12	545.65	548.05	544.45
39350	565.52	568.17	566.20	551.21	552.14	550.37
39640	565.53	568.17	566.20	551.30	552.22	550.46
40020	565.55	568.18	566.22	551.35	552.30	550.50
40230	565.55	568.17	566.22	551.58	552.71	550.63
40410	565.76	568.31	566.41	551.82	553.07	550.78
40620	565.97	568.48	566.62	551.97	553.28	550.88
40840	566.11	568.58	566.77	552.09	553.44	550.95
41030	566.25	568.71	566.91	552.23	553.61	551.06
41220	566.65	569.03	567.29	552.53	554.06	551.25
41250	566.68	569.04	567.32	552.54	554.07	551.26
41280	566.71	569.05	567.34	552.56	554.10	551.28
41310	566.72	569.06	567.36	552.59	554.13	551.30
41340	566.73	569.06	567.36	552.62	554.17	551.32
41350	566.73	569.05	567.36	552.63	554.18	551.33
41405	566.55	568.91	567.18	552.65	554.19	551.35
41450	568.30	570.08	568.82	552.69	554.26	551.37
41500	569.47	571.03	569.96	552.93	554.64	551.51
41825	569.60	571.14	570.09	553.13	554.89	551.67
42020	569.70	571.23	570.19	553.25	555.03	551.76
42230	569.81	571.35	570.30	553.38	555.17	551.87
42430	569.89	571.42	570.38	553.56	555.35	552.03
42630	569.99	571.51	570.48	553.78	555.59	552.24
42740	570.16	571.77	570.69	555.38	557.20	553.76
42810	570.65	572.12	571.13	559.06	561.43	556.80
43310	570.73	572.18	571.20	559.80	561.74	558.05
44540	570.84	572.28	571.31	561.21	562.05	560.35
45480	571.57	572.82	571.98	565.32	566.28	563.92
45860	571.87	572.99	572.23	566.06	567.04	564.57
46200	573.39	574.21	573.65	567.45	568.63	566.29
46500	574.74	575.41	574.96	569.55	570.35	568.39
46650	574.91	575.57	575.13	569.72	570.54	568.55
46980	576.67	577.26	576.88	570.20	571.32	568.86
47100	576.75	577.33	576.95	570.22	571.36	568.88
47220	577.29	578.01	577.54	570.28	571.45	568.92
47270	577.88	578.85	578.23	570.08	571.12	568.8

Table B-2. Water Surface Elevation for Applied Scenarios

HEC-2 Station	Flood Elevation for 100-Year Event (ft)			Flood Elevation for 1-Year Event (ft)		
	Existing	Future	Future-iSWM	Existing	Future	Future-iSWM
49300	578.40	579.25	578.7	570.81	572.05	569.42
50210	580.69	581.17	580.88	573.24	574.89	571.68
51410	585.43	585.97	585.69	576.21	578.12	574.27
52950	590.67	591.33	590.96	580.40	582.36	578.47
53820	593.92	594.54	594.22	583.81	585.76	582.13
54410	595.32	595.98	595.63	586.18	587.81	584.91
57110	599.45	600.06	599.74	591.29	592.53	590.25
57780	602.71	603.88	603.28	592.85	594.17	591.80
57830	602.05	602.99	602.54	593.89	594.85	593.21
57870	602.84	604.73	603.34	593.99	595.00	593.27
57920	605.84	607.84	606.47	594.43	595.58	593.59
58420	606.53	608.27	607.08	595.87	597.13	594.84
58620	606.79	608.46	607.32	596.22	597.54	595.13
58670	607.86	609.07	608.27	596.29	597.64	595.18
58770	607.93	609.13	608.34	596.43	597.81	595.31
58970	607.96	609.15	608.37	596.48	597.88	595.34
59070	607.96	609.16	608.37	596.65	598.05	595.51
59110	608.73	609.57	609.01	596.82	598.26	595.64
59160	608.74	609.58	609.01	597.09	598.48	595.99
59260	608.92	609.75	609.19	597.87	599.20	596.82
60540	612.16	612.81	612.31	604.16	605.42	603.05

Hydraulic Modeling Results

Review of table B-2 and the plots of floodplain maps for the 1- and 100-year storm events (Figures 5 and 6) indicate good agreement with the expectation of the modeling effort. The hydraulic modeling effort developed a comparison of the three watershed scenarios. Review of Table B-2 reveals a decrease in the water surface elevations of both the 1- and 100-year storm events between the future *without* iSWM conditions and the future *with* iSWM conditions scenarios. The plots of the floodplain maps reveal the width of the 100-year floodplain is reduced between the future *without* iSWM conditions and the future *with* iSWM conditions scenarios (see Figures 5 and 6 of the Summary).

Appendix C – Water Quality Analysis

The amount of total suspended solids (TSS) in a stream is a fair indicator of the overall water quality of the stream. Other pollutants attach themselves to the suspended solids and are transported downstream. Suspended solids interfere with the transmission of light and settle out in receiving streams and lakes. Turbid water is a result of excessive suspended solids in a stream. Reduction of TSS values in a stream has long been considered the best way to improve a stream's water quality and thus increase its potential uses.

The Simple Method was used to determine seasonal TSS loadings for the Big Fossil Creek Watershed. The Simple Method, developed by the Center for Watershed Protection, incorporates a land-use approach to estimating annual and/or seasonal non-point source loads from direct runoff based upon the event mean concentrations (EMCs) and runoff volumes. The approach is based on the fact that the type and concentration of pollutants in storm water is related to the amount of imperviousness and type of land use contributing to the runoff. Data required to execute the Simple Method water quality model include EMCs for TSS, land use, average annual/seasonal precipitation, and estimates for percent imperviousness on the sub-basin level. In summary, the Simple Method provides a basis for planning level evaluations of the long-term (annual or seasonal) non-point pollution loads and the relative benefits of non-point source pollution management strategies to reduce these loads.

During a storm event, the concentration of pollutants in the runoff varies considerably over time. For example, the concentration of oily substances on roadways are highest during the first part of the storm, and then decline quickly when the bulk of the material is washed off. This is known as the first-flush phenomenon. However, the concentration in the first-flush runoff is not representative of the entire storm. In order to estimate the loading from a storm, the flow-weighted average concentration is needed. Known as the Event Mean Concentration (EMC), the flow-weighted concentration is found by dividing the average of total loading by total runoff for a series of storm events.

The EMCs used in the Simple Method water quality model for the Big Fossil Creek Watershed were based upon a qualitative in-stream monitoring program completed by the NCTCOG. The NCTCOG completed a comprehensive sampling program of 22 separate outfalls for a wide range of pollutants, including total suspended solids. The sampling was conducted from September 1997 to August 2000. Although many other pollutants were included in the analysis, TSS is the pollutant of concern for this study. In order to model TSS values in the watershed, sampling sites were classified into five separate land use categories in order to differentiate water quality from diverse sources. For each sampling interval, the concentration and the quantity of runoff were combined to determine a TSS loading for the interval. At the end of the storm event, the results were used to develop the EMC (total mass/total runoff), which describes the average concentration for the storm. These results were combined with the results from several storm events and statistically evaluated to arrive at a representative EMC for each land use on a seasonal or average annual basis. Storm water loadings tend to be highly variable from one storm event to another, even for the same sampling site. This is attributable to variable antecedent weather conditions, which affect the amount of runoff; variable rainfall for a given event; seasonal variations in land use (e.g., spring fertilization of lawns); and other factors. Consequently, it is desirable to obtain a good statistical representation of the EMC.

A summary of the EMCs used in the Simple Method water quality model are presented in Table C-1.

Table C-1. Event Mean Concentrations, TSS (mg/l)

Type of Land Use	Season 1 (Sep – Oct)	Season 2 (Nov – Feb)	Season 3 (Mar – Jun)	Season 4 (Jul – Aug)
Commercial	41.5	37.5	46	37
Highway	62	142	134	142
Industrial	54	86	135	86
Open	118	332	118	332
Residential	90	73	116	73

Rainfall
The rainfall data used in the Simple Method water quality model were the long-term records of the National Weather Service recording station at Dallas/Fort Worth International Airport. Annual/Seasonal precipitation values were obtained from the National Oceanic and Atmospheric Association (NOAA).

Pollutant Data
As previously discussed, EMCs were derived from actual wet weather samples taken from 22 sites across the area. These sites were located within five different land uses types: commercial, industrial, highway, open, and residential.

Mapping
All mapping data was obtained from NCTCOG geographic information system. Digital base data included contours, orthophotographs, and existing and future land use. Basin and sub-basin boundaries were delineated during the development of the hydrologic models.

Model Development
The Simple Method water quality model was incorporated into a spreadsheet format for evaluation of the impacts on water quality from traditional non-point sources. The model is a user-friendly database model that simulates the generation and outcome of pollutant loads from a number of watershed pollutant sources. The model's primary function is to estimate pollutant loads from storm water runoff (non-point source pollution). For simulation of storm water runoff pollutant loads, the model uses land use and the associated runoff volume and event mean concentrations (EMCs) for total suspended solids.

Designated sub-basins within the Big Fossil Creek Watershed were simulated using existing and future land uses. The developed model is beneficial to NCTCOG future planning efforts because it can provide a forecast of the approximate impact of planned actions or alternatives on water quality and pollutant loads. The model may also be used to estimate and analyze trade-offs between planning objectives through the management of all watershed pollution sources (including non-point sources, such as storm water runoff, and point sources, such as wastewater treatment plant discharges, CSOs, etc.)

Land Use
The pollutant loading calculation is derived from land uses. Existing and future land use data, provided by the NCTCOG and the City of Fort Worth, were used as the basis for determining the land use classes employed in the water quality calculations. The provided land use was classified into the five land use types, as determined in the monitoring study completed by the NCTCOG; by grouping similar land use types. For example, regional commercial uses, office commercial uses, community commercial uses, and heavy commercial uses were all combined

into a larger “commercial” category. Table C-2 displays the land uses from the model and their corresponding percent imperviousness.

Table C-2.
Land Use Designations

Number	Description	Percent Imperviousness
1	Commercial	85
2	Highway	90
3	Industrial	72
4	Open	3
5	Residential	30

Pollutant Loads

Pollutant load is simply the product of runoff volume and event mean concentration. In order to generate the input data, land use-based runoff coefficients, land use-based EMCs, and rainfall depths are needed. Rainfall/runoff relationships are needed to estimate non-point pollution load factors (lbs/acre/year) for the various land use categories. The load factors are then used to calculate the annual load of a certain parameter from a drainage basin (lbs/year) based on the area of that land use.

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$\mathbf{L = 0.226 * R * C * A}$$

L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration or Event Mean Concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

Annual Runoff

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$\mathbf{R = P * P_j * Rv}$$

R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

For the modeling, a runoff coefficient of (0.05 + 0.009(I)) was used to predict runoff, where I is the percent of impervious area. For completely pervious surfaces, the R_v would be 0.05. For completely impervious surfaces, the R_v would be 0.95.

iSWM Application
In order to simulate the future conditions *with* iSWM scenario, a 75 percent reduction in TSS loadings was applied to each sub-basin. This application was made to reflect the design recommendations of the iSWM structural Best Management Practices (BMPs). Recommended water quality BMPs will remove 80 percent of the average annual TSS load in typical urban post-development runoff and a proportional removal of other pollutants, if designed and installed properly.

Model Results
Table C-3 presents the TSS loadings computed for each sub-basin for the existing conditions scenario and the future conditions scenarios, both *without* and *with* iSWM design criteria. Red text denotes application of iSWM design criteria for Future Conditions.

Table C-3. Comparison of TSS Loadings

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	580	745	1,440	328	308	395	765	174	231	297	574	131
BF1	Highway	5,137	16,953	24,889	7,477	6,186	20,417	29,975	9,004	4,640	15,313	22,481	6,753
	Industrial	570	1,307	3,193	577	3,525	8,091	19,760	3,568	2,644	6,068	14,820	2,676
	Open	6,815	27,629	15,278	12,185	158	642	355	283	158	642	355	283
	Residential	672	786	1,942	346	19,177	22,415	55,415	9,885	14,383	16,811	41,561	7,414
	Total	**13,772**	**47,420**	**46,743**	**20,913**	**29,355**	**51,960**	**106,269**	**22,915**	**22,055**	**39,130**	**79,790**	**17,257**
	Commercial	0	348	0	0	0	348	1	0	0	261	1	0
BF2	Highway	1,087	3,588	5,267	1,582	955	3,153	4,629	1,391	717	2,365	3,472	1,043
	Industrial	0	0	0	0	5,277	12,111	29,578	5,341	3,958	9,083	22,183	4,006
	Open	6,219	25,215	13,943	11,120	3	13	7	6	3	13	7	6
	Residential	0	0	0	0	15,741	18,399	45,486	8,114	11,806	13,799	34,115	6,086
	Total	**7,306**	**29,151**	**19,210**	**12,703**	**21,977**	**34,024**	**79,701**	**14,852**	**16,484**	**25,521**	**59,778**	**11,140**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF3	Highway	681	2,246	3,298	991	662	2,185	3,209	964	497	1,639	2,406	723
	Industrial	0	0	0	0	166	380	929	168	124	285	697	126
	Open	6,699	27,161	15,019	11,979	25	100	55	44	25	100	55	44
	Residential	1,254	1,466	3,624	647	22,293	26,058	64,420	11,492	16,720	19,543	48,315	8,619
	Total	**8,634**	**30,873**	**21,941**	**13,616**	**23,146**	**28,724**	**68,613**	**12,668**	**17,366**	**21,568**	**51,473**	**9,512**
	Commercial	0	0	0	0	888	1,141	2,207	503	666	856	1,655	377
BF4	Highway	1,041	3,436	5,044	1,515	1,006	3,319	4,873	1,464	754	2,489	3,655	1,098
	Industrial	2,648	6,078	14,844	2,680	9,101	20,886	51,010	9,211	6,826	15,665	38,257	6,909
	Open	5,979	24,241	13,404	10,691	709	2,873	1,588	1,267	709	2,873	1,588	1,267
	Residential	6,106	7,137	17,644	3,147	17,143	20,038	49,538	8,837	12,858	15,029	37,154	6,628
	Total	**15,774**	**40,891**	**50,936**	**18,034**	**28,847**	**48,257**	**109,216**	**21,282**	**21,812**	**36,911**	**82,309**	**16,279**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	116	149	288	66	116	149	288	66
BF5	Highway	436	1,437	2,110	634	1,131	3,733	5,480	1,646	1,131	3,733	5,480	1,646
	Industrial	152	348	850	154	0	0	0	0	0	0	0	0
	Open	2,843	11,528	6,374	5,084	148	599	331	264	148	599	331	264
	Residential	8,461	9,890	24,449	4,362	16,647	19,458	48,104	8,581	16,647	19,458	48,104	8,581
	Total	**11,891**	**23,203**	**33,784**	**10,233**	**18,042**	**23,938**	**54,203**	**10,557**	**18,042**	**23,938**	**54,203**	**10,557**
	Commercial	0	0	0	0	221	285	550	125	166	213	413	94
BF6	Highway	781	2,578	3,785	1,137	2,304	7,603	11,163	3,353	1,728	5,703	8,372	2,515
	Industrial	2,471	5,670	13,847	2,501	2,605	5,978	14,599	2,636	1,954	4,483	10,950	1,977
	Open	2,718	11,021	6,094	4,861	72	293	162	129	72	293	162	129
	Residential	0	0	0	0	7,274	8,502	21,018	3,749	5,455	6,376	15,764	2,812
	Total	**5,970**	**19,269**	**23,727**	**8,498**	**12,476**	**22,661**	**47,493**	**9,994**	**9,375**	**17,069**	**35,660**	**7,528**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF7	Highway	1,895	6,255	9,183	2,758	1,940	6,402	9,399	2,823	1,455	4,802	7,049	2,118
	Industrial	2,554	5,861	14,313	2,585	2,466	5,660	13,822	2,496	1,850	4,245	10,367	1,872
	Open	4,378	17,749	9,814	7,828	290	1,174	649	518	290	1,174	649	518
	Residential	2,151	2,514	6,215	1,109	15,151	17,710	43,782	7,810	11,363	13,282	32,836	5,858
	Total	**10,977**	**32,378**	**39,526**	**14,279**	**19,847**	**30,946**	**67,652**	**13,648**	**14,958**	**23,503**	**50,902**	**10,365**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF8	Highway	135	444	652	196	890	2,938	4,314	1,296	668	2,204	3,235	972
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,200	8,918	4,931	3,933	7	30	17	13	7	30	17	13
	Residential	1,476	1,725	4,264	761	8,016	9,369	23,163	4,132	6,012	7,027	17,372	3,099
	Total	**3,810**	**11,087**	**9,848**	**4,890**	**8,913**	**12,337**	**27,493**	**5,441**	**6,687**	**9,260**	**20,624**	**4,084**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	1	1	0	774	994	1,922	438	580	745	1,442	329
BF9	Highway	2,596	8,569	12,580	3,779	1,528	5,044	7,405	2,225	1,146	3,783	5,554	1,668
	Industrial	0	0	0	0	537	1,232	3,008	543	403	924	2,256	407
	Open	5,048	20,466	11,317	9,026	877	3,555	1,966	1,568	877	3,555	1,966	1,568
	Residential	1,174	1,373	3,393	605	13,904	16,252	40,178	7,167	10,428	12,189	30,134	5,376
	Total	**8,819**	**30,408**	**27,292**	**13,411**	**17,620**	**27,076**	**54,480**	**11,941**	**13,434**	**21,196**	**41,351**	**9,348**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF10	Highway	479	1,580	2,320	697	674	2,225	3,267	981	506	1,669	2,450	736
	Industrial	0	0	0	0	1,355	3,109	7,593	1,371	1,016	2,332	5,695	1,028
	Open	4,116	16,687	9,227	7,359	1	3	2	2	1	3	2	2
	Residential	2,300	2,688	6,646	1,186	14,203	16,601	41,041	7,321	10,652	12,451	30,780	5,491
	Total	**6,895**	**20,955**	**18,193**	**9,242**	**16,232**	**21,938**	**51,902**	**9,675**	**12,175**	**16,455**	**38,927**	**7,257**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF11	Highway	46	152	223	67	210	692	1,016	305	157	519	762	229
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,600	10,543	5,830	4,650	5	21	11	9	5	21	11	9
	Residential	265	309	765	136	8,402	9,821	24,279	4,331	6,302	7,366	18,209	3,248
	Total	**2,911**	**11,004**	**6,818**	**4,853**	**8,617**	**10,533**	**25,306**	**4,645**	**6,464**	**7,905**	**18,982**	**3,486**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF12	Highway	2,234	7,374	10,827	3,252	599	1,977	2,903	872	449	1,483	2,177	654
	Industrial	0	0	0	0	2,326	5,338	13,036	2,354	1,744	4,003	9,777	1,766
	Open	8,893	36,057	19,938	15,902	283	1,146	634	506	283	1,146	634	506
	Residential	0	0	0	0	26,399	30,856	76,284	13,608	19,799	23,142	57,213	10,206
	Total	**11,128**	**43,431**	**30,765**	**19,154**	**29,607**	**39,318**	**92,857**	**17,340**	**22,276**	**29,775**	**69,801**	**13,131**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	300	385	745	170	618	794	1,535	350	463	595	1,151	262
BF13	Highway	946	3,123	4,585	1,377	989	3,263	4,790	1,439	741	2,447	3,593	1,079
	Industrial	19	44	107	19	580	1,332	3,252	587	435	999	2,439	440
	Open	4,972	20,159	11,147	8,891	2,193	8,892	4,917	3,922	2,193	8,892	4,917	3,922
	Residential	0	0	0	0	8,408	9,827	24,296	4,334	6,306	7,371	18,222	3,251
	Total	**6,237**	**23,711**	**16,583**	**10,457**	**12,788**	**24,108**	**38,790**	**10,632**	**10,139**	**20,304**	**30,322**	**8,955**
	Commercial	387	498	962	219	2,376	3,052	5,903	1,346	1,782	2,289	4,428	1,010
BF14	Highway	1,517	5,007	7,350	2,208	4,147	13,688	20,095	6,037	3,110	10,266	15,072	4,527
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,681	23,032	12,736	10,158	4,122	16,712	9,241	7,370	4,122	16,712	9,241	7,370
	Residential	3,567	4,170	10,308	1,839	5,674	6,632	16,395	2,925	4,255	4,974	12,296	2,193
	Total	**11,152**	**32,706**	**31,357**	**14,424**	**16,318**	**40,083**	**51,634**	**17,677**	**13,269**	**34,240**	**41,036**	**15,101**
	Commercial	33	42	81	19	771	991	1,917	437	578	743	1,438	328
BF15	Highway	1,614	5,327	7,821	2,349	2,039	6,729	9,880	2,968	1,529	5,047	7,410	2,226
	Industrial	0	0	0	0	2,878	6,605	16,131	2,913	2,159	4,954	12,099	2,185
	Open	3,940	15,974	8,833	7,045	3,610	14,638	8,094	6,456	3,610	14,638	8,094	6,456
	Residential	1,557	1,820	4,499	803	9,987	11,674	28,860	5,148	7,490	8,755	21,645	3,861
	Total	**7,144**	**23,163**	**21,234**	**10,215**	**19,286**	**40,637**	**64,882**	**17,922**	**15,367**	**34,137**	**50,685**	**15,055**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BF16	Highway	2,202	7,267	10,669	3,205	2,783	9,184	13,483	4,050	2,087	6,888	10,112	3,038
	Industrial	1,920	4,407	10,764	1,944	7,083	16,256	39,702	7,169	5,313	12,192	29,776	5,377
	Open	7,883	31,963	17,674	14,096	3,516	14,254	7,882	6,286	3,516	14,254	7,882	6,286
	Residential	0	0	0	0	20,479	23,937	59,178	10,557	15,360	17,953	44,384	7,918
	Total	**12,006**	**43,637**	**39,107**	**19,245**	**33,861**	**63,631**	**120,244**	**28,063**	**26,275**	**51,287**	**92,154**	**22,619**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	8,759	11,254	21,767	4,963	6,569	8,440	16,325	3,722
BF17	Highway	0	0	0	0	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,179	20,998	11,611	9,261	5,159	20,918	11,567	9,225	5,159	20,918	11,567	9,225
	Residential	0	0	0	0	8,958	10,470	25,884	4,617	6,718	7,852	19,413	3,463
	Total	**5,179**	**20,998**	**11,611**	**9,261**	**22,876**	**42,642**	**59,218**	**18,806**	**18,447**	**37,211**	**47,305**	**16,411**
	Commercial	4,217	5,418	10,480	2,390	5	7	13	3	4	5	10	2
BF18	Highway	2,122	7,005	10,284	3,089	2,656	8,767	12,872	3,867	1,992	6,576	9,654	2,900
	Industrial	818	1,877	4,585	828	21,242	48,749	119,057	21,499	15,931	36,562	89,293	16,125
	Open	3,766	15,269	8,443	6,734	3,159	12,807	7,082	5,648	3,159	12,807	7,082	5,648
	Residential	1,546	1,807	4,468	797	1,552	1,813	4,483	800	1,164	1,360	3,362	600
	Total	**12,470**	**31,377**	**38,261**	**13,838**	**28,614**	**72,144**	**143,507**	**31,817**	**22,250**	**57,310**	**109,401**	**25,275**
	Commercial	1,544	1,984	3,838	875	681	876	1,694	386	511	657	1,270	290
BF19	Highway	8,105	26,751	39,275	11,798	9,452	31,195	45,798	13,757	7,089	23,396	34,348	10,318
	Industrial	0	0	0	0	22,699	52,095	127,228	22,975	17,025	39,071	95,421	17,231
	Open	5,361	21,735	12,019	9,586	1,386	5,621	3,108	2,479	1,386	5,621	3,108	2,479
	Residential	2,086	2,438	6,026	1,075	1,704	1,992	4,924	878	1,278	1,494	3,693	659
	Total	**17,096**	**52,909**	**61,158**	**23,334**	**35,923**	**91,777**	**182,752**	**40,476**	**27,289**	**70,238**	**137,841**	**30,976**
	Commercial	545	701	1,355	309	2,717	3,490	6,751	1,539	2,037	2,618	5,063	1,154
BF20	Highway	1,331	4,392	6,448	1,937	1,351	4,457	6,544	1,966	1,013	3,343	4,908	1,474
	Industrial	1,435	3,293	8,042	1,452	16,452	37,756	92,209	16,651	12,339	28,317	69,157	12,488
	Open	3,665	14,860	8,217	6,553	27	109	60	48	27	109	60	48
	Residential	1,801	2,105	5,204	928	0	0	0	0	0	0	0	0
	Total	**8,777**	**25,350**	**29,266**	**11,180**	**20,545**	**45,812**	**105,564**	**20,204**	**15,416**	**34,386**	**79,188**	**15,165**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	150	192	372	85	112	144	279	64
BF21	Highway	83	273	401	121	130	428	628	189	97	321	471	141
	Industrial	74	169	412	74	3,229	7,409	18,096	3,268	2,421	5,557	13,572	2,451
	Open	805	3,265	1,805	1,440	0	1	1	1	0	1	1	1
	Residential	12	14	34	6	0	0	1	0	0	0	1	0
	Total	**974**	**3,721**	**2,654**	**1,641**	**3,508**	**8,031**	**19,097**	**3,542**	**2,631**	**6,024**	**14,323**	**2,657**
	Commercial	2,779	3,571	6,907	1,575	4,680	6,013	11,630	2,652	4,680	6,013	11,630	2,652
BF22	Highway	2,984	9,847	14,457	4,343	4,268	14,087	20,682	6,213	4,268	14,087	20,682	6,213
	Industrial	1,872	4,297	10,494	1,895	1,330	3,053	7,455	1,346	1,330	3,053	7,455	1,346
	Open	2,135	8,658	4,787	3,818	1,337	5,422	2,998	2,391	1,337	5,422	2,998	2,391
	Residential	5,206	6,085	15,044	2,684	5,838	6,823	16,869	3,009	5,838	6,823	16,869	3,009
	Total	**14,977**	**32,458**	**51,690**	**14,315**	**17,453**	**35,398**	**59,635**	**15,611**	**17,453**	**35,398**	**59,635**	**15,611**
	Commercial	6,936	8,911	17,236	3,930	4,106	5,275	10,202	2,326	4,106	5,275	10,202	2,326
BF23	Highway	2,278	7,517	11,036	3,315	2,416	7,975	11,709	3,517	2,416	7,975	11,709	3,517
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,503	6,093	3,369	2,687	2,088	8,466	4,681	3,734	2,088	8,466	4,681	3,734
	Residential	1,631	1,906	4,713	841	2,112	2,468	6,102	1,088	2,112	2,468	6,102	1,088
	Total	**12,347**	**24,427**	**36,354**	**10,773**	**10,721**	**24,184**	**32,694**	**10,665**	**10,721**	**24,184**	**32,694**	**10,665**
	Commercial	821	1,055	2,041	465	5,658	7,269	14,060	3,206	4,243	5,452	10,545	2,404
BF24	Highway	3,704	12,224	17,947	5,391	2,896	9,558	14,032	4,215	2,172	7,168	10,524	3,161
	Industrial	1,956	4,490	10,966	1,980	0	0	0	0	0	0	0	0
	Open	1,920	7,785	4,305	3,433	1,148	4,653	2,573	2,052	1,148	4,653	2,573	2,052
	Residential	1,872	2,189	5,411	965	2,134	2,495	6,168	1,100	1,601	1,871	4,626	825
	Total	**10,274**	**27,743**	**40,669**	**12,235**	**11,836**	**23,974**	**36,832**	**10,573**	**9,164**	**19,144**	**28,267**	**8,443**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	2,650	3,405	6,587	1,502	5,569	7,155	13,839	3,155	5,569	7,155	13,839	3,155
BF25	Highway	9,750	32,179	47,243	14,191	7,908	26,099	38,317	11,510	7,908	26,099	38,317	11,510
	Industrial	1,910	4,384	10,708	1,934	702	1,611	3,934	710	702	1,611	3,934	710
	Open	3,307	13,406	7,413	5,912	2,554	10,353	5,725	4,566	2,554	10,353	5,725	4,566
	Residential	2,917	3,409	8,428	1,504	4,737	5,537	13,688	2,442	4,737	5,537	13,688	2,442
	Total	**20,534**	**56,784**	**80,378**	**25,043**	**21,469**	**50,754**	**75,502**	**22,384**	**21,469**	**50,754**	**75,502**	**22,384**
	Commercial	2,229	2,863	5,538	1,263	7,905	10,156	19,644	4,479	7,905	10,156	19,644	4,479
BF26	Highway	7,775	25,662	37,675	11,317	5,935	19,589	28,760	8,639	5,935	19,589	28,760	8,639
	Industrial	70	160	390	70	0	0	0	0	0	0	0	0
	Open	1,797	7,288	4,030	3,214	715	2,900	1,603	1,279	715	2,900	1,603	1,279
	Residential	7,610	8,895	21,991	3,923	7,255	8,479	20,963	3,740	7,255	8,479	20,963	3,740
	Total	**19,481**	**44,868**	**69,624**	**19,788**	**21,810**	**41,124**	**70,970**	**18,137**	**21,810**	**41,124**	**70,970**	**18,137**
	Commercial	207	265	514	117	3,048	3,916	7,575	1,727	2,286	2,937	5,681	1,295
BF27	Highway	3,678	12,138	17,820	5,353	3,385	11,173	16,403	4,927	2,539	8,379	12,302	3,696
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,680	6,810	3,766	3,004	1,065	4,319	2,388	1,905	1,065	4,319	2,388	1,905
	Residential	5,833	6,818	16,855	3,007	5,520	6,452	15,951	2,846	4,140	4,839	11,963	2,134
	Total	**11,397**	**26,032**	**38,955**	**11,481**	**13,019**	**25,859**	**42,317**	**11,405**	**10,030**	**20,474**	**32,335**	**9,030**
	Commercial	1,453	1,867	3,611	823	2,914	3,744	7,242	1,651	2,914	3,744	7,242	1,651
BF28	Highway	8,571	28,287	41,529	12,475	6,907	22,796	33,468	10,054	6,907	22,796	33,468	10,054
	Industrial	1,978	4,541	11,089	2,002	1,646	3,777	9,223	1,666	1,646	3,777	9,223	1,666
	Open	538	2,180	1,206	962	486	1,972	1,091	870	486	1,972	1,091	870
	Residential	9,685	11,320	27,986	4,993	9,757	11,404	28,193	5,029	9,757	11,404	28,193	5,029
	Total	**22,225**	**48,195**	**85,422**	**21,255**	**21,710**	**43,693**	**79,217**	**19,270**	**21,710**	**43,693**	**79,217**	**19,270**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	86	111	214	49	4,781	6,142	11,880	2,709	3,586	4,607	8,910	2,032
BF29	Highway	4,474	14,765	21,677	6,512	4,014	13,248	19,450	5,843	3,011	9,936	14,588	4,382
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,701	6,896	3,813	3,041	365	1,479	818	652	365	1,479	818	652
	Residential	7,543	8,817	21,798	3,888	8,029	9,385	23,201	4,139	6,022	7,039	17,401	3,104
	Total	**13,804**	**30,589**	**47,502**	**13,490**	**17,189**	**30,254**	**55,350**	**13,343**	**12,983**	**23,060**	**41,717**	**10,170**
	Commercial	3,280	4,214	8,151	1,858	6,416	8,244	15,945	3,636	6,416	8,244	15,945	3,636
BF30	Highway	10,576	34,906	51,247	15,394	8,247	27,219	39,961	12,004	8,247	27,219	39,961	12,004
	Industrial	1,342	3,079	7,520	1,358	231	531	1,296	234	231	531	1,296	234
	Open	661	2,682	1,483	1,183	661	2,681	1,482	1,182	661	2,681	1,482	1,182
	Residential	13,653	15,958	39,451	7,038	13,089	15,299	37,823	6,747	13,089	15,299	37,823	6,747
	Total	**29,512**	**60,839**	**107,852**	**26,831**	**28,645**	**53,973**	**96,508**	**23,803**	**28,645**	**53,973**	**96,508**	**23,803**
	Commercial	3,617	4,647	8,988	2,049	5,854	7,522	14,549	3,317	5,854	7,522	14,549	3,317
BF31	Highway	6,360	20,990	30,816	9,257	4,312	14,230	20,892	6,276	4,312	14,230	20,892	6,276
	Industrial	1,005	2,307	5,634	1,017	0	0	0	0	0	0	0	0
	Open	2,116	8,579	4,744	3,783	2,065	8,372	4,629	3,692	2,065	8,372	4,629	3,692
	Residential	3,347	3,912	9,671	1,725	3,478	4,065	10,049	1,793	3,478	4,065	10,049	1,793
	Total	**16,444**	**40,434**	**59,852**	**17,832**	**15,708**	**34,188**	**50,118**	**15,078**	**15,708**	**34,188**	**50,118**	**15,078**
	Commercial	2,114	2,716	5,254	1,198	2,498	3,209	6,207	1,415	2,498	3,209	6,207	1,415
BF32	Highway	4,397	14,513	21,307	6,400	4,330	14,291	20,981	6,302	4,330	14,291	20,981	6,302
	Industrial	57	130	317	57	0	0	0	0	0	0	0	0
	Open	812	3,292	1,820	1,452	549	2,227	1,232	982	549	2,227	1,232	982
	Residential	7,973	9,319	23,039	4,110	8,558	10,003	24,729	4,411	8,558	10,003	24,729	4,411
	Total	**15,353**	**29,970**	**51,737**	**13,217**	**15,935**	**29,730**	**53,148**	**13,111**	**15,935**	**29,730**	**53,148**	**13,111**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	2,776	3,566	6,898	1,573	4,169	5,357	10,361	2,362	4,169	5,357	10,361	2,362
BF33	Highway	9,673	31,924	46,869	14,079	9,073	29,946	43,966	13,207	9,073	29,946	43,966	13,207
	Industrial	284	651	1,591	287	52	118	289	52	52	118	289	52
	Open	1,143	4,635	2,563	2,044	590	2,392	1,323	1,055	590	2,392	1,323	1,055
	Residential	12,227	14,291	35,331	6,303	13,295	15,539	38,416	6,853	13,295	15,539	38,416	6,853
	Total	**26,102**	**55,068**	**93,252**	**24,286**	**27,179**	**53,352**	**94,355**	**23,529**	**27,179**	**53,352**	**94,355**	**23,529**
	Commercial	467	600	1,160	264	11,109	14,273	27,608	6,295	11,109	14,273	27,608	6,295
BF34	Highway	6,365	21,008	30,843	9,265	4,960	16,369	24,031	7,219	4,960	16,369	24,031	7,219
	Industrial	4,323	9,922	24,232	4,376	545	1,250	3,053	551	545	1,250	3,053	551
	Open	3,273	13,272	7,339	5,853	1,558	6,317	3,493	2,786	1,558	6,317	3,493	2,786
	Residential	947	1,107	2,736	488	968	1,131	2,797	499	968	1,131	2,797	499
	Total	**15,376**	**45,909**	**66,310**	**20,247**	**19,140**	**39,340**	**60,982**	**17,350**	**19,140**	**39,340**	**60,982**	**17,350**
	Commercial	0	0	0	0	0	1	1	0	0	0	1	0
BFA40	Highway	4,965	16,387	24,059	7,227	4,467	14,744	21,646	6,502	3,350	11,058	16,235	4,877
	Industrial	239	548	1,338	242	0	0	0	0	0	0	0	0
	Open	3,400	13,787	7,624	6,080	30	122	68	54	30	122	68	54
	Residential	0	0	0	0	11,134	13,014	32,172	5,739	8,350	9,760	24,129	4,304
	Total	**8,604**	**30,722**	**33,021**	**13,549**	**15,632**	**27,881**	**53,888**	**12,296**	**11,731**	**20,941**	**40,433**	**9,235**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA41	Highway	126	416	611	183	268	886	1,301	391	268	886	1,301	391
	Industrial	734	1,685	4,116	743	0	0	0	0	0	0	0	0
	Open	3,133	12,704	7,025	5,603	1,166	4,730	2,615	2,086	1,166	4,730	2,615	2,086
	Residential	3,135	3,664	9,058	1,616	9,853	11,517	28,473	5,079	9,853	11,517	28,473	5,079
	Total	**7,129**	**18,470**	**20,810**	**8,145**	**11,288**	**17,132**	**32,389**	**7,556**	**11,288**	**17,132**	**32,389**	**7,556**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	88	113	219	50	96	124	239	54	96	124	239	54
BFA42	Highway	2,694	8,891	13,054	3,921	2,811	9,277	13,620	4,091	2,811	9,277	13,620	4,091
	Industrial	0	0	0	0	120	276	673	122	120	276	673	122
	Open	2,190	8,881	4,911	3,917	1,345	5,453	3,015	2,405	1,345	5,453	3,015	2,405
	Residential	10,068	11,767	29,092	5,190	12,586	14,711	36,369	6,488	12,586	14,711	36,369	6,488
	Total	**15,040**	**29,653**	**47,275**	**13,078**	**16,958**	**29,840**	**53,917**	**13,160**	**16,958**	**29,840**	**53,917**	**13,160**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA43	Highway	1,423	4,698	6,897	2,072	1,246	4,114	6,040	1,814	935	3,085	4,530	1,361
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	5,032	20,402	11,282	8,998	1	3	2	1	1	3	2	1
	Residential	0	0	0	0	16,043	18,752	46,360	8,270	12,033	14,064	34,770	6,203
	Total	**6,455**	**25,100**	**18,179**	**11,070**	**17,291**	**22,869**	**52,401**	**10,086**	**12,968**	**17,152**	**39,301**	**7,565**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA44	Highway	562	1,854	2,721	817	486	1,603	2,354	707	364	1,203	1,766	530
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	4,396	17,822	9,855	7,860	5	21	12	9	5	21	12	9
	Residential	0	0	0	0	13,957	16,314	40,331	7,195	10,468	12,235	30,248	5,396
	Total	**4,957**	**19,676**	**12,576**	**8,677**	**14,448**	**17,938**	**42,697**	**7,911**	**10,837**	**13,459**	**32,025**	**5,936**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA45	Highway	624	2,059	3,023	908	552	1,821	2,673	803	552	1,821	2,673	803
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	7,334	29,737	16,444	13,115	83	337	186	148	83	337	186	148
	Residential	1,644	1,921	4,750	847	24,668	28,833	71,282	12,716	24,668	28,833	71,282	12,716
	Total	**9,602**	**33,718**	**24,217**	**14,870**	**25,303**	**30,991**	**74,141**	**13,667**	**25,303**	**30,991**	**74,141**	**13,667**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA46	Highway	35	117	172	52	0	0	0	0	0	0	0	0
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,832	7,427	4,107	3,276	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	5,825	6,809	16,833	3,003	4,369	5,107	12,625	2,252
	Total	**1,867**	**7,544**	**4,279**	**3,327**	**5,825**	**6,809**	**16,833**	**3,003**	**4,369**	**5,107**	**12,625**	**2,252**
	Commercial	403	517	1,000	228	62	80	154	35	62	80	154	35
BFA47	Highway	4,383	14,466	21,238	6,380	4,117	13,589	19,951	5,993	4,117	13,589	19,951	5,993
	Industrial	1,079	2,477	6,050	1,092	3,612	8,288	20,242	3,655	3,612	8,288	20,242	3,655
	Open	5,385	21,833	12,073	9,629	571	2,313	1,279	1,020	571	2,313	1,279	1,020
	Residential	8,060	9,421	23,290	4,155	21,818	25,502	63,046	11,247	21,818	25,502	63,046	11,247
	Total	**19,310**	**48,714**	**63,650**	**21,484**	**30,179**	**49,773**	**104,673**	**21,951**	**30,179**	**49,773**	**104,673**	**21,951**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFA48	Highway	2,525	8,333	12,234	3,675	2,989	9,866	14,485	4,351	2,242	7,400	10,864	3,263
	Industrial	2,778	6,377	15,573	2,812	9,964	22,867	55,847	10,085	7,473	17,150	41,885	7,564
	Open	3,788	15,359	8,493	6,774	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	6,266	7,324	18,107	3,230	4,700	5,493	13,580	2,423
	Total	**9,091**	**30,069**	**36,300**	**13,261**	**19,219**	**40,058**	**88,439**	**17,666**	**14,415**	**30,043**	**66,329**	**13,250**
	Commercial	0	0	0	0	5	6	12	3	4	5	9	2
BFA49	Highway	1,356	4,476	6,571	1,974	2,414	7,968	11,698	3,514	1,811	5,976	8,774	2,636
	Industrial	2,042	4,685	11,443	2,066	4,154	9,533	23,281	4,204	3,115	7,150	17,461	3,153
	Open	3,432	13,913	7,693	6,136	1,078	4,371	2,417	1,928	1,078	4,371	2,417	1,928
	Residential	0	0	0	0	8,310	9,713	24,014	4,284	6,233	7,285	18,010	3,213
	Total	**6,829**	**23,074**	**25,708**	**10,176**	**15,961**	**31,591**	**61,422**	**13,932**	**12,240**	**24,786**	**46,671**	**10,931**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	639	821	1,589	362	0	0	0	0	0	0	0	0
BFB50	Highway	1,819	6,002	8,812	2,647	1,313	4,333	6,362	1,911	985	3,250	4,772	1,433
	Industrial	1,470	3,373	8,238	1,488	6,449	14,801	36,146	6,527	4,837	11,100	27,110	4,896
	Open	3,332	13,508	7,470	5,957	631	2,559	1,415	1,129	631	2,559	1,415	1,129
	Residential	8,870	10,367	25,630	4,572	14,443	16,881	41,735	7,445	10,832	12,661	31,301	5,584
	Total	**16,129**	**34,072**	**51,739**	**15,027**	**22,836**	**38,575**	**85,658**	**17,012**	**17,285**	**29,571**	**64,597**	**13,041**
	Commercial	289	371	718	164	0	0	0	0	0	0	0	0
BFB51	Highway	4,471	14,756	21,664	6,508	5,619	18,545	27,226	8,179	4,214	13,909	20,420	6,134
	Industrial	307	705	1,723	311	22,759	52,232	127,562	23,035	17,069	39,174	95,671	17,276
	Open	7,923	32,122	17,762	14,167	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	7,583	8,863	21,912	3,909	5,687	6,648	16,434	2,932
	Total	**12,990**	**47,954**	**41,867**	**21,149**	**35,961**	**79,640**	**176,701**	**35,123**	**26,971**	**59,730**	**132,526**	**26,342**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB52	Highway	2,800	9,242	13,569	4,076	3,049	10,065	14,776	4,439	2,287	7,549	11,082	3,329
	Industrial	0	0	0	0	10,938	25,103	61,307	11,071	8,204	18,827	45,981	8,303
	Open	4,702	19,062	10,541	8,407	0	0	0	0	0	0	0	0
	Residential	347	405	1,001	179	6,757	7,898	19,525	3,483	5,068	5,923	14,644	2,612
	Total	**7,848**	**28,709**	**25,111**	**12,661**	**20,745**	**43,066**	**95,609**	**18,993**	**15,559**	**32,300**	**71,707**	**14,245**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB53	Highway	1,385	4,572	6,712	2,016	1,217	4,016	5,895	1,771	913	3,012	4,422	1,328
	Industrial	2,058	4,722	11,532	2,083	9,851	22,608	55,213	9,970	7,388	16,956	41,410	7,478
	Open	6,572	26,645	14,734	11,751	102	412	228	182	102	412	228	182
	Residential	889	1,039	2,568	458	15,533	18,156	44,885	8,007	11,650	13,617	33,664	6,005
	Total	**10,903**	**36,978**	**35,546**	**16,308**	**26,702**	**45,191**	**106,221**	**19,930**	**20,052**	**33,997**	**79,723**	**14,993**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB54	Highway	9,895	32,658	47,946	14,403	9,615	31,734	46,591	13,996	7,211	23,801	34,943	10,497
	Industrial	553	1,268	3,098	559	6,127	14,061	34,339	6,201	4,595	10,545	25,754	4,651
	Open	5,684	23,047	12,744	10,164	4,334	17,574	9,718	7,750	4,334	17,574	9,718	7,750
	Residential	0	0	0	0	13,861	16,202	40,055	7,145	10,396	12,151	30,041	5,359
	Total	**16,132**	**56,973**	**63,788**	**25,126**	**33,938**	**79,571**	**130,702**	**35,092**	**26,537**	**64,072**	**100,456**	**28,257**
	Commercial	0	0	0	0	0	0	0	0	0	0	0	0
BFB55	Highway	728	2,403	3,528	1,060	326	1,075	1,579	474	244	806	1,184	356
	Industrial	0	0	0	0	821	1,883	4,599	830	615	1,412	3,449	623
	Open	2,020	8,190	4,529	3,612	0	0	0	0	0	0	0	0
	Residential	0	0	0	0	5,993	7,004	17,316	3,089	4,494	5,253	12,987	2,317
	Total	**2,748**	**10,593**	**8,056**	**4,672**	**7,139**	**9,963**	**23,494**	**4,394**	**5,354**	**7,472**	**17,620**	**3,295**
	Commercial	1,637	2,103	4,067	927	236	303	586	134	236	303	586	134
BFB56	Highway	2,108	6,956	10,212	3,068	4,473	14,763	21,674	6,511	4,473	14,763	21,674	6,511
	Industrial	0	0	0	0	4,866	11,168	27,274	4,925	4,866	11,168	27,274	4,925
	Open	2,406	9,757	5,395	4,303	63	254	141	112	63	254	141	112
	Residential	4,254	4,972	12,291	2,193	8,164	9,543	23,591	4,209	8,164	9,543	23,591	4,209
	Total	**10,404**	**23,787**	**31,966**	**10,491**	**17,802**	**36,031**	**73,266**	**15,890**	**17,802**	**36,031**	**73,266**	**15,890**
	Commercial	7	9	17	4	55	70	136	31	41	53	102	23
BFB57	Highway	2,955	9,752	14,317	4,301	4,145	13,681	20,085	6,033	3,109	10,260	15,064	4,525
	Industrial	0	0	0	0	9,516	21,840	53,338	9,632	7,137	16,380	40,004	7,224
	Open	3,031	12,289	6,795	5,420	176	715	396	315	176	715	396	315
	Residential	5,675	6,633	16,398	2,925	6,768	7,911	19,558	3,489	5,076	5,933	14,669	2,617
	Total	**11,667**	**28,682**	**37,527**	**12,649**	**20,661**	**44,218**	**93,513**	**19,501**	**15,540**	**33,342**	**70,234**	**14,705**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	3,407	4,377	8,467	1,930	3,067	3,941	7,623	1,738	3,067	3,941	7,623	1,738
BFC60	Highway	8,025	26,485	38,883	11,680	9,062	29,909	43,911	13,190	9,062	29,909	43,911	13,190
	Industrial	0	0	0	0	6,445	14,791	36,124	6,523	6,445	14,791	36,124	6,523
	Open	2,083	8,446	4,670	3,725	767	3,111	1,720	1,372	767	3,111	1,720	1,372
	Residential	14,300	16,715	41,322	7,372	17,809	20,817	51,463	9,180	17,809	20,817	51,463	9,180
	Total	**27,815**	**56,023**	**93,343**	**24,707**	**37,151**	**72,569**	**140,840**	**32,004**	**37,151**	**72,569**	**140,840**	**32,004**
	Commercial	3,203	4,115	7,959	1,815	1,280	1,645	3,182	725	1,280	1,645	3,182	725
BFC61	Highway	12,368	40,820	59,929	18,002	11,650	38,450	56,450	16,957	11,650	38,450	56,450	16,957
	Industrial	0	0	0	0	3,989	9,156	22,361	4,038	3,989	9,156	22,361	4,038
	Open	**777**	3,150	1,742	1,389	306	1,241	686	547	306	1,241	686	547
	Residential	16,663	19,476	48,149	8,589	17,131	20,024	49,503	8,831	17,131	20,024	49,503	8,831
	Total	**33,010**	**67,560**	**117,779**	**29,795**	**34,357**	**70,515**	**132,181**	**31,099**	**34,357**	**70,515**	**132,181**	**31,099**
	Commercial	1,819	2,338	4,521	1,031	7,903	10,153	19,639	4,478	5,927	7,615	14,729	3,358
BFD70	Highway	4,910	16,205	23,791	7,147	6,186	20,417	29,975	9,004	4,640	15,313	22,481	6,753
	Industrial	440	1,010	2,466	445	1,492	3,424	8,362	1,510	1,119	2,568	6,271	1,132
	Open	3,578	14,506	8,021	6,397	700	2,837	1,569	1,251	700	2,837	1,569	1,251
	Residential	4,276	4,998	12,356	2,204	6,725	7,860	19,432	3,466	5,044	5,895	14,574	2,600
	Total	**15,023**	**39,056**	**51,156**	**17,224**	**23,005**	**44,692**	**78,977**	**19,710**	**17,429**	**34,228**	**59,625**	**15,095**
	Commercial	1,910	2,454	4,746	1,082	4,968	6,382	12,345	2,815	4,968	6,382	12,345	2,815
BFD71	Highway	8,656	28,567	41,941	12,599	9,015	29,755	43,684	13,122	9,015	29,755	43,684	13,122
	Industrial	66	151	368	66	387	888	2,169	392	387	888	2,169	392
	Open	3,090	12,527	6,927	5,525	649	2,630	1,455	1,160	649	2,630	1,455	1,160
	Residential	9,068	10,599	26,203	4,674	13,762	16,085	39,766	7,094	13,762	16,085	39,766	7,094
	Total	**22,789**	**54,297**	**80,184**	**23,946**	**28,780**	**55,741**	**99,419**	**24,583**	**28,780**	**55,741**	**99,419**	**24,583**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	142	182	352	80	1,664	2,138	4,135	943	1,664	2,138	4,135	943
BFD72	Highway	10,098	33,329	48,931	14,699	9,224	30,442	44,693	13,425	9,224	30,442	44,693	13,425
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,104	4,475	2,475	1,974	670	2,718	1,503	1,199	670	2,718	1,503	1,199
	Residential	14,738	17,226	42,587	7,597	15,288	17,869	44,176	7,881	15,288	17,869	44,176	7,881
	Total	**26,081**	**55,212**	**94,344**	**24,349**	**26,846**	**53,167**	**94,507**	**23,448**	**26,846**	**53,167**	**94,507**	**23,448**
	Commercial	513	659	1,275	291	1,116	1,434	2,773	632	1,116	1,434	2,773	632
BFD73	Highway	7,137	23,554	34,580	10,388	6,187	20,419	29,978	9,005	6,187	20,419	29,978	9,005
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	533	2,160	1,195	953	407	1,650	913	728	407	1,650	913	728
	Residential	9,663	11,294	27,922	4,981	10,061	11,760	29,074	5,187	10,061	11,760	29,074	5,187
	Total	**17,845**	**37,667**	**64,972**	**16,612**	**17,771**	**35,264**	**62,738**	**15,552**	**17,771**	**35,264**	**62,738**	**15,552**
	Commercial	3,341	4,293	8,304	1,893	5,189	6,667	12,895	2,940	5,189	6,667	12,895	2,940
BFD74	Highway	8,000	26,403	38,763	11,644	6,697	22,102	32,449	9,748	6,697	22,102	32,449	9,748
	Industrial	649	1,489	3,637	657	670	1,538	3,757	678	670	1,538	3,757	678
	Open	587	2,379	1,316	1,049	250	1,015	561	448	250	1,015	561	448
	Residential	8,379	9,793	24,212	4,319	8,560	10,005	24,734	4,412	8,560	10,005	24,734	4,412
	Total	**20,956**	**44,358**	**76,231**	**19,563**	**21,366**	**41,328**	**74,397**	**18,226**	**21,366**	**41,328**	**74,397**	**18,226**
	Commercial	35	45	87	20	1,147	1,474	2,851	650	1,147	1,474	2,851	650
BFD75	Highway	4,163	13,739	20,171	6,059	2,632	8,686	12,752	3,831	2,632	8,686	12,752	3,831
	Industrial	1,271	2,916	7,122	1,286	1,028	2,360	5,763	1,041	1,028	2,360	5,763	1,041
	Open	1,919	7,782	4,303	3,432	1,589	6,444	3,563	2,842	1,589	6,444	3,563	2,842
	Residential	2,889	3,377	8,348	1,489	4,000	4,675	11,558	2,062	4,000	4,675	11,558	2,062
	Total	**10,277**	**27,858**	**40,030**	**12,286**	**10,396**	**23,639**	**36,487**	**10,425**	**10,396**	**23,639**	**36,487**	**10,425**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	861	1,106	2,140	488	1,558	2,002	3,873	883	1,558	2,002	3,873	883
BFD76	Highway	5,027	16,593	24,361	7,318	4,173	13,772	20,219	6,074	4,173	13,772	20,219	6,074
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	455	1,847	1,021	814	321	1,301	719	574	321	1,301	719	574
	Residential	6,721	7,856	19,422	3,465	7,015	8,200	20,272	3,616	7,015	8,200	20,272	3,616
	Total	**13,065**	**27,402**	**46,944**	**12,085**	**13,067**	**25,275**	**45,083**	**11,147**	**13,067**	**25,275**	**45,083**	**11,147**
	Commercial	237	304	588	134	2,388	3,068	5,933	1,353	2,388	3,068	5,933	1,353
BFD77	Highway	4,484	14,800	21,729	6,527	3,020	9,969	14,636	4,396	3,020	9,969	14,636	4,396
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	1,307	5,301	2,931	2,338	780	3,164	1,749	1,395	780	3,164	1,749	1,395
	Residential	1,428	1,670	4,127	736	2,058	2,405	5,947	1,061	2,058	2,405	5,947	1,061
	Total	**7,457**	**22,075**	**29,376**	**9,735**	**8,246**	**18,606**	**28,265**	**8,206**	**8,246**	**18,606**	**28,265**	**8,206**
	Commercial	62	79	153	35	545	700	1,354	309	409	525	1,016	232
WC10	Highway	1,448	4,780	7,018	2,108	3,185	10,511	15,432	4,636	2,389	7,883	11,574	3,477
	Industrial	785	1,803	4,403	795	9,695	22,250	54,340	9,813	7,271	16,688	40,755	7,360
	Open	5,684	23,046	12,743	10,164	64	261	144	115	64	261	144	115
	Residential	0	0	0	0	9,655	11,285	27,900	4,977	7,241	8,464	20,925	3,733
	Total	**7,979**	**29,707**	**24,317**	**13,102**	**23,144**	**45,008**	**99,171**	**19,850**	**17,374**	**33,821**	**74,414**	**14,916**
	Commercial	0	0	0	0	13	17	33	8	10	13	25	6
WC11	Highway	647	2,134	3,133	941	2,227	7,351	10,792	3,242	1,670	5,513	8,094	2,431
	Industrial	31	71	174	31	1,038	2,382	5,817	1,050	778	1,786	4,363	788
	Open	4,895	19,845	10,974	8,752	235	951	526	419	235	951	526	419
	Residential	532	622	1,538	274	13,669	15,977	39,497	7,046	10,251	11,982	29,623	5,284
	Total	**6,104**	**22,672**	**15,818**	**9,999**	**17,182**	**26,678**	**56,666**	**11,765**	**12,945**	**20,246**	**42,631**	**8,929**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	0	0	0	0	2	3	6	1	2	2	4	1
WC12	Highway	885	2,919	4,286	1,288	1,858	6,131	9,001	2,704	1,393	4,598	6,751	2,028
	Industrial	0	0	0	0	5,584	12,815	31,298	5,652	4,188	9,611	23,473	4,239
	Open	6,910	28,015	15,491	12,355	208	845	467	373	208	845	467	373
	Residential	471	551	1,362	243	16,918	19,775	48,887	8,721	12,689	14,831	36,666	6,541
	Total	**8,265**	**31,485**	**21,139**	**13,886**	**24,570**	**39,569**	**89,659**	**17,451**	**18,480**	**29,888**	**67,361**	**13,181**
	Commercial	0	0	0	0	15	19	37	8	11	14	28	6
WC13	Highway	1,916	6,325	9,286	2,789	2,972	9,810	14,402	4,326	2,229	7,357	10,802	3,245
	Industrial	390	895	2,186	395	19,423	44,576	108,866	19,659	14,567	33,432	81,649	14,744
	Open	5,526	22,405	12,389	9,881	55	222	123	98	55	222	123	98
	Residential	0	0	0	0	2,216	2,591	6,404	1,142	1,662	1,943	4,803	857
	Total	**7,832**	**29,625**	**23,861**	**13,065**	**24,681**	**57,217**	**129,832**	**25,234**	**18,525**	**42,969**	**97,404**	**18,950**
	Commercial	39	50	96	22	59	76	146	33	44	57	110	25
WC14	Highway	182	601	882	265	2,288	7,552	11,087	3,331	1,716	5,664	8,316	2,498
	Industrial	0	0	0	0	3,132	7,188	17,554	3,170	2,349	5,391	13,166	2,377
	Open	3,835	15,551	8,599	6,858	621	2,518	1,393	1,111	621	2,518	1,393	1,111
	Residential	1,013	1,184	2,928	522	8,599	10,051	24,848	4,433	6,449	7,538	18,636	3,325
	Total	**5,069**	**17,385**	**12,505**	**7,667**	**14,699**	**27,385**	**55,029**	**12,077**	**11,180**	**21,168**	**41,620**	**9,336**
	Commercial	1,805	2,319	4,486	1,023	1,911	2,455	4,749	1,083	1,433	1,841	3,562	812
WC15	Highway	996	3,289	4,828	1,450	5,845	19,293	28,324	8,508	4,384	14,469	21,243	6,381
	Industrial	0	0	0	0	3,750	8,607	21,019	3,796	2,813	6,455	15,765	2,847
	Open	8,186	33,190	18,353	14,637	1,648	6,682	3,695	2,947	1,648	6,682	3,695	2,947
	Residential	1,266	1,479	3,658	652	18,818	21,995	54,377	9,700	14,113	16,496	40,782	7,275
	Total	**12,253**	**40,277**	**31,324**	**17,763**	**31,973**	**59,032**	**112,164**	**26,034**	**24,391**	**45,945**	**85,047**	**20,262**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	35	44	86	20	476	612	1,183	270	357	459	888	202
WC16	Highway	2,127	7,021	10,308	3,097	1,610	5,315	7,803	2,344	1,208	3,986	5,853	1,758
	Industrial	3,963	9,096	22,215	4,012	7,633	17,518	42,782	7,726	5,725	13,138	32,087	5,794
	Open	3,411	13,829	7,647	6,099	99	403	223	178	99	403	223	178
	Residential	623	728	1,801	321	8,259	9,653	23,865	4,257	6,194	7,240	17,898	3,193
	Total	**10,159**	**30,719**	**42,057**	**13,548**	**18,078**	**33,501**	**75,856**	**14,774**	**13,583**	**25,226**	**56,948**	**11,125**
	Commercial	15	20	38	9	1,345	1,729	3,344	762	1,009	1,296	2,508	572
WC17	Highway	1,941	6,407	9,406	2,825	3,385	11,173	16,403	4,927	2,539	8,379	12,302	3,696
	Industrial	1,587	3,643	8,898	1,607	16,925	38,842	94,861	17,130	12,693	29,131	71,146	12,848
	Open	8,099	32,837	18,158	14,482	839	3,402	1,881	1,500	839	3,402	1,881	1,500
	Residential	586	685	1,692	302	9,959	11,640	28,777	5,133	7,469	8,730	21,583	3,850
	Total	**12,229**	**43,592**	**38,192**	**19,225**	**32,453**	**66,785**	**145,265**	**29,453**	**24,549**	**50,939**	**109,419**	**22,465**
	Commercial	0	0	0	0	16	20	39	9	12	15	29	7
WC18	Highway	735	2,426	3,562	1,070	5,246	17,315	25,421	7,636	3,935	12,986	19,066	5,727
	Industrial	0	0	0	0	1,261	2,893	7,065	1,276	945	2,170	5,299	957
	Open	5,124	20,774	11,487	9,162	1,039	4,212	2,329	1,858	1,039	4,212	2,329	1,858
	Residential	5,811	6,792	16,791	2,995	15,428	18,033	44,581	7,953	11,571	13,525	33,436	5,965
	Total	**11,670**	**29,992**	**31,841**	**13,227**	**22,989**	**42,473**	**79,436**	**18,731**	**17,502**	**32,908**	**60,159**	**14,513**
	Commercial	700	899	1,739	397	50	64	124	28	50	64	124	28
WC19	Highway	6,816	22,495	33,026	9,921	9,959	32,868	48,255	14,495	9,959	32,868	48,255	14,495
	Industrial	0	0	0	0	0	0	0	0	0	0	0	0
	Open	2,365	9,588	5,302	4,228	933	3,783	2,092	1,668	933	3,783	2,092	1,668
	Residential	13,280	15,523	38,376	6,846	16,674	19,489	48,182	8,595	16,674	19,489	48,182	8,595
	Total	**23,161**	**48,505**	**78,442**	**21,391**	**27,616**	**56,204**	**98,653**	**24,787**	**27,616**	**56,204**	**98,653**	**24,787**

Sub Basin	Land Use	EXISTING CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE CONDITIONS Pollutant (TSS) Loading By Rainfall Season (lbs)				FUTURE WITH ISWM 70% Pollutant (TSS) Loading By Rainfall Season (lbs)			
		1	2	3	4	1	2	3	4	1	2	3	4
	Commercial	1,126	1,447	2,799	638	1,495	1,921	3,715	847	1,495	1,921	3,715	847
WC20	Highway	3,367	11,114	16,317	4,902	7,479	24,683	36,238	10,886	7,479	24,683	36,238	10,886
	Industrial	1,113	2,554	6,238	1,126	1,499	3,441	8,404	1,518	1,499	3,441	8,404	1,518
	Open	3,509	14,227	7,867	6,274	952	3,860	2,134	1,702	952	3,860	2,134	1,702
	Residential	7,284	8,513	21,047	3,755	12,558	14,679	36,289	6,474	12,558	14,679	36,289	6,474
	Total	**16,399**	**37,855**	**54,267**	**16,695**	**23,983**	**48,583**	**86,780**	**21,426**	**23,983**	**48,583**	**86,780**	**21,426**
	Commercial	2,288	2,940	5,686	1,296	6,143	7,893	15,266	3,481	6,143	7,893	15,266	3,481
WC21	Highway	8,551	28,221	41,433	12,446	8,622	28,457	41,780	12,550	8,622	28,457	41,780	12,550
	Industrial	624	1,433	3,499	632	0	0	0	0	0	0	0	0
	Open	2,382	9,657	5,340	4,259	2,084	8,449	4,672	3,726	2,084	8,449	4,672	3,726
	Residential	11,492	13,432	33,208	5,924	9,593	11,213	27,720	4,945	9,593	11,213	27,720	4,945
	Total	**25,337**	**55,683**	**89,166**	**24,557**	**26,442**	**56,011**	**89,438**	**24,702**	**26,442**	**56,011**	**89,438**	**24,702**
	TOTAL WATERSHED	**935,230**	**2,504,454**	**3,148,510**	**1,104,361**	**1,536,896**	**2,916,779**	**5,655,309**	**1,286,205**	**1,311,525**	**2,515,762**	**4,777,553**	**1,109,387**

Appendix D – Streambank Protection Analysis

Channel erosion is effected by such factors as flow regime, climate, and types of channel beds and bank material. Within a specific stream reach, change in flow rate can be considered to be the determining factor when comparing erosion losses subject to different flow conditions. The channel erosion concepts presented in the technical paper *Erodibility of Urban Bedrock and Alluvial Channels, North Texas* (Allen, Peter M., et.al. Journal of The American Water Resources Association, Vol.38, No. 5, October 2002) were used to quantify the degree of potential channel erosion in the study portion of Big Fossil Creek for future conditions *without* and *with* iSWM design criteria.

The technical paper found that approximately 75 percent of channels in North Texas basins have alluvial banks with gravel or rock bottoms and the active channel width and depth could be determined through regression analysis. From the extensive field survey results, regression equations were developed to determine the active channel width (ACW) and active channel depth (ACD) based on the flow rate of the channel. These relationships are as follows:

$$ACW = 1.28 * Q^{0.48} \quad , \quad R^2 = 0.83$$
$$ACD = 0.208 * Q^{0.44} \quad , \quad R^2 = 0.91$$

(R= regression coefficient, Q expressed as 1-year event)

To determine the relative effects of future conditions *without* iSWM and future conditions *with* iSWM scenarios on erosion losses of the channel, two cross section locations along the main stem of Big Fossil Creek within the hydraulic study area were selected (See Figure D-1). Cross Section location 1 is located 500 feet upstream of Glenview Drive. Cross Section location 2 is located approximately 1700 feet upstream of Haltom Road. Figures D-2 and D-3 were obtained during field visits to Cross Section 1 and 2, respectively. The bed and bank materials show a dominance of gravel bed and alluvial channel bank. Figure D-3 shows existing channel erosion.

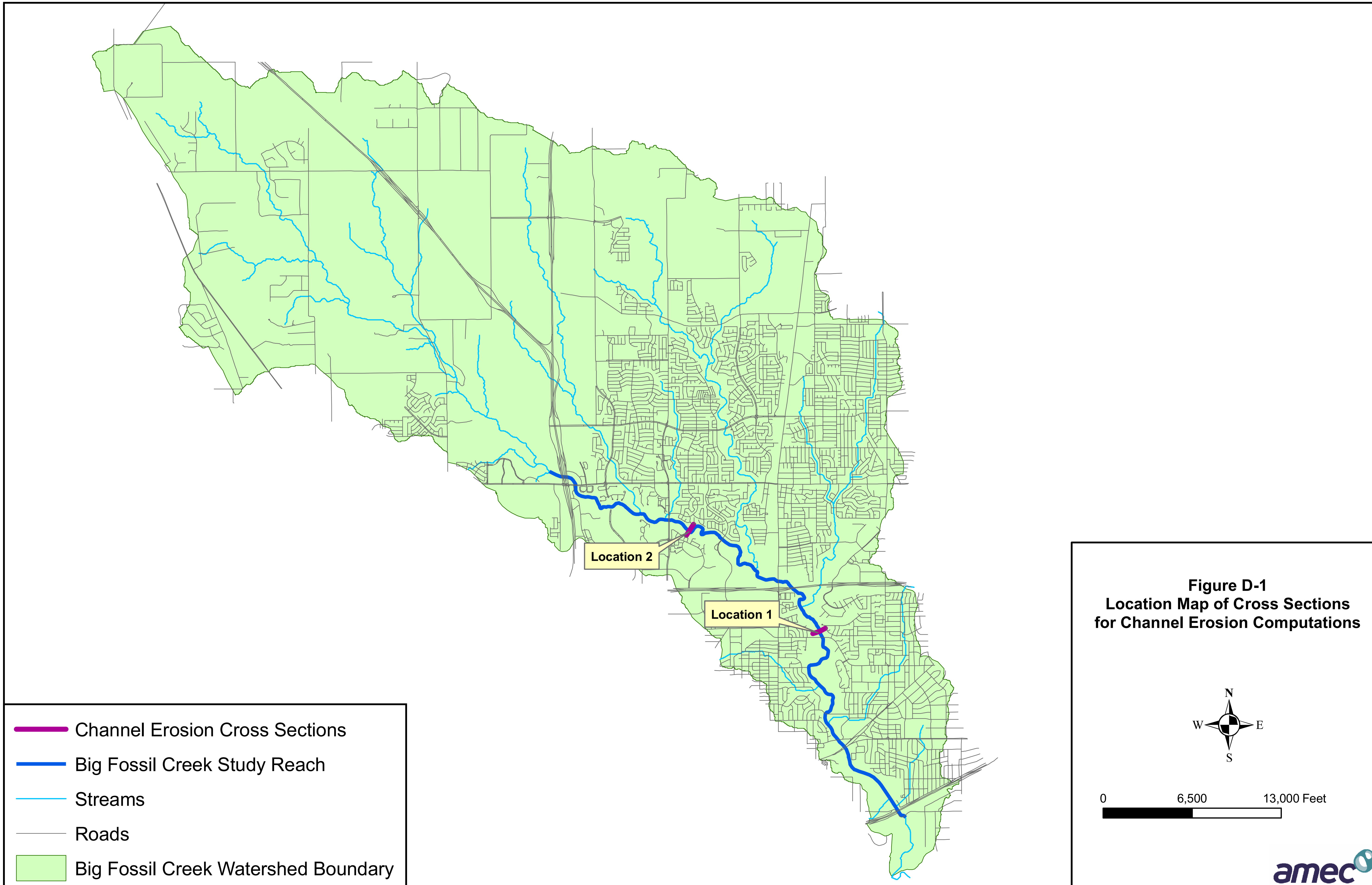


Figure D-1
Location Map of Cross Sections for Channel Erosion Computations

Figure D-2. Cross Section location 1 - 500 feet upstream of Glenview Drive

Figure D-3. Cross Section location 2 - 1,700 feet upstream of Haltom Road

The drainage area and corresponding frequency discharges for the 1-year storm event for the three watershed scenarios, at each cross section location, were determined from the hydrologic analysis. The cross sections were located in the field and photographed and the channel sections in the available hydraulic models were identified. The regression equations outlined above were used to calculate active channel width (ACW) and active channel depth (ACD) for the three watershed scenarios. Results of the analysis are presented in Table D-1.

Table D-1. Potential Channel Erosion for Future, and Future-iSWM condition

Description	Parameters	1-Yr Event Future	1-Yr Event Future-iSWM
Location 1 Drainage Area, 50.63 (mi^2)	**Discharge (cfs)**	8,765	5,034
	Active channel Width (ft)	99.9	76.6
	Active Channel Depth (ft)	11.3	8.8
	Area of Channel (ft^2)	1129	678
Location 2 Drainage Area, 31.77 (mi^2)	**Discharge (cfs)**	5,798	2,564
	Active channel Width (ft)	82.0	55.4
	Active Channel Depth (ft)	9.4	6.6
	Area of Channel (ft^2)	772	364

Channel Impact Model Results

The data from the analysis in Table D-1 can be used to quantify the potential increase in channel erosion in the study reach. It is clear that applying iSWM design criteria would mitigate the potential for channel erosion, since the model shows that the active channel size without iSWM conditions is significantly greater than the active channel size with application of iSWM design criteria. However, if iSWM design criteria are not applied, the potential for erosion in the study area is significant. Assuming cross section locations 1 and 2 are typical of the 4.75 miles of the upper and lower portion of the study reach (total study reach length of 9.5 miles), and the channel sections could be represented accurately for this calculation as a rectangles, the potential increase in channel erosion under future conditions without iSWM compared to future conditions with iSWM is equal to 797,916 cu yards of material, or 83,991 cu yards per linear mile of stream.

APPENDIX B

INTERVIEW SCRIPT

Interview Script

Thank you for your participation in this research study. As indicated previously during the recruitment process, the purpose of this study is to gather information on the storm water best management practice selection process for structural or built solutions from regulatory, designer, and developer viewpoints.

The following questions are identical to those previously provided to you upon your acceptance into the study. Your responses to the questions will be taped recorded to ensure accuracy during transcription.

Please answer each of the questions to the best of your knowledge and ability:

- What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens and/or other similar “green” storm water best management practices (BMP) in North Texas?
- What is your perception with storm water BMPs in general?
- What methods do you employ in the BMP selection process?
- What drives the final selection of specific storm water BMPs?
- What advantages do you see with the implementation of storm water BMPs?
- What disadvantages do you see with the implementation of storm water BMPs?
- What insights can you provide regarding storm water codes or ordinances?
- What advice would you like to offer regarding the selection of storm water BMPs?

Thank you for your participation in this study. Your time and information have been invaluable to this research study. Please feel free to contact me if you have any questions.

APPENDIX C

INTERVIEW TRANSCRIPTIONS

Interview #1 – Bureaucrat #1

Interviewer said: "Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints.

The following questions are identical to those previously provided to you on your acceptance into this study and the responses to the questions will be tape recorded to ensure accuracy of the transcription.

Please answer each of the questions to the best of your knowledge and ability and let's start!

What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas?"

Interviewee said: "Yet we are just at the starting point at trying to implement some of these, and the implementation is long overdue. We have put some of these kinds of things into place as a part of some previous developments but not very many. And they've not really been done in a fashion to try and optimize their benefit to improvements in water quality in the area.

If you've spent some time in the creeks and the by-ways around here, the water quality is not that great. It's not that bad, but it's not that great. This is not a place where you're going to find babbling trout brooks and clear drinkable water running down the creeks and the drainageways, but they are interesting. They're somewhat attractive. There's some neat wildlife that lives out there. We have beavers in our stream around here. We have lots of raccoons and possums and crawfish and sunfish and other kinds of fish that live in the creeks and the drainageways. All these things that we can do to improve water quality and maintain the water quality at least where it is but preferably improve it, would make these a lot better habitats for those kinds of things and may make visiting those creeks and drainways a lot more enjoyable. These kinds of structures that you're talking about green roof, bio-swales, all those kinds of things that we can do to take and improve the water quality, those are just one element in that whole collection of things that we need to do. From watching the kinds of things that are discharged into the storm drains, putting up the poop, to when we fertilize and what kind of fertilizers we use, all go into contributing to the quality for those drainage swales—that's water quality. These are just one element of a whole collection of elements that would have to be implemented to benefit and improve the water quality. Make those areas even more desirable to visit."

Interviewer said: "So you're a proponent?"

Interviewee said: "Absolutely. These things all need to be implemented to the maximum extent practicable and beyond. It is a neat environment out there. There are some neat places to go and visit in these creeks and these streams and these drainageways. And they're very sensitive to what goes upstream of them. From development and silt and sediment that is discharged into the streams and drainageways during the development process to the spills from automobile accidents to deliberate dumping of waste chemicals, waste products, washing down house exteriors to washing down your vehicles to washing the parking lot around all of the fast-food restaurants and convenience stores around here. All of those things washed in to the streams and drainageways negatively impact the water quality in those places, and fairly easily we can take and do things, easily in the sense that what a restaurant owner or a fast-food owner can do to take and clean up the parking lot as opposed to washing it all down the storm drain and degrading the water quality in the creeks and drainageways out there."

Interviewer said: "What is your perception of the structural stormwater BMPs in general?"

Interviewee said: "We've got a long way to go. It's not an easy process to get implemented, and part of the reason it's not an easy process to get implemented is that to do these things requires changes in how you approach doing things around your operations. Like I said, if I'm a fast-food restaurant operator, I need to clean my parking lot periodically. I've got spills and dumped products out there. I need to clean that up. The traditional way to do this is to hose it down and wash it into the storm drain. That's not the way I need to be doing it. I need to be picking the materials up, not washing them down into the storm drain. I need to put those in the sanitary sewer or into the trash drain.

From the standpoint of building facilities and building properties--development properties. I need to be cautious during the building phase to minimize the amount of sediments that I lose off the property. But more importantly, what I want to do is build that property where I do some things that might benefit the water quality when I have the opportunity to, and I don't have that opportunity very often.

I want to take and use a bio-swale. I want to use vegetative areas to drain the storm water through to try to improve the water quality. I want take and judiciously use plantings and trees to shade the property to try and provide some more surfaces, so when rainwater falls I can absorb that rainwater into those trees and those plantings and keep it onsite as clean rainwater and not have it runoff which contributes to the increased runoff of the development. But more importantly, to try and improve the water quality that runs off from the property."

Interviewer said: "So more water quality improvement?"

Interviewee said: "Well, you have to deal with both of them. You have to deal with water quality. You've got and take and control flooding. You've got take and design systems that will handle the water to prevent the flooding. But when you do those things you can take and with a little bit of additional effort and an additional cost, do some things to improve water quality. There are things that go hand-in-hand and there are competing interests to some extent. From a flooding standpoint, the cheapest way to deal with it is to put it in a pipe, and get it in the pipe and get in out of there quick. From a water quality standpoint, I want to take and hold it onsite. I want to take and put it into some kind of structure where I can absorb some of the water. I don't want to put it into a pipe, which moves it fast, I want to put it into vegetative swale which moves it slowly, and let it be treated with the vegetation. Let it be absorbed into the ground.

Also there are competing interests, and they both can be accomplished, but it cost just a little bit more. It typically is cheaper to take and put in a concrete ditch that will move the water faster than it is to put a vegetative swale in that moves the water slowly. I've got to have a bigger vegetative swale than I do a concrete ditch. Then I've got to do maintenance on it. I've got to do maintenance on that vegetative swale. I've got to mow it periodically. I'm going to have to pick up trash and litter out of it. If I put in the concrete ditch, it's gone fast and I don't have to do nearly as much maintenance. So, all these things that we're talking about have an increased cost. Yeah, they make the property more desirable. It's a lot more desirable to walk up to a fast-food restaurant that has a vegetative swale that the water drains off and through, than it is to walk up to a fast-food restaurant that's got a concrete ditch beside it or a pipe that carries the water off quickly. It takes land. It takes cost and money and landscaping, and it takes cost and money to maintain it."

Interviewer said: "What methods to you implore in the BMP selection process?"

Interviewee said: "From a regulatory standpoint, you need to have some mechanism that requires it being done. The approach to having people do it voluntary is great. If it works, and it does work in some situations, and you can get some really great things out of voluntary standpoint, but the vast majority of developments don't have a driver that let's them do it voluntarily. There is not some increased economic advantage by providing most of these permanent BMPs if you're dealing with most developments. There's just not an economic driver out there for it. That can't be the only mechanism. You need to have a regulatory mechanism that requires these things. You have to take and basically police it. Voluntary compliance with these rules is great, but it creates a situation where there is an economic advantage for not complying. And if there is an economic advantage for not complying, you're going to find people that don't comply. If you're building environmentally friendly and it costs you a little bit more, and you don't get all of it back in increased value of your property, and I can do it through the development and not dedicate some land to water quality, I've got an economic advantage over you to do that. If there is not some driver out there to make me do it, then I'm going to go with the cheaper way to do it, the way that makes the most money for me in developing the property. So, there has to be a regulatory component to these BMPs. You have to have some way where you can fairly and equitably require them to be implemented. Otherwise, they won't be implementing them."

Interviewer said: "What is a method of policing?"

Interviewee said: "Well, there are going to be two components to the policing. There is the component of policing to get it done and then the component that keeps it in place. Those have to be some kind of inspection program, some kind of monitoring program, some kind of permitting programs, all of those things combined together. I've got to give you basically some kind of permit to do it, then I've got to give you some kind of an inspection program to make sure that you are continuing to do it—maintaining the system."

Interviewer said: "Is there a device for doing that? Or is it an ordinance in other words?"

Interviewee said: "It's basically an ordinance right now. It's done through an ordinance that way that we've chosen to do it. The monitoring portion of the program is the part that is probably the weakest of our program right now. But the ordinance is relatively strong, but again it's only as strong as those people that are doing the permitting and making you comply to the ordinances. So, there's a permitting part of it that has to function with the ordinance, and you've got to have a combination of those two things working together to get the ordinance requirements implemented."

Interviewer said: "What drives the final selection specifically for structural storm water BMPs?"

Interviewee said: "Probably cost is going to be the driver of what is selected. It's dependent upon those specific sites. For each site you've got to sort of look at it and say, "Well, what particular thing can I most cost effectively implement on this site?" When say cost effectively, you have to look at what is the thing I want to do here that's going to get me the best return for my investment. Do I need the square footage of the property more than I need… whether it has more value to me than dedicating it off to natural vegetative area? Do I need to put in some kind of underground structure in it? Or do I need to put some kind of aboveground structure in it. That is going to typically drive whether or not I'm going to take it. And the land cost is going to drive that typically.

Nearly all the selection processes are going to be driven by one, site conditions. What can I put in there? I just can put some of these things in. I can't put in a detention pond in some places. There is no place that's suitable to put it in. If I'm going to put the detention pond in, there's no reason to develop the property. So, I've got to put in some other kind of device in, then it sort of a matter of what's the most cost-effective device that I can put in. From a regulatory standpoint, you're always faced with the developer wants to do the minimum. What's the cheapest thing I can do, and from the regulatory standpoint, what can you do to best benefit the water quality and typically they are not the same thing."

Interviewer said: "What advantages do you see with the implementation of storm water being used?"

Interviewee said: "The main advantages are that I should get some improvement in the water quality. The real problem is that how do I determine that. I can't measure it very easily. It is very, very difficult to measure what the water quality is at a specific time before development and then measure it again after the development to see if I got an improvement in water quality. The dynamics of the things that impact water quality are so huge that you just can't, you spend all your money monitoring and measuring. And so you do it based on a perception, the subjective judgment of what it is that you're doing. The biggest benefit of these things is basically creating an environment that should be better and should have better water quality. It should have an environment that makes it more desirable to visit, more accessible, more usable. You should get better use out of it. Utilization is not necessarily all easy. Park land and people being in it makes it a better habitat for the critters that live out there which makes the environment a more pleasant place live. So, it not necessarily a man's access to the area that is necessarily the approval that you're looking for. You're looking for all the kinds of things that you could do to improve the quality of the environment. Since this is a storm water program, the first thing you're looking at is the water quality, of course. You really do look at well beyond the water quality. I'm looking at just the overall benefit to the environment in general."

Interviewer said: "Conversely, what are some disadvantages?"

Interviewee said: "The biggest disadvantage is that these things cost money. They're going to make for more cost. The first cost of including them in or dedicating the land to them, and there is the secondary cost of maintaining them whatever they are. But that's just part of the cost of using a piece of space. Yeah, the biggest disadvantage is the cost of doing it."

Interviewer said: "How about from a regulatory standpoint?"

Interviewee said: "From a regulatory standpoint, you've got this long-term cost of how do you maintain them. If I require you to put in a structure, then I need to take it. I've got the cost as a regulator of monitoring that structure over its life to make sure that it is maintained. Some facilities or some areas have adopted a program where "let's put in regional water quality devices." Let's put in a regional trash exclusion system, and we'll make it the responsibility of the regulatory authority to maintain that regional water quality device. California has done a bunch of these trash exclusion systems in Los Angeles River for example. Then it becomes a long-term cost in maintaining that structure that municipality has to assume. We do that as a part of allowing a lot of water quality structures to go in. You put in a pipe, a concrete ditch whatever. That becomes then a part of the infrastructure here in the City of Arlington, and you're going to maintain that structure. Natural structures, natural ditches which we like to see because we don't have to maintain them. They become part of the property owners' responsibility for maintaining those things. So that long-term cost has been the responsibility of the adjacent property owner. But somebody has to pay for it somewhere along the line. If it's a natural drainage swale, somebody has got to go out there and maintain it periodically to make sure that it still functioning and it is still conveying the water that it needs to convey, and if it is eroding, then you do some things to try and protect it and keep it from eroding. Somebody has to do that. The natural ones, the way we've chosen to do them with the property owners. Again, that changes all the time. When you change administration, you change how you manage these things, then that's going to change, too. Somewhere you've got to have that maintenance cost. If I can design them where there is minimum maintenance cost that makes for a lot better BMP. Typically, those kinds of structures are going to take up more space. If they design a natural drainageway that needs minimal maintenance, it's going to be a lot bigger drainageway than if I put a concrete ditch in or I put in a pipe. You make the choice, which way is the way you want to go with it. Cheaper first cost, cheaper second cost. It really gets down to a cost analysis. That's probably the biggest thing missing from most of these selection processes is that we don't go through a life-cycle cost analysis on it, and look at what the real long-term cost of things are and what…how that should be evaluated. It is a very complicated evaluation because you really don't know sometimes what the long-term cost is going to be.

You don't know what the maintenance cost is going to be on natural swale or concrete ditch. Concrete ditches we do know. We can pretty well predict what the maintenance cost will be on those. We know how they're going to last and what we're going to have to do to maintain them. The natural ones get to be really tough because we really don't know what it is going to take to maintain them.

Then a lot of these structures that we're dealing with, we don't have a real long-term operation history on them. So we don't know what they're going to cost."

Interviewer said: "What insights can you provide regarding storm water codes or ordinances?"

Interviewee said: "They need to be fluid to some extent, and they need to build on what's worked for other entities. We intend to take and develop them independently. We're unique. Ours has to be different. This is a different place. We got to take and write our own ordinance in our own way. And the biggest handicap to doing that is that then you have to take and incorporate all the things into it that are going to be necessary to make it sustainable, to make it something that you can use over a long period of time and that will have all the elements that you need to have in it.

We typically write ordinances starting with technical people and then going through some kind of legal review. Then it is reviewed by the community that is going to have to comply with them. Those get technical reviews and legal reviews. Then we implement them, and they get implemented by sometimes a lot of different people that have written and conveying what the intent of it is to that whole process, and over time it's really tough. Frequently the intent of the ordinances as was written, and the implementation of the ordinances are two different things. We only implement parts. We only implement those things that we like right now. The key to it is writing good ordinances up front. Writing good coherent strong ordinances to begin with what expresses the desires and the intents of what you're trying to do with the ordinance. It's just a complicated process and there is not an easy one. Probably the best insight is to be prepared to change them. They have to be revised periodically, and they probably need to be revised fairly frequently. Try to be as clear in the ordinance about what your intent is as possible. And that's tough to do."

Interviewer said: "What advice would you like to offer regarding the selection of storm water BMPs?"

Interviewee said: "You have to be as thorough as possible. Don't get sucked into first judgments. Make sure you go through the life-cycle cost of the thing. Understand what the long-term impacts of the system that you're trying to propose on. Have some provisions for all the things that have to be done.

One of the common problems in designing retention/detention ponds systems is that people don't put a way to clean the damn things out. They don't put a way to maintain them. So, you design a pond, you dig it, and drive the tractors off and it sits there and ten years later when someone has to come in a maintain it, there is no access to it. There's no way to get in to clean the thing out. There is no way they can get in to maintain the thing. It makes for some real problems.

If you make sure that you include in the design all the provisions that are necessary to maintain it over its life, and then you evaluated that as a part of the selection process of picking the BMPs that you picked, then you've got a better chance of having a new something that works. Make this holistic approach to the evaluation of the BMP then include what the long-term cost is and make the provisions necessary to maintain the system. Unfortunately, that makes a more expensive job."

Interviewer said: "Any last thoughts?"

Interviewee said: "Good luck! If you just have to do it as a holistic thing and that's the hardest possible thing to do because so often the guy that's doing the development doesn't reap the benefit of the long-term cost. It's hard for somebody to see that that's a benefit to them when they buy it. We tend to look for lowest initial cost and buy below initial cost. That's not always the best choice to make, but that's the way we are driven. Lowest initial cost or lowest cost to me. So the guy that's the developer, he's looking at how can I get this developed and sold and maximize my profit. Typically, the cheapest way I can do it, first cost, is the way I'm going to do it. Building things for the long term. That's why our ordinances with regard to road structures, road widths, thickness of concrete and size of the pipe for the water distribution systems and kinds of pipes that you use for the sanitary sewer systems are as strong as they are because I've got to have stuff in there that's going to last some time. If I put cheap inferior products in there, I'll be in there replacing them and repairing them very, very quickly. That makes for a long-term cost that is very high, but it makes for a cheap first cost.

Generally ordinances that have dealt with those kinds of things and design principles that people have accepted for those kinds of things pretty readily. But we haven't yet gotten that low in a lot of our storm water BMPs. We haven't gotten into that mode where we're looking beyond the initial cost of the item of what it is that's going in. We've got to get beyond that like we have with some many of the other kinds of things that we think of as being a part of the development design.

It's like even when you buy your house, how many of us really buy a house with the concept of knowing that the house is going to be maintained over a long term. Most people don't look real closely at the siding that is used on the house, and what kind of siding, and what kind of finishes that are used on those things, and what the long-term cost of maintaining those are. And there are ordinances that typically address those kinds of things. They don't design them for long term. We don't build houses for energy efficiency because that cost more money, it saves more long term operating costs, but it makes that first cost higher, and people buy the house on the seller's first cost. It is the same thing that applies to all these other things. It's that holistic evaluation that you have to do. You have to take it. Convince everybody involved in the process that this is the economic development that needs to be done here in order to achieve the goal.

One of the goals has to be water quality. It is not a separate goal. It is an integrated goal with all the other goals that you have in any kind of design of the system. It is an intimately integrated in with the water costing goals that you have to have. The guys designing the storm water system for water conveyance systems have to be a part of that process of designing the water quality goals out there, and they are typically not. They typically are often separate departments. Here's the environmental guy and here's the water quality guy. The water quality guy is designing for lowest first cost. He may take some operating cost now. This should be in a pipe. Well, pipe is not really the water quality best way to do this. How much more cost does it cost to go to a water quality design? If I put it in a pipe and have to put a collection device or control device on it, is the pipe really the best way to go? They have to do it together. They have to be a partner in the same evaluation."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable to the research study. Please feel free to contact me if you have any further questions."

Interviewee said: "Alright, sounds cool!"

Interview #2 – Designer #1

Interviewer said: "Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study, and the responses to the questions will be tape recorded to ensure accuracy of the transcription. Please answer each of the questions to the best of your knowledge and ability and let's start!

"What is your perception of storm water wetlands, green roofs, bioswales, rain gardens, and/or similar green storm water best management practices in North Texas?"

Interviewee said: "My perception is somewhat, well it's positive and it's negative. I think unfortunately a lot of times we get ugly concrete structures when we're talking about how municipalities, builders, or anyone, designer deal storm water flow and how you manage it. I think things like bio-swales and rain gardens should be used more often. The knowledge is out there but a lot of people are not aware of it. Or it's just not something they think of when they're planning their projects. I am aware of it to a certain extent because I've been trying to get a bio-swale built for awhile, and I've research rain gardens on a couple of projects. What ends up happening though is budgets are a factor. Because sometimes trying to employ these best management practices can get expensive, and so unfortunately typically what happens is sticking in a concrete pipe and running it to the nearest creek is what happens a lot. I guess my perception is that these types of storm water best management practices people need to be better educated about them. But I think they are very needed. I think people need to quit doing what they've always done. I think more people are aware of it, sort of in the back of the minds but not to the extent where they say, "Oh, we can solve this problem that way. We could put a rain garden here."

Interviewer said: "What is your perception of storm water BMPs in general?"

Interviewee said: “I think I just answered it with that first one.” In general, I think unfortunately still in a lot of situations what happens ugly concrete structures are put in to move water from one place to another. Although you see more and more retention/detention ponds are put on sites. They just stick a fence around because they think its an attractive nuisance. I think that they are not often as they should be employed as a part of the landscape as an amenity. I know that there is plenty of literature out there, it’s just not practiced. But a lot of the solutions that could be used could be used in such a way that they actually become an amenity for a park or a site and not just an ugly piece of infrastructure.”

Interviewer said: “What methods to you implore in the BMP selection process?”

Interviewee said: “I can address that because I’ve been dealing with this just this week on a project. We’re trying to plat a 20.47-acre property for a new park, and we are looking at the BMPs that they will give us for doing certain things.” One of the methods that we employ is they’re asking us basically to grant them a flood water storm water easement that basically encompasses the entire 100-floodplain on the property. It means that we won’t be able to build within that easement, but we get two BMPs for doing that. Basically the methods we employ are how can we get the BMPs we need for this project and the easiest way possible. Some of its budgetary and some of it is just practicality. I think the methods we use in the selection process are primarily. Is this going to be practical for our site? Is it going to be a nuisance? Is it going to be a maintenance problem? Those are the criteria we look at or the questions we ask. For instance, if the City says they’ll give us one BMP for using impervious pavement. We say great but sometimes that’s twice as expensive as concrete. Not only that, sometimes it creates problems. Because if your substructure or subgrade is also impervious then the water just backs up and runs over line anyway. We ask the questions, “Can we do it practically and what’s it going to cost?”

Interviewer said: “The follow up to that is what drives your final selection of these specific structural storm water BMPs?”

Interviewee said: "I know you've probably heard this before but budget has a lot to do with it, and everyone is going to tell you that because typically that's it. Every project has a tight budget because we always want to do more than we can. So, that's what we end up looking at. I hate to say that but if we had an unlimited budget we would do what they wanted us to do, but typically we try to say well we can't really afford that so how else can we get it done and still get the BMPs that we need. Budget is not the main thing we do think about. I'd say maybe its 55 percent budget and 45 percent aesthetics something like that. We do think about aesthetics. It was a big consideration on the Howard-Moore project where I recently put in a large concrete infrastructure, and we did work with the designer to make sure there wasn't some very ugly piece of concrete."

"Well maintenance is also another issue. Yes, we look at maintenance as well. That does drive the final selection. Another is thing is in the long run concrete is very easy to maintain. It's ugly but it lasts a long time to a certain extent. Yes, we look at cost. We think of aesthetics, and we also consider maintenance. That's another very important issue, especially to the Parks Department."

Interviewer said: "What advantages do you see with the implementation of storm water being used?"

Interviewee said: "The advantages are environmental, I think, almost entirely, and also their aesthetics. I don't know someone may have done a study, if they haven't someone should, but I myself personally would much rather look at a bio-swale than a big ugly piece of concrete. We all know that the bio-swale is better for the environment because it allows recharge. So, I think the advantages are two-fold. Well, there are other advantages. Say we built a large parking lot and instead of running the water straight into an adjacent creek, we build a large bio-swale and it's fairly attractive and we put some signage out. Every time someone reads that sign, we help the public become more aware of the fact that we all need work on applying some of these storm water BMPs instead of the old way of stick it in a pipe and shooting it to the nearest creek. I think the advantages help the environment instead of passing our storm water problems to the next county or the next city, we're going to take that water and try hold it on our site longer so that we can allow it recharge back into the ground where it really needs to be—water quality. These

BMPs help storm water quality, and also I think they help to put infrastructure elements into our parks that are much more aesthetically pleasing. It is better for the environment, if we could do something, planting plants instead of laying more concrete because the very process of making concrete and shipping it to a site is environmentally unfriendly."

Interviewer said: "On the flip side, how about disadvantages of storm water BMPs"

Interviewee said: "At this point to a certain extent maybe upfront cost is thing. If you really think about that should not be a disadvantage but it is. Budget drives things. One disadvantage is that there's not enough education about it. More people need to know about some of the other possibility or some of the other practices that can be used for storm water management. Long-term maintenance is also an issue. If you do bio-swales and rain garden, they tend to soak up. You've got to back in and rework them from time to time. Maintenance is a big issue. I think the advantages for outweigh the disadvantages. I think once people start implementing more of these BMPs that you're talking about they'll see that the disadvantages are very minimal compared to the advantages for everybody."

Interviewer said: "What insights can you provide regarding storm water codes or ordinances?"

Interviewee said: "I think that the codes and ordinances probably need to be addressed in order for people to start practicing or using more of these environmentally friendly BMPs that you're talking about. I think it's still in a lot of cities codes and ordinances don't allow designer and builders to do things that we really should be doing. I'm sure that's political, and it's also driven by the economy and by the budget. But I think that probably the status quo is going to continue and it's going to remain the same until codes and ordinances are changed to reflect the BMP that you're talking about. It is happening. I'll use the Howard-Moore Parks project as an example. The fact that they are allowing us, or they're actually trying to get us to use pervious pavement and run water overland instead of just in a pipe. It's good and some things have changed. But I think the codes and ordinances still need to be changed further in order to try to encourage more use of green roofs, bio-swales, and rain gardens and other methods of storm water practices."

Interviewer said: "What advice would you like to offer regarding the selection of storm water BMPs?"

Interviewee said: "I think the advice for developers would be to ask them to prove consider spending a little more money and trying to do something the right way instead of always going for the cheapest fix, which is typically what they do. If you tell them, well we could do a really beautiful bio-swale here, or we could do a chain of detention ponds and could turn this part of your site into almost a park-like environment where people would love to see it. And when they find out its going to cost $20,000, they'll say no we don't want to do that we just want to put the culvert in here and we want to put the pipe in there and they'll shoot the water out over there. Some my advice is that for the long-term benefit of everybody on the planet, they we really need to much more seriously consider how they're going to deal with water coming off a large site. More education. I want the developers to consider, research, look into other possibilities to search beyond the status quo which what is typically done now. Almost always the developers will tell the designer, do the minimum. What's the ordinance? Ok, that's all want to do. Occasionally you'll get a developer or builder who realizes the importance of doing right or doing something that will benefit the site or will benefit the environment, but they are few and far between unfortunately. My advice would we need more education. We need developers and builders to try and seek out better solutions to storm water management. Occasionally you will see developments where a lot consideration has gone into the project, how they're going to deal with the storm water flow on the site and getting it off the site or keeping it on the site. As mentioned before, codes and ordinances are changing around the country, which is a good thing but considering your question on design, I just ask them to please spend a little more time and money in try to do something better for all of us."

Interviewer said: "Are you familiar with any woodlands type developments in North Texas?"

Interviewee said: "Occasionally I do see a really good site, but I have to think about it. I not sure what they're doing with Viridian here. I think they're working on something that's along those lines. Most of the time unfortunately what I see is that you see the same old thing over and over again. You'll see where they will put a retention pond on the site, and you know that's what it is for. It's collecting the water coming off a parking lot. It's just usually a rectangular hold in the ground. Here's an example but it's not in your neck of the woods, but it's a DART train station on the DART line. It's in east Dallas. It's actually just northwest of White Rock Lake. It's called the White Rock Station. It's really a very nice development, and what they did was they ran the storm water off some of the more heavily paved areas and they've got it running through little runnels and then they tied it to the flowerbed and it's a good solution. It's pretty and attractive piece of infrastructure."

Interviewer said: "Any last thoughts?"

Interviewee said: "I think it is an interesting issue and important issue and anyone who works with and deals with the environment has to deal with it because we all need fresh water. It's an issue that's not going to go way. I think it also a good project to work on for a thesis. I glad someone is looking into it."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable to the research study. Please feel free to contact me if you have any further questions."

Interviewee said: "Sure, sure, thank you!"

Interview #3 – Developer #1

Interviewer said: "Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints.

The following questions are identical to those previously provided to you on your acceptance into this study, and your responses to the questions will be tape recorded to ensure accuracy during transcription.

Please answer each of the questions to the best of your ability."

Interviewer said: "What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas?"

Interviewee said: "Well, from a developer's standpoint, it's expensive. I think a neat application and I'm for it from a conservation standpoint. But as a developer, we always have to be conscious of the cost and the impact and how that plays into the return of the project. That being said, I'm a firm believer in trying to incorporate some of those things in developments where possible. Specifically, you get into some of these things and some of the practical issues that come about from them.

Bio-swales tend to stay pretty moist and so can a lot of the other storm water solutions. Can provide a space for mosquitoes to grow. There can certainly be some smell that come from those that are a little less than favorable. So the thing when going about the development is to be careful about which ones you us and where they are placed. If your prevailing wind is southwest, you do need to use a bio-swale where you just don't want to put a restaurant upwind from something like that."

Interviewer said: "What is your perception with storm water BMPs in general?"

Interviewee said: "Looking at from a holistic standpoint, I mean certainly it was, it's unfortunate that a current storm water system can't handle the demand on it, but I can certainly understand that original design didn't anticipate the amount of runoff due to the large developments that we've put in.

I think that we certainly all need to be responsible for what we're doing and how to keep our city moving forward. I think innovative solutions on storm water management are appropriate. That being said some of the things fight against each other, large detention basins work against urban sprawl. If you have to have more square feet of land to accommodate some kind of detention basins that kind of works against urban sprawl, which you have to drive further then you're burning more gas, which is not a great concept, and then it makes it harder to bring mass transit the more and more you sprawl and spider out.

There are some neat solutions out there but they get really expensive. If you have collection system that you use to irrigate, then you have to put in underground tanks or some kind of tank system and pump that out. That also involves mechanics which breakdown and have a maintenance cost. Anytime you can do something that you don't have to have a motor in it, I'm definitely in favor of that.

The big pipe systems you can put under parking lots which are again pretty expensive. Probably not a huge cost to maintain but certainly there is a cost to the maintenance of that.

Can they keep the runoff clean before it hits any of our wetlands and rivers and things like that. It's a tough problem. It's going to take everybody solving it. Obviously it's going to take policy and mandates from government authorities which kind of where things start so that it keeps the playing field equal for all of us so that we all have the same cost going into these things."

Interviewer said: "Do you think that it's inefficient use of space?"

Interviewee said: "I think we definitely need to be more efficient but it's hard to…. Some of the design principles I think everybody is leaning toward is now is trying to get everything back to a central city. And to keep urban sprawl down…and if we're kind of talking about this from a "green" standpoint, we've got to catch this water and we've got to contain it. A lot what is being done now is detention ponds. Well, that obviously takes up acreage. So, the acres or land square feet for building square feet increase due to that, so that does kind of promote urban sprawl. You have to be more efficient with your building, or use some of these other solutions, tanks and underground separators and put them under your parking lots. If you're going to do the tanks, and if you're going to capture it you might as well as use it for irrigation but if you use it for irrigation, then you've got motors and maintenance and things. It's tough nut to crack. It's kind of like the energy code and when did that come into play, four or five years ago. It was the right thing to do and it was a good thing to do, and I think the market was moving that direction. I don't know if we have gotten as far or as fast as if… When it's mandated and everybody has to do it then it kind of makes it a little easier to digest. If I want to be a responsible developer and develop this in an energy-efficient manner, but my competitor doesn't do that so my cost to hire why I can't compete with him. It kind of makes it a little bit difficult. I think we're definitely moving there. I think that more and more tenant from a developer's perspective are looking at these things for two reasons: 1) will it decrease cost if I get into an energy-efficient building and I decrease my electrical cost and/or gas cost. Yeah, I pay a little bit more rent but my utilities are less so it kind of balances out; and 2) from a corporate responsibility type standpoint. Being corporately responsible for the environment, I think that's good. I definitely think we are moving in the right direction. It's just going to take and understanding from everybody as well as city mandates to get us there."

Interviewer said: "What methods do you employ in the BMPs selection process with your projects?"

Interviewee said: "A lot times it is dictated project by project. We probably tend to have a fairly dense development, as dense as we can. I think that a lot to do with land costs in many cases. A lot of times we use detention basins with a build a pond with some free bore for the detention component of it, and try to use that as an amenity. That also allows you to put a fountain or pump or something in the water. We kind of put something mechanics in there. It becomes a little bit of amenity and that helps keep the water from stagnating and helps keep the smell down and keep the bugs and stuff away. If you have a detention basin that just wet and it dries up and doesn't have the cost of pond and aeration, well if it stays wet for days at a time and doesn't drains as well as you had hope, it becomes an opportunity for smells and mosquitoes."

Interviewer said: "What drives the final selection of your storm water selection for the BMPs?"

Interviewee said: "I definitely think that there is some conscious decision-making on how it does affect the environment and how can we use this for irrigation and how we can do things like that. From a developer's standpoint, I think that a lot times it does get down to the cost, and how does that work, and how does it fit within the project. There are certain things that are not going to work due to whatever the project is and what the project dictates. It depends on the combination of those three things."

Interviewer said: "What advantages do you see with the implementation of storm water BMPs?"

Interviewee said: "It is definitely something we're all going to have to pay a lot of attention to because the repercussion to our cities and our roads and infrastructure could just be almost catastrophic really. I lived over in the TCU area about two or three years; I saw enough water to pop manhole covers off and floods some houses that were certainly out of the floodplain. If we don't do something now, we're just going to exacerbate that problem. If we start overloading those pipes on a regular basis and it creates too much pressure, you could have a big storm water pipe rupture and then your road could fail and sinkholes, and there are some safety issues that kind of go along with it too. Certainly, if you're the first guy to drive down the road after that manhole cover has been popped off, you're tire get down in there that's not going to make you very happy either. It goes with saying that the homeowners and people definitely deserve better than having their homes flooded when they weren't in a flood zone. Then there is always the liability that might come back to the City when all that stuff happens. It's obviously a problem we have to take care of because there is a change reaction that comes if we do not."

Interviewer said: "How about specific to your development?"

Interviewee said: "You can make these things an amenity. You got to be careful with them though. You've got to make sure that you design them properly because they can be liability and cause could be an attractive nuisance to a kid."

Interviewer said: "What are the disadvantages that you see with the implementation of storm water BMPs specific to your development?"

Interviewee said: “The smell, the cost, the attractiveness. You’ve just got to cover all those different things and the use of the land.”

Interviewer said: “What insights can you provide regarding storm water codes or ordinances?”

Interviewee said: “From a developer’s standpoint, it gets pretty expensive and this goes beyond storm water stuff. City mandates and codes have almost made it where you practically have to halfway develop the site plan before you can even get a zoning change or do anything to see if she can use the property for how you want to use it.

From a developer’s standpoint, it’s hard to even really move very far with the project until you’ve done a big storm water analysis and studied the watersheds and studied it for ten acres around your property or whatever it might be. So there is a certain amount of frustration that comes from that. If you’re doing an in-field development, whether you’re uphill or downhill from somebody, you kind of get to deal with the other guy’s problems a little bit, too. Because a lot of times it seems like they’ll only let so much into a storm water system, but depending upon the capacity that is left, and if you’re downhill and you’re collecting it and the guy uphill developed his 20 years from now and he’s shedding across you. Well, you know it’s definitely a disadvantage because now all of a sudden you kind of have to accommodate something that wasn’t necessarily your fault to begin with. It seems that way, in theory I don’t really think it is but it certainly seems that way when you start talking some of the staff members in the City.

Sometimes the amount of information is tough to get. It’s adequate or it’s got a lot of holes in it and isn’t always exactly what’s there. You have to be very conscious about grades, etc. It just really proposes a whole list of other challenges.”

Interviewer said: “What advice would you like to offer regarding the selection of storm water BMPs?”

Interviewee said: “One of the better ones that I think is out there is permeable paving. It does involve a motor, doesn’t involve a big hole, can be done attractively and doesn’t seem like there is major maintenance issues that go along with it. I like that idea. I was kind of against bio-swales earlier for several reasons. If you can kind of figures out ways to get around some of those issues, I like them if you can incorporate them into the landscaping requirements that you already have. I think that cities really ought to look at and I think a lot do. But if you are doing the detention then things definitely need to toward your landscaping. Maybe there is a way to that if you could dig the hole deeper, or you could make it a little bit bigger maybe the city could help accommodate the problem that already exists. For example, your neighbor uphill built 20 years ago, and he's shedding across you and so you're only required to catch the water on your property post development vs. predevelopment, but you can catch some of his and help keep the capacity while maybe they can give you a credit for trees or something like that."

Interviewer said: "Do you see any cost sharing with cities in North Texas, such as you can solve a problem like that?"

Interviewee said: "Yeah, they could definitely if they came in and threw some money in it! Yeah, I'd think that would be great! Is there way to do a fund where they would go in and start, instead of requiring a bunch of stuff, can they increase the capacity of their storm system instead of having a bunch of best management practices onsite. That might be it. From a father's, perspective it wouldn't probably hurt to start a little bit of filtration as we put this water into the storm system. I know that again slows things down and comes with it own set of problems but I was kind of giving you answers from a developer's perspective."

Interviewer said: "Last thoughts that you might want to add?"

Interviewee said: "I certainly believe that this is something that is coming to the forefront. Our storm systems are just undersize and inadequate. It's going to kind of take everybody working together to get this problem resolved. It seems like a combination of solutions probably in most situations works better than one single solution."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable to the research study. Please feel free to contact me if you have any further questions."

Interview #4 – Developer #2

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study, and the responses to the questions will be tape recorded to ensure accuracy of the transcription. Please answer each of the questions to the best of your knowledge and ability and let’s start!

“What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas?”

Interviewee said: “I think these green solutions, at least for my developments, are inappropriate and are very costly.”

Interviewer said: “What is your perception with structural storm water BMPs in general?”

Interviewee said: “I think I just answered that but I tend to leave the selection of specific storm water BMPs to the engineers or architects I employ. The selection of these is obviously driven by cost.”

Interviewer said: “What methods do you employ in the BMP selection process…for the structural or permanent BMP solutions?”

Interviewee said: “What’s worked for me in the past. I have done storm water detention credits. I’ve done that in the past in some cities like San Antonio…buy storm water detention credit. If I can’t find a couple acre site on my land itself, then there are land banks that people hold it just as a detention pond. It has to be within the same catchment area of your city. If you’re storm water is going into ultimate certain creek. There is a designation about what say 15 square miles going to that creek. So, if you cannot provide the detention pond on your side, then you can actually purchase say 2 acres for a detention pond through the detention pond bank. I have not seen too many of that in Dallas area. We’ve have seen similar thing about the green building about the wetlands. In certain categories wetland also you’ve got wetlands banks. So, if you have to have some wetlands in your particular site, then part of that you can actually defer to the area around, and get a little of your wetlands. It's case by case and normally it's to make it fair game for the developer as well as the environmentalist. As long as the spirit is kept. A 5-acre site on the corner Business Park for example. But the environment sees the 20-mile radius of the habitat and wetland. So they said okay if you cannot preserve it, but a mile away from it you will make a dollar guarantee of that wetland then we will swap it with you. It is done like that. So that's the answer for wetland.

Interviewer said: "What drives the final selection of your storm water BMP?

Interviewee said: "What drives the final decision—money."

Interviewer said: "What advantages do you see with the implementation of storm water BMPs?"

Interviewee said: "I can answer that question. Who knows? It's costly.

Interviewee said: "Who requires this BMP besides cities?"

Interviewer said: "It's usually ordinance driven. There's federal regulations through the…

Interviewee said: "Is it the Corps of Engineers?"

Interviewer said: "No, it's through the EPA."

Interviewee said: "Oh, the through EPA."

Interviewer said: "EPA is dedicated that authority to TCEQ and then, of course, local municipalities they don't want to flood your neighbor, so they got ordinance in place to for you to keep those…"

Interviewee said: "I think it does connect to Corps of Engineers also."

Interviewer said: "Yeah, if you have do have watercourse or wetland on your property, you try to incorporate that into your BMP. Yeah, you will have Corps of Engineers implication."

Interviewee said: "I bet you not one developer can answer this question. This question's more geared to civil engineers. Not too many architects would be to answer this. These are civil engineering questions. I have you talked to any civil engineers?"

Interviewer said: "I have, yes!" Them and landscape architects as well. Since they're essentially doing some of the site work."

Interviewee said: "The civil engineer and landscape and to a certain extent architects will be able to answer. Developers are to damn dumb and fat and happy to answer this question, I think."

Interviewer said: "Overall what disadvantages do you see with the implementation of these?"

Interviewee said: "You know every case is different. If I have inexpensive land, large land that I can afford. For example, I have a 14-acre site that I need a shopping center at Frisco and Little Elm on the northeast corner of the quadrant metroplex. I had a couple of acres of extra land and that I really wanted to be developed for that shopping center at the corner, but I didn't want to do anything. So I actually made a park, and I have a huge detention pond and all the water management was done on my site. So there I preferred it all onsite. Now many times I don't have enough land, so I had to go underground storage or I buy the BMPs from different place or something like that. So, it's really from a developer's perspective. Some trick you can do, but the bottom line is dollars and cents. If this management becomes management becomes privy to you, then we'll just fund that site and go somewhere else. But it is a cost issue. The answer for civil engineers will be totally different because, they don't give any hoot to cost. They do but that's not their responsibility. They're responsibility is to abide by the codes and the legislation and the management practices, and then just tell the developer this is what it is, and then we make the decisions if that cost is affordable or we need to go to the next site."

Interviewer said: "And that's what I've been finding."

Interviewee said: "Correct." "What insights can you provide regarding storm water codes or ordinances?" I think that they're fair, play fair game. It's a totality of the picture that they call the way up to the final shade of the ocean. The Corps of Engineers beautifully manage that all over the country. Unfortunately, we had some incidences where a 1,000-year flood occurred this year in Ohio,

Missouri, and we had floods 6-months ago, if you remember. All the management and all the actions were totally were proved wrong because pretty much on which they were based exceeded the actual rainfall exhibit, so that it was pretty pathetic. Other than that for the normal 50-year and 100-year flood, they are management quite well.
What advice would you like to offer regarding the selection of storm water BMPs? Well, I'm busy with my developments and the next deal in the works. I leave the nitty gritty to the people I hire. I can't simply answer that."

Interviewer said: "Well, I appreciate your time and information."

Interviewee said: "Sorry I couldn't help you any better."

Interviewer said: "Hey, you at least answered what the predominant answer for the developer is that cost drives the selection."

Interviewee said: "That's right. The cost. That's true. Okay."

Interviewer said: "Well, thank you, sir!"

Interviewee said: "Thank you, Jason!"

Interview #5 – Bureaucrat #2

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study, and the responses to the questions will be tape recorded to ensure accuracy of the transcription. Please answer each of the questions to the best of your knowledge and ability and let’s start!

Interviewee said: “Question 1 with the perception of storm water wetlands, green roofs, bio-swales, rain gardens and other similar green storm water best management practices in North Texas?” I think right now they’re not being utilized anywhere close to they’re full extent. We’ve actually been trying to get people to do them here in the City of Denton. We have one project which is a large planned community Ranger Ranch, which we’re actually requiring them to apply integrated storm water management techniques via the ISWM Manual…for the COG. We have a wetland system. We have bio-retention areas and some swales and some other things. We’re actually doing a project right now where we’re looking at some of these types of activities at our airports…at one of our fire stations. At one of our dog parks, well our only dog park. I think that they’re going to be something that is definitely needed as the population increases and you see more water quality issues. Texas is a very interesting place from a water quality standpoint because of our eutrophic lake systems. I think as the populations increase, we’re going to see increased impacts to our water supply. We really can’t officially treat these things like wastewater treatments, so we’re going to have to look at better management practices to do these. My perception is that they’re a necessity. From a policy standpoint, they’re almost an unknown, but unfortunately the public doesn’t see the necessity until a point that it’s a problem. So, if we try anything with an ounce of prevention from a regulated standpoint or from a city staff standpoint it’s hard to get that ounce of prevention to occur. I think it’s a necessity, but I don’t think the general public has really an idea of what it means.”

Interviewer said: “Okay!” What is your perception of storm water BMPs in general?”

Interviewee said: “I think in general right now storm water BMPs are very misunderstood. I think all way down from the engineers, designers, architects, to the site operators, construction people and even a lot of the city and regulatory staff. I don’t think they really understand very well what that means. Case in point, I have a friend who is an engineer down in San Antonio and works with one of the river authorities. There was a plan that they brought to put a BMP at the site. We both thought about that and you can’t just say a BMP; you have to say what you’re going to put in. And a lot people just say “I’ll put a BMP there,” and that’s suppose to make everything right. A BMP is a design solution to correct a potential problem. A lot of people will look at a BMP as oh I’ll put silt fence up or construction fencing and everybody’s happy. A lot of times they’ll put a silt fence in the area that is either too large or the slope is too high or it’s just not really effective. They won’t maintain their BMPs, and also I think a lot people from standpoint of storm water look at BMPs only from the sediment control standpoint. They don’t want look at erosion control. As a matter of fact, I’ve talked to somebody from other state, Michigan, that actually requires certification across the board in erosion control. They said erosion/sediment, they said they just don’t get it here right now because they just look at a BMP as a silt fence and that’s it. And I think the other part of it is they don’t look at BMPs from a storm water standpoint as a management structure. So the educational staff and a good understanding of how your site works is the BMP in itself. I can tell you right now I go to many sites and I ask many of people on the site, and they have no clue what’s going on. So that’s the failure in a BMP because you’re suppose to be educating staff as to what is going on and what actually to take in positive corrections and how to identify problems, and if you’re not doing that, then you’re silt fence or wetlands is going to fail because you won’t have the maintenance or the awareness on the staff level.

Interviewer said: “So education…that pertains to structural built storm water solutions?”

Interviewee said: “Yeah, definitely structural, and also just understanding where to place things. Because if you’re the person who is in charge of managing the storm water BMPs and you’re not there today and they happened to put a pile of dirt in the road, then you’ve go a failure of a BMP right there.”

Interviewer said: “What methods do you employ in the BMPs selection process in terms of structural BMPs?”

Interviewee said: “Typically it’s going to depend on site, so we’re probably going to be looking at things like hydrology, size of the site. We really haven’t got to the point at looking at a really good way to look at ecosystem impacts. But I think we’re going to look at the specifications of the BMP and whether or not it’s correct for the site. Once again, the BMP of choice for everybody is a silt fence. And time and time again, you see that just does not work or that has problems. Then they’re also not looking at erosion control. What we will be looking from a BMP selection standpoint is know we’re looking at a stand back, big picture look at the site and how best a BMP is going to address the runoff coming from the site.”

Interviewer said: “What BMPs do you see predominately installed in developments aside from the silt fence protection… structural solutions?”

Interviewee said: “Not many. Most probably detention ponds. We see a very small number using sediment vortex/separators. We actually have one here inside of this location. By and large the two things you’re going to see is either silt fence or detention pond. You don’t see much else. We have that wetland system and see a wetland system that we’re requiring to be put in. At our site relatively few, we’ve put in some swales and some other things, but unfortunately that’s required. It’s not the development team.”

Interviewer said: “For structural or built BMPs, what drives the final selection of those?”

Interviewee said: “Probably cost.”

Interviewer said: “Are there any other drivers other than cost, or is it …?”

Interviewee said: “At this point, I would say it’s going to be short-term, upfront cost. Nobody’s looking at ease of maintenance, long-term stability or long-term viability. I would say at this point in time it’s upfront cost because we’ve actually tried to address other types of BMPs with the development community. Pervious concrete various things like that and the answer has been it cost too much. The market is just not where it needs to be for these things. I think our biggest problem is cost and understanding the difference between a short-term cost and a long-term cost.”

Interviewer said: “In your opinion why are those solutions so expensive?”

Interviewee said: “I think right now it’s because nobody is doing it. A lot of the stuff you have to export from other parts of the country where the market has already been developed. So that’s just a supply and demand simple economic model. Whether if they have to get it here. The other problem is people aren’t buying, so the people who are selling around here to make ends meet have to increase the cost. Until the market increase, they’re not going to be low to cost. The other problem is there are not many people who develop a lot of those methodologies. So, until we get more competition in the market, we’re getting there, but I think Texas really hasn’t addressed it from market economic standpoint. The other problem with Texas is we just implemented our storm water permit very recently. So, from a regulatory standpoint at the local level, we’ve spent the last few years saying either like Peter and the Wolf saying, saying the wolf is coming, the wolf is coming, and eventually people who actually find are going to be like you’ve been saying this for two and half years. They don’t really hear that the sky is falling, and until there is a regulatory driver to force them to do it.”

Interviewer said: “This was a Phase II?”

Interviewee said: “We are a Phase II.”

Interviewer said: “What advantages do you see with the implementation of structural or built storm water BMPs?”

Interviewee said: “I think you have a little bit better efficiency. I think you can actually, there’s a little more demonstrable efficiency. I think there’s more of a long-term efficiency. I think your maintenance in some ways closed down. You really need to be checking it all the time. And I told you this before, if you put in certain other things, you may not have to be checking it quite as much because with a very large site with the silt fence it's a lot of perimeter that you're going to have to go and check and replace. That can add up in a matter of time. If you put in some kind of structural thing which is going to capture it, you have one place that you have to go to limited maintenance is not going to change much. Overall I think sometimes we hope the water quality output will be an advantage. Higher efficiency of removal TSS and solids, nutrients, phosphorus, etc. I think the overall advantage of storm water quality is the plus, but the big problem with that is most people think about water quality as far what they're doing to water resources and lake downstream."

Interviewer said: "Conversely, what disadvantages do you see with the implementation and structural or built solutions?"

Interviewee said: "It goes back to the question of maintenance. Who is going to maintain it? Whose is going to pay for that maintenance? And I don't think you have a good feeling on how it's going to happen. If it's on the public side then you'll have to find some way to fund that, either through some type of fee structure or something else. We have drainage fee here but if we get to the point we're actually maintaining all those things, then we could have to increase our drainage fee on the commercial side. If it's on the private side, then you have a question of are they maintaining it and whose watching and maintaining it. And I think everything goes back to maintenance on structural or nonstructural. The question is you put this in, it's not going to fix itself, it's not going to clean itself. Someone has to regularly inspect it even if it's on a yearly basis. You have to go check it. Someone has to clean those things out."

Interviewer said: "So cost is it?"

Interviewee said: "It's going to be cost. Maintenance cost I guess would be my best, and that's a hidden cost because you put it in and nobody thinks about much it's going to cost over the next year. Or also replacement cost because people don't plan for replacement if its 10 years or if its 20 years. Nobody is saving for that I guess I should say."

Interviewer said: “What is insights can you provide regarding storm water codes or ordinances?”

Interviewee said: “I don’t think they’re where they need to be as aligning with either the federal or the state codes or Phase II permit. We just actually passed our Subchapter 18 relating to land disturbing activity through planning and zoning last night. And that has been literally five years in the making since the original permit was going to be put out in 2003. I don’t feel that there’s a really good understanding of tying everything in together. There’s a lot loose ends to be…local government development process and the state or federal codes. So, I think there needs to be a lot more alignment of those things so that the development community is aware that they need to do these things and what role their going to play as is what role the city will play. What city departments are spearheading these ordinances, and once the ordinances are put in whose going to administer the ordinance. Right now and with most cities, I see the ordinances and codes being kind of a catch-all between building inspections, engineering inspections, planning and zoning, and if you have utility function they’re going to be involved, too. Well, someone really needs to be “in charge.” Right now I think that’s kind of a loophole because you got periods where public improvements are being done and the engineering inspections that deal with that and the private goes on with the building inspection and before that even happens you’ve got planning functions. From a code standpoint or ordinance standpoint whose in charge? So there are a lot areas where…uhm

Interviewer said: “Too many Indians!”

Interviewee said: “A lot of Indians and a lot of chiefs and a lot of places where things can fall through the cracks. And I think that’s one of the big problems with a lot of work codes. I think that might be the nature of government because a lot places where projects or implementation of projects can fall through the cracks.”

Interviewer said: “What advice would you like to offer regarding the selection of built or structural storm water BMPs?”

Interviewee said: “I think we’re going to need to look to more natural solutions and also a lot of preservation. We’ve had some situations where a developer can in and clear cut the entire, totally stripped, clean cut the entire site. We had suggested prior to them coming in that perhaps they'd preserve this area of natural trees and vegetation. After they did that, the runoff went right down the road into some guy's property and filled his pond with sediment. He called the City Manager and complained and we dealt with that for years literally. The backlash was pretty significant. But if they developer would have given it a little bit more thought, and thought of perhaps these trees and preservation of the natural vegetation as a BMP, I think we would have never had the problem. I think also there's going to have to be a change in philosophy because a lot of BMPs really are addressing just storm water quantity, or they're really not addressing storm water quality. Once again the silt fence is a good example. Yeah, it kind of puts a structural barrier but its some ability to really impact water quality improvements, in my opinion it's not really that great. There are a lot of things that you can implement from a natural standpoint as just not tearing up as much or phasing in your project or doing other things. Management-type BMPs could actually do better, but a lot of people don't look at it. They think there is a very quick and dirt answer. I think there's going to have to be public education process. Really a philosophy change paradigm as for as the selection of storm water BMPs. I think initiative is going to involve a little bit more cost maybe from the fact that you're using structural, or a little bit more cost because nobody would have to take a bit more time to look at how you designed your project. So, maybe an engineering phase will have to take a little bit more cost because they design it to occur at a different level. But I think it's going to definitely take a change of philosophy at multiple levels. I think that's where were at, and we probably have easily several years before we get to where we need to be. Unfortunately, I would like to be able to snap my finger and make it happen tomorrow. It would make our job a lot easier."

Interviewer said: "Would you like to add any last thoughts?"

Interviewee said: "I think that we're going in the right direction, but I think there is a long road ahead of us. I myself have been working with this for several years, and I don't think a week goes by that I don't learn something that really helps me as far my ability to define problems with BMPs, and also to think about different ways of approaching a construction project. I think there's just going to be a learning process that going to have grow over a long period of time. I think there's been a long period where we've done things the same and they've worked but that was a period of time when the population wasn't as concentrate. There was more water to go around and we didn't have the issues that we have now. I think there has to be a more holistic watershed level view on the selection of BMPs. Not so much what does this BMP do for your site, but what does this BMP do for the entire watershed? Like a future kind of situation. I think that's where we need to get. Perhaps it plugs into a model and you can actually see step-by-step the decrease in some type of pollutant, so there's actually justification of saying we need to put this here and I'm sorry it's going to cost you an additional $4,000 or $10,000, but your project is $450 million, so sorry."

Interviewer said: "Is Denton maintaining a database for the type, location and design criteria of storm water BMPs?"

Interviewee said: "No, we do not."

Interviewer said: "Nobody does."

Interviewee said: "We have ours, but no we don't really have a good thing related to that. When I was first was here about eight years ago, we were doing something with our drainage engineer at the time. We were surveying other cities and looking at their drainage criteria. They were actually trying to plug that into the BMP selection. He was doing a lot of good work but obviously got another job and left. That kind of faltered at the time. And I think you really need to have an engineer who understands that but is also an engineer so that he can ride the fence on both sides. I think you need an engineer who understands ecology because a lot of their mindset is this is the way we do things. I think our definition of structural has to change as far as BMPs. I think structural needs to get a little bit less structural.

Interviewer said: "Thank you for your participation in this research."

Interviewee said: "Hey, glad to have you! I hope you change the world or at least North Texas."

Interview #6 – Bureaucrat #3

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) for the selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study. Your responses to the questions will be tape recorded to ensure accuracy during the transcription. Here we go!
What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas and we’re talking structural the built ones?”

Interviewee said: “Well in my personal opinion, I wish we could do more. I see that the typical curb and gutters going in, and I see that as outdated. I wish we could do away with them and do more swales and rain gardens.”

Interviewer said: “Okay!” What is your perception of storm water BMPs in general?”

Interviewee said: “Storm water in general? As they relate to construction?”

Interviewer said: “What do you think? Do you think they’re functional? Do you think they’re working? Can they be better?

Interviewee said: “In general, I think the concept of the Best Management Practices is works well. We’ve only been under the requirements for a year now. From a city perspective, we are just now starting to implement those BMPs. I don’t have a long-term knowledge of how they’re working out for the City of Burleson, but it seems to be on the right track. At least, it sets a standard that gives us something to work with instead of having to use a concept out there. At least we have a standard to follow. In that sense I think they’re in a appropriate place to get going.

Interviewer said: “Are ya’ll using the ISWM Guidelines?”

Interviewee said: “We’re not. We have our own design manual that the Engineering Department has been working on, and they’re done their first reading in front of City Council to update that manual. We're hoping get it updated before the end of the year."

Interviewer said: "What methods do you plan to use the BMPs selection process?"

Interviewee said: "It's through the design manual, and there is a point system that they use. They have a list of optional BMPs that the developer can choose from to implement, or if they have their own idea they can bring that in, but it has to be approved through the Engineering Department. But it's primarily through the manual."

Interviewer said: "Is that based on acreage?"

Interviewee said: "Yes. I think its 12,000 square feet.

Interviewer said: "Do you know if those fees are all in?'

Interviewee said: "I don't know, but we could look at them. Of course, as I said which it's in the works. It's not actually approved yet, and they differ between residential and commercial construction."

Interviewer said: "I guess what I'm trying to identify is does the manual offer the option of providing wetlands, green roofs, bioswales, etc."

Interviewee said: "Yes, it does! Somewhere between residential and commercial although they are essential the same, then within that breakdown you have you're permanent BMPs vs. temporary. The temporary being the ones that are under construction and the permit being the long-term. For the permanent BMPs, yes, preservation is at the top of the list. We have preservation of natural creeks, layout, retaining walls, swales, the 100-year drainage easement, cluster design, detention and retention ponds, and preservation of trees, dedication of linear parks, mixed use or other."

Interviewer said: "So yours is a little more progressive than what was in planning."

Interviewee said: "It's still not finalized but it looks like it's going to be."

Interviewer said: "I guess what is in your opinion what drives a developer to finally select a specific BMP?"

Interviewee said: "Well, they will come to the city with their proposed erosion and sediment control. We haven't named it. We call it the storm water management site plan. So they have to bring it to us, and then it is review through a committee. If there are ever any details to work out then they'll come about but I think there necessarily a push toward a certain way. We set the standard and they can choose within their framework."

Interviewer said: "In your opinion why would they to choose a detention pond or a detention basin over a more naturalistic system?" Is it ordinance driven? Do you think it's inappropriate? Do you think it's out of ignorance? Do you think its cost?

Interviewee said: "I honestly couldn't answer that question because I don't directly work with them that much to know."

Interviewer said: "That's fine. What advantages do you see with the implementation of these storm water BMPs in structural?"

Interviewee said: "That is a big one. Appropriately reducing erosion to our natural creeks that these eventually drain into. Filtration of sediment. Overall improvement to the environment."

Interviewer said: "What conversely disadvantages do you see with the implementing these?"

Interviewee said: "Long-term maintenance. From a city perspective we have it written in that it will be the responsibility of the owner to maintain but there still has to be some tracking of that and inspection. From the city's perspective that could be a negative."

Interviewer said: "What is insights can you provide regarding storm water codes and ordinances specific to Burleson?"

Interviewee said: "Our storm water ordinances actually passed in 2001. Whenever we were anticipating that the Phase I permit was going to be issued, and then an incident came about until 2007. So, we are now in the process of going back to that 2001 ordinance and updating it to make sure that it's in line with the rules as they actually were issued. Basically our ordinance covers general almost nuisance-type issues of don't discharge these specific things, motor oils included there. Of course, we use that catch-all statement. Then it spells out specific requirements for fertilizers, pesticides, and herbicides. It gets into more detail about used oil regulation, and then it gets into the skinny about industrial and construction." Those are the main highlights of our ordinance. I think that again the framework is there for this, there's just a few things that need to be...

Interviewer said: "Is it well received by the people that come in and try facilitate a development? You don't hear them complain about that?

Interviewee said: "No"'

Interviewer said: "Everything is spelled out and it's easy to find?"

Interviewee said: "Yeah, I guess so because you only hear about something if people are unhappy with it." I haven't heard anything."

Interviewer said: "What advice would you like to offer regarding the selection of storm water BMPs? Would you like to see to see more green solutions?"

Interviewee said: "I think the BMPs are good framework. I think they could go but it would be wonderful if we could come up with a more comprehensive, low impact development and combine all the important elements together, so that you're not just trying to get a point system to make sure you fit the rules but that you're looking at that comprehensive, overall perspective.

Interviewer said: "Any last thoughts that may not have been covered in these questions?"

Interviewee said: "I think the storm water program is a great environmental perk for the protection of water quality. I glad that we have it, and I hope it gets us where we need to be in this nation."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable, and please feel free to contact me if you have any questions."

Interview #7 – Bureaucrat #4

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) for the selection process for structural or built solutions from regulatory designer and developer viewpoints. The questions are identical to those previously provided to you on your acceptance into this study. Your responses to the questions will be tape recorded to ensure accuracy during the transcription. If you’re ready….

Interviewee said: “Sure, I’m ready!”

Interviewer said: ‘Then proceed.”

Interviewee said: “I work for the City of Hurst and have been with Hurst for nine years. I’m kind of giving you a little background on me. I’m a retiree from Dallas Water Utilities. I worked there 28 years.

Interviewer said: “I just saw Larry Patterson.”

Interviewee said: “I know Larry Patterson. He’s a real good friend, and he’s an outlaw relative to my wife.”

Interviewer said: “Oh, really! How about that!”

Interviewee said: “It’s a small world. Did Larry interview?”

Interviewer said: “No, we were actually knee deep in Lake Ralph Hall.”

Interviewee said: “There a lot of us who worked with Dallas Water Utilities that are not with other agencies. My boss Ron Haynes worked for Dallas Water Utilities at one time. Ron’s a graduate of UTA, and I’m a graduate of UTA. It’s a small world. Yeah, I’m looking forward to answering your questions.”

Interviewer said: “What is your perception of structural solutions such as wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas?”

Interviewee said: “You’ll find I’m pretty much going to cut to the chase here because I’ve been involved with storm water for a number of years now, and most recently with the City of Hurst. We have become involved with Phase II storm water regulations. Within those regulations we're to come up with a management plan for storm water for those cities under 100,000 population, so having a management plan that also includes minimum control measures and best management practices for those minimum control measures. Therefore, inside of those we've also been working with NCTCOG for the integrated storm water management. After all of that we actually get down to the ISWM. ISWM is a document that actually was prepared through NCTCOG by Freese and Nichols. Alan Greer with Freese and Nichols pretty much put his heart and soul into the ISWM document. We had representatives from Hurst work on the ISWM Committee…our previous city engineer with Hurst. I basically convinced our director to get involved with ISWM and to support ISWM through financial contributions that Hurst makes to NCTCOG for that program. We've been paying for the ISWM program for the last four years now.

Interviewer said: "So Hurst is a member of ISWM?"

Interviewee said: "Well, we haven't ran the process of doing so. In fact, I just got the e-mail from our City Engineer this morning about us adopting ISWM with some Hurst addendums to it. We intend to adopt it with some Hurst addendums to it. You will probably find that's pretty much been a common denominator. A lot of things that are created by group agencies, whether it be NCTCOG for instance. Dallas does the same thing. We'll have addendum to NCTCOG. We use those special cases in a sense for construction purposes, and everybody uses them with some addendums to them. Basically within ISWM there definitions for the rain gardens, the wetlands, the green roofs, the bio-swales, so yes, I know them by their definitions in the ISWM. I won't pretend to be an expert on this, but I have used the ISWM documents actually just recently went there and looked at these and found hey here they are in our ISWM document. They are there for whoever adopts the ISWM to use or doing an addendum around them so to speak.

Interviewer said: "Are you a proponent or an opponent of those green solutions?"

Interviewee said: "I'm a proponent. I think we're good. I think we do need to do more of that. I also feel professionally as well that not everything is going to pertain to every city. I'm pretty much a proponent of , yes, make each city aware of what is available, but let each city or community choose what they want to use in their city area, village as the President would say, but kind of have a cafeteria menu type approach to it. Here's what's available. Use and choose what would be applicable to your city. Some can use more than others, and some can't use any of it for some reason or another."

Interviewer said: "What is your perception of the storm water BMPs in general?"

Interviewee said: "My first response when I read your request earlier, you throwed the word "BMP" out there. I guess it could be basic multilingual plain. I went out there and search on some things. What I'm probably confused the most with is one of the computer terms "bitmap"? So we won't confuse it. What does it stand for to me? I relate it really as best management practices which my most recent involvement has been with the ISWM program and our storm water management plan. We've developed best management practices for Hurst for our six minimum control measures under our storm water management plan. I've kind of got some tunnel vision here so to speak in that I'm looking at it on a Phase II storm water viewpoint as actually being a regulatory agency for the City of Hurst."

Interviewer said: "In your opinion are they beneficial nor not beneficial to the City of Hurst?"

Interviewee said: "They're going to be beneficial because it's a way for us to define and measure to some extent how Hurst is doing, and in turn when we do those reports it will allow the State to compare one city to another as how well they're doing relative to their plan and relative actually to other plans. They're good! It's a very good acronym that is catching on more and more and actually best management practices are used other terminologies, too. Mine is kind of tunneled in here to the storm water management plan."

Interviewer said: "What methods do you employ in the structural or built BMP selection process? Now I understand that you're not actually implementing these but what mechanisms through the City of Hurst."

Interviewee said: "We are a Phase II city. We're under actually permit 40,000 right now in the first year's stages of that. It's a five-year staged implementation where we're suppose to as a Phase II city become compliant within five years to all of the regulatory requirements. We have a five-year plan of becoming compliant with the Phase II storm water regulations. The City of Hurst and likely the other suburb cities in the Dallas-Fort Worth area. We're having to do this along with the other things that we're doing water and wastewater wise with the resources that we have in place right now. As we begin this, my director anointed me, so to speak, as the storm water lead person. I've become the Storm Water Committee Chairman for Hurst, and we have a committee of 13 individuals from various departments throughout the city. We work together as a team to meet the requirements that we've actually set up for ourselves in our storm water management plan. Then again storm water management plant, minimum control measures, we have six of those, and then we have several best management practices for each of those minimum control measures. Control measures are educating the public for the mainland, and we've been kind of skipping through them not going through any particular order of them. One of them is where we adopt the ISWM. One of them is the good housekeeping and that's pretty much in my specific area since I'm over water, wastewater and street operations. We have a lot of the good housekeeping items to do specifically within Public Works. It goes on through the other ones. For the most part, we're probably going to have more within the good housekeeping than we're going to have in the others. Right now it's for the most part it's educating both city employees and the citizens and our customers. Along with that we'll be adopting ordinances to our city code that will give us the right to implement these programs, regulate and enforce them. We're also in order to be compliant we've got have more resources to do this. We are in the process of developing a storm water utility fee finding different names and acronyms for them throughout the cities. Hurst is probably one of the few cities that still does not have a storm water utility fee, and we're in the process of going to our Council and to our citizens to adopt a storm water fee for Hurst. These fees will be used to support the cost associated with our storm water management plan and the best management practices for doing for each of those. I'm kind of a key guy right now in Hurst for this but I have a lot good helpers. An environmental specialist has assisted me with this. We have a committee of 13 people that are pulling together from each of the departments to do their part of it. The Parks [Department] has a dog poop program where they have the bags to pick up the dog poop in the parks. In Public Works we have street sweeping machines. We have two street sweepers, and we go about and sweep the streets. Key things to keep your streets clean so that debris and potential contamination goes into our waters of the State."

Interviewer said: "In your opinion what drives the final selection of specific storm water BMPs for the City of Hurst and as far as developments?"

Interviewee said: "The improvements just recently and made those decisions. We had the help of NCTCOG. We went to many of the NCTCOG meetings. There's actually six Phase I cities, Dallas, Fort Worth, Arlington, Irving, Garland and Grand Prairie. Phase I cities have been through this program, and I had a little bit of exposure to it when I worked for the Dallas Water Utilities. Larry McDaniel headed it up for Dallas when Phase I first started. You may have met Larry McDaniel along the way somewhere. I think he's over at Park Cities."

Interviewer said: "Yeah, I think Plummer had some interaction with him."

Interviewee said: "The point I'm trying to make is that Phase I cities have been through this, and they've helped coach and mentor the Phase II cities that are doing into this. NCTCOG has kind of been an agency that's pulled those two together in that they've come up with their regional best management practices. John Promise coached us on those that NCTCOG has put together. I've listened to the NCTCOG, and I've listed to John Promise. There's been a lot of input to those and probably too much input as far some of my professional opinions. You can actually get too much input on some things. It gives you a good menu to choose from, but the whole menu not is not what everybody needs to eat. NCTCOG has helped. I've found that Dallas-Fort Worth area has got one of the best engineering communities. I can pick up the phone and I can call just about anybody and they will share with you the knowledge they have and they'll work with you on these things. Hurst is no different that any other cities. We have consultants that work for us. I recommended that the City of Hurst choose a consultant to assist us with our storm water management plan, including all of these best management practices. Carter Burgess which is now Jacob

Carter Burgess. There is a gentleman with them Curtis Biddle. I've known Curtis for years. He was with Freese and Nichols. We did Bachman Lake together. He was consultant, and I was a project manager. He's with Carter Burgers in their environmental group. He's brilliant person that knows more about this than anybody. He's the one who could answer these without any notes. I convinced my director that we should have such brilliant person helping us with this because Larry Martin didn't have enough time to do all this himself. Hurst used Carter Burgess and we worked with the knowledge of NCTCOG and their regional BMPs and we got our committee of 13 people, and the committee, Carter Burgess and sharing of the NCTCOG information we came up with our best management practices to support our minimum control measures, therefore the storm water management plan. My philosophy is to absorb as much as I can but I'm still a free thinker and I like to choose what I think is the best for Hurst. I think that's what they expected me to do. I think with putting a good consultant and NCTCOG together that we've come up with really good plan for Hurst. So far, our submittal we sent to NCTCOG came back no exceptions so far. We've posted it in the newspaper. We're waiting for comments for the hearing right now. I guess it passed the first litmus test with TCEQ. We're pretty proud of that so far. I saw Southlake and Roanoke in the paper so a few more of the cities you see in the public notices section of the Star-Telegram where they have their notification that they have a storm water plan. It's taken all those to share all the information to come up with each plan. Each plan is going to be different."

Interviewer said: "If a developer came to the City of Hurst and said this is my BMP, what was his selection criteria for selecting that particular BMP?"

Interviewee said: "We're trying to put that into place so developers/engineers/architects/ landscape architects, all those folks that really should be involved in the development have a starting point. I think that the integrated storm water management plan that Hurst has with its addendums is going to give the developers and engineers and architects that starting point. Then a basis that this is a plan that Fort Worth has and Fort Worth as I understand and NCTCOG has adopted the ISWM, and there's not many. If you're in the processing do that it's much easier to adopt that created by Freese and Nichols than it is to go out on your own and try to create you own. Been there, done that, and its tough. It's much easier to review one than to start from scratch. I applaud Alan Greer for doing that. He's exceptional. If you have a chance, interview Alan Greer because he's sharp as a tack, and also Curtis Biddle."

Interviewer said: "What advantages do you see with the implementation of structural or built storm water BMPs?"

Interviewee said: "Water quality is going to be better for sure in our streams. It's not only going to be better, but it's going to look better, feel better, and probably for a few fish and aquatic life it's going to taste better. Just all around it's going to help be one of the most valuable resources that we have and that's our water. If we can keep our wall water is what we use for purification, surface water is what Texas in this area uses for potable water supply. The five streams here in Arlington flow south directly to the Trinity River. The Trinity River's support system for Houston will probably do more good for Houston than we are for ourselves. All of those watersheds north of us that come into reservoirs we want them in turn to do this because we're drinking that water. We all want as pure and safe drinking water supply as possible, as well as an abundant supply. This helps tremendously when protect it at the very top of the, so to speak, recycle stream for water."

Interviewer said: "Contrary to that what disadvantages do you see with the implementation of structural storm water BMPs?"

Interviewee said: "For the most part probably the cost. The cost of having to implement some of these programs. There's some very common sense, reasonable things that you can do that are cost-effective. There's some out there that, as far as I'm concerned, that are to me unreasonable, very costly and aren't for a particular area or city. Maybe they are for another particular area or city but we don't have livestock here. We don't have runoff from fertilized fields and diaries and these sorts of things. There are some areas, Waco comes to mind. They have a different contamination. They may need to go to higher extremes to take of that. Whereas, Hurst wouldn't necessarily need that. Hurst does not have a whole lot of industry either, so we don't necessarily need all those things to protect you from factories and runoff from major industries. Whereas, cities that do have that they may need that. Cost is the one of the deterrents. It's interesting you contacted me before all of the recent recession that's going on. Cost is going to mean a lot more now. We're tightening belts here at the City that we have never tightened before. Hurst is financially in pretty good shape. Northeast Mall is one of our leading businesses which our General Fund is supported by sales tax revenues and a mall is a great place. Northeast Mall is probably one of the best in the area. We're tightening our belt because we're expecting that this holiday [season] is not going to be as good a sales holiday has it's been in the past. We came through pretty during 9-11. This is looking a lot tougher than even the impact that 9-11 had on the economy."

Interviewer said: "What insights can you provide regarding storm water codes and ordinances?"

Interviewee said: "Yes, we'll lead them! Every agency and when you're talking about municipalities and cities, cities have codes, city codes that they follow that give the city the right to administer, regulate and enforce controls. Hurst is no different. Our codes will need to be expanded, improved and broaden in order to administer our storm water management plan. We will be writing and adopting codes. Again, we must pull together the experts to do that. We have city attorneys to help with the legal wording of that. We have various department heads that help with the details as they pertain to each aspect. Hurst has a code enforcement section, and they are basically the agency that will have the right to enforce when you have to. If somebody deliberately tries to contaminate the system, we'll have on that end of the spectrum a way to fine or apprehend those that contaminant the system. Otherwise, it will be matter of educating, informing, warning letters, these sorts of things. It will take ordinances. For you to write an ordinance that has the modification to the code that will be the history that goes before Council; they'll look at an ordinance that changes a chapter or a section within the city codes. We'll have that as other cities do. Here's you a word 'plagiarize'. They ought to have a class on that in college. How do you plagiarize because so many of the things are sharing. You want to take good experience and bad experiences—the best of the two, then you want to share that with others so they can use it and they don't have to go through some of the same clumsy steps to make you improve in developing that. We will borrow from Fort Worth in the Phase I cities. I know the folks over in Dallas and Fort Worth both, and they don't share their ordinances with us. We will use the best of both worlds there that we see will be applicable to the City of Hurst. That's what I consider somewhat plagiarizing. We'll take those and put parts of them together for our as well. I think one of the reasons the State did this the way they did they knew they couldn't bite the whole thing off at one time so they started with the large cities which really have the resources to do it. The Dallas, the Fort Worth, the Arlington, they have the bigger populations, bigger budgets and are staffed a little bit better to do these things. They've taken the lead and that will help the Phase II cities in implementing their program."

Interviewer said: "What advice would you like to offer regarding the selection of structural or built storm water BMPs?"

Interviewee said: "I kind of touched on them awhile ago but they should be reasonable. They should be flexible to fit realistic needs. They should be common sense based, and be cost-effective.
Thirteen years I went to UTA. I started when it was Arlington State College and was under A&M then it was under UT. This professor of modern physics said, 'It's as simply as it can possibly be but not simpler.' That's the way it needs to be."

Interviewer said: "Any last thoughts?"

Interviewee said: "You've taken on a good subject matter. I hope you do well."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable, and please feel free to contact me if you have any questions."

Interview #8 – Designer #2

Interviewer said: "Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) for the selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study. Your responses to the questions will be tape recorded to ensure accuracy during the transcription. Here we go!
What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green storm water best management practices in North Texas and we're talking structural the built ones?"

Interviewee said: "The number one questions on storm water wetlands. As far as in my opinion from working with developers and other engineering firms, storm water wetlands are either: 1) ignored or 2) to be feared and be fooled with. As far as in Texas, I've never seen any green roofs, bio-swales, rain gardens are anything else in Texas. I think we're a little behind the gun here in Texas. Just in my two months up in Washington State those were all design criteria up in the Washington area. I think eventually they're coming here. I think we're just ignoring some of these issues and they're bound to be coming our way eventually.

Interviewer said: "What is your perception of storm water BMPs in general? Structural that is, the built ones."

Interviewee said: "Right in this area most of our storm water BMPs…. You talk about… You get your storm drainage inlets and you put silt beds but that's really erosion control but other than that its gabions and its all about erosion control. That's really the only good thing you see here or detention ponds. There's a lot of detention ponds, a lot of retention ponds. There's really nothing about treatment, it's all about trying to maintain floodways and those types of things to keep people from being flooded. Those seem to be the primary BMPs. Most cities have been around here have started to get a little more toward the retention ponds, detention or retention ponds, and making policy and making those requirements. But on the flip side I think they're being a little short-sighted, and they're trying to make everybody to detain and retain the difference between existing and proposed even the smaller than they be. I've done one detention pond where it was only 3 cfs difference and they made me detain it, which is negligible. There ought to be some kind of minimum requirement but there's not, and that's a little frustration sometimes. I don't think there's any reasonable requirement by a lot of cities.

Interviewer said: "What methods do you employ in the BMP selection process?"

Interviewee said: "When I think of BMPs, I think of, probably in this vicinity, I think mainly of detention and retention ponds. Most of the methods are usually dictated by the cities and what they want or they require. The only thing I've done in more erosion control than any thing else is, I try to get a little outside the box as far it seems like we always start throwing riprap down or gabions, and I'd kind of like to get a little bit away from that and start doing more to the permaflex blocks or erosion control match. Stuff like that so that it's not just where you see a bunch of rocks somewhere along the creek. Where you can tell a creek crossing has come. Where you can see at least some vegetation growing back through. It seems like we sometimes get short-sighted and that's the only solution."

Interviewer said: "What drives the final selection of specific structural storm water BMPs?"

Interviewee said: "Unfortunately it's usually the cost. I mean that's primarily what most of these comes out to. Sometimes it's not about cost. Sometimes it's just about the city always wants gabions or the city always wants the detention ponds always needs to be this size. I have argued with the City once before and got it to detain a 25-year difference because it was in a park. Like you really need a 100-year on a park. You might be able to make argument where you could shrink down some things if you have a valid argument."

Interviewer said: "What advantages do you see with the implementation of structural built storm water BMPs?"

Interviewee said: "The retention/detention ponds I think are good. A retention pond in particular can be good. Number one you're going to have water there to aesthetic feature that you can use. Of course, you might see an oversize a little bit, but at least if you have something there it becomes an aesthetic feature. You can also turn a detention pond doing a regional detention pond where maybe you can have a park. You can put soccer fields or baseball fields or something in the detention pond. When it's flooding, people aren't going to go out there and play baseball or soccer and even when it stops raining after a flood, people aren't going to go out there right away. Have some build uses for it. If you can't do a retention pond, then do a detention pond where it can be used for something other than just a low spot. Sometimes it can be an eyesore. Oh, I know what that's for and it's a wasted piece of land. Use it for something. It doesn't have to be wasted. I've also used one where we've had a small basin where we were detaining about 25 cfs, but we used a parking lot. I did a series where we never got really high depth but we were able to use a detention pond on the parking lot.

Interviewer said: "Conversely, how about disadvantages of storm water implementation of structural storm water BMPs?"

Interviewee said: "Same thing. There either has to be some criteria. There has to be a difference of 10 cfs or more before you start talking about detention ponds. Sometimes they get so small they're wasted space. They're not practical. They're just wasted money that could be used elsewhere. Cities are the one that are making this and also it's not their money, but maybe you could get a nicer building or a nicer development to save some money or do a regional detention pond where the developers are able to chip in money for a detention pond instead of having a series of small little detention ponds."

Interviewer said: "So cost seems to be the disadvantage."

Interviewee said: "Cost is a huge disadvantage."

Interviewer said: "So inappropriate, cost, and ordinance driven."

Interviewee said: "Yes. It's primarily ordinance driven, but if you just had some foresight in planning in particular. You've got planning and zoning committees. If you've got to the point right now where planning and zoning committees where cities would step up and say, "For this area right here, we need a detention pond sized for whatever storm and this needs to be this big." If the City would step forward and say that, then part of the impact seed for these developers to chip forth. I was only in Washington State for two months but cities were already making those type of plans in those areas. It seems like to me that where it needs to go instead of these little regional ones. You can make it a retention pond and make it a nice aesthetic pump. Cities would have to be willing to step forward that money upfront but it seems like you're obviously going to get that money in return from the developer eventually."

Interviewer said: "You mentioned ordinances. What insights can you provide regarding storm water codes and ordinances?"

Interviewee said: "Storm water codes and ordinance most are based off 100-year storms. Sometimes they'll take into account streets, allowing for streets to flood up to the right-of-way lines or detention ponds in parking lots. There are certain things that storm water codes sometimes can be short sided. Looks like they try to just say, "Well, what's the difference been a 100 and your existing conditions or 100-year and a residence will rate. I think they have to be looked at almost on an individual basis or is it really going to impact anybody or if it's in a park how much are you really changing the environment from a .3 c-factor to a .4, is that really that much of a difference."

Interviewer said: "Are there any other progressive ordinances that you've come across in North Texas?"

Interviewee said: "In North Texas the one thing I have learned recently is that the COG has put together the ISWM storm water management book. I've been a little more impressed that it used to based on just technical papers No. 40. I noticed that ISWM is actually taken into account some of the differences in infiltration rates. If you get several storms over a shorter time period, you're obviously not infiltrating any more because your ground is saturated. It does take that into account nowadays which it didn't use to. I think that it has been approved. Once again in my opinion you hear a 100-year storms is all theory. It's all modeling. It's all theory and sometimes I think we get caught up in this is what it is. Everybody makes educated engineering judgments and as long as you're able to prove those judgments and you have good basis."

Interviewer said: “Lastly, what advice would you like to offer regarding the selection of structural storm water BMPs?”

Interviewee said: “One you’ve got to understand what the ordinance is. Two you’ve got to kind of know what you’re clients’ want. If the ordinance is the Gospel and have to live with it no matter what you do, but you kind of feel those right off the bat. For instance, TXDOT is TXDOT and never going to get TXDOT to change. So you might as well face up to the fact they’re going to have certain requirements. There are other cities that know their ordinance has not really been reviewed, it’s just a blanket deal. Don’t just think the ordinance is the only way around. The best thing is that you’re trying to work with your client to save them money, but you also want to make sure that it’s aesthetic and it’s not just a hole in the ground just to get them through development. You can do that in a short time right off the bat by talking to the city and saying, “Here’s what we think.” or “We probably could reduce it to 25 year park. Do you really need it? Maybe you could do a couple of series of smaller detention ponds depending on where you are. May you can detain a 25 and 25 and a 25 and you can reduce the sizes and make it more usable for land. You can even do underground detention but that’s more costly. It all depends on site-specific. If you just think the gospel is the ordinance, you need to look elsewhere. It almost never is. At least what I think.”

Interviewer said: “Any last thoughts that haven’t been addressed in these questions?”

Interviewee said: “I guess the biggest thing to me was, I do think there are thing that we can do different especially in this area. You mentioned rain gardens and other green facts. I know that in some of the northwest they had LIDs (low impact developments) where you can get credits on those types of things to help developers. I do think eventually we’re getting to that point. Counting for infiltration use that will count as “some of your detention” and some of your drainage area. I think that in North Texas we don’t really think about the environment. I think it’s going to eventually come up and catch us at some point in time. The only thing we thought about environment here seems to be wetlands. We don’t talk about first flush, oil separators, or anything else for storm. I know Austin starts to do that because they’re looking at the aquifers. Unfortunately, here in North Texas we don’t really concentrate on the environment. We're talking about storms. That's a little disturbing to me because I look at the Trinity River instances and I look at that and it looks so horrible looking. I know that it is not rock bottom and it's not filtered and I wouldn't jump in there. It would be nice to at least think you could jump into a creek or river and it would be safe. I wouldn't trust any of these creeks or rivers around here. I know there's nothing to really treat that storm water or do anything different. All we're concentrating on in this area is detaining water…trying to keep people from flooding. I think that's very short-sighted."

Interviewer said: "Thank you for your participation in this study. Your time and information have been invaluable, and please feel free to contact me if you have any questions."

Interview #9 – Designer #3

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on storm water, best management practices (BMPs) for the selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study. Your responses to the questions will be tape recorded to ensure accuracy during the transcription. “

Interviewer said: “What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar green structural storm water best management practices?”

Interviewee said: “I would say that all of these are useful and applicable to specific situations. We’ll have to look at the situation, the quality of the water that’s decided coming out from the best management practices—the influent/outflow. What’s feasible and what’s applicable and what’s pertinent to particular situation. Then you have the public perception too that we have to deal with. For example, a detention pond right in front of the driveway or right next to it may not be the best option. Anything that would enhance the environment would be appropriate answer.”

Interviewer said: “In general, what is your perception of the structural storm water BMPs?”

Interviewee said: “I guess I could say perception as far as how effective they are. I think structural BMPs are pretty important. For example, silt fences.”

Interviewer said: “No…the perception with storm water BMPs in general…that is for the structural or built solutions”

Interviewee said: “Yeah, as far as the perception of storm water BMPs in structures given the previous question we alluded to the fact that structural BMPs when planned and designed and calculated and reinforced for the short-term or the long-term depending on the specific application would be viable in terms of storm water quality as well as controlling storm water. Most often what is seen is people just throw thing around. They throw a silt fence. They throw a straw bale when actually designing it for the quantity of water and the velocity. Half the time, as the city engineer says whenever there was a storm, and I've seen silt fences laying on the ground and straw bales 300 feet from where they were suppose to be. So, I think someone with experience should design it so that it'll withstand type of storm that's being forecast by the weather bureau."

Interviewer said: "How about for the built ones? The post-construction ones that stay permanently."

Interviewee said: "As for as the post-construction ones that stay permanently, I would say there are specific situations in which you may want those. I'm sure that silt fences and straw bales, some of these would have to be left in place until the stabilization is complete. When we say post-construction, I think we offering to after stabilization some have to maintain…."

Interviewer said: "The ones that maintain the pre-existing condition onsite…"

Interviewee said: "Oh, I got you! Yeah, yeah! It's storm water controlled. Definitely. As far as detention basins, my perceptions are that if properly designed and properly placed within the watershed, detention basins should work. The only problem with detention basins is that if its used as a cookie cutter for all solutions, data has indicated that detention basins could actually cause flooding if improperly applied. For example, if a guy is living at the corner of Flag Street and Beyond River and it getting flooded by 1,000 cfs, you would want to put a detention basin at the corner of Flag Street and Beyond River because you're not reducing your peak volume but if you're way up and the watershed and way up to point that you're one-third the distance of the watershed from any creek or lake, then design, calculations and modeling is good and extremely applicable. As the development approaches the creek or the lake the whole watershed is draining to there should be extreme caution in the application of detention ponds because you don't want to hold the water and then release it to the lake at its peak because that's going to cause flooding."

Interviewer said: "Ok! What methods do you employ in the structural or that post-construction BMP selection process?"

Interviewee said: "As far as matters referencing to the evaluation process, right?"

Interviewer said: “Yeah!” Why do you choose one solution over the other?”

Interviewee said: “As engineers we really shouldn’t be looking at what’s a regulation and try to meet to the bare minimum. As engineers, we really need to be looking at the end product and enhancements. More often engineers are more up to coming up with solution that may not be environmentally acceptable. The key that I would use is the first thing that I would do is to look at the list of alternatives and do value engineering for all of the ordinances, and one of the heavyweights on the ordinances should be environmental enhancement and environmental adaptability. How does this fit into the environment? Basically you don’t want to have huge concrete retention pond in the middle of 2,000-acre jungle that impacts all kinds of wildlife. So it’s got to be adaptable.”

Interviewer said: “I guess the follow up to that would be, ‘What drives the final selection of specific structural storm water BMPs?’”

Interviewee said: “The final selection of post-construction BMPs is really based on three factor: 1) its effectiveness, 2) implementabilty to BMP, and 3) cost. Effectiveness goes back to the goals of the BMPs. What exactly are we’re trying to do or is it water quality drive? Is it water quantity driven? Preventing flooding? Or do you really want to keep the sediment from washing off into the downstream wetlands? So, it has to be looked at from water quantity as well as a water quality perspective. What kind of quality do you want? Are you going to be building a pond for the 20-year storm or the 100-year storm? But with effectiveness, it also means that that solution must be effective in the environment in which it’s placed. If you’re going to be doing something to destroy the habitat for some sensitive environments by the implementation of a BMP, then that’s not a very effective alternative. Effectiveness you’ve got to do an engineering analysis to see how effective it is. You’ve got to see what’s coming in and what’s going out. Do a lot of modeling. Dive into experience and do a complete value engineering, probably at 10-point scale on different factors. Implementability is actually “We can come up with a great alternative? It’s a wonderful design. It’s better than putting concrete on the moon, but what will the regulatory feel about it. You’ve got to have the citizens on board. You’ve got to have the regulators on board. You’ve got to have the engineers on board and everyone at FEMA on board. If you have one party dead against it, then something is not implementable. Thirdly and finally, you have the cost. The necessity of the cost is because you've got to look the effectiveness and implementability and satisfy yourself that among the 15 alternatives that you came with five dropped out because it was not effective and seven dropped out because it was not implementable and all have is three. I would say that instead of wasting your time doing cost for all the 15; I would suggest that you do the cost estimates for the remaining for three and then go back to the public, regulators and the team and say, "Here's one, one is $50 million, another one is $300 million, and the last one is $1 trillion, and all of them are effective and implementable so which do you want to spend your tax dollars on? Obviously, the one with the lowest cost is going to be selected. In fact the effective implementability cost can be broken down to EPA criteria which we use in the environmental feasibility studies."

Interviewer said: "What advantages do you see with these structural storm water BMPs?"

Interviewee said: "Advantages are specific to the type of BMP implemented. It's something that's very visible and well-known is detention ponds. A detention pond can be designed for quantity as well as quality. If it is strategically placed within the watershed, then the peaks in the lake or the creek that's carrying water from the watershed can be actually reduced, and you can release water from the detention pond through the creek or the lake at a point where the surges passed away and you've got more hydraulic capacity, so basically you're holding it and the key thing is to maximize the hydraulic capacity of the creek and the lake which actually is a real pain thing. I'm beginning to think that creek capacity and lake is an absolute thing. It changes with time depending on how much its carrying. If it is specifically designed then a detention pond for example can be very effective. Also, a difference in pond that was the quantity part, if it can be designed with adequate detention time, a detention pond can also be more like a storm water settling pond where it can capture all the sediments and some of the toxic metals that come from gas stations, off the surface asphalt, etc. That's example of how a water quality structural BMP can be really effective."

Interviewer said: "Ok. How about conversely disadvantages to these systems?

Interviewee said: “This is when this comes from improper applications. There are a suite of BMPs to choose from. For example, we had a project in Oakridge which was environmentally sensitive. They had a huge dam that had trace of radio-nucleotides. Our path was to go take a bulldozer and clean it up, but what we did was we brought out some long-term BMPs. Basically what we did was we had some salt licks for the deer. We looked at what the environment is doing. The environment had by itself built its own best management practices, which was a sedimentation basin at the bottom of the red trace radio-nucleotide dam. We studied what nature was doing, and we enhanced it to help nature do a better job of settling down the solids that come off this dam and carried the radio-nucleotides to the wetlands downstream. We excavated and made the settling tank a little bigger (natural gravity settling tank), and then beyond the settling tank there was a natural wetland. Anything the settling tank didn’t catch, the wetlands caught. The wetlands did chemical as well as physical treatment and so basically the wetlands was in the wrong spot nature didn’t have the help to put the wetlands in the right spot, so we had to make the natural sedimentation bigger and more effective and move the wetlands downstream. It became a good environmental feat that was accomplished, and I think that the project was a Department of Energy project which won the national environmental pollution engineering or protection engineering award. Properly applied BMPs can have a lasting, positive impact on the environment in which the BMPs are implemented. For example, if you put a wetlands right next to the Dallas Cowboys’ football stadium that may not be the best option.”

“If properly applied it could be a reasonable cost. As far as the impacts of not doing best management practices as being engineers. You know we’ve got to be careful. Back in the’40s they dumped everything in the backyard and put a metal plate over it. Now it’s all being dug up and those engineers who have been happily retired settled down to the beach of Florida, 85 years, have all been called back and the property has been confiscated because the toxic waste has leaked into groundwater. Well, engineers beware because we’re the next generation. We squeal at the cost of best management practices, but you know, maybe you will retire in California at 85 years old and you’re going to be called back because we had silt and sediment and trace radio-nucleotides and some stuff from the gas station that cased the whole family to died of cancer and now you have to pay for the funeral and attorney fees and everything. Just not consequences but the fact that cost should be balanced with value, and value should weighed in strongly with enhancing the environment.

Interviewer said: “What insights can you provide regarding storm water codes or ordinances?”

Interviewee said: “Storm water codes and ordinances I would encourage any city that is coming up with storm water codes and ordinances to make sure that they have discussed with other cities succumb to the birth pains. You know having been in a city environment, I just want to be frank, the creation of storm water codes and the implementation of storm codes have cost the job of the City Engineer and Director of Public Works in many cities. The best way to come up with a storm water code and ordinance with the city is to have a meeting with all the stakeholders. Let them know that these are the goals and objectives and come to a mutual meeting point on what is the level of am I going to be looking strictly at water quality? Am I going to be looking strictly controlling the storm water enough? Am I going to be looking at a combination of parks and detention ponds where you’re trying to make re-creation of facilities into a combined storm water facility? We need to have buy in from all of these stakeholders and come up with objectives of the code. What is it going to achieve? The first question you said when you’re having a meeting, the first meeting included the storm water code for the city from the developer. The first person will ask you, “Ok, what have you done drawn and what is the problem?” That we need another code. Then you have to really describe to them here is the problem. You flooded this guy, washed all this clay into the lake and he was the heir to the throne. You’ve got to give some real examples how you filled this guy’s living room with silt and what we’re trying to do is just planting trees in the City of Temple is not adequate. Look at the previous subdivision that you built. The grass didn’t grow for the next three years and when they had a storm it washed off in subdivision B and you were right upon the hill so you weren’t impacted. We have real world examples photographs, videos help. Before a city comes up with a storm water code, I strong encourage taking a video camera and camera. Go through the City, go through other cities. Look at College Station they’ve come up with very publicly acceptable storm water codes that encourages using the recreation of the facilities for storm water controls. Soccer fields and walking tracks and children's playground and the soccer field becomes a detention pond when it's not being used. Coming up with a code independently and unilaterally may cost you your career. You have to define the boundaries and then when everyone is in sync come up with a storm water code and say "Ok, this is what I've come up with guys. I'm saying that in the City of Waco will have to design storm water detention ponds for the 100-year storm, then start communicating. One evening you'll feel like you have a majority of the stakeholders and the city staff, and from the citizens living in the city should you even release the first draft of the storm water code. I think that should be passed on in black and white and read and then you can call a hearing where the Council comes together and you present the storm water code. What you need to have in that is details on how the storm water code is going to affect the cost of the developers to build a solution. Basically what the developers want to know is can a 2,500 square feet home, on a half acre lot be developed, and it costs me about $50,000 bucks. Now how much is my cost going to go up? Is this going to add $5,000 to my $50,000? Did I make a profit of $45,000 or is this going to add $75,000 to my $50,000 where my profit reduces to $400,000. They usually want to know the bottom line is the dollar impact. If all these are carefully done, you could come up with the storm water code. When you come up with the storm water code, you can also come up with some storm water fee scenario, because having a code alone is not adequate. You have to have a team, a department, and a code enforcement officer. You're going to have a sublet or subdivision or a section at least and a handful of people and all they're doing is storm water control because it's a full-time job. The a city of 50,000 people, it's a full-time job for three people."

Interviewer said: "What advise would you like to offer regarding the selection of storm water BMPs?"

Interviewee said: "The advice that I would like to offer is you know that this is not rocket science. This has probably been used for the last 50 to 75 years. The first thing I would do is go ahead and walk around, talk to the people that live in the neighborhood of regions where storm water controls has been used and you will more than often find out from Uncle Tom, who is 95 years old, because he told the engineer who designed it that it won't work, and the engineer didn't listen because he felt like he done it before and it will. So the detention pond is dry most of the time, and the water goes to Tom Hankins backyard and fills up his swimming pool. Basically you've got to go look what has been done in the past; learn from the past mistakes; learn from the past successes, not get some book off the shelf in the library that talks about engineering design but look at what is reality and practical in the field. Walk around. See what worked and what didn't work. Why it didn't work. How it was designed. How it should be design. Living in the 21st century how we can add a twist to it and do an innovative design so we don't make it cumbersome and too much government red tape. How can facilities be combined into storm water controls, for example, you have the Parks Department and you have the Storm Water Department, common criteria that would apply for all departments."

Interviewer said: "Thank you for your participation in this study. Your time and info have been invaluable."

Interview #10 – Developer #3

Interviewer said: “Thank you for your participation in this research study as indicated previously during the recruitment process. The purpose of this study is to gather information on the structural storm water, best management practices (BMPs) selection process for structural or built solutions from regulatory designer and developer viewpoints. The following questions are identical to those previously provided to you on your acceptance into this study. Your responses to the questions will be tape recorded to ensure accuracy during the transcription.”

Interviewer said: “What is your perception of storm water wetlands, green roofs, bio-swales, rain gardens, and/or similar storm water best management practices in North Texas?”

Interviewee said: “In North Texas or as used as a developer? In North Texas they are way underutilized. Very rarely do you see them implemented. I’ve worked for a couple of different aspects from a developer. I’ve worked for home builders, they are just way underutilized.”

Interviewer said: “Why is that from a developer’s standpoint?”

Interviewee said: “For…Huffines is very innovative and creative, and they try and do things like that. As a matter of fact, the project that we’re working on now here in Arlington, we’re utilizing rain gardens and bio-swales. We’re going to try and do green roofs. Those are most cost prohibitive because they’re a structural design vs. a nature filter.

Interviewer said: “What is your perception of structural storm water BMPs in general?”

Interviewee said: “Some are effective, some or not effective. If you don’t install a silt fence correctly it’s not very effective. Certain cities have taken the regulations to another step. You have a project on the hillside at the top of the hill they still want you to silt fence it. It becomes costly for non-effective uses.”

Interviewer said: “What methods do you employ in the structural or the final BMP selection for your projects? The ones that are staying in permanently.”

Interviewee said: "We'd like to use the lake systems in the detention and retention ponds. That tends to work a lot better because then the silts has time to fall out versus putting in a detention pond per se. If you can utilize the lake system or some other type of pond that is already there that has another purpose than just a hole in the ground."

Interviewer said: "You said dual purpose. Is that for…?"

Interviewee said: "Dual purpose, it could be a recreational lake. It could be a fishing lake. It could be a something you can canoe on, but people have access to it. It not something you fence off and you tell everybody to stay out and then it's just an eyesore. You utilize a lot of property that way. There's not a second purpose to it."

Interviewer said: "So inefficient…"

Interviewee said: "Very inefficient."

Interviewer said: "What drives the final selection of those permanent solutions?"

Interviewee said: "Cost. That's the number one issue. How can you do it and how can you do it effectively, and then how can you do it in a cost-effective way. From a developer's standpoint, once they're out there and down the road to ensure for the future but it's a lot of dollars up front."

Interviewer said: "So you're not concerned with the long-term costs."

Interviewee said: "No, as a developer after we install it, long-term it's something the HOA or the city or somebody else manages it."

Interviewer said: "What advantages do you see with the implementation of these permanent storm water BMPs?"

Interviewee said: "It keeps the rivers and creeks a lot cleaner as long as they're installed effectively; they're maintained. That's a huge one. If they're not maintained then they're not effective at all, over time."

Interviewer said: “Conversely, how about the disadvantages with these?”

Interviewee said: “The cost and the ineffectiveness of some cities or agencies or governing bodies have regulations in place, and the things that the require you to install or really aren’t effective management of storm water. It just meets the regulation.”

Interviewer said: “You just mentioned codes and ordinances kind of drives some of that process. What insights can you provide?”

Interviewee said: “Well, the intent of the codes and purposes I agree with. They are put in place for a reason and that’s they keep the rivers and creeks clean and to clean up the pollutants and to keep the dirt where it suppose to be, but a lot of the cities when they require you to do it to the letter, a lot of times it just doesn’t make sense. The example of putting the silt fence at the top of the hill because in order to protect themselves you wrap your whole site whether it is upstream or downstream. When you have a 200-acre site, it gets very costive (costly). Cost prohibitive to do that but cities still require that. Not all cities, just a lot of the cities who haven’t investigated the reasoning for they just follow the letter of the law.”

Interviewer said: “What advise would you like to offer regarding the selection of permanent storm water BMPs?”

Interviewee said: “Advice? Investigate the different alternatives and talk to the different governing bodies because a lot of times you can come to a solution that makes sense, that’s cost-effective, and that matches the letter of the law but it becomes effective in lower maintenance down the road. Some cities will work with you. A lot of cities will work with you, not often.”

Interview said: “Would you like to add any last thoughts that we haven’t covered in interview?”

Interviewee said: “No, but I’m a big proponent of the green filters, the rain gardens, the bio-swales. In this community that we’re working on we’re doing curbless streets, super elevated zero elevation that it’s filtered by the grasses. We’re designing rain gardens into the system at the storm rock falls before it gets into the lakes. We have a series of bio-swales and rain gardens, and we’re actually designing them in the community. I think that's a much better alternative and it has a lasting benefit and aesthetically it works."

Interviewer said: "Do you think that's a customer driven solution or little more altruistic…"

Interviewee said: "It's more we're working in a green community. So we had to investigate different green alternatives. They were new to us to be honest with you."

Interviewer said: "Thank you for your participation, and I appreciate your time."

APPENDIX D

COMMON THEMES MATRIX

TABLE D-1: FREQUENCY OF RESPONSES TO COMMON THEMES DURING THE INTERVIEW PROCESS

	COMMON THEMES									
	ALTRUISM									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	-	-	-	-	-	-	-	-	-	1
Q2	1	-	-	-	-	-	1	-	-	-
Q3	-	-		-	-	-	2	-	-	-
Q4	-	-	-	-	-	-	-	-	-	-
Q5	-	-	-	-	-	-	1	-	-	-
Q6	-	-	-	-	-	-	-	-	-	-
Q7	-	-	-	1	-	-	-	-	-	-
Q8	-	-	-	2	-	-	-	-	-	-
Total	1	0	0	3	0	0	4	0	0	1
Sum Total	**9**									
Individual Totals	1			3			5			

	COMMON THEMES									
	APPROPRIATENESS									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	1	1	-	2	-	1	-	-	-	2
Q2	3	1	1	3	-	4	-	1	-	-
Q3	1	-	-	3	-	1	-	1	-	-
Q4	-	-	1	1	-	2	2	-	-	1
Q5	-	-	-	-	2	-	-	-	-	-
Q6	1	-	1	-	1	2	-	-	-	1
Q7	1	-	1	1	2	1	-	-	-	-
Q8	1	-	1	1	2	2	-	-	-	1
Total	8	2	5	11	7	13	2	2	0	5
Sum Total	**55**									
Individual Totals	15			31			9			

	COMMON THEMES									
	COST/EXPENSE									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	2	1	1	2	-	-	-	-	-	-
Q2	3	1	-	-	-	-	6	-	-	-
Q3	1	-	-	3	-	-	6	-	-	5
Q4	1	1	2	6	1	3	6	5	-	-
Q5	1	1	-	-	-	-	1	-	-	-
Q6	1	1	1	3	3	1	16	6	1	5
Q7	2	-	1	1	-	2	-	-	-	-
Q8	1	1	1	3	1	-	2	3	-	1
Total	12	6	6	18	5	6	37	14	1	11
Sum Total	**116**									
Individual Totals	24			29			63			

	COMMON THEMES									
	HOLISTIC									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	-	-	-	-	-	-	3	-	-	-
Q2	1	-	-	-	-	-	1	-	-	1
Q3	-	1	1	-	-	-	-	2	-	-
Q4	1	1	-	-	-	-	1	-	-	-
Q5	-	-	1	3	-	1	3	1	1	1
Q6	-	-	-	-	-	-	-	-	-	-
Q7	-		1	-	-	-	-	-	-	-
Q8	-	-	-	-	-	-	1	1	1	-
Total	2	2	3	3	0	1	9	4	2	2
Sum Total	**28**									
Indivdual Totals	7			4			17			

	COMMON THEMES									
	IGNORANCE/EXPERIENCE									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	-	-	1	3	2	-	1	3	1	1
Q2	-	1	-	1	2	-	1	6	1	-
Q3	-	1	1	-	1	-	-	-	-	3
Q4	-	-	-	-	-	-	-	1	-	1
Q5	-	-	-	-	-	-	-	-	-	-
Q6	-	-	-	1	-	-	-	-	-	-
Q7	1	-	1	-	-	1	2	3	-	3
Q8	-	-	-	2	1	2	2	4	-	-
Total	1	2	3	7	6	3	6	17	2	8
Sum Total	**55**									
Indivdual Totals	6			16			33			

	COMMON THEMES									
	ORDINANCE									
	DEVELOPER			DESIGNER			BUREAUCRAT			
INTERVIEW QUESTIONS	DV1	DV2	DV3	DS1	DS2	DS3	B1	B2	B3	B4
Q1	-	-	-	-	-	-	-	1	-	-
Q2	1	-	-	-	2	-	-	-	-	-
Q3	-	-	-	1	1	1	8	-	1	2
Q4	-	1	-	-	1	-	-	-	1	-
Q5	-	-	-	-	-	-	-	-	-	-
Q6	-	-	-	-	2	-	-	-	-	-
Q7	-	-	-	1	-	-	-	2	1	1
Q8	-	-	-	1	2	-	-	-	-	-
Total	1	1	0	3	8	1	8	3	3	3
Sum Total	**31**									
Indivdual Totals	2			12			17			

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BIOGRAPHICAL INFORMATION

Jason Christopher Voight was born and raised in Texas. He graduated from Baylor University in 1994 with a bachelor's degree in biology with an emphasis on aquatic ecology and plant taxonomy. He also received a minor in environmental science. He is currently employed with an environmental engineering firm in Fort Worth, Texas. From his educational background, he naturally gravitated toward landscape architecture albeit in a circuitous route. Outside of work, his interests are all things with the outdoors. Those interests include hunting, fly fishing, triathlons, marathons, cycling, skiing, and especially hiking and camping in the Rocky Mountains.