Final Study Report: Cypress Creek Overflow Management Plan

August 18, 2015

Prepared for:

Harris County Flood Control District	Harris County	Texas Water Development Board

Texas Water Development Board Contract Report Number 1248321466

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Table of Contents

List of Figures

List of Tables

List of Appendices

1 Executive Summary

The Cypress Creek Overflow refers to a large overflow of stormwater runoff from the Cypress Creek watershed into the Addicks and Barker Reservoir watersheds during moderate to severe storm events in the upper Cypress Creek watershed, upstream of US 290. When rainfall levels reach the 20% (5-year) storm event level (and greater), runoff drains into upper Cypress Creek and makes its way downstream. The overflow begins to occur at the point where the creek shifts from a north-south flow direction to an east-west flow direction near the Waller-Harris county line, and has the potential to inundate substantial areas of land as the overflow makes its way overland south toward tributaries of Addicks and Barker reservoirs and finally to the reservoirs themselves. Knowledge of this overflow dates back to at least the 1940s, but there has been little effort to attempt to manage it as the affected area is generally undeveloped and agricultural in nature. However, growth projections prepared by the Region H Water Planning Group and the Texas Water Development Board (TWDB) forecast substantial population growth within the study area, much of which is predicted to occur between 2010 and 2020. Development coordination activity with the Harris County Flood Control District (HCFCD) supports this projection, as development interests have approached the HCFCD with large master drainage plans for projects in the overflow area.

Development in Harris County follows criteria established by the Harris County Public Infrastructure Department, including the Permit Office of the Harris County Engineering Division’s subdivision regulations and the HCFCD's Policy, Criteria and Procedure Manual. The criteria and regulations for development in the 1% (100-year) floodplain overflow area described above are tailored to the traditional riverine floodplains, and do not consider the unique aspects of the overflow. Furthermore, while the overflow is relatively shallow, it conveys a substantial volume, introducing unique challenges to the development process.

The overflow area is also located in an area known as the Katy Prairie, and there is an ongoing effort to secure land in this area for conservation and preservation purposes. In addition, there is limited capacity in Addicks and Barker reservoirs, and while current development policy is geared to maintain existing flow rates in downstream channels, it does not take into consideration the increase in runoff volume from land development activity.

In light of these challenges, HCFCD secured a flood mitigation planning grant from the TWDB that provided funding for the study of the overflow, and the development of a plan to manage the overflow to help mitigate flood risk. The following eight sections describe the eight tasks the study was required to address as part of the TWDB grant process.

1.1 Task 1 – Quantifying and Delineating Flood Risk

The purpose of Task 1 is to define the quantity, areal extent and depth of flooding associated with the Cypress Creek overflow as well as locally generated runoff. Because of the unique nature of overflow flooding, a two-dimensional model was developed to simulate the overflow. This facilitated the detailed quantification and mapping of the overflow area, including the development of a depth grid associated with different events along with the determination of flooding elevations, flow rates and overflow volumes.

The model indicated that, during a 1% (100-year) storm event, the peak overflow rate is 12,678 cubic feet per second (cfs). During this event, the simulation estimates that 23,355 acre-feet of volume will overflow from Cypress Creek toward the Addicks and Barker reservoirs, with the majority (about 97%) of the overflow reaching Addicks Reservoir. During such an event, almost 21,000 acres of land are inundated.

A study of Addicks Reservoir was performed by reviewing observed data from two storm events: the 1991-92 event and the 2009 event. Mass balance analyses were performed in order to better understand the impact that increased volume from land development may have on the reservoirs. The Barker Reservoir's 1% (100-year) pool currently exceeds the limit of land owned by the federal government for the reservoirs (commonly known as the “government-owned land”), and the Addicks Reservoir's 1% (100-year) pool currently is contained within the limit government-owned land. The analysis indicated that increases in stormwater runoff from development would cause the predicted pool elevation to increase; however, there is limited capacity in the reservoir(s) for the additional runoff volume.

The Task 1 investigations are described in Section 3 of this report.

1.2 Task 2 – Identifying Mitigation Strategies

The purpose of Task 2 is to estimate the size of storage and conveyance facilities needed to respond to changes in land uses from undeveloped (agriculture/prairie) to developed (residential/commercial) in the study area, and to evaluate the sizing and practicality of implementing alternative strategies to manage the volume and peak rate of runoff. This includes runoff in the Cypress Creek and the Addicks Reservoir watersheds, both in Waller County and Harris County.

The detailed plan development supporting this task is a significant component of the study. Measures that were investigated included structural (storage and conveyance) and nonstructural (acquisition, conservation and policy/criteria) options. As required in the grant application, two alternative mitigation plans have been developed. Furthermore, a "no-action" alternative is included as a potential conclusion.

The two mitigation plans identified as "preferred plans" both included a substantial storage element using a bermed reservoir, enlargements to Bear Creek in the overflow area, detention in the Harris County John Paul’s Landing stormwater detention basin (JPL), and specific development criteria to address runoff volume.

The first plan, known as Plan 3 – Mound Creek Reservoir with Overflow Conveyance “B”, is schematically depicted on Figure 1.1. This plan is estimated to cost approximately $271 million, however with in-kind contributions from partners this cost may be reduced to $177 million. It will manage the overflow impacts for about 18,500 acres of land in the 1% (100-year) overflow area, and will increase the area's conservation footprint by about 3,100 acres.

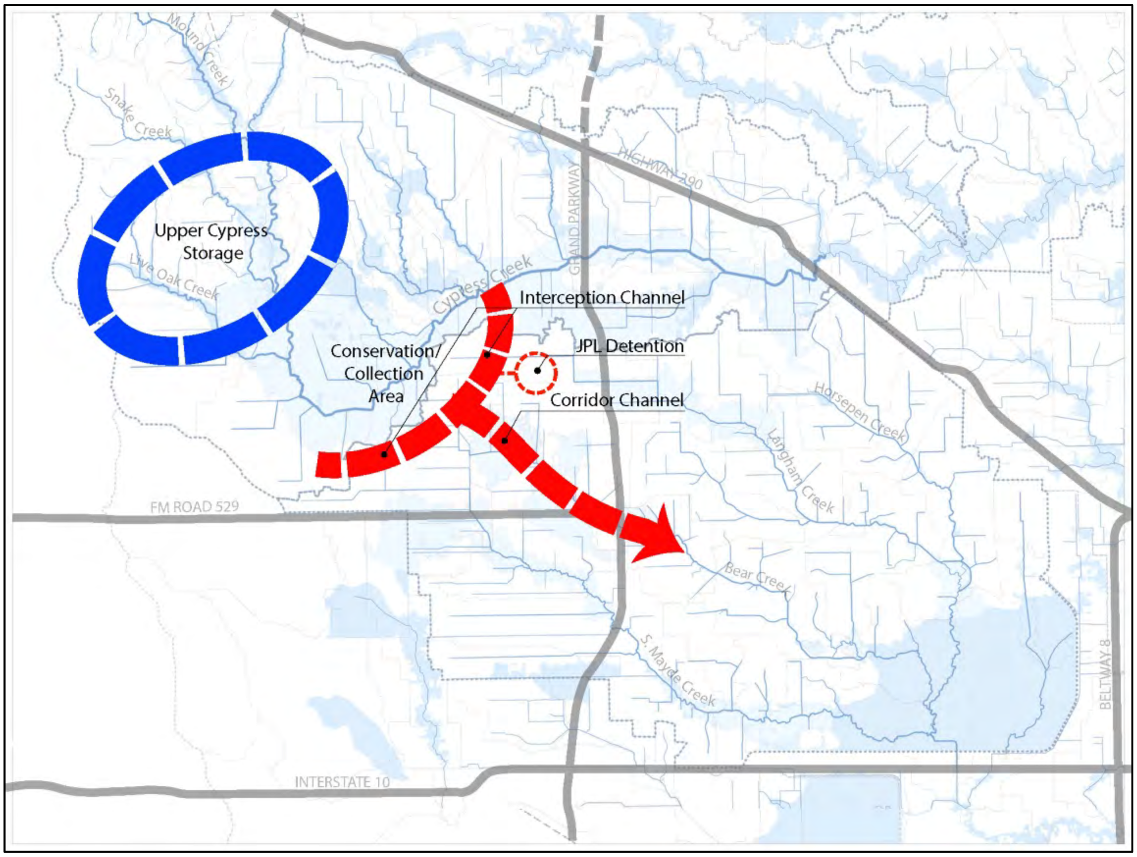


Figure 1.1 Plan 3 schematic – Mound Creek Reservoir with Overflow Conveyance "B"

The second plan is known as Plan 5 – Katy-Hockley N – Cypress Reservoir, and is shown schematically on Figure 1.2. This plan is estimated to cost approximately $369 million, however with in-kind contributions from potential partners this cost may be reduced to $243 million. It will manage the overflow impacts for about 18,000 acres of land in the 1% (100-year) overflow area, and will increase the area's conservation footprint by 5,000 acres.

The development process of these mitigation strategies is described in Section 4 of this report.

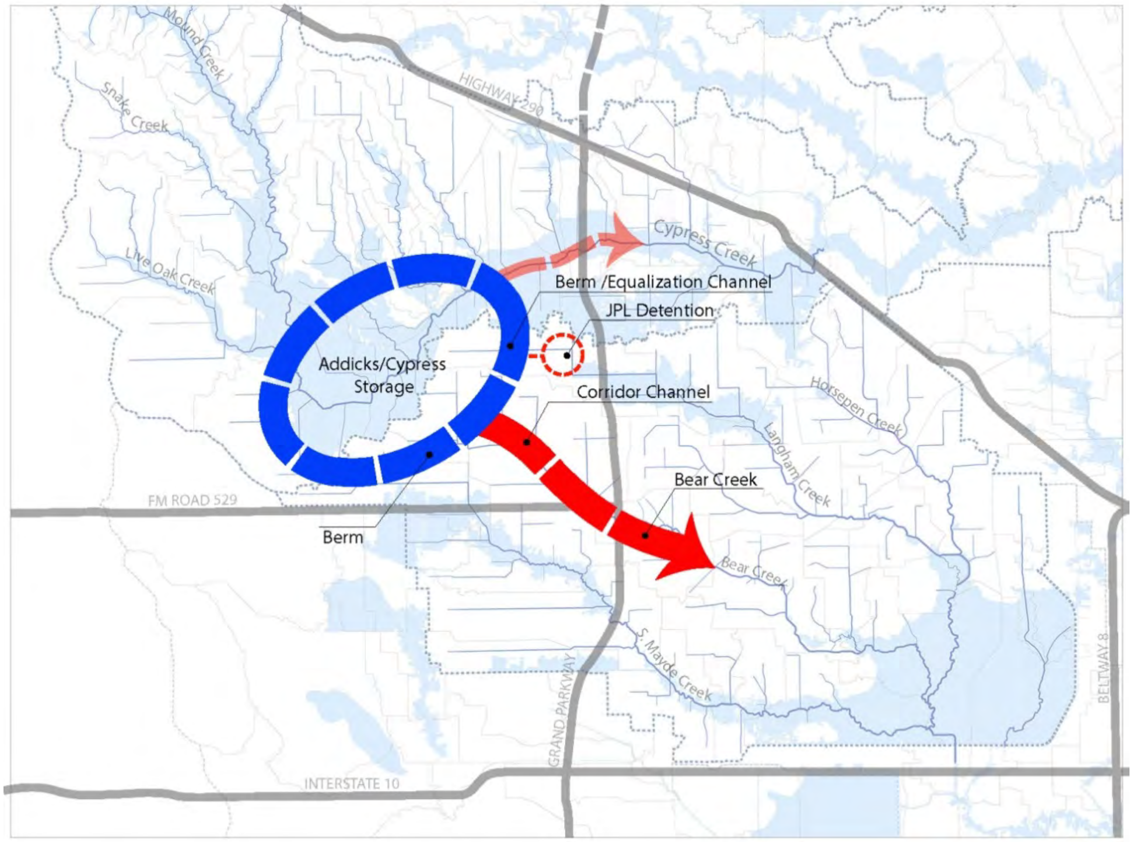


Figure 1.2 Plan 5 schematic - Katy-Hockley N - Cypress Reservoir

1.3 Task 3 – Benefits of Prairie Restoration for Flood Control

The purpose of this task is to determine the flood reduction benefits associated with prairie grasslands, both in terms of infiltration and time of concentration.

There are two elements to this task. The first element is a cursory research effort conducted that includes the review of studies by others, and the evaluation of the rainfall-runoff relationship using hydrology models. In addition, the relationship was evaluated using the observed Addicks Reservoir data as described in Task 2.

The second element is HCFCD's plan to conduct a long-term study that evaluates the relationship between rainfall and runoff for different land types. To accommodate this study, monitoring stations have been installed throughout the study area and data is being observed and evaluated. HCFCD has collected approximately 12 months of data, and preliminary results suggest that prairie vegetation improves the infiltration capacity of the soil; however, additional data collection and analysis is needed to provide more reliable results. HCFCD will continue to collect data for a period of five years.

This task is described in Section 5.

1.4 Task 4 – Identifying Critical Conservation Areas

The purpose of this task is to define tracts of land in the study area that, because of their unique flood management potential, environmental habitat or wetland characteristics, would ideally remain as open space for environmental preservation or restoration.

As part of this task, tracts in the study area were investigated and analyzed based upon specific conservation criteria. A map was developed to identify preferred critical conservation areas. The conservation criteria used to generate the map is listed in Section 6 of the report.

1.5 Task 5 – Cost/Benefit Analysis

The purpose of this task is to determine the value in establishing a regional drainage plan for the watershed(s), and to quantify that value in terms of avoided costs and benefits to the community. Planning level cost estimates were developed for the two preferred alternatives. These cost estimates considered land, construction and professional services costs in current year dollars. In lieu of a detailed categorization of financial benefits, the benefits were characterized by determining the increment in construction cost savings that could be achieved by utilizing a regional plan. Some benefits, such as ecological benefits, are difficult to quantify and therefore are represented qualitatively.

The analysis indicated that Plan 3, with in-kind contributions from partners, has a benefit-to-cost ratio of 1.14. Plan 5, with in-kind contributions from partners, has a benefit-to-cost ratio of 0.89. There are numerous benefits that were not quantified. Recognition of these benefits would result in a higher benefit-to-cost ratio.

The benefit-cost analysis is described in Section 7 of this report.

1.6 Task 6 – Project Financing and Cost Pro Forma

The purpose of this task is to develop alternative strategies for financing a regional plan, and to identify the roles and responsibilities that public, private, and non-profit interests would assume in order to collectively implement any strategy.

To support this task, a cash flow model was developed to simulate different financial scenarios. The model included the phasing of project features, land recovery over time, and an initial startup cost that would be required to launch the project. While specific roles assigned to the various parties would be formally developed in subsequent implementation phases, a general framework has been provided.

An implementation scenario with five specific project elements was developed for each of the management plans. The main purpose of the implementation strategy is to initiate phasing of project features, where feasible, to establish the building blocks of the plan, and to enable financial participation from near term land development. This recognizes the near term development pressures, and allows for the establishment of cash flow for the project elements that will facilitate future plan elements. In addition, this allows for the preparation of the environmental investigations required to support the permitting of the large storage reservoir elements, which could take a number of years to complete.

The implementation plan identified an initial startup cost of approximately $50 million. This "seed" money would facilitate the initial project implementation activities; the project revenue derived from this initial development would then fund subsequent project elements. These financing and implementation elements are described in Section 8 of this report.

1.7 Task 7 – Public Outreach Program

The purpose of the outreach program is to engage the public in this planning effort as well as to solicit input that may be incorporated into the study.

The public outreach program included a steering committee that met twice monthly for the duration of the study, and a stakeholder group that was engaged at two meetings. HCFCD also held three public meetings at which the public was educated and updated about the study process, and public comments were received and given due consideration. The outreach efforts are described in Section 9 of this report.

1.8 Task 8 – Final Report

The purpose of this task (represented by this document) is to summarize the findings of all study investigations into a final report for adoption by Harris County Commissioners Court and potentially Waller County Commissioners Court, as well as a final submittal to the TWDB.

2 Introduction

This study of the stormwater overflow from Cypress Creek into the Addicks Reservoir watershed was launched to consider potential management strategies to address the phenomena commonly known as the Cypress Creek Overflow, which occurs, on average, about once every 5-10 years in areas of western Harris County and Waller County (Figure 2.1). During these occasional overflow events, flood flows in upper Cypress Creek exceed the channel's capacity, spill over the channel's banks, and ultimately overtop the natural divide separating the Cypress Creek and Addicks Reservoir watersheds. Consequently, floodwaters flow overland to Addicks Reservoir tributaries, such as Bear Creek, South Mayde Creek, and Langham Creek. During a 1% (100-year) annual chance event, 20,838 acres of land in the Addicks Reservoir watershed are inundated by the overflow. The volume of this overflow is 23,355 acre-feet of stormwater – enough water to fill the Houston Texans' football stadium more than 2,000 times. During this event, the majority of the overflow remains within the Addicks Reservoir watershed; however, a small volume (about 3% of the total overflow) crosses the divide between the Addicks Reservoir watershed and the Barker Reservoir watershed, and flows toward Barker Reservoir via Cane Island Branch. This overflow into the Barker Reservoir watershed is minor and considered insignificant for the purpose of this study.

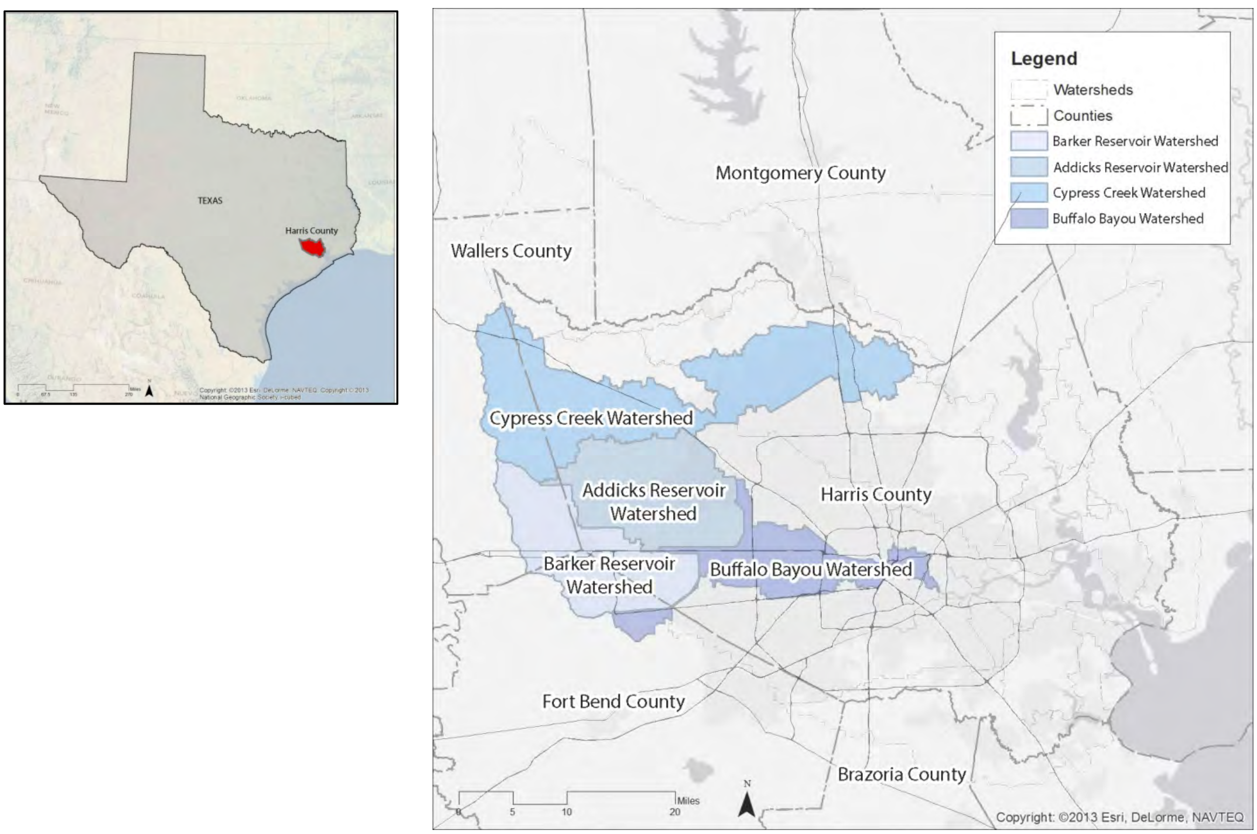


Exhibit 2.1 Study location

Current population and growth projections for Harris and Waller counties by the Texas Water Development Board suggest that substantial new development will occur within the study area, including the overflow area, in the next 40 years. In early 2014, the Grand Parkway (SH 99) Segment E opened, connecting IH -10 and US -290 in the middle of the study area. The Grand Parkway provides improved transportation access to the area, and has expedited land development pressure in the areas within and near the overflow.

The study area contributes drainage to Addicks Reservoir, which, along with the Barker Reservoir, was constructed by the U.S. Army Corps of Engineers (USACE) in the 1940s to provide flood risk reduction to downtown Houston. The reservoirs retain water that would otherwise flow south into Buffalo Bayou as it flows through the City of Houston into the Houston Ship Channel, and, finally, to Galveston Bay. Any proposed management measures, whether they involve structural features or development criteria, should recognize potential impacts on the operations and function of the reservoir system. In addition, consideration should be given to the public's desire for the preservation of conservation land in the upper Cypress Creek and Addicks Reservoir watersheds in the area known as the Katy Prairie.

HCFCD received a planning grant from the Texas Water Development Board to conduct a study to examine future conditions and mitigation strategies in the Cypress Creek Overflow area. The grant application identified eight specific tasks required for the study. These tasks were introduced in Chapter 1, and are further discussed in Section 2.3. This report is structured and organized around these tasks. Technical appendices have been prepared to provide additional detail to the investigations described in this report.

2.1 Background

The general study area for the Cypress Creek Overflow Management Plan includes the Upper Cypress Creek watershed and the Addicks Reservoir watershed, as depicted in Figure 2.2. The Upper Cypress Creek watershed is defined as the watershed area that contributes to stormwater flows in Cypress Creek upstream of US 290. The total study area covers 277 square miles, with 141 square miles in the Upper Cypress Creek watershed and 136 square miles in the Addicks Reservoir watershed. The Addicks Reservoir watershed is distinctly different from other Harris County watersheds in that the tributaries and channels drain into a man-made impoundment (Addicks Reservoir) that has a limited discharge rate and limited storage capacity. Approximately 63 square miles of the study area is in Waller County, all of which is in the Upper Cypress Creek watershed. The remaining 214 square miles are located in Harris County.

The Cypress Creek Overflow has been documented and recognized throughout recent history. The initial flood control concept for the Houston region, developed by the USACE in 1940, is depicted in Figure 2.3. As the figure indicates, the USACE's 1940 Flood Control Plan included a levee along the watershed divide between the Cypress Creek watershed and the Addicks Reservoir watershed that was intended to prevent floodwater from overflowing into Addicks Reservoir from Cypress Creek. Components of this plan were constructed, such as the Addicks Reservoir and the Barker Reservoir; however, the USACE plan was never fully completed as originally designed and subsequent project configurations and operations were adjusted to account for the deletion of other plan components. The levee along the watershed divide was not constructed, as it was determined that it would be more cost effective to mitigate the overflow by acquiring additional land behind the Addicks Reservoir dam, which the USACE did before completing constructing Addicks Reservoir in the latter 1940s. Also, downstream facilities included in the original plan, such as the enlargement of Buffalo Bayou, were never constructed, so gates were installed to limit outflows from the reservoirs. As a result, Addicks and Barker reservoirs are operated together as an integrated system such that if one reservoir requires greater discharge capacity, the discharge of the second reservoir can be throttled back or completely closed.

As mentioned, the study area lies within a region known as the Katy Prairie, which covers more than 1,000 square miles bordered by the Brazos River on the southwest, the pine-hardwood forest on the north, and the City of Houston on the east. It is part of a larger prairie region known as the Western Gulf coastal grasslands. The natural setting is characterized by tall-grass prairie with pothole wetlands and riparian corridors along waterways. However, in the past 100 years, changing land uses have reduced the natural prairie considerably. Much of the area has been converted to agricultural use, which stifles natural prairie functions; and measures were put in place to prevent and extinguish the wildfires that naturally sustain prairie habitat. Figure 2.4 shows existing areas of remnant prairie (areas of remaining natural and diverse prairie lands). Based upon this information, which was compiled by HCFCD, there are only about 20,000 acres of remnant prairie in the study area.

In 1992, the local non-profit organization Katy Prairie Conservancy (KPC) was established to conserve and provide stewardship over what is left of the Katy Prairie. The KPC's mission is to protect prairie land and agricultural land through acquisition, conservation easements and management easements. The KPC’s goal is to protect approximately 50,000 acres of remnant prairie.

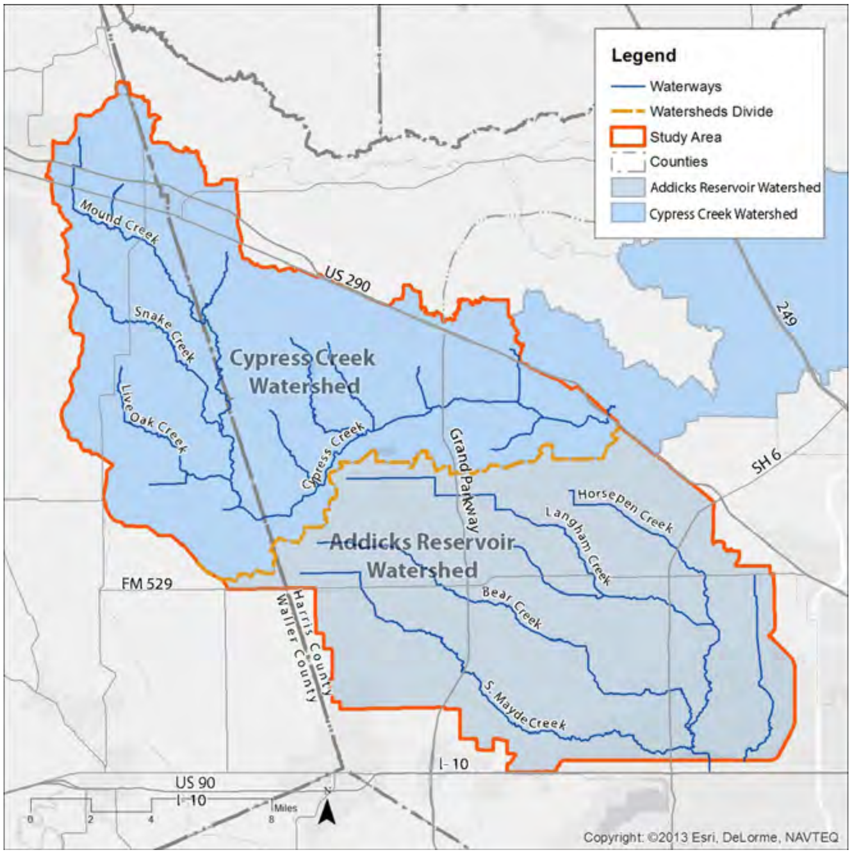


Figure 2.2 Cypress Creek Overflow Management Plan – study area

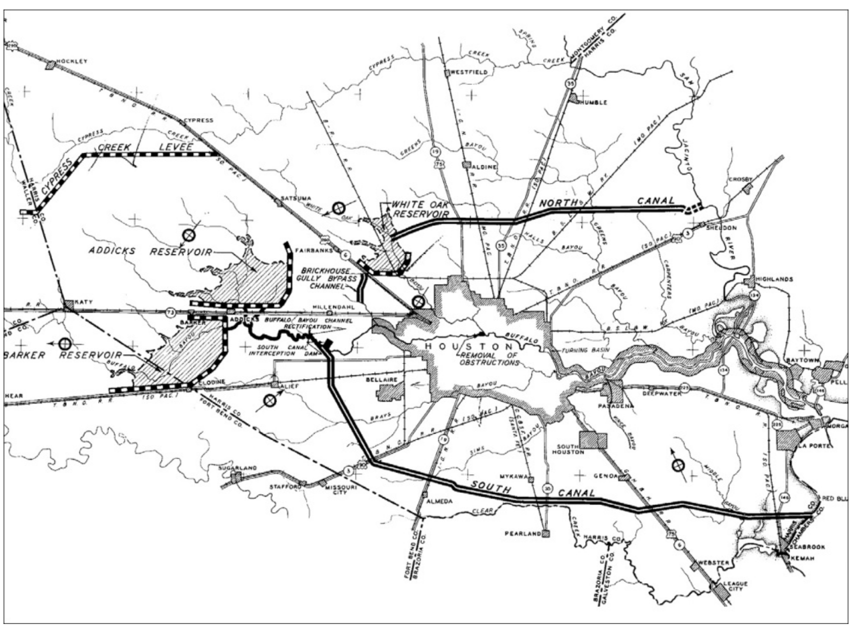


Figure 2.3 1940 Flood Control Plan (USACE)

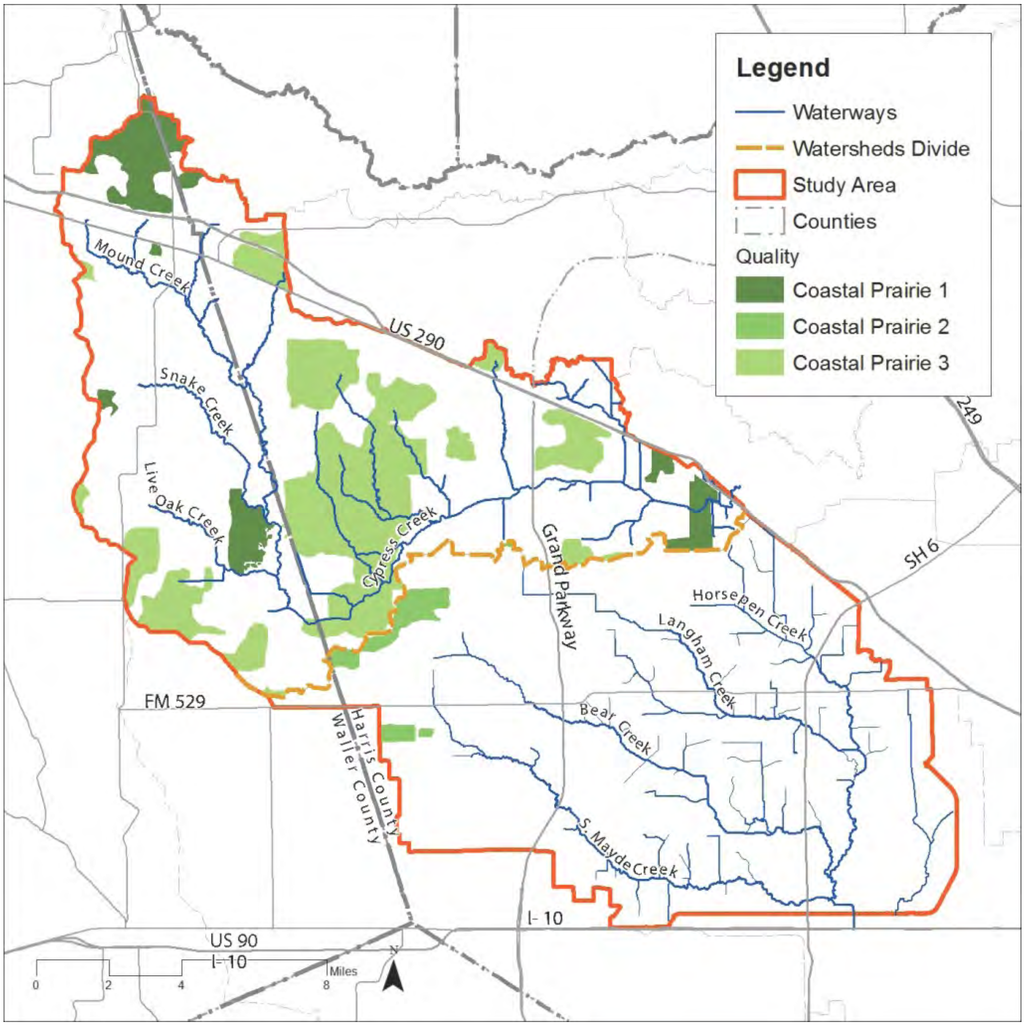


Figure 2.4 Remnant prairie in the study area

The natural topography of the study area is primarily flat, and generally drains from the northwest to the southeast. However, the northern one-third of the study area – the portion of the Upper Cypress Creek watershed that includes Mound Creek – has steeper topography than the rest of the study area. Figure 2.5 depicts the topography, with elevations as high as 300 feet above mean sea level in the upper portion of the Cypress Creek watershed in Waller County, and as low as 80 feet in Addicks Reservoir. In the northern third of the study area natural land slopes approximately 10-20 feet per mile, while the remainder of the study area slopes approximately 4-6 feet per mile.

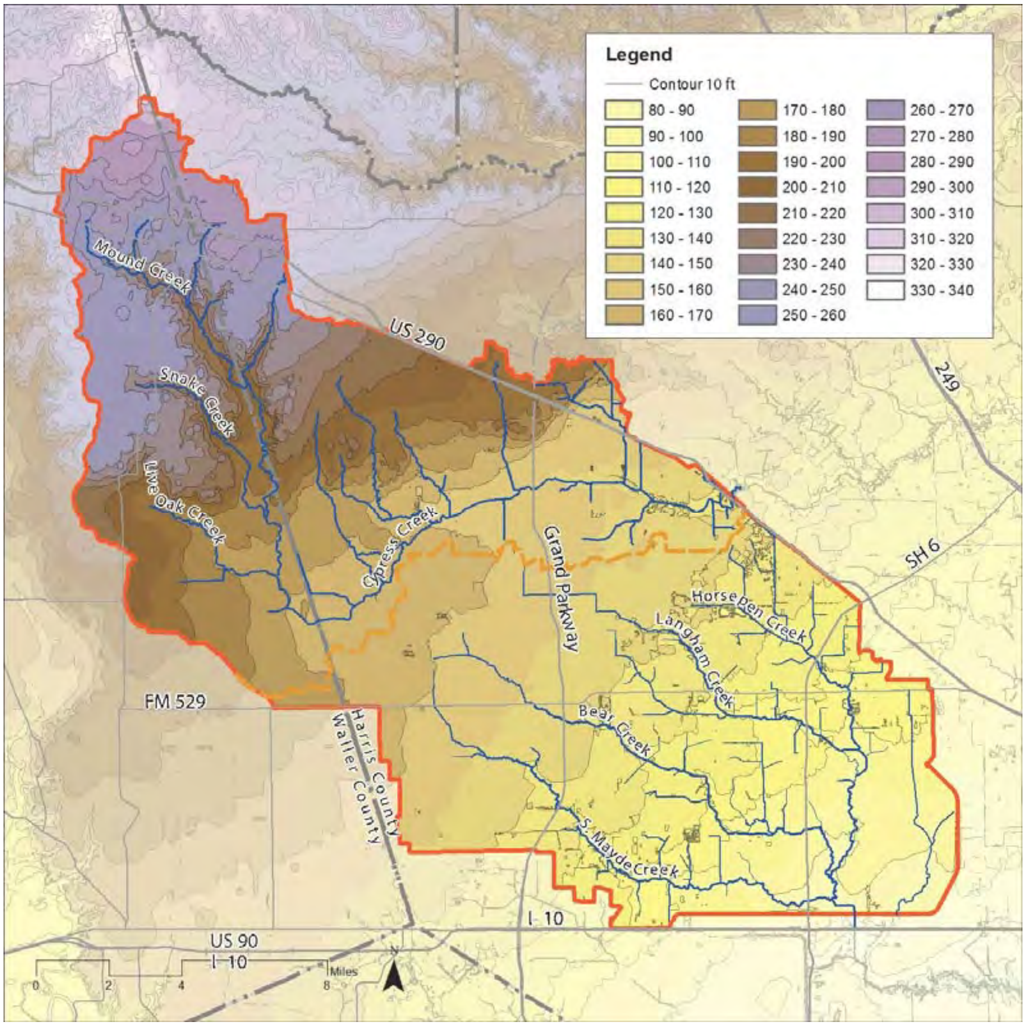


Figure 2.5 Topography

Figure 2.6 depicts stream locations in the study area. The uppermost portion of the Upper Cypress Creek watershed drains to Mound Creek, which originates upstream of US290 near the City of Waller. Mound Creek then drains south approximately 10 miles to its confluence with Snake Creek. The confluence of Mound Creek and Snake Creek forms the headwaters of Cypress Creek, which flows southward for about 3 miles until it makes an abrupt turn to the northeast. As Cypress Creek flows to the northeast and then gradually toward the east, it receives flow from the north via a number of tributaries. After making the turn towards the east, Cypress Creek flows for about 14 miles until it crosses US 290. It then extends another 33 miles downstream to its confluence with Spring Creek. The main channel of Cypress Creek and many of its lateral tributaries were channelized in the 1950s. Since that time they have become incised and unstable, and today they are highly vegetated, with little evidence of channelization.

Addicks Reservoir was created by constructing a dam across two channels – Langham Creek and Turkey Creek. Langham Creek includes four major tributaries: South Mayde Creek, Bear Creek, Horsepen Creek, and Dinner Creek. These streams have been substantially enlarged in their downstream reaches where the channels drain adjacent developments.

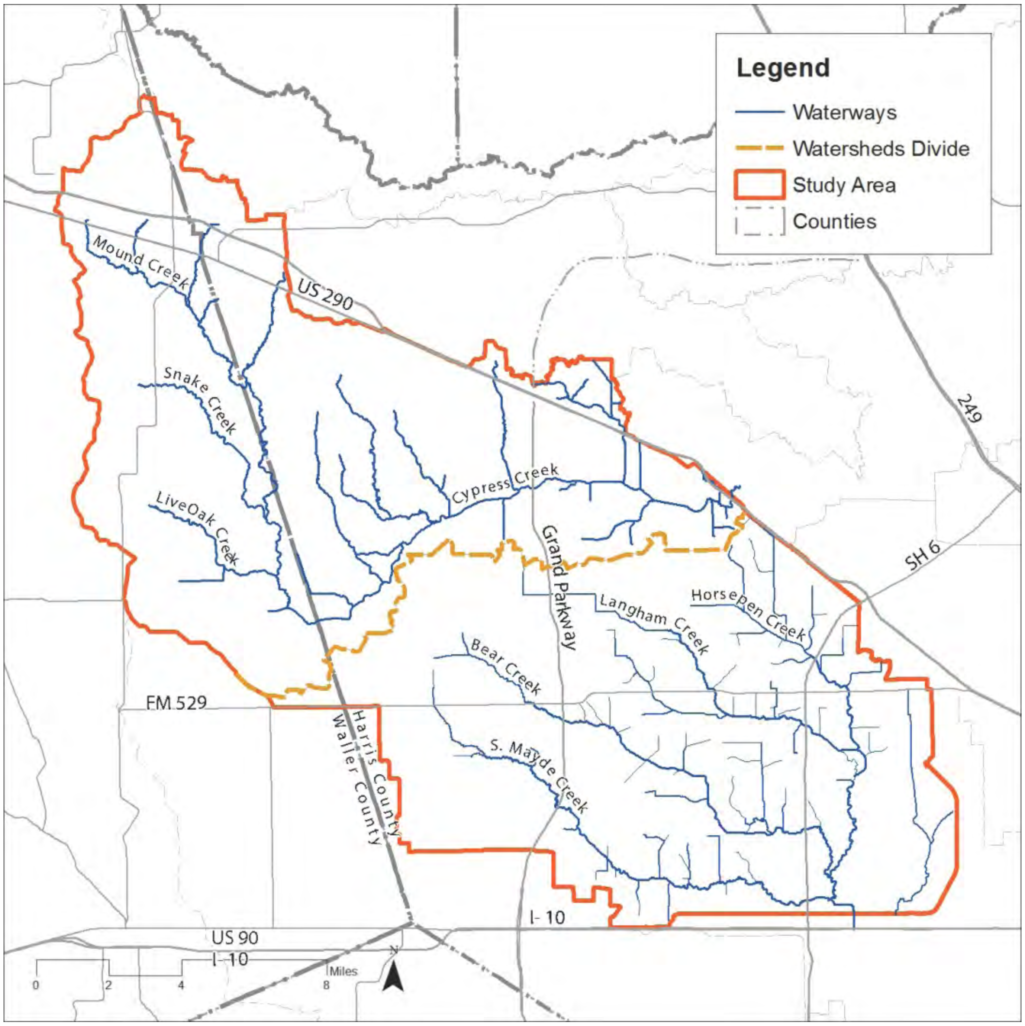


Figure 2.6 Channels in the study area

Figure 2.7 shows the 1% (100-year) floodplains in the study area as depicted on the Federal Emergency Management Agency (FEMA) effective Flood Insurance Rate Maps (FIRM Panel Nos. 48201C0160L, 48201C0190L, 48201C0595L, 48201C0605L, 48201C0610L, 48201C0615L, 48201C0620L, 48201C0630L, and 48201C0640L, all dated June 18, 2007; 48201C0170M, 48201C0360M, 48201C0370M, 48201C0380M, 48201C0385M, 48201C0390M, 48201C0395M, 48201C0405M, 48201C0410M, 48201C0415M, 48201C0420M, 48201C0580M, and 48201C0585M, all dated October 16, 2013; and 48473C0175E, 48473C0275E, 48473C0375E, all dated February 18, 2009). There are large natural floodplains in the Cypress Creek watershed, and smaller floodplains along the channels in the Addicks Reservoir watershed, primarily upstream of the reaches where the channels have been enlarged. There has been historic flooding in developments along South Mayde Creek, Bear Creek and Horsepen Creek. The floodplain maps for these channels depict some flood risks associated with a 1% (100-year) storm event, particularly along South Mayde Creek. There is also a large floodplain associated with the overflow from the Cypress Creek watershed to the Addicks Reservoir watershed.

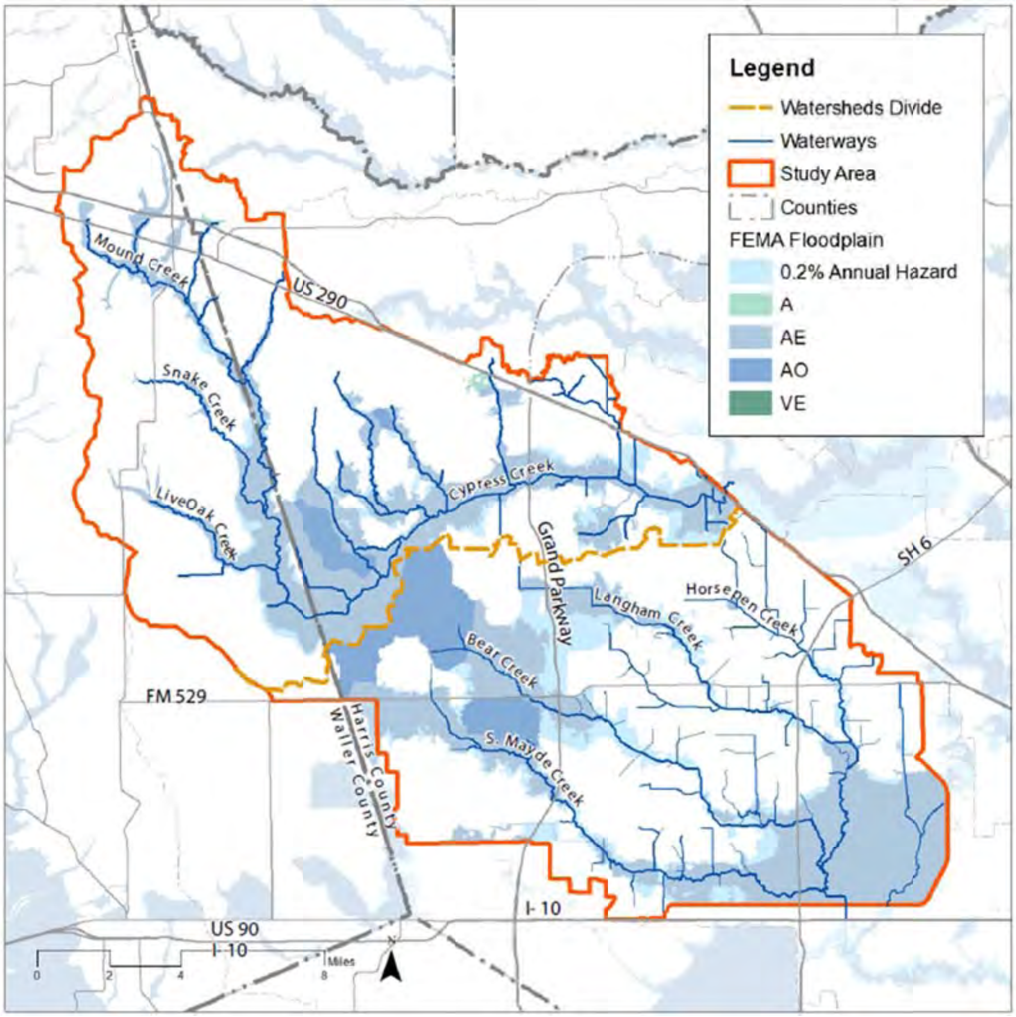


Figure 2.7 Effective special flood hazard areas (from FIRM Panels effective as of April, 2014)

Figure 2.8 depicts the development in the study area. Approximately 55 square miles of the study area are developed. Most development is concentrated in the eastern and southern portions of the study area, in areas closer to the urbanized Houston metropolitan area. Development is predominantly single family residential with commercial and retail along the major transportation corridors. The undeveloped land is primarily agricultural, with a combination of ranch land and row crops. Historically, much of the area was used for rice farming; however, the majority of the rice fields have been converted to corn in the past 20 years. Rice farming required the construction of agricultural berms to facilitate flooding of the rice fields. As these farms have converted away from rice to other crops, berms have been modified, removed entirely, or are no longer functional at certain locations.

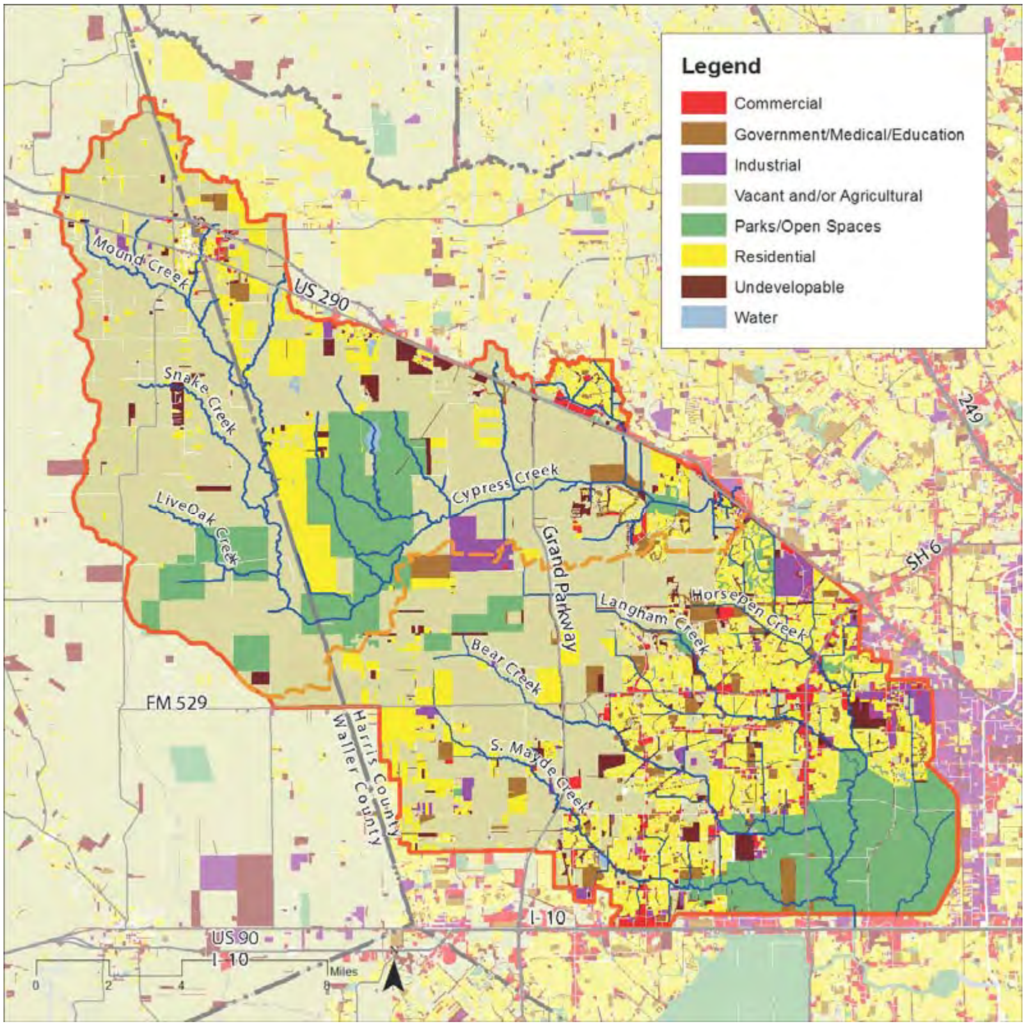


Figure 2.8 Land use in the study area (Source: Houston-Galveston Area Council)

The location of highways and major roadways in the study area is shown in Figure 2.9. There are three existing major grade-separated highways in the study area: US 290 runs from the southeast to the northwest, and serves as the northern and eastern boundary of the study area (Mound Creek drains a small area north of US 290 to the south); IH 10 is oriented east-west, and is generally located along the southern boundary of the study area; and Segment E of the partially constructed Grand Parkway (SH 99) was constructed in 2012 and 2013, and opened in early 2014. Segment E runs north-south through the study area and connects IH 10 and US 290.

Major thoroughfares are generally planned on a 1-mile grid. Major east-west thoroughfares are Little York, Clay Road, FM 529, Longenbaugh Road and West Road. Major north-south thoroughfares are FM 362, SH 99 (The Grand Parkway) and SH 6. Much of the road grid in the undeveloped areas has not been constructed. Figure 2.10 depicts the Houston-Galveston Area Council's (H-GAC) Major Thoroughfare Plan (MTP), which is administered by cities and counties in the region and forms the basis for roadway planning activities.

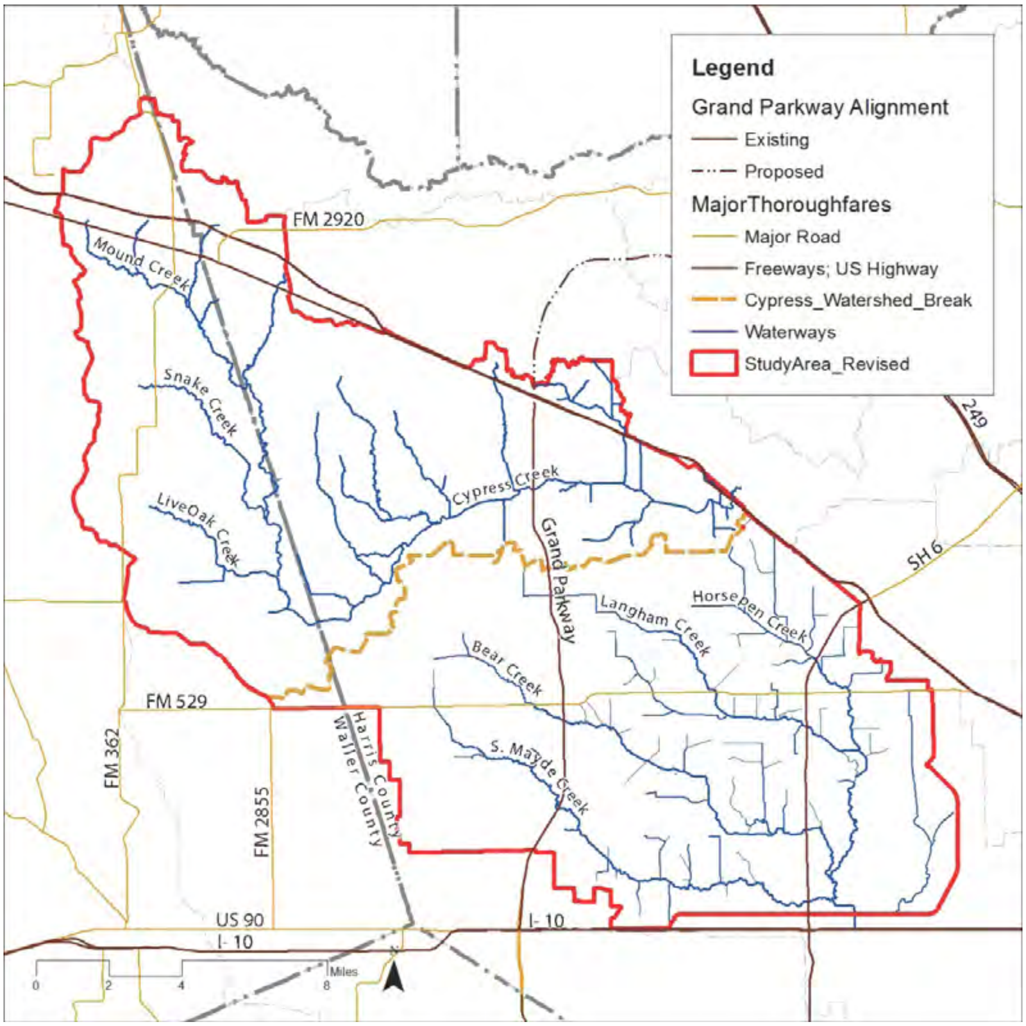


Figure 2.9 Major roadways in the study area

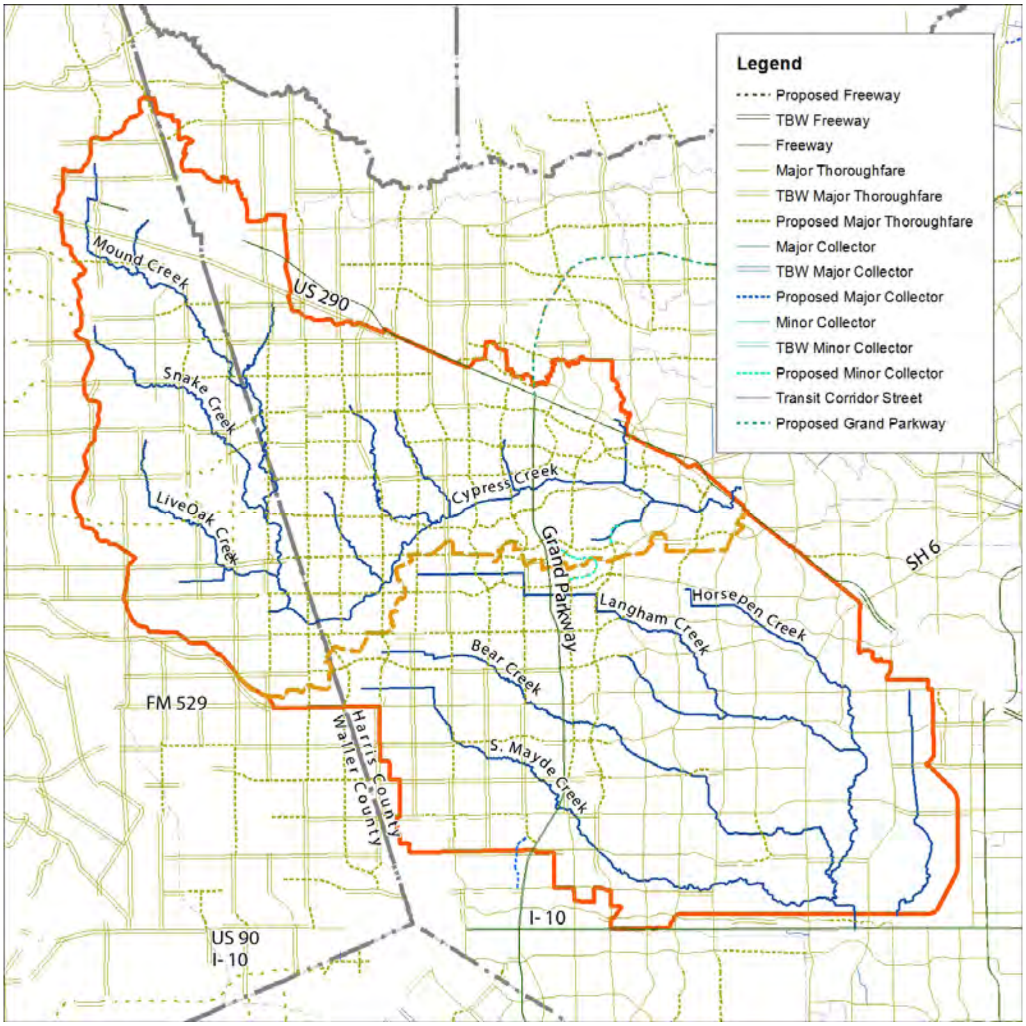


Figure 2.10 2012 Major Thoroughfare Plan

2.2 Purpose and Need

The overflow from Cypress Creek to the Addicks Reservoir watershed inundates about 20,000 acres of undeveloped land in the Addicks Reservoir watershed during a 1% (100-year) annual chance storm event. Until recent times, this has not been considered a significant problem because property within the area affected by the overflow is relatively undeveloped and has limited drainage infrastructure. The area is primarily used for agricultural purposes or is covered by grasslands and open space. However, rapid growth is anticipated within the study area, as depicted in Table 2.1. This table, which is based upon growth projections by the TWDB's Region H Water Planning Group, indicates a population increase of over 200,000 residents in the study area between 2010 and 2060, with much of this growth predicted to occur before 2020. To accommodate this growth, it is estimated that 30,000 acres will be developed between 2010 and 2020, much of it within the area affected by the Cypress Creek Overflow.

Table 2.1 Study Area Population Projections

Year	Population
2010	313,000
2020	459,000
2030	482,000
2040	505,000
2050	522,000
2060	535,000

Much of the projected growth will be in an area that is located within the 1% (100-year) floodplain. As growth occurs, development activity will attempt to recover land from the floodplain in a manner consistent with development practices throughout the Houston area. Harris County and HCFCD development criteria have been written in a manner that ensures that new development does not aggravate or increase flood risks by limiting peak rates of stormwater runoff into the existing stream network that serves the development. While the current criteria address peak flow rates, the criteria do not address runoff volume.

The study area is also affected by a large, shallow overflow floodplain that occurs when stormwater along Upper Cypress Creek overtop the watershed divide and flow toward Addicks Reservoir. This situation is unique when compared to typical riverine floodplains, and current development criteria do not address overflow conditions. Given the nature of the overflow, including the large volume of flow associated with it, ad hoc mitigation strategies at an individual development level may be difficult to plan, analyze and monitor.

Additionally, while flow rates from developments are regulated to ensure that they do not increase peak flow rates into the open channel systems that they drain into, current development criteria does not address the volume of water that drain from the developments. Given the limited storage capacity within the Addicks and Barker reservoirs and their controlled discharge rate, it is necessary to consider what impacts, if any, future development may have on existing communities upstream and downstream of the reservoirs.

2.2.1 Problem Statement

Overall, the problem is multi-faceted, and can be summarized as follows:

- Significant land development activity is projected over the next 10 years in the study area, portions of which are subject to frequent inundation from the Upper Cypress Creek watershed overflows to the Addicks Reservoir watershed (see Appendix A). Current development criteria are not tailored to this phenomenon, and mitigation requirements are unclear.

- Portions of the study area, many of those in the epicenter of immediate development pressure, are subject to frequent inundation from stormwater overflow from the Cypress Creek watershed to the Addicks Reservoir watershed. Ad-hoc solutions to the overflow, at an individual development level, may not provide a sustainable or economical solution to the overflow flooding.

- The Katy Prairie is an endangered environmental resource that may have natural features that provide a measure of flood damage reduction for downstream communities. There are active interests, including the Katy Prairie Conservancy, that are trying to protect and preserve portions of the Katy Prairie. These efforts are aligned with HCFCD's goal to reduce flood risk (see Appendix D).

- The Addicks and Barker reservoirs have limited capacity, their outflows are restricted, and they do not have capacity to receive additional runoff volume. Current criteria are geared at maintaining peak flow rates into the reservoirs, but development activity under existing criteria will increase the volume of runoff and the expected pool elevations associated with flood events (see Appendix B).

- The Cypress Creek watershed, including areas downstream of the study area, has a history of flooding. Cypress Creek is unable to accept additional flows, including any additional flows that would result from accepting stormwater that currently goes to the Addicks Reservoir watershed.

2.2.2 Project Purpose

The purpose of the Cypress Creek Overflow Management Study is to identify a management plan that addresses the competing interests of land conservation, property development and flood risk reduction as each pertains to the study area, as well as how to address impacts of the Cypress Creek Overflow into the Addicks Reservoir watershed.

As stated in the TWDB grant application, the study goals are to:

1. Gain consensus among key stakeholder groups (business, residential, environmental, regulatory, community) about the facts relating to flooding, flood volumes, flood peaks and flood risk in the Cypress Creek Overflow area;

2. Gain an understanding of the needs and objectives of interested parties as they pertain to land preservation, environmental mitigation and property development;

3. Develop a management plan for flood risk reduction that balances the needs and objectives of key stakeholder groups based on their collective interests involved and that is supported by all parties;

4. Establish interim development criteria that can be applied while the final consensus plan is in the development and adoption stages;

5. Design a business plan that encompasses implementation strategies identified during the study, and that defines the roles and responsibilities of all parties involved; and

6. Gain adoption of the management and business plans by Harris County Commissioners Court.

2.3 Scope of Study

The scope of the study is presented in the TWDB grant application, and includes eight separate tasks that are as described in the following sections. The study and report follow this task structure.

2.3.1 Task 1 – Quantifying and Delineating Flood Risk

The purpose of Task 1 is to define the quantity, areal extent and depth of flooding associated with the Cypress Creek Overflow and the locally generated stormwater runoff. Because of the unique nature of the overflow flooding, a two-dimensional model was developed to simulate the overflow. This facilitated the detailed quantification and mapping of the overflow area, including the development of a depth grid associated with different events along with the determination of flooding elevations, flow rates and overflow volumes.

A study of Addicks Reservoir was performed by reviewing observed data from two storm events – the 1991-92 event and the 2009 event. Mass balance analyses were performed in order to better understand the impact that increased volume from land development may have on the reservoirs.

The Task 1 investigations are described in Section 3 of this report. Appendix A provides a detailed description of the two-dimensional modeling and Appendix B summarizes the investigations into the Addicks Reservoir.

2.3.2 Task 2 – Identifying Mitigation Strategies

The purpose of Task 2 is to estimate the size of storage and conveyance facilities needed to respond to changes in land uses from undeveloped (agriculture/prairie) to developed (residential/commercial) in the study area, and to evaluate the sizing and practicality of implementing alternative strategies to manage the volume and peak rate of runoff. This includes runoff in the Cypress Creek and Addicks Reservoir watersheds, both in Waller County and Harris County.

The detailed plan development supporting this task is a significant component of the study. Measures investigated included structural (storage and conveyance) and nonstructural (land acquisition, land conservation and policy/criteria) options. In accordance with the grant application, two alternative mitigation plans have been developed. Furthermore, a "no-action" alternative is included as a potential conclusion.

The development of the mitigation strategies is described in Section 4 of this report, and is presented in greater detail in Appendix C.

2.3.3 Task 3 – Benefits of Prairie Restoration for Flood Control

The purpose of this task is to determine the flood reduction benefits associated with prairie grasslands, both in terms of infiltration and time of concentration.

There are two elements to this task. The first element is a cursory research effort conducted that includes a review of studies by others, and the evaluation of the rainfall-runoff relationship using hydrology models. In addition, the relationship was evaluated using the observed Addicks Reservoir data as described in Task 2.

The second element is HCFCD's plan to conduct a long-term study that evaluates the relationship between rainfall and runoff for different land types. To accommodate this study, monitoring stations have been installed throughout the study area and data is being observed and evaluated. HCFCD has collected approximately 12 months of data, and preliminary results are presented in this report (see Chapter 5). However, additional data collection and analysis is needed to provide more reliable results.

This task is described in Section 5. Additional information about the cursory research effort is described in Appendix D, and the data collection and preliminary analysis is presented in Appendix I.

2.3.4 Task 4 – Identifying Critical Conservation Areas

The purpose of this task is to define tracts of land in the study area that, because of their unique flood management potential, environmental habitat or wetland characteristics, would ideally remain as open space for environmental preservation or restoration.

As part of this task, tracts in the study area were investigated and analyzed based upon specific conservation criteria. A map was developed to identify preferred critical conservation areas. The conservation criteria used to generate the map is listed in Section 6 of the report, and is also described in greater detail in Appendix J.

2.3.5 Task 5 – Cost/Benefit Analysis

The purpose of this task is to determine the value in establishing a regional drainage plan for the watershed(s), and to quantify that value in terms of avoided costs and benefits to the community. Planning level cost estimates were developed for the two preferred alternatives. These cost estimates considered land, construction and professional services costs in current year dollars. In lieu of a detailed categorization of financial benefits, the benefits were characterized by determining the increment in construction cost savings that could be achieved by utilizing a regional plan. Some benefits, such as ecological benefits, are difficult to quantify and therefore are represented qualitatively.

The benefit-cost analysis is described in Section 7 of this report, and presented in greater detail in Appendix E.

2.3.6 Task 6 – Project Financing and Cost Pro Forma

The purpose of this task is to develop alternative strategies for financing a regional plan, and to identify the roles and responsibilities that public, private and non-profit interests would assume in order to collectively implement any strategy.

To support this task, a cash flow model was developed to simulate different financial scenarios. The model included the phasing of project features, land recovery over time, and an initial startup cost that would be required to launch the project. While specific roles assigned to the various parties would be formally developed in subsequent implementation phases, a general framework has been provided.

An implementation scenario with five specific project elements was developed for each of the management plans. The main purpose of the implementation strategy is to initiate features where feasible, to establish the building blocks of the plan, and to enable financial participation from near term land development. This recognizes the near term development pressures, and allows for the establishment of cash flow for the project elements that will facilitate future plan elements. In addition, this allows for the preparation of the environmental investigations required to support the permitting of the large storage reservoir elements, which could take a number of years to complete.

The financing and implementation elements are described in Section 8 of this report, and presented in greater detail in Appendix F.

2.4 Task 7 – Public Outreach Program

The purpose of the outreach program is to engage the public in this planning effort as well as to solicit input that may be incorporated into the study.

The public outreach program included a steering committee that met twice monthly for the duration of the study and a stakeholder group that was engaged at two meetings. HCFCD also held three public meetings at which the public was educated and updated about the study process, and public comments were received and given due consideration. The outreach efforts are described in Section 9 of this report, and presented in greater detail in Appendix H.

2.5 Task 8 – Final Report

The purpose of this task is to summarize the findings of all study investigations into a final report for adoption by Harris County Commissioners Court and potentially Waller County Commissioners Court, as well as a final submittal to the TWDB.

3 Quantifying and Delineating Flood Risk

The identification of management plans to address a perceived problem requires a thorough understanding of the problem. Historically, the conventional computational and modeling tools used to understand flooding were not adequate to simulate the overflow, and the high-end tools were not readily available and accessible. As a result, historically it has been a challenge to quantify the extent and magnitude of the Cypress Creek Overflow.

Technical advances in software, hardware and topographic data have provided the engineering community the ability to better simulate the Cypress Creek Overflow using two-dimensional (2D) models. This study included the development of a coupled one-dimensional and two-dimensional (1D/2D) model specifically tailored to support the planning activity described in this report.

The evaluation of flood risk in the study area is complicated by the presence of the Addicks Reservoir, which receives all stormwater runoff from the 136-square-mile Addicks Reservoir watershed as well as the Cypress Creek Overflow. While it is known that the current operation of the reservoir limits its ability to accommodate additional volume, the actual impact of land development on the reservoir is relatively uncertain. There have been efforts to study this through simulations. This study considered the land development potential as it pertained to the two observed events (1991-92 and 2009). These events resulted in the two highest recorded pool elevations in the Addicks Reservoir.

Section 3.1 describes the quantification and delineation of the overflow, while Section 3.2 describes the investigation into what effect(s) future development in the study area may have on the Addicks Reservoir.

3.1 Quantification and Delineation of Overflow Flooding

The local community has had knowledge of the overflow from Cypress Creek into the Addicks Reservoir watershed for quite some time. In fact, the original plan for Addicks and Barker reservoirs developed by the USACE in the 1930s included construction of a levee along the watershed divide to prevent floodwaters in the Cypress Creek watershed from spilling over into the Addicks Reservoir watershed. The levee along the watershed divide was not constructed, as it was determined that it would be more cost effective to mitigate the overflow by acquiring additional land behind the Addicks Reservoir dam. The additional land was acquired before completing construction of the Addicks Reservoir in the latter 1940s. According to the USACE, approximately one-third of volume in the Addicks Reservoir right-of-way is reserved for overflows from the Cypress Creek watershed.

The overflow is predicted to occur about once every 5-10 years. The total number of times the Cypress Creek overflow has occurred has not been well documented; however, the overflow has been recorded five times in the past 30 years. Two of the largest overflow events were observed in October 1994 and October 1998; smaller overflow events were also recorded in 2002, 2003 and 2012. Figure 3.1 shows photographs taken from the air by the HCFCD during the overflow event in November 2002. As the photographs in Figure 3.1 indicate, the inundation from the overflow covers a vast area. The overflow is relatively shallow, with depths less than 3 feet.

Once stormwater along Cypress Creek overtops the watershed divide during a 1% (100-year) storm event, the overflow itself continues for approximately 1-2 days. During such an event, the inundation in the overflow area will last for several days, particularly in low-lying areas.

The Cypress Creek Overflow Management Plan study utilized a two-dimensional model to simulate the overflow. While a one-dimensional model utilizes cross sections along a channel, a two-dimensional model utilizes a grid. This allows for the simulation of flow to and from a grid cell to its neighboring cells, and therefore takes into account two potential directions. Two dimensional models have existed for some time; however, they are computationally intense and require vast volumes of data storage. The advent of faster processors and more economical storage media have resulted in a significant expansion of two-dimensional modeling. Furthermore, the availability of digital elevation models, such as those developed from LiDAR (Light Detection and Ranging) technology, has facilitated the use of two-dimensional modeling software.

The two-dimensional component was utilized to represent the overflow, and was “coupled” to a one-dimensional representation of defined streams, such as Cypress Creek, Bear Creek and South Mayde Creek. Consequently, the model utilized in this study is known as a “coupled 1D/2D” model.

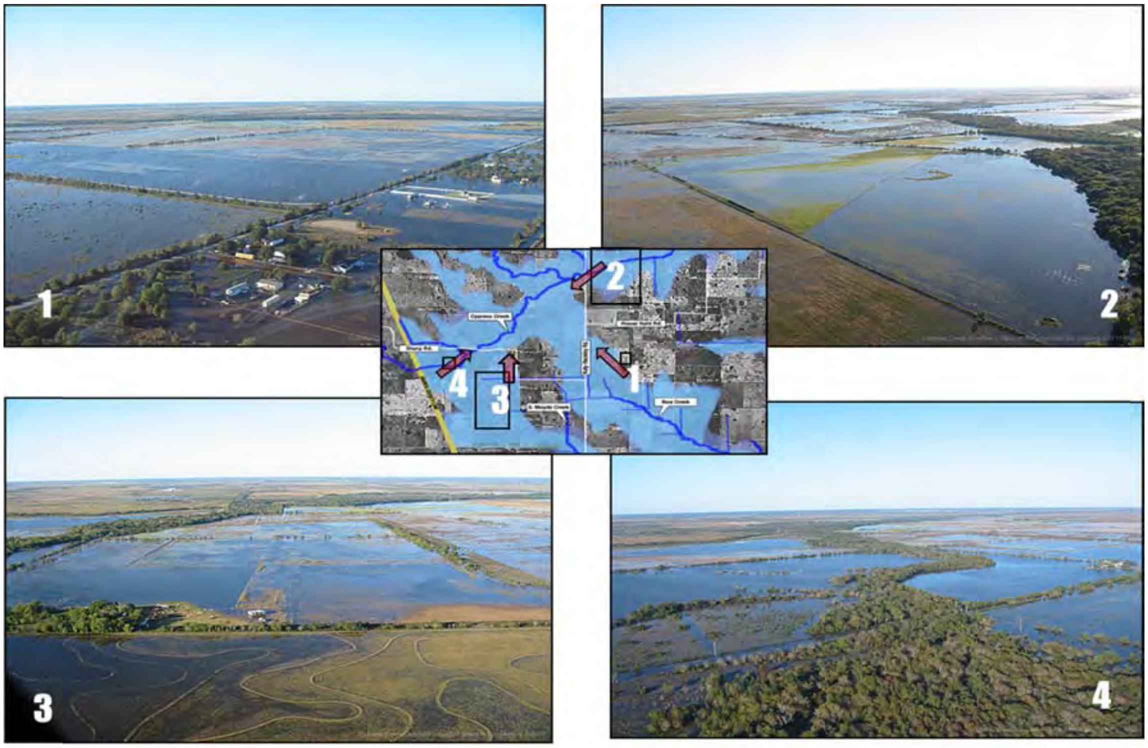


Figure 3.1 November, 2002 event (Note: arrows in center image depict camera location and angle)

3.1.1 Quantification of the Overflow

Using the model, hydrographs were determined at the locations depicted on Figure 3.2, and these locations are summarized in Table 3.1.

Table 3.1 Hydrograph locations

No	Location	Description
1	Mound Creek/Little Mound Creek	Represents Cypress Creek flow upstream of the overflow the line crosses Cypress Creek tributaries DS of where the overflow begins.
2	Cypress Creek downstream of Katy-Hockley Road	Represents Cypress Creek flow at the Katy-Hockley Road gage
3	Cypress Creek upstream of Grand Parkway	Represents Cypress Creek flow downstream of the overflow
4	Overflow “1” – west (toward S. Mayde Crk)	Represents overflow that flows toward South Mayde Creek
5	Overflow “2” – middle (toward Bear Crk)	Represents overflow that flows toward Bear Creek
6	Overflow “3” – east (toward Langham Crk)	Represents overflow that flows toward Langham Creek
7	North Overflow at Katy-Hockley Road (to Bear Creek)	Represents overflow that flows across JPL to Bear Creek about halfway across the overflow
8	Middle Overflow at Katy-Hockley Road (to Bear Creek)	Represents overflow that flows south of JPL to Bear Creek about halfway across the overflow.
9	South Overflow at Katy-Hockley Road (to S. Mayde Crk) Creek	Represents flow along South Mayde Creek about halfway across the overflow.
10	Diversion from Bear Creek to South Mayde Creek	Overflow that is diverted from Bear Creek to South Mayde Creek
11	Flow entering South Mayde Creek development area	Represents overflow in South Mayde Creek as it enters the developed reach
12	Flow entering Bear Creek development area	Represents overflow in Bear Creek as it enters the developed reach
13	Flow entering Langham Creek development area	Represents the overflow in Langham creek as it enters the developed reach

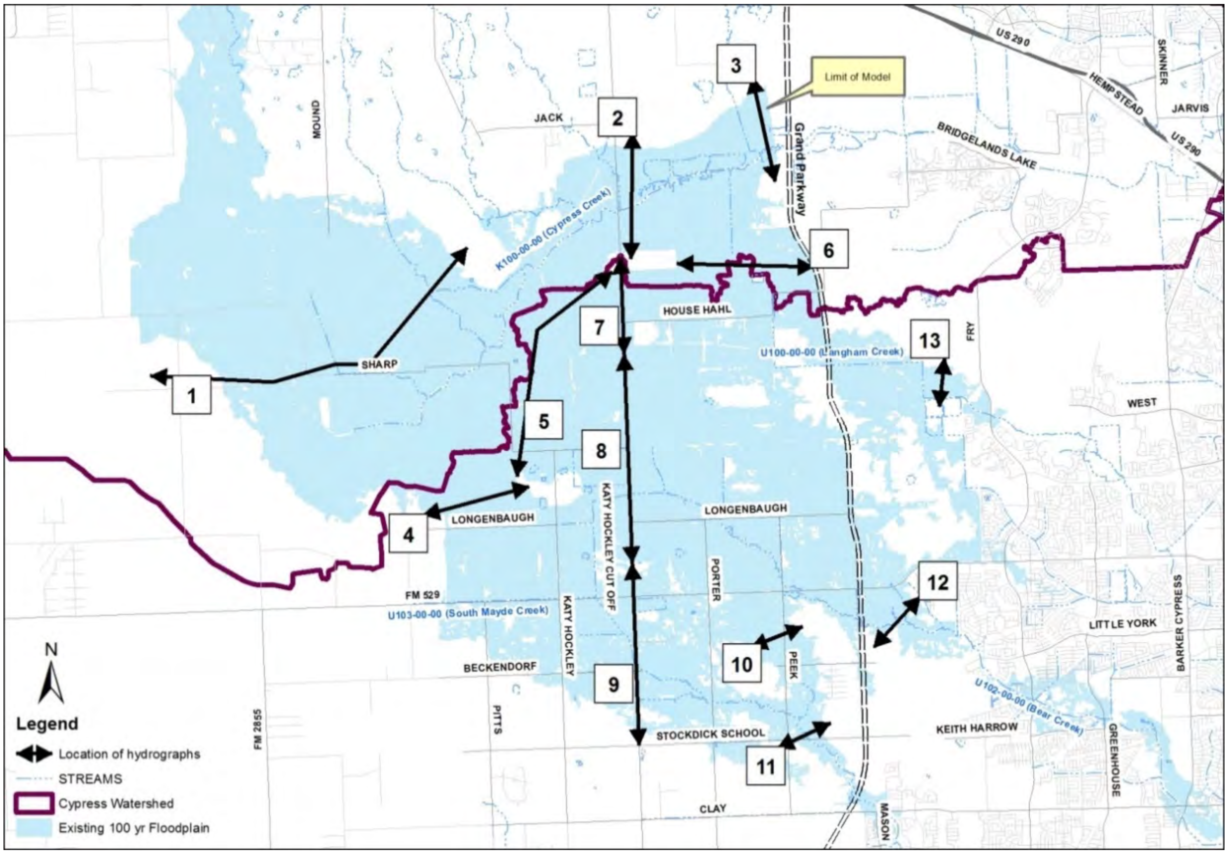


Figure 3.2 Hydrograph computation locations

Table 3.2 presents the computed peak discharges, and Table 3.3 presents the computed volumes at these key locations.

Table 3.2 Computed peak discharges

Location		**Peak Discharge (cfs)**			
No	**Description**	**1% (100-yr)**	**10% (10-yr)**	**20% (5-yr)**	**50% (2-yr)**
1	Mound Creek/Little Mound Creek	18,419	7,424	4,681	2,233
2	Cypress Creek downstream of Katy-Hockley Road	5,231	1,711	1,189	871
3	Cypress Creek upstream of Grand Parkway	5,138	1,675	1,111	802
4	Overflow “1” – west (toward S. Mayde Crk)	3,258	569	117	0
5	Overflow “2” – middle (toward Bear Crk)	8,590	2,476	1,297	349
6	Overflow “3” – east (toward Langham Crk)	829	232	58	0
	Total Overflow at Watershed Divide (4, 5, & 6)	**12,678**	**3,278**	**1472**	**349**
7	North Overflow at Katy-Hockley Road (to Bear Creek)	2,858	1,161	614	112
8	Middle Overflow at Katy-Hockley Road (to Bear Creek)	4,221	633	263	34
9	South Overflow at Katy-Hockley Road (to S. Mayde Crk)	1,958	83	0	0
10	Diversion from Bear Creek to South Mayde Creek	589	0	0	0
11	Flow entering South Mayde Creek development area	1,918	62	0	0
12	Flow entering Bear Creek development area	2,593	459	214	23
13	Flow entering Langham Creek development area	394	55	7	0
	Total Overflow Entering Addicks Reservoir	**4,905**	**576**	**214**	**0**

Table 3.3 Computed flow volumes

Location		Flow Volume (ac-ft)			
No	**Description**	**1% (100-yr)**	**10% (10yr)**	**20% (5yr)**	**50% (2yr)**
1	Mound Creek/Little Mound Creek	28,846	12,281	8,319	4,972
2	Cypress Creek downstream of Katy-Hockley Road	19,916	9,850	6,015	5,215
3	Cypress Creek upstream of Grand Parkway	29,861	13,162	6,428	5,393
4	Overflow "1" – west (toward S. Mayde Crk)	5,192	783	160	0
5	Overflow "2" – middle (toward Bear Crk)	16,583	5,263	2,699	541
6	Overflow "3" – east (toward Langham Crk)	1,580	394	73	0
	Total Overflow at Watershed Divide (4, 5, & 6)	**23,355**	**6,439**	**2,933**	**541**
7	North Overflow at Katy-Hockley Road (to Bear	6,856	2,744	1,275	187
8	Middle Overflow at Katy-Hockley Road (to Bear	8,852	1,567	444	27
9	South Overflow at Katy-Hockley Road (to S. Mayde	3,302	193	0	0
10	Diversion from Bear Creek to South Mayde Creek	747	0	0	0
11	Flow entering South Mayde Creek development area	5,939	783	160	0
12	Flow entering Bear Creek development area	15,836	5,263	2,699	541
13	Flow entering Langham Creek development area	1,580	394	73	0
	Total Overflow Entering Addicks Reservoir	**23,355**	**6,439**	**2,933**	**541**

The computed flows and volumes are discussed below.

Total Overflow

The computed 1% (100-year) peak discharge along Cypress Creek upstream of the overflow is 18,419 cfs. The peak 1% overflow discharge is 12,678 cfs. The computed 1% (100-year discharge along Cypress Creek downstream of the overflow is 5,138 cfs.

The total volume that overflows from the Cypress Creek watershed to the Addicks Reservoir watershed during the 1% (100-year) event is computed to be 23,355 acre-feet, which is 83% of the stormwater volume flowing through Cypress Creek upstream of the overflow. The majority of the overflow drains into Addicks Reservoir. It is estimated that for a 1% (100-year) event, approximately 650 acre-feet of the 23,355 acre-feet (about 3%) leaving the Cypress Creek watershed drains into the Addicks Reservoir watershed and then overflows into the Barker Reservoir watershed. For the purpose of this study, the overflow reaching Barker Reservoir is considered negligible. However, the potential impacts of an increased volume of inflow associated with future land development in the Barker Reservoir is not considered negligible, and will be discussed further in Section 3.2.

For the 10% (10-year) event, the peak discharge along Cypress Creek upstream of the overflow is 7,424 cfs, and the peak 10% overflow discharge is 3,278 cfs. The total volume that overflows from the Cypress Creek Watershed to the Addicks Reservoir watershed during the 10% (10-year) event is computed to be 6,439 acre-feet, which is 56% of the volume flowing in Cypress Creek upstream of the overflow.

Figure 3.3 shows the hydrographs in Cypress Creek, along with the overflow hydrograph and the hydrograph in Cypress Creek downstream of the overflow for the 1% (100-year) and 10% (10-year) storm events.

As the calculations indicate, during a flood event a substantial amount of the Upper Cypress Creek flows divert into the Addicks Reservoir watershed.

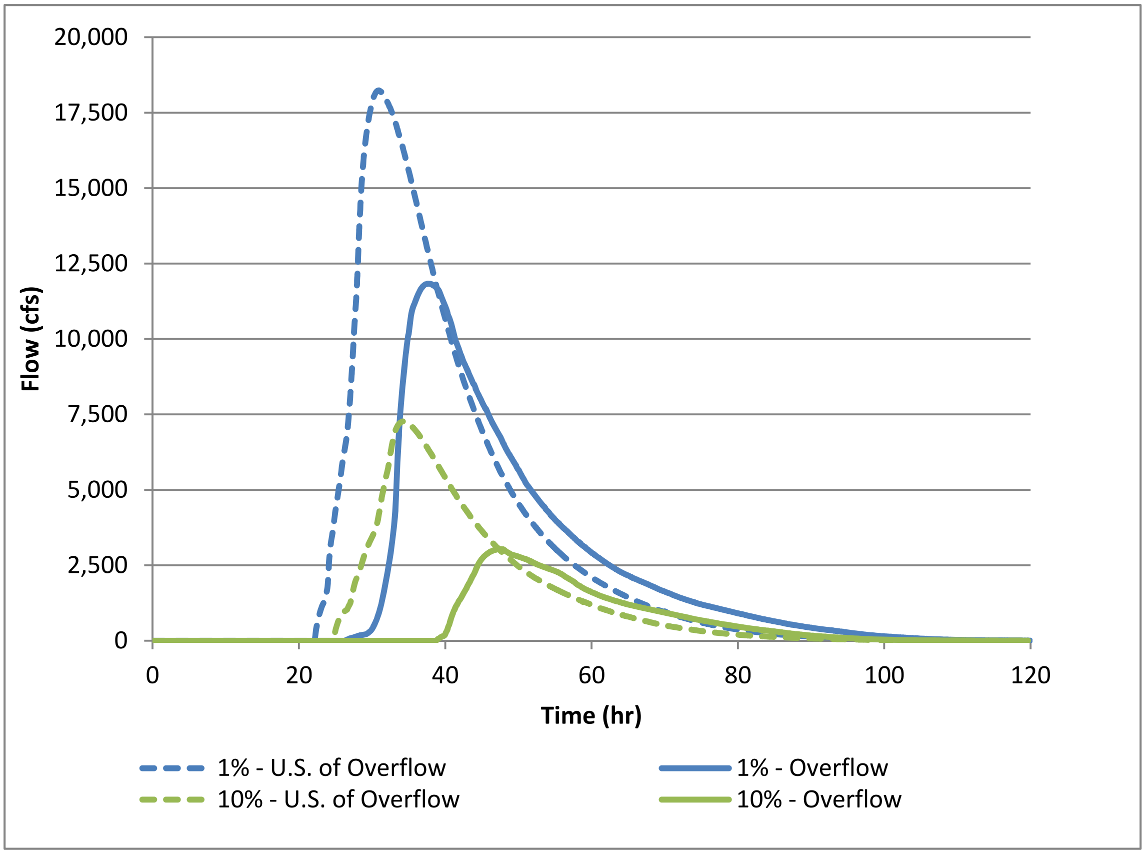


Figure 3.3 Cypress Creek and overflow hydrographs (at watershed divide)

South Mayde Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper portion of South Mayde Creek is 3,258 cfs, with a total volume of 5,192 acre-feet.

In addition, a portion of the overflow that reaches Bear Creek eventually overflows into South Mayde Creek. During a 1% (100-year) event, the peak overflow rate from Bear Creek is 589 cfs, and the total overflow volume is 747 acre-feet. South Mayde Creek ultimately receives about 20% of the total overflow volume during the 1% (100-year) event. See Figure 3.2 for location reference.

The peak discharge is substantially attenuated as the overflow flows across open land. The peak 1% flow rate from the overflow along South Mayde Creek at the Grand Parkway (where South Mayde Creek begins to flow through existing development) is reduced to 1,918 cfs. It takes about 38 hours for the peak flow to move from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate from a local rainfall event (without the occurrence of the overflow) is 4,473 cfs. This event would typically peak much more quickly than the overflow event - by approximately two days. Consequently, the local event will dissipate prior to the overflow event. The 1% peak flow rate for the local event is much higher than the peak 1% peak flow rate from the overflow; however, the total volume for each event is similar. The total 1% volume for the local event along South Mayde Creek at the Grand Parkway is 6,627 acre-feet, while the total 1% volume for the overflow event is 5,939 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of South Mayde Creek is 569 cfs. During this event there is no further overflow from Bear Creek to South Mayde Creek. This flow rate is attenuated to 62 cfs near the Grand Parkway. The total 10% (10-year) overflow volume into South Mayde Creek is 783 acre-feet.

Figure 3.4 shows the 1% (100-year) and 10% (10-year) overflow hydrographs at upper extent of South Mayde Creek and at the Grand Parkway.

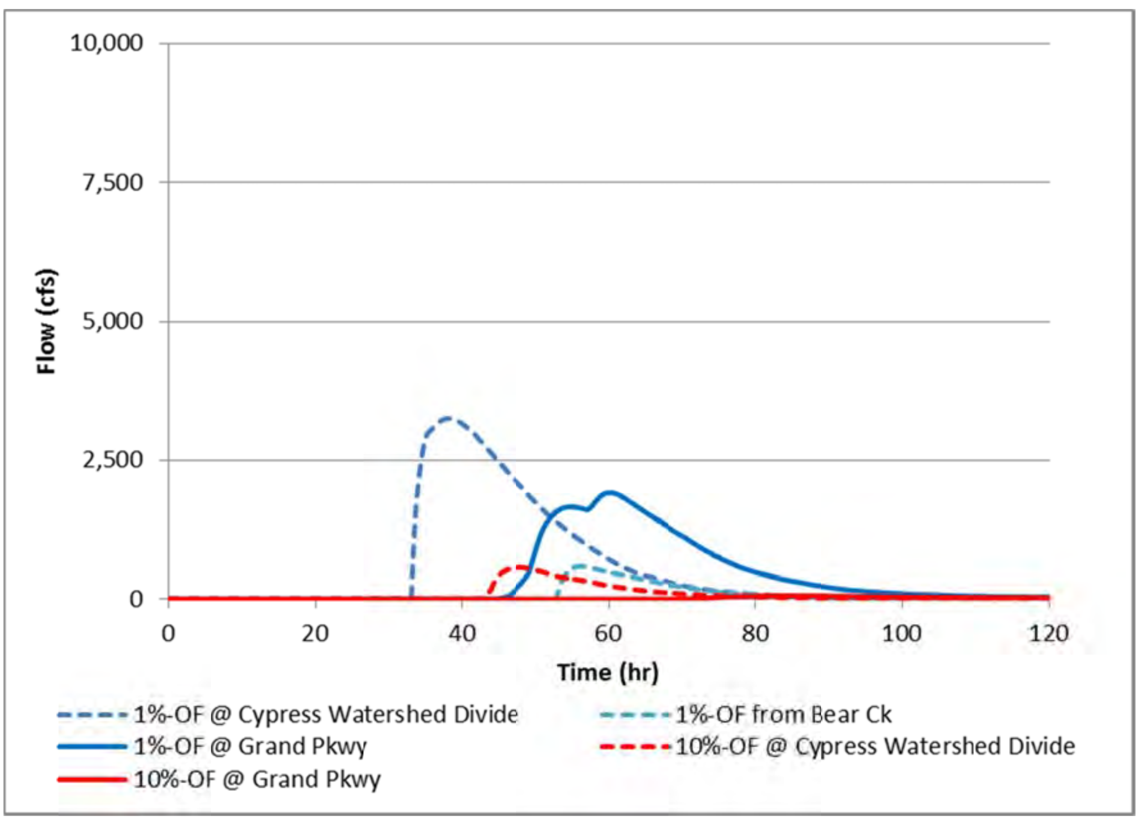


Figure 3.4 South Mayde Creek overflow hydrographs

Bear Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper extent of Bear Creek is 8,590 cfs, with a total volume of 16,583 acre-feet. As noted in the previous section, a portion of this volume (747 acre-feet) overflows to South Mayde Creek. Bear Creek receives about 75% of the total overflow volume during the 1% (100-year) event.

The peak discharge is substantially attenuated as the overflow flows across the open land in the Addicks Reservoir watershed. As the overflow passes Katy-Hockley Road, the 1% peak discharge has been reduced to 7,079 cfs; and by the time it reaches the developed area just upstream of Fry Road, the 1% peak discharge has been reduced to 2,593 cfs (see Figure 3.2 for location reference). It takes about 40 hours for the peak flow to convey from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate at this location from a local rainfall event (without overflow) is 6,031 cfs. This event would typically peak much more quickly than the overflow event. Assuming that rainfall occurs simultaneously across the upper Cypress Creek watershed and the Addicks Reservoir watershed, the peak runoff rate from the local event is anticipated to occur about two days before the overflow reaches Bear Creek and would dissipate prior to the overflow event. While the 1% peak flow rate for the local event upstream of Fry Road is much higher, the computed volume for the overflow event is significantly higher than the local event. The total 1% volume for the local event along Bear Creek upstream of Fry Road is 8,514 acre-feet, while the total 1% volume for the overflow event at the same location is 15,836 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of Bear Creek is 2,476 cfs. During this event there is no further overflow from Bear Creek to South Mayde Creek. This flow rate is attenuated to 459 cfs upstream of Fry Road. The total 10% (10-year) overflow volume into Bear Creek is 5,263 acre-feet.

Figure 3.5 shows the overflow 1% (100-year) and 10% (10-year) overflow hydrographs along Bear Creek in upper portion of the watershed and just upstream of Fry Road.

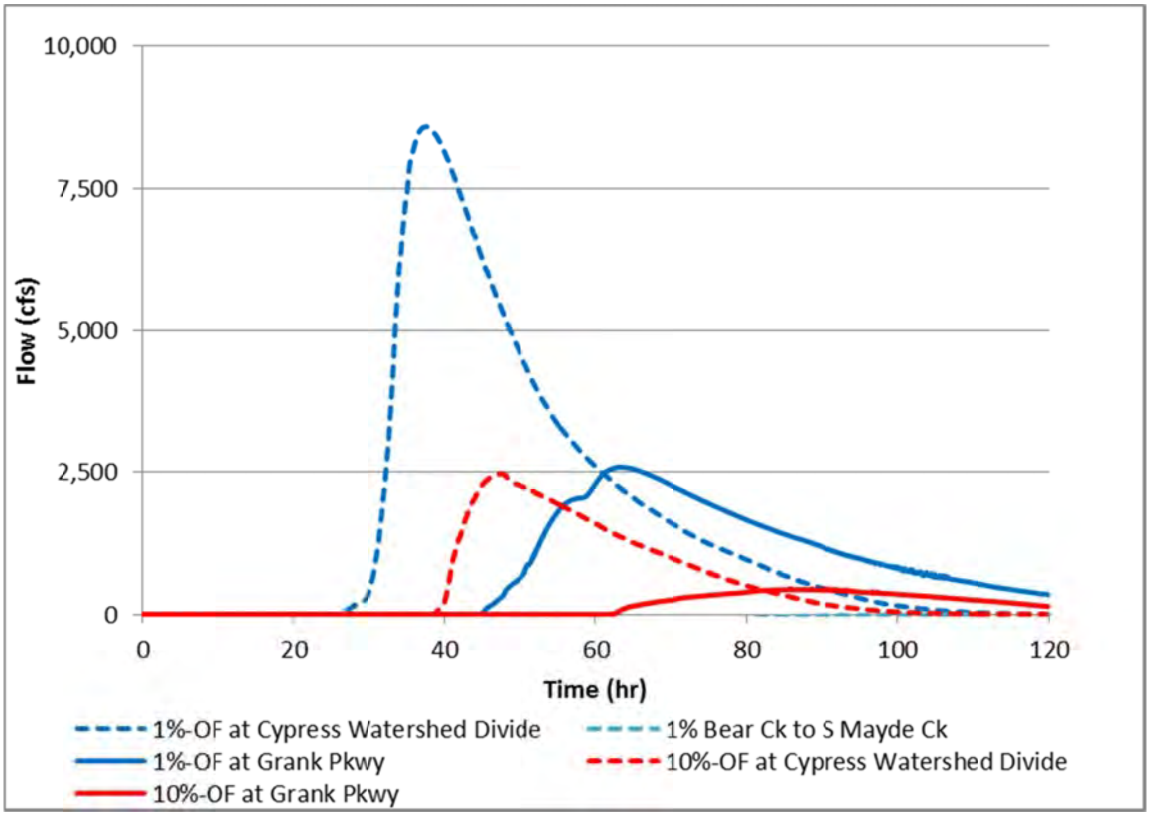


Figure 3.5 Bear Creek overflow hydrographs

Langham Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper portion of Langham Creek is 829 cfs, with a total volume of 1,580 acre-feet. Langham Creek receives about 5% of the total overflow volume during the 1% (100-year) storm event.

The peak discharge is substantially attenuated as the overflow moves across open land. By the time it reaches the developed area near Fry Road, the 1% peak discharge has been reduced to 394 cfs. It takes about 40 hours for the peak flow to move from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate at this location from a local rainfall event (without overflow) is 1,980 cfs. This event would typically peak more quickly than the overflow event – by approximately two days. Consequently, the local event will dissipate prior to the overflow event. The total volume for the local event is much higher than the overflow event. The total 1% volume for the local event along Langham Creek upstream of Fry Road is 3,143 acre-feet, while the total 1% volume for the overflow event at the same location is 1,580 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of Langham 232 cfs. The total 10% (10-year) overflow volume into Langham Creek is 394 acre-feet.

Figure 3.6 shows the 1% (100-year) and 10% (10-year) overflow hydrographs along Langham Creek in the upper portion of the watershed and near Fry Road.

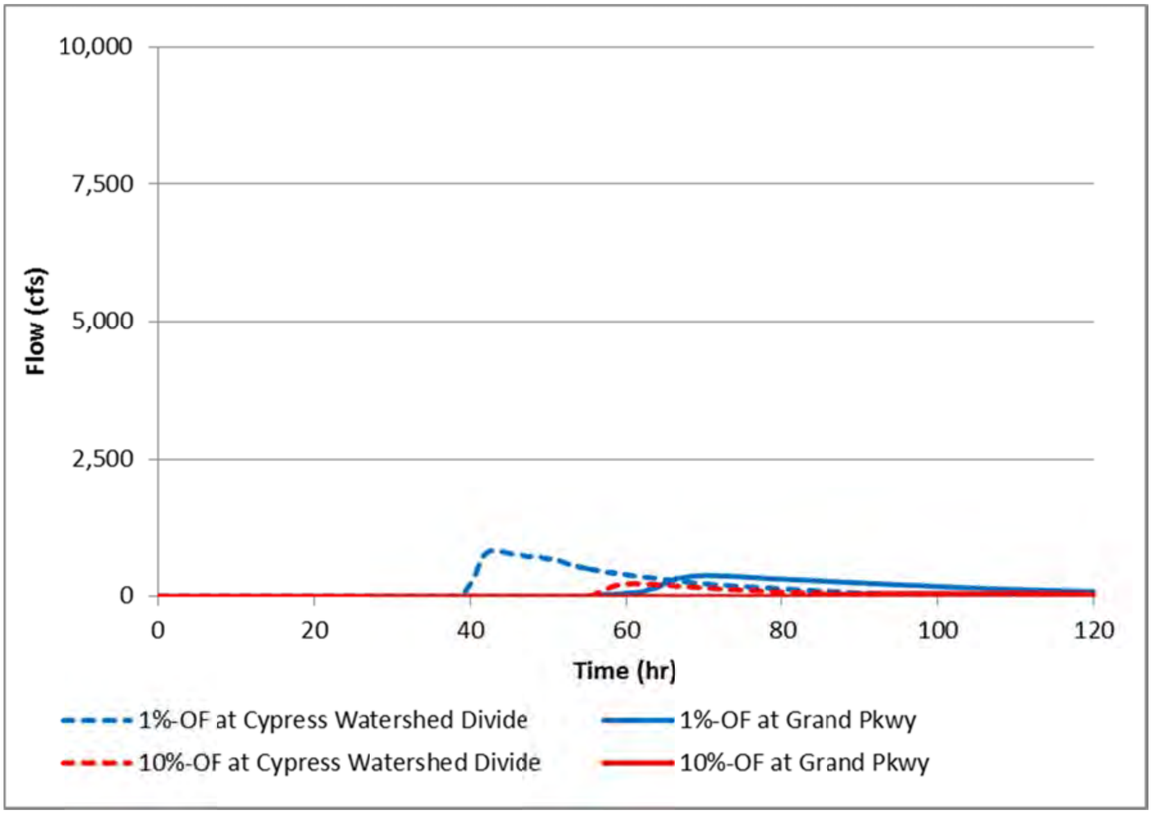


Figure 3.6 Langham Creek overflow hydrographs

Addicks Reservoir

During a local 24-hour 1% (100-year) event, the Addicks Reservoir watershed is expected to deliver 67,005 acre-feet of stormwater runoff volume to the reservoir (under current development conditions). The resultant 1% peak discharge into the reservoir, considering all of the tributaries, is 42,731 cfs.

For a similar overflow event and under current development conditions, Cypress Creek is expected to contribute 23,355 acre-feet of overflow volume at a peak discharge of 4,905 cfs. This peak discharge is anticipated to occur about two days later than the local event.

For a combined 24-hour 1% (100-year) rainfall event over both the Addicks Reservoir watershed and the Upper Cypress Creek watershed, the peak flow rates would remain unchanged. The total runoff volume under current development conditions is estimated to be 90,360 acre-feet. Of this, 74% is from rainfall over the Addicks Reservoir watershed, and 26% is from rainfall over the Upper Cypress Creek watershed.

The peak flow rates and total volumes from the 1% (100-year) rainfall event for Addicks Reservoir and the its three tributaries are summarized in Table 3.4

Table 3.4 Peak 1% flow rates and flow volumes along Addicks Reservoir tributaries

Parameter	**Addicks Watershed Rainfall (Local)**		**Upper Cypress Watershed Rainfall (Overflow)**	
	Peak Flow (cfs)	**Volume (ac-ft)**	**Peak Flow (cfs)**	**Volume (ac-ft)**
Langham Creek				
At Fry Rd	1,980	3,143	394	7,941
Entering Addicks Reservoir	8,701	13,568	394	7,941
Bear Creek				
At Katy-Hockley Road	N/A*	N/A*	4,221	10,252
At Fry Rd	6,031	8,514	2,593	9,505
Entering Addicks Reservoir	7,959	11,899	2,593	9,505
South Mayde Creek				
At Katy-Hockley Road	N/A*	N/A*	1,772	5,162
At The Grand Parkway	4,473	6,627	1,918	5,909
Entering Addicks Reservoir	11,508	17,123	1,918	5,909
Addicks Reservoir				
Total Addicks Reservoir	42,731	67,005	4,905	23,355

**Local flows not computed – at headwaters of channel*

An additional hydrologic analysis was conducted to estimate the increase in the overflow volume that could result from development in the Upper Cypress Creek watershed. This analysis assumes that (1) the land will develop in a manner typical of typical mixed-use suburbia, with the exception of existing lands held in conservation (which will remain undeveloped); (2) current detention policies are in place; and (3) current detention policies are adequate to offset the potential increase in peak flow rate.

The analysis indicates that the peak flow rates of the overflow would not be impacted, and would remain the same. However, Cypress Creek would stay at flood stage for a slightly longer duration as the detention basins empty, resulting in a 15% increase in the overflow volume. With full development and current policy, it is estimated that the overflow volume would increase from 23,355 acre-feet to 26,267 acre-feet. Figure 3.7 presents a comparison of the Upper Cypress Creek overflow hydrographs for both the existing and ultimate development during the 1% (100-year) storm event.

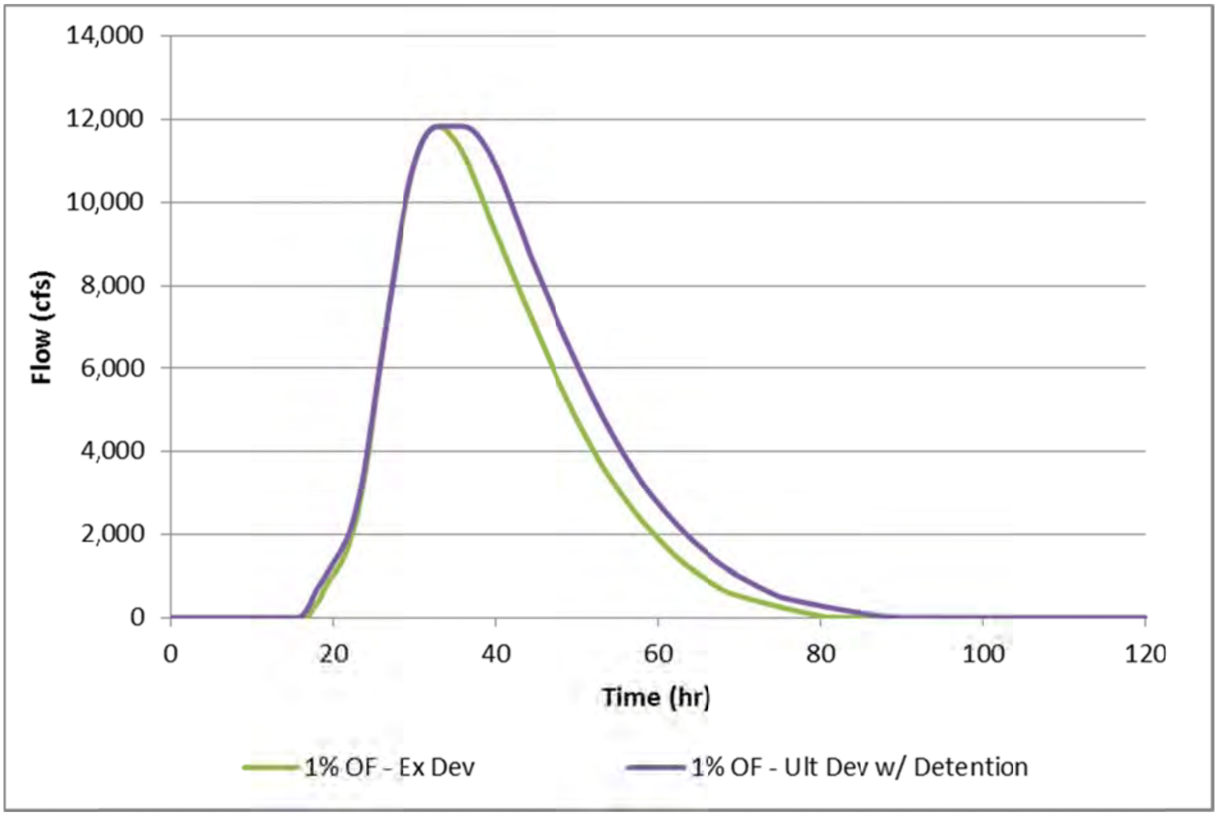


Figure 3.7 Existing and full development overflow hydrographs (with current design criteria in place)

3.1.2 Delineation of the Overflow

The two-dimensional simulation facilitated the determination of areas that would be inundated by the overflow for various events. Furthermore, the model allowed the development of a depth-grid that depicts flow depths across the overflow area. Depth grids were developed for the 1% (100-year), 10% (10-year), and 20% (5-year) events. Lastly, lines of equivalent water surface elevation were developed for the 1% (100-year) event.

The area inundated by the 1% (100-year) overflow is depicted in Figure 3.8; the area inundated by the 10% (10-year) overflow is depicted in Figure 3.9; and the area inundated by the 20% (5-year) overflow is depicted in Figure 3.10. These maps also display the peak depth of inundation throughout the overflow area, which are also summarized in Table 3.5 for the 1% and 10% annual storm events. Areas inundated by flooding caused by stormwater overtopping channel banks are not included on the map - only the overflow floodplain is depicted.

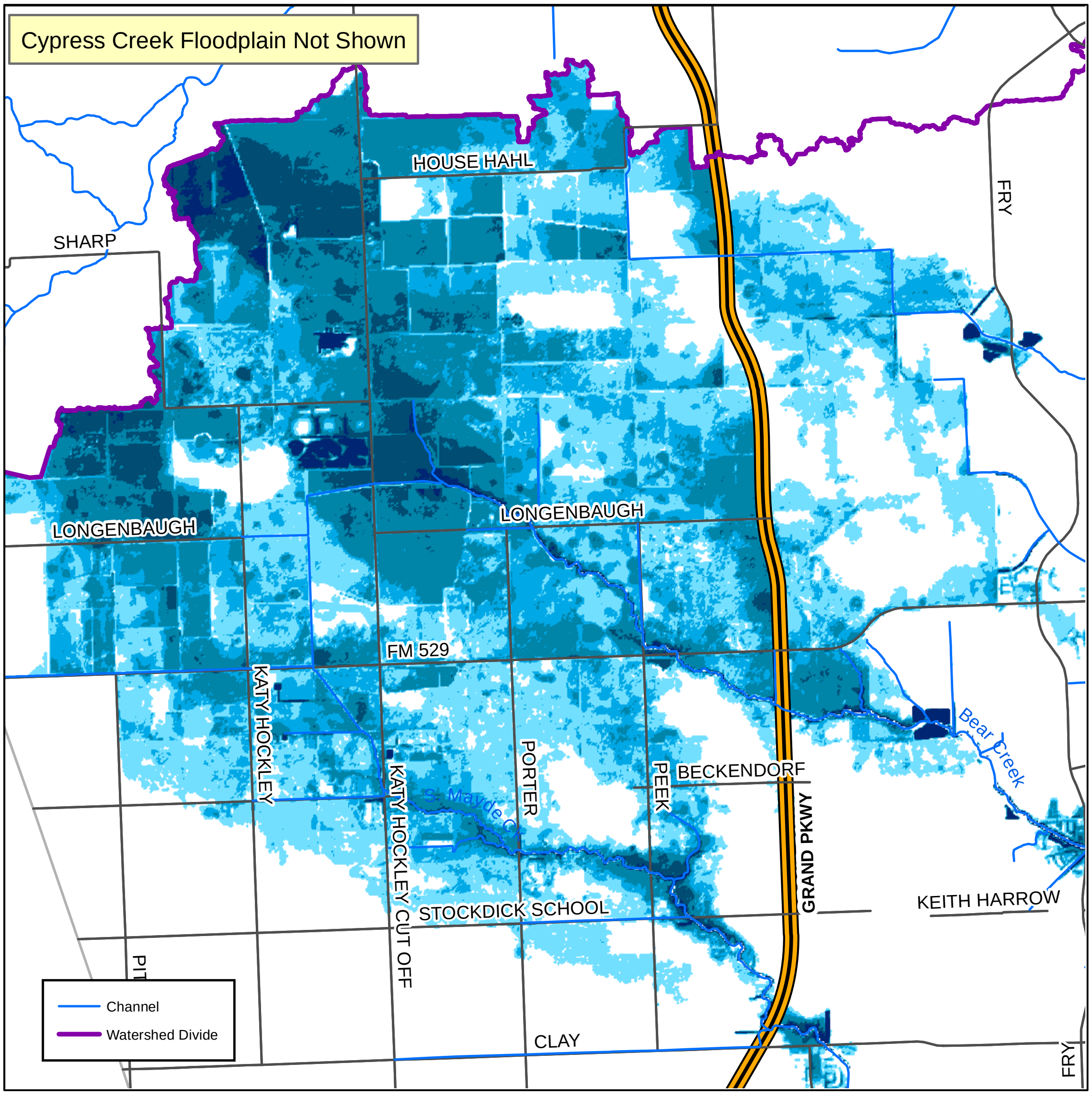


Figure 3.8 1% (100-year) overflow inundation (riverine floodplains not depicted)

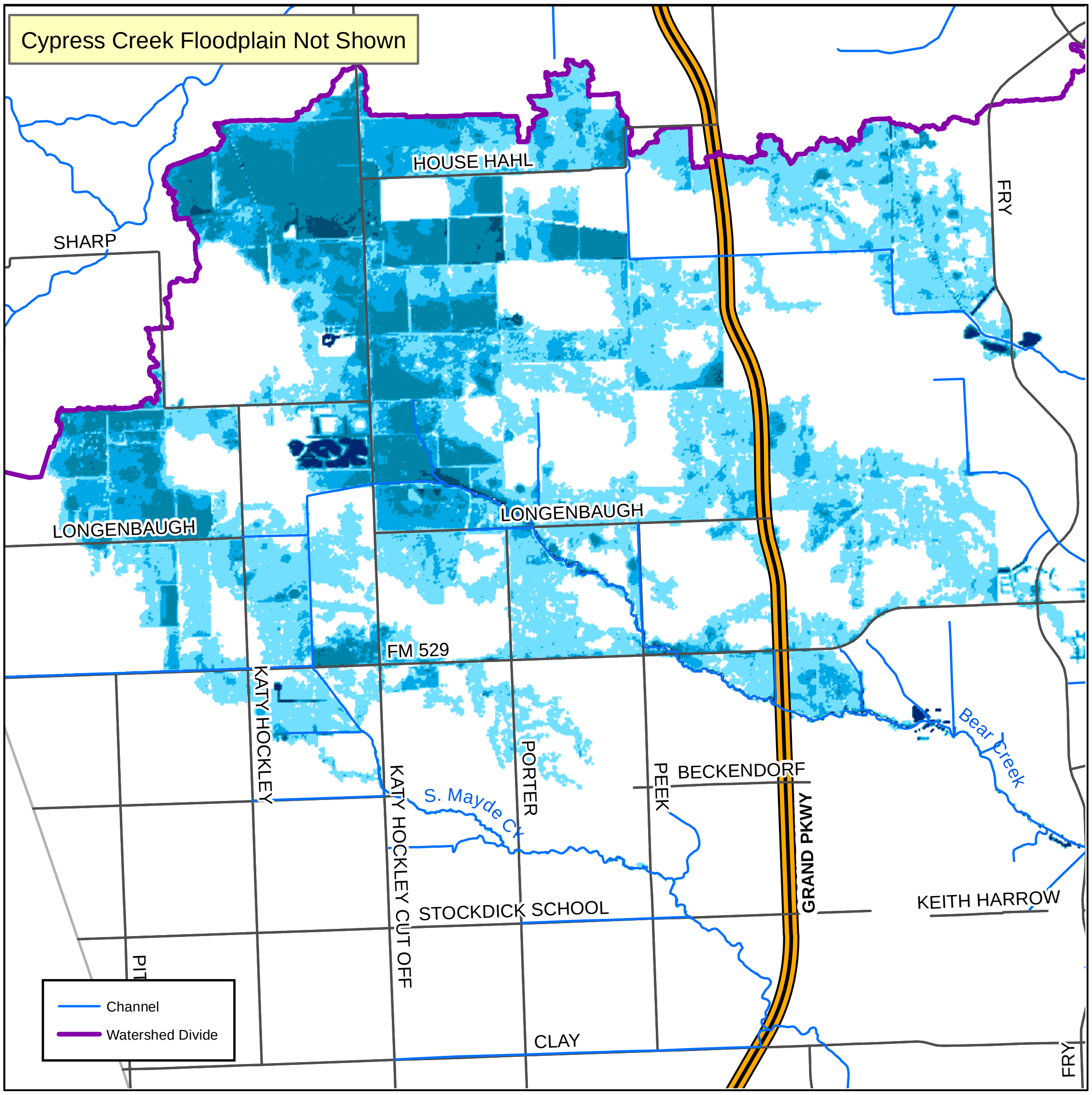


Figure 3.9 10% (10-year) overflow inundation (riverine floodplains not depicted)

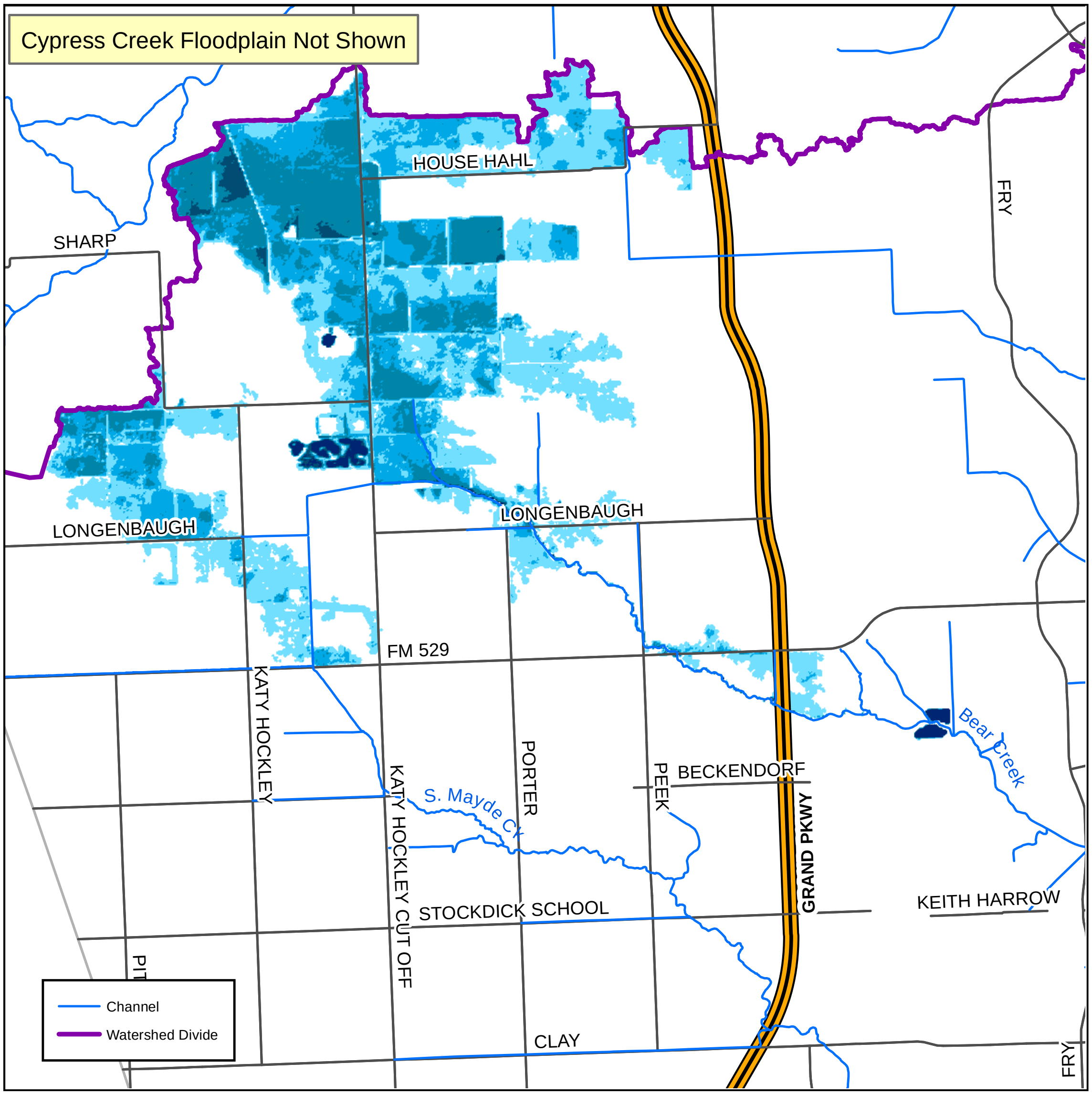


Figure 3.10 20% (5-year) overflow inundation (riverine floodplains not depicted)

Table 3.5 Total area (Acres) of overflow, by depth

Overflow Depth (feet)	10% (10-year)	1% (100-year)
0.0 – 0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	8,606	20,838

As indicated in Table 3.5, the total area inundated by the 1% (100-year) overflow event is 20,838 acres. Of this, over one-half (12,730 acres) has an inundation depth of less than 1 foot, and the overwhelming majority (almost 90%) of the area has an overflow depth of less than 2 feet.

During the 10% (10-year) event, 8,606 acres would be inundated, with 6,356 acres inundated at a depth of 1 foot or less.

The deeper overflow areas are generally located within or near existing drainage channels, such as along or near Bear Creek.

3.2 Effect of Development on Addicks and Barker Reservoirs

Addicks Reservoir and the adjacent Barker Reservoir combine to protect the City of Houston from flooding from Buffalo Bayou. These reservoirs were constructed, and are currently operated by, the USACE. They were constructed in the 1940s, after floods devastated downtown Houston in 1927 and 1935. The Addicks Reservoir occupies 12,460 acres of land north of IH -10 and west of Beltway 8. The reservoir is bisected by SH 6, which runs north-south through the reservoir. The locations of the Addicks Reservoir and Barker Reservoir are shown in Figure 3.11.

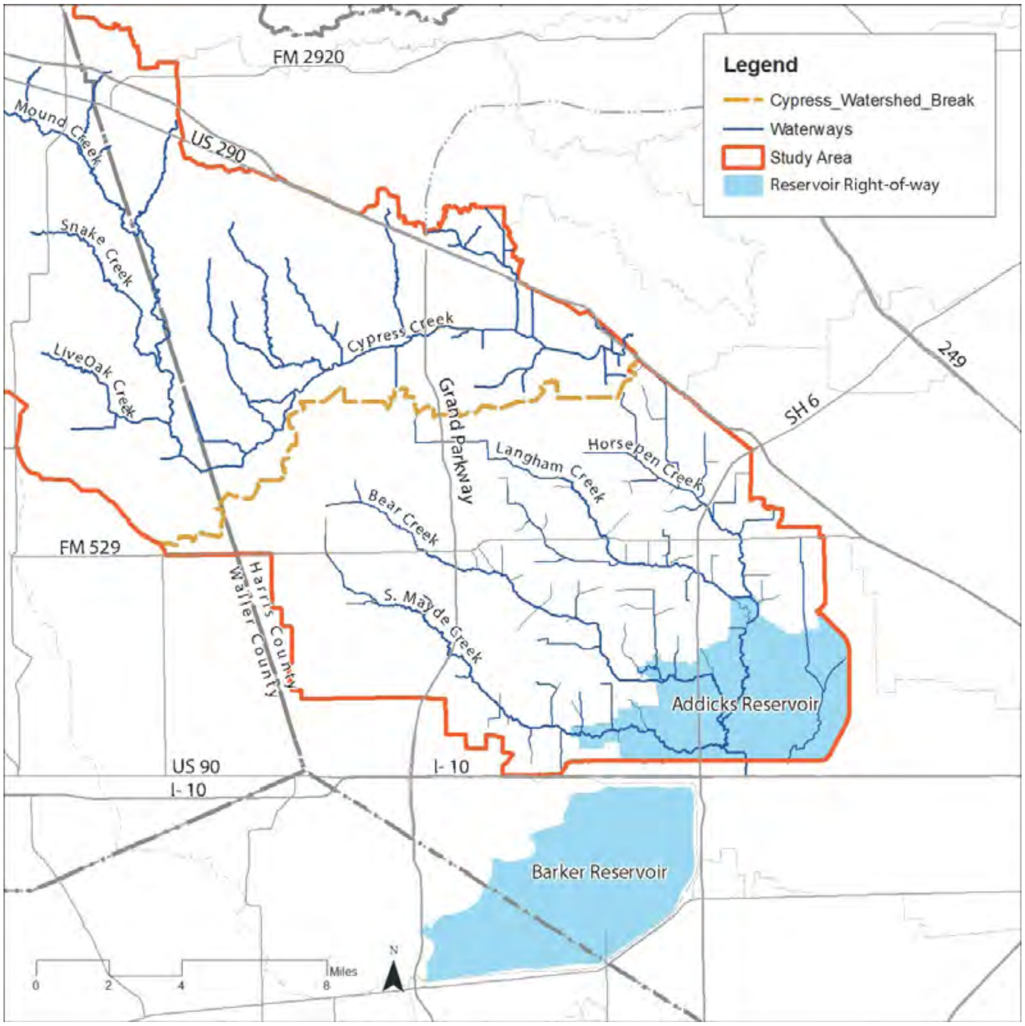


Figure 3.11 Addicks and Barker Reservoirs

Addicks and Barker Reservoirs were components of a larger flood control plan developed by the USACE in the 1930s. However, due to changing conditions throughout Harris County, such as rapid development and increased property costs, modifications were made to the original plan. These included adding capacity to Addicks Reservoir to accommodate the overflow from Cypress Creek in lieu of constructing a levee along Cypress Creek to prevent the overflow, as well as reducing the combined discharge rates from the two reservoirs down to 2,000 cfs or less to avoid damages downstream along Buffalo Bayou. These modifications resulted in a higher expected pool elevation during rainfall events. For Barker Reservoir, the computed 1% (100-year) pool elevation slightly exceeds the limits of government-owned land for the reservoir, while the computed 1% (100-year) pool elevation for Addicks Reservoir remains within the limits of government-owned right-of-way for the reservoir. Furthermore, land development had occurred adjacent to the reservoirs.

While there is sufficient government-owned right-of-way within the Addicks Reservoir for the 1% (100-year) pool elevation, there is little if any additional capacity available to accommodate increases in the 1% pool elevation if the inflow into Addicks Reservoir is increased, or if discharge from Addicks Reservoir is further restricted in the future. And since the Barker Reservoir's 1% (100-year) pool elevation exceeds the limit of government-owned land, there is no additional capacity for increased stormwater runoff volume into that reservoir.

The study considered the current operation of Addicks and Barker reservoirs as it relates to future development and potential management measures. The purpose of this analysis was to determine what flood risk reduction measures and/or policies are desirable within the study area upstream of the Addicks Reservoir. This section describes the analysis in support of this; further detail can be found in Appendix B. Ultimately, this section concludes that the Addicks Reservoir does not have the capacity to accept additional runoff anticipated from land development activities in the Addicks Reservoir watershed and the Upper Cypress Creek watershed, and recommends that development policy include mitigation measures to prevent the increase in runoff volume that may exacerbate flood risks upstream and downstream of the Addicks and Barker reservoirs.

3.2.1 The Effect of Development

The Addicks Reservoir watershed has been steadily developing since the late 1970s. Since 1980, HCFCD has required that new development install adequate detention to ensure that peak downstream flow rates are not increased. However, this relatively short-term detention mitigation measure does not offset the impact of development on runoff volume, and it is well known that development activity decreases the pervious characteristics of land and increases stormwater runoff volume.

A five-year moving average of the peak annual pool volume in Addicks Reservoir between 1973 and 2012 is depicted in Figure 3.12. In addition, the figure shows a computed trend line. As the graph indicates, the peak storage volume in Addicks Reservoir has been steadily rising.

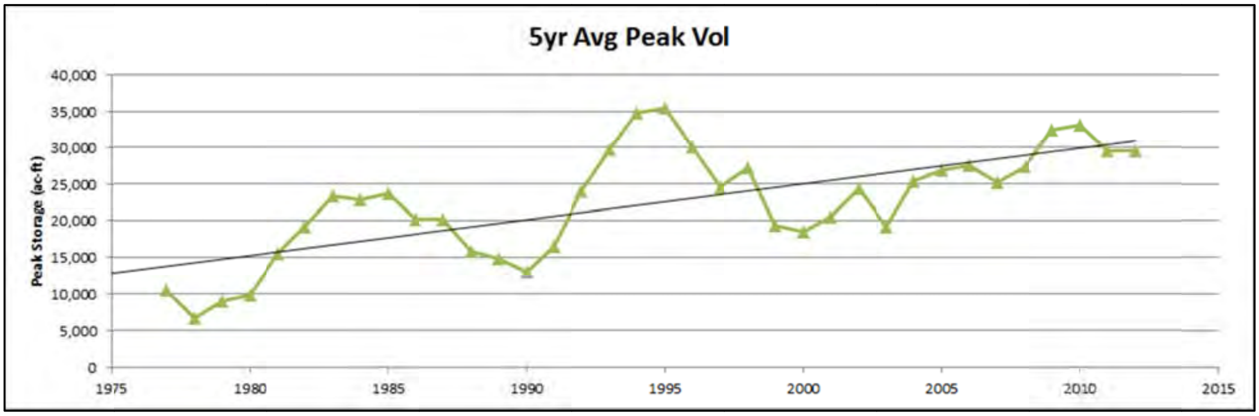


Figure 3.12 Addicks Reservoir annual peak volume - five year moving average with trend line

Figure 3.13 shows annual rainfall amounts over the same time period. This data is based on observed data within the reservoir after 1985 and from recorded data at the National Oceanic and Atmospheric Administration (NOAA) gage at George Bush Intercontinental Airport for the years prior to 1985. As the figure indicates, there is no discernible trend in the rainfall amounts, and therefore the upward trend in reservoir storage pools cannot be correlated to increases in rainfall.

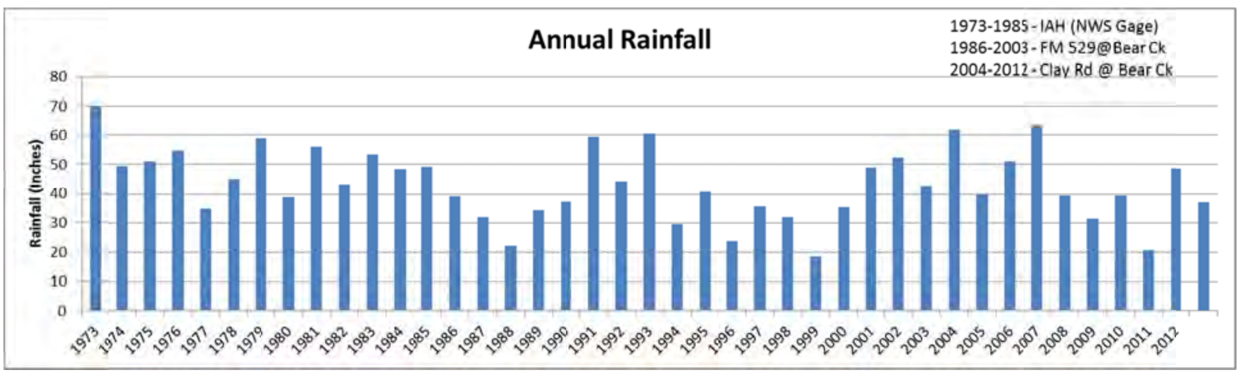


Figure 3.13 Annual rainfall - 1973 to 2012

The Addicks and Barker Reservoirs can be filled from a large single rainfall event as well as multiple smaller rainfall events, which was demonstrated in 1992 and 2009 when the top record pool levels were recorded in the Addicks Reservoir. While both rainfall events were significant in terms of their impact on pool elevations in the Addicks Reservoir, the characteristics of the two rainfall events were very different. In 2009, a moderately severe rainfall, approximately equivalent to a 10% (10-year) annual chance flood event, occurred in the Addicks Reservoir watershed. The rainfall fell over a 14-day period in late April through early May. A storm that resulted in a large amount of rainfall occurred at the end of April. While the rainfall amount was approximately equivalent to a 10% annual storm event during this period, Addicks Reservoir filled to almost half of the storage capacity within the government owned right-of-way.

In 1992, a series of small to moderate floods occurred over a 90-day period, with an estimated 21 inches of rainfall occurring between December 1991 and March 1992. It is estimated that the combined rainfall amount that fell during this 90-day period approximated a 3% annual chance storm event. Similar to the March 2009 event, Addicks Reservoir was filled to just over half of the storage capacity within the government owned right-of-way.

In both 1992 and 2009, Addicks Reservoir was well within the limits of government-owned land. The two rainfall events were moderate, and in neither case did a significant overflow from Cypress Creek occur.

A mass balance of the 1991-92 event that resulted in then record pool elevations in the Addicks Reservoir was conducted using observed data from the USACE, as well as rainfall data collected from the HCFCD. The observed peak stage in the Addicks Reservoir in 1992 was 100.6 feet, and the rainfall runoff rate was estimated to be about 75%. If this rainfall runoff rate was to increase to 90%, which is an expected result of development, the peak stage would have been 104.1 feet, which is equivalent to the current 1% (100-year) pool elevation in the reservoir, and would represent a 59% increase in the peak storage volume during the event. This is particularly significant, considering that the 1% (100-year) pool elevation would be achieved without a similarly large rainfall event or an overflow event.

A similar exercise was conducted for the 2009 event. Reservoir elevation and release data was not available for this event and had to be approximated. The elevation was estimated using rating curves for the Addicks Reservoir published by the USGS. The estimated peak stage in 2009 was 100.7 feet. If the rainfall runoff rate were to increase to 90%, the peak stage would have been 102.6 feet, which would represent a 32% increase in the peak storage volume during the event.

The resultant stage is lower for the 2009 event, when compared to the 1991-92 event, because the 2009 event was the result of a short duration of intense rainfall, and the 1991-92 event was the result of several smaller events over a prolonged period of time.

3.2.2 Summary – Addicks and Barker Reservoirs

The following summary and conclusions have been identified as a result of this review and analysis:

- Addicks Reservoir is subject to operational constraints that prohibit it from performing in the manner that was originally planned. The reservoir maintains sufficient capacity to manage the expected runoff volume from typical design events in Harris County, including the 24-hour, 1% (100-year) storm event. During such an event, pool elevations will be maintained within the boundaries of government-owned land for the reservoir under current land use conditions.

- The Addicks Reservoir pool has the capacity to impound a significant volume of water before pool elevations rise to the level of the spillways. Eventually, pool elevations would exceed reservoir lands and inundate private property at the reservoir's fringes. At current development levels, it would take an extraordinary rainfall to achieve these pool elevations.

- Current development policy requires that detention basins temporarily store water to ensure that downstream peak discharges are not increased as a result of development. However, detention basins only address the peak flow rate and do not provide mitigation for the increase in stormwater volume due to development. While this may not be a concern in free-flowing watersheds, the impact of increased volumes should be considered when long-term storage features, such as the Addicks and Barker reservoirs, are located downstream.

- Simulations of the two largest recorded storm events on the Addicks Reservoir suggest that the increase in the rainfall runoff relationship associated with new development will significantly increase pool elevations in the Addicks Reservoir if not mitigated,.

- Simulations of these events suggest that during larger storm events, about 75% of the rainfall volume is converted to runoff that makes its way into the Addicks Reservoir. Furthermore, past studies suggest that developed watersheds convert about 90% of rainfall to runoff. This 15%increase is equivalent to 2 inches when considering a 1% (100-year) 24-hour rainfall amount of 13.5 inches.

- Under current detention criteria, land development activity in the Upper Cypress Creek watershed will result in a longer duration of flood flows. This will result in a higher volume of overflow into the Addicks Reservoir watershed, and eventually will increase the expected pool elevation in the Addicks Reservoir.

- This analysis did not consider Barker Reservoir; however, Barker Reservoir is subject to the same operational constraints as Addicks Reservoir, and the two reservoirs function as a single system. Furthermore, current estimates of the 1% (100-year) pool elevation in Barker Reservoir indicate that it would exceed the limit of government owned land in the reservoir. All conclusions relating to available capacity in the Addicks Reservoir can be applied to the Barker Reservoir.

4 Identifying Mitigation Strategies

The identification of mitigation strategies involved a deliberate process of identifying potential measures and combining them into viable management plans. The planning process involved extensive coordination with the steering committee, which was a group of key stakeholders and decision makers that met approximately twice a month throughout the study (see Section 9.1). The committee received regular briefings and provided feedback on the proposed options and strategies. The steering committee was also instrumental in identifying the planning objectives and constraints that guided the planning process.

4.1 Planning Objectives and Constraints

Planning objectives and constraints provide structure and direction for the planning process. A thorough understanding of these is essential to ensuring that plans are developed that fully address the purpose and need of the project. Likewise, it is essential that the stated objectives and constraints provide a framework for that pursuit.

4.1.1 Planning Objectives

Planning objectives are used to formulate and evaluate alternative strategies. These are different than overall study goals and objectives, which provide a more comprehensive overview regarding the study's general purpose. In contrast, planning objectives are specifically directed at management strategies - and management strategies are evaluated based on how well they address the planning objectives without violating planning constraints.

The primary motive of the planning objectives is to address the flood control benefit of the resultant strategy. However, objectives of other stakeholders are relevant as well as, addressing multiple needs will encourage community support and possible funding participation by others.

The planning objectives utilized in this study are as follows:

Objective 1 – Overflow Management - *Identify and implement a management plan consisting of structural and/or nonstructural measures that allows for predictable, fair and sustainable approach for a regional management plan.*

The development of the overflow area is a near certain. Current development policy and flood plain criteria is tailored to riverine flooding, however the unique phenomena of the large overflow area requires specific development policy and guidelines. To maintain orderly development of the area, and to avoid future drainage problems caused by a lack of overall planning, it is necessary to take a comprehensive look at how a public policy drainage plan can be implemented. This planning effort must balance the competing interests of land use: preservation, business interests, and environmental mitigation needs.

The overflow management objective strives to identify development policies that recognize the unique nature of the overflow; and to identify a regional structural solution that is more economical and favorable to land utilization and development practices than individual ad -hoc solutions, if such solutions exist.

This objective, the management of the overflow, drives the planning effort. While the remaining objectives are vital to the study, this objective underscores the overall purpose and need of the planning study.

Objective 2 – No Adverse Flood Risk to the existing communities upstream and downstream of the Addicks Reservoir - *Estimate the impacts of future runoff on Addicks Reservoir and determine if additional development guideline should be adopted to protect the existing communities adjacent to the reservoir.*

The Addicks Reservoir, as well as the Barker Reservoir, does not have available capacity to accept additional runoff volume. Most of the study area drains to the Addicks Reservoir; however, a small portion of the Cypress Creek Overflow makes its way to the Barker Reservoir via Cane Island Branch. Anticipated land development activity in the Addicks Reservoir watershed will increase the total volume of stormwater runoff into the Addicks Reservoir. In addition, increased runoff volume in the upper Cypress Creek watershed will lead to a longer duration of flow that produces overflows into the Addicks Reservoir watershed, and consequently, a larger volume of overflow that will drain to the Addicks and Barker reservoirs.

The Cypress Creek Overflow Management Planning Study provides an opportunity to identify measures, structural and/or non-structural, to offset this anticipated increase – and even to provide for a net decrease in volume into the reservoirs.

Objective 3 – Conservation *- Preserve contiguous green-space in the study area, including the preservation and re-establishment of native prairie grasslands.*

The Katy Prairie includes remnant prairie vegetation, wetlands and agricultural practices that provide a measure of flood control to areas downstream, including Cypress Creek, the tributary channels that drain to Addicks Reservoir, and Addicks Reservoir itself. These systems also make a positive contribution to water quality and natural habitat. There is a flood control interest in the preservation of this land. Given the challenges of addressing flooding problems throughout the county, HCFCD does not have the reasonable financial resources to secure vast amounts of land in the Katy Prairie, nor does it have the authority to prohibit development activity that conforms to established policy. However, the Katy Prairie Conservancy has a stated goal to secure 50,000 acres of contiguous land within the Katy Prairie, and there is a flood control interest in supporting this goal.

Objective 4 – Flood Damage Reduction - *Reduce flood risk to existing structures in the overflow area*

While the reduction of flood risk in the overflow area is a primary objective of the study, the reduction of flood risks in riverine areas within the study area was also considered. There are rural homes and structures in the study area that are subject to riverine flooding and flood risk associated with the Cypress Creek Overflow. This objective considers the potential reduction in flood risks for these structures.

Objective 5 – Facilitate Projects by Other Public Entities - *Implement strategies that assist others, including Waller County, Harris County Precincts 3 and 4, and Harris County Public Infrastructure Department, in the implementation of their respective plans and programs.*

There are many public entities with master plans and programs that overlay the study area. Where possible, it is desirable to identify common elements among those plans and programs and mitigation strategies that support the Cypress Creek Overflow Management Planning Study. The convergence of plans in the study area will provide a greater efficiency in land utilization, the delivery of public infrastructure, and the encouragement of partnerships and cost sharing.

4.1.2 Planning Constraints

Planning constraints are elements that should be avoided or minimized. Some constraints are absolute, and cannot be violated, while others are not absolute and mitigation strategies are evaluated on their success in minimizing violation of the constraint. The planning constraints utilized in the study area are as follows:

Constraint 1 – Avoid Increase in Flood Risk *- Avoid any action or measure that will increase the risk of flooding within, and downstream of, the study area.*

This is an absolute constraint that is common to HCFCD planning studies. No measure will be considered that increases water surface elevations associated with the 1% (100-year) event unless proper provisions are included in the plan (such as property acquisition or drainage easements) that contain the 1% (100-year) flood. The consideration of potential impacts should include simulations of the overflow independent of local flows from rainfall in the Addicks Reservoir watershed.

This constraint also recognizes that no measure or strategy will be considered that increases flood risk associated with pool elevations in the Addicks Reservoir.

Constraint 2 – Value *- Strategies should be economically viable, with net benefits in excess of costs.*

An economic analysis will be conducted for any recommended strategy to ensure that it yields benefits in support of investment. A wide range of economic benefits may be considered, including flood damage reduction, intensification of land use, environmental benefits, and other tangible and intangible benefits.

Constraint 3 – Implementable *- Strategies should be implementable, with a reasonable implementation strategy that recognizes cost and cash flow, funding partnerships, phasing, and near-term delivery. Implementation may not delay ongoing land development activity.*

There must be a reasonable means to implement the recommended strategies. The market demand for new housing is current, and land development activity is certain in the near term. Strategies may not unnecessarily delay current activity, and implementation plans must take the demand for development into consideration. Implementation strategies must identify a funding source, and the plans shall be implementable in a manner that recognizes the cash flows from various funding sources.

Constraint 4 – Compatible with Plans and Programs of Other Public Entities *- Strategies must be compatible with features, plans, and program of other public entities in the study area,* *including Waller County, Harris County Precincts 3 and 4, and the Harris County Engineering Division.*

While Objective 5 strives to identify synergies between other entities and strategic measures, this constraint requires that recommended strategies not compromise infrastructure owned and maintained by others. If compromised, the plan must include provisions to mitigate impacts and coordinate with the affected entities.

Furthermore, strategies should be in alignment with other entities' plans and programs. Wherever and whenever this is not possible, the affected entity will be engaged to determine if there is an acceptable refinement or revision to the plan and program can be identified.

4.2 "Do-Nothing" Strategy

This section describes the current and future conditions should "no action," structural or non-structural, be taken. As such, this "do-nothing" strategy is a viable strategy, and all other management strategies will be compared to the "do-nothing" strategy, as a baseline for plan comparison and evaluation.

4.2.1 Land Development in the Overflow Area

Eventual and imminent development of undeveloped land in the study area is highly likely. Within the 277 square mile study area, approximately 210 square miles are undeveloped. When conservation land, the Addicks Reservoir, parkland, and other public land is excluded, 165 square miles have future development potential. Of this, about 32.5 square miles (almost 21,000 acres) are subject to inundation from the Cypress Creek Overflow. Land development activity is expected to proceed from the east and from the south, and the land with the highest immediate land development pressure is primarily land within the overflow area. Figure 4.1 shows an aerial photograph of the study area along with the overflow and illustrates the amount of land subject to future development. This is also illustrated in the land use map developed by the Houston-Galveston Area Council, shown in Figure 4.2.

The inundation associated with the overflow from Cypress Creek to the Addicks Reservoir watershed presents challenges to land development activity in the areas subject to inundation. These challenges are different and more complex than those associated with traditional riverine flooding. The delineation of this area was accomplished by using an approximation method since a precise determination method is not available. Engineers will be required to demonstrate that land development projects result in no net loss of conveyance and no net increase in conveyance. This will typically require the development of a pre-project condition and post-project condition calculation.

The availability of two-dimensional models, such as the one utilized for this overflow study, are well suited for the simulation of the overflow. As such, two-dimensional models may be used to evaluate the impact of land development projects as it pertains to the overflow.

Developments will likely have to reserve land for accommodation of the overflow. Furthermore, additional land and facilities will likely be required to store the overflow in order to avoid increasing the rate of conveyance of the overflow through the site. Large master planned communities in the overflow area have the opportunity to develop and implement large scale master drainage plans to manage the overflow through their property. However, smaller developments, and those properties located in the deeper portions of the overflow, will be challenged in identifying economically-feasible development plans.

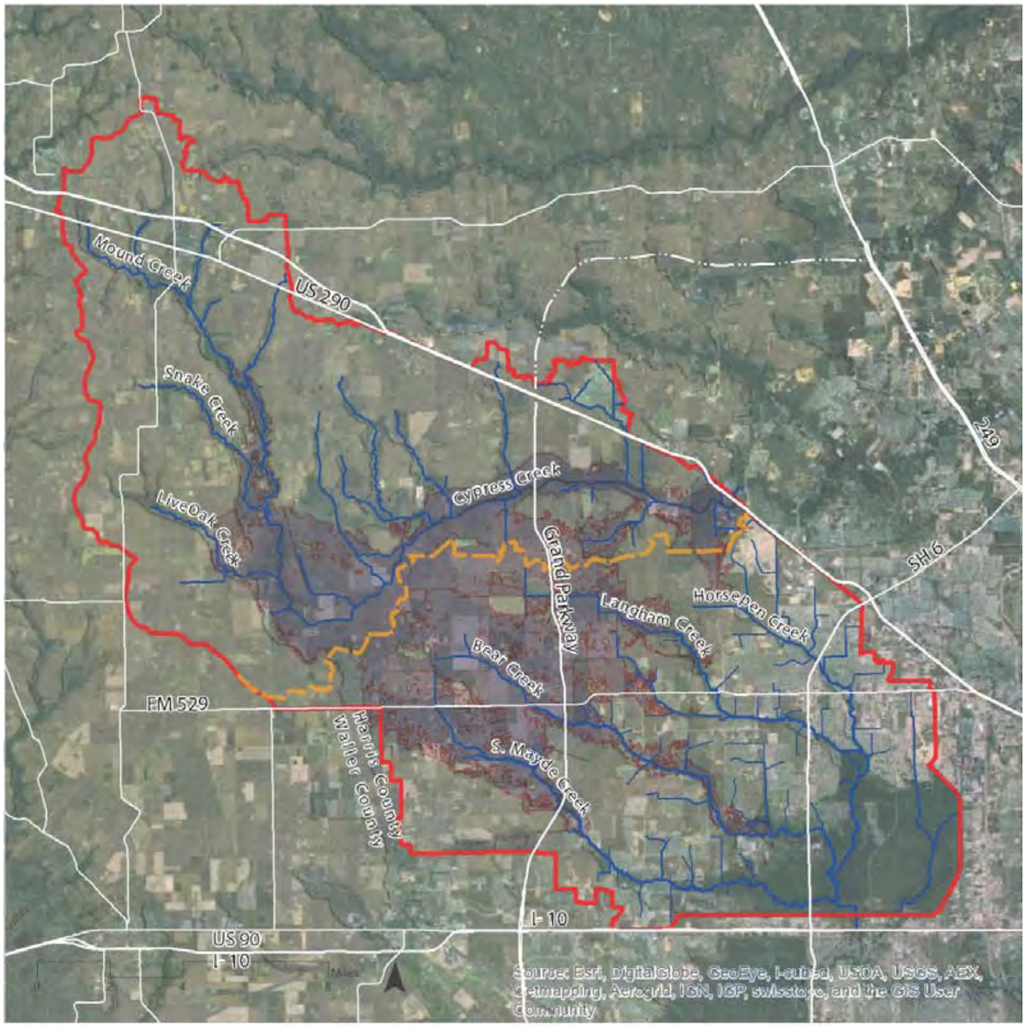


Figure 4.1 Aerial Photograph with 1% Floodplain

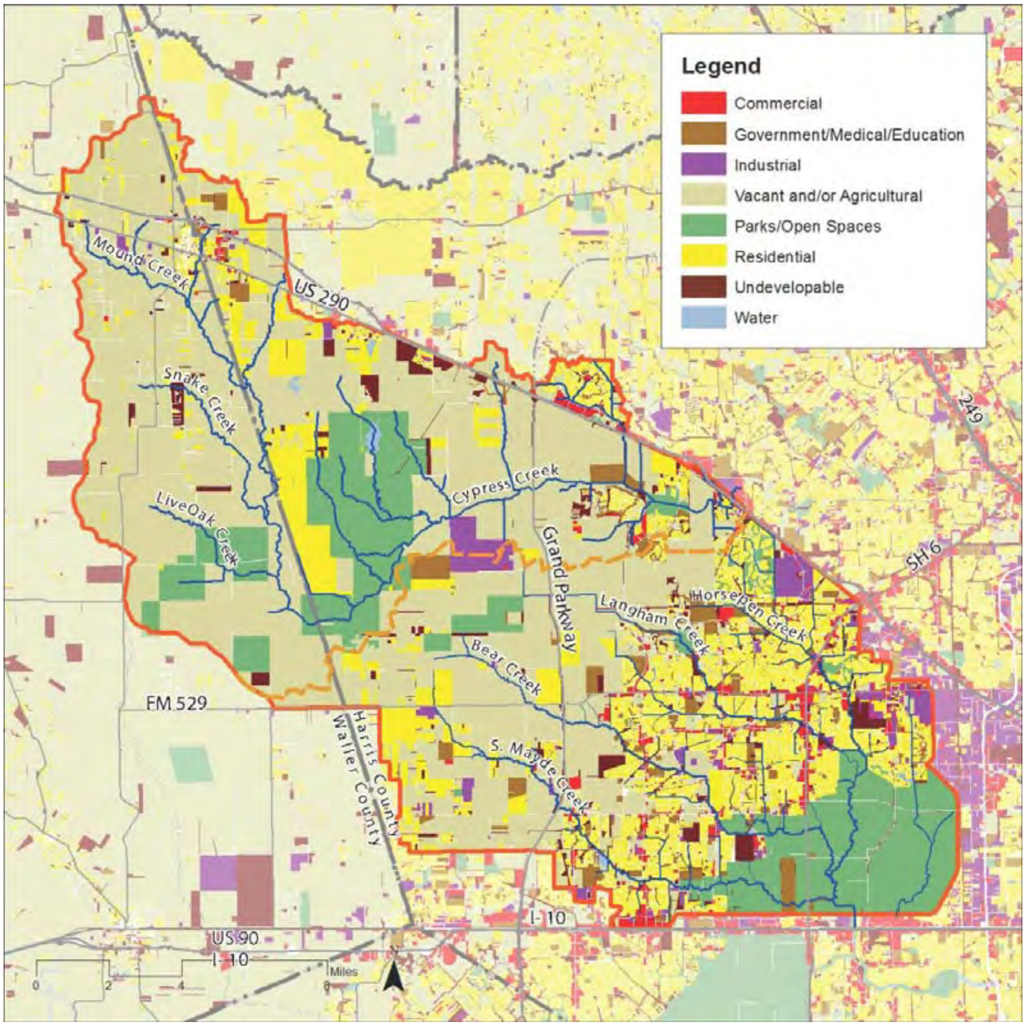


Figure 4.2 Land use in study area (Source: Houston-Galveston Area Council)

Development activities will be required to demonstrate no adverse impact in accordance with HCFCD and Harris County criteria. While these criteria were developed to ensure no increase in flood risk, they were developed with consideration of flooding along channel systems throughout Harris County rather than consideration of the overflow phenomena. In order to ensure no increase in flood risk and to avoid unintended impacts associated with management of the overflow, additional measures are likely needed.

One potential risk is the loss of overflow dissipation provided by the natural undeveloped and agricultural land. As mentioned earlier, smaller overflow events have been observed near the watershed divide that are not later observed in the Addicks Reservoir.

This has been attributed to the infiltration and attenuation provided by the existing undeveloped land. If this land is developed, the overflow will be conveyed and stored, but it is unlikely that the dissipation provided by the undeveloped areas will be duplicated.

As development in the area progresses, there will be market pressure on undeveloped tracts to follow the same course. Potential real estate values will rise, increasing development margins and allowing for the development of tracts with a lower housing yield than has been traditionally been constructed in the region. In such cases, areas deeper in the overflow will also develop. While all developments must demonstrate no downstream or upstream impact, land development activity in areas of higher and deeper flood risk have a much smaller margin of error.

Absent a regional management plan, smaller-scale management plans will be devised for new communities as they are developed, leading to a series of disconnected plans that will protect the individual developments but won't necessarily work in concert to provide protection throughout the region. It is possible that problems may occur that are not captured in impact studies, and those impacts will need to be addressed and mitigated in the future.

Land development activity in the Upper Cypress Creek watershed (upstream of the overflow) and the Addicks Reservoir watershed will also contribute additional runoff volume to the Addicks Reservoir. With the current operating policies, there is no availability for additional runoff volume in the reservoir.

4.2.2 Structural Flood Damage

Most flood risks to existing structures in the study area lies within the Addicks Reservoir watershed, where homes in the watershed's riverine floodplains have the potential to be inundated during storm events. There has been a history of house flooding along South Mayde Creek, Bear Creek, and Horsepen Creek. In addition, there are structures subject to flooding in the overflow and along upper Cypress Creek and Mound Creek, although these areas are mostly undeveloped.

The HCFCD has developed a structural database of homes estimated to be subject to flooding. This database estimates the first floor elevation for each structure. This estimation is typically based on an adjustment to the LiDAR data to reflect the elevation of the structure above grade. In some instances, this estimated elevation has been updated with information from a field survey. This structural database was utilized, along with computed flood elevations, to assess the structural risk associated with major flooding sources in the study area. This is discussed in greater detail in Appendix E.

Without a regional plan, development criteria strive to ensure that new development does not increase existing flood risk. Therefore, it is assumed that in the "without project" condition, the current risk of flooding for these structures will remain unchanged. It is also assumed that new development will occur despite the existing flood risk, and therefore new structures will be constructed 1.5 feet above the base flood (1%, or 100-year) elevation, in accordance with Unincorporated Harris County Floodplain regulations.

In addition, without a regional plan, current flood risk along existing channels will not be addressed. While development will likely avoid the floodplain along the upper portion of Cypress Creek, there is already development within the 1% (100-year) floodplain along many of the Addicks Reservoir tributaries, including South Mayde Creek, Bear Creek, and Horsepen

Creek. Homes, infrastructure, and parks in the overflow floodplain will continue to be subject to flooding from overflows.

4.2.3 Addicks Reservoir

The unique hydrology for Addicks Reservoir is discussed in Appendix B: Addicks Reservoir Hydrology. In summary, the Addicks and Barker reservoirs were initially designed under a different operating concept than is currently implemented. The original concept called for un-gated conduits with a combined peak discharge of 15,700 cfs. However, the design and operational procedures for the Addicks and Barker Reservoirs were modified, and today the reservoirs are gated, with a maximum combined release of 2,000 cfs when the gates are open (the gates are closed when there is existing rainfall or the threat of rainfall).

The federal government acquired land upstream of the reservoirs based on the original operating plan, which called for a levee along the Cypress Creek and Addicks Reservoir watershed divide to prevent the overflow from entering the Addicks Reservoir watershed. They later purchased additional land upstream of the Addicks Dam when it was determined that this would be more cost effective than constructing the levee.

Table 4.1 depicts key data associated with both the Addicks and Barker reservoirs.

Current development policy aims to prevent the increase in peak discharge from development activity, as peak discharges define flood risk along downstream channels. However, the flood risk within the Addicks and Barker reservoirs, with their restricted release policy, is driven by inflow volume. Detention associated with land development in the Addicks Reservoir watershed will offset peak discharges, and will delay the time it takes for runoff to reach the watershed; however, it will not mitigate the increase in volume associated with land development.

Development in the Cypress Creek watershed will also result in an increase in runoff volume. Although the peak discharge associated with the overflow will not increase, flood flows along Cypress Creek will rise for a longer duration as the watershed develops, resulting in an increased overflow volume. A large portion of the upper Cypress Creek watershed lies within Waller County, and is outside the jurisdiction of the HCFCD and Harris County. However, Waller County has adopted similar criteria as Harris County, and it is anticipated that their policy will continue to mirror Harris County policy.

Table 4.1 Addicks and Barker Reservoir data

	Addicks Reservoir	**Barker Reservoir**
Watershed area (square miles)	136	130
Elevation (1973 adj. of 1929 datum)		
Top of dam	122.7	114.7
Standard project flood (approx. a 1,000 yr frequency for Addicks Res. and a 500-yr frequency for Barker Res.)	110.6	100.4
Natural ground at ends of dam	112.0	106.0
Government owned land	106.1	97.3
1% (100-Year)	104.1	97.8
March 1992 flood (Barker flood of record)	100.6	95.9
Conduit invert	71.1	73.2
Storage Capacity (acre-feet)		
Standard project flood	178,556	123,653
Natural ground at ends of dam	200,800	209,000
Government owned land	116,263	83,410
March 1992 flood of record	57,956	66,910
Surface area (acres)		
Natural ground at ends of dam	16,423	16,739
Government owned land	12,460	12,060

Note: Data in Table 4.1 was obtained from the U.S. Army Corps of Engineers – Galveston District's 1995 report "Buffalo Bayou and Tributaries, Texas Reconnaissance Report on Section 216 Study of Addicks and Barker Reservoirs at Houston, TX".

Appendix D: Land Use and Stormwater Runoff Rates Investigation considers the impact of land development on runoff volume. It was determined that, for a single 24-hour 1% (100-year) rainfall event, a typical land development will increase the volume of runoff by the volume equivalent to two inches over the development. Appendix B considered the cumulative risk to Addicks Reservoir based on long term simulations. These analyses determined that the future development of the Addicks Reservoir watershed and Upper Cypress Creek watershed would increase the total pool volume and elevations in the Addicks Reservoir.

4.2.4 Conservation Land

Approximately 15,400 acres of land in the study area is currently held in conservation interests. Existing covenants and easements ensure the preservation of this land and there is no risk of future development of this property. In addition, the HCFCD holds 440 acres of land for conservation interests. There are a number of potential uses for the conservation lands, including the maintenance of current agricultural practices; the preservation of existing remnant prairies and wetlands; and the restoration of prairie, wetlands and natural streams. Some of the latter take the form of mitigation banks, where credits are sold to offset impacts elsewhere.

Substantial ecological value is obtained from contiguous green space when compared to non-contiguous green space in the same area. It is anticipated that conservation interests will continue to move to secure more land; however, development pressure in the study area will impact land prices and affect landowner motivations. This could potentially hinder conservation interests.

Without a regional plan, land development interests will be required to dedicate substantial land to facilities that convey the overflow. This will result in green space preservation, but this land will be altered and excavated to convey and store the overflow. Economics may dictate that certain smaller tracts, and tracts subject to deeper overflows, may not develop, leaving some intermittent vacant tracts in the overflow area. The cumulative impact of this type of land development will likely result in intermittent areas that are undeveloped and green space; however, these areas will probably not be contiguous and will have minimal ecological value.

4.2.5 Summary

Without a management plan, land development activity will continue. However, the development yield on the property will be incrementally reduced because of the need to convey the overflow.

The “do nothing” strategy will result in a missed opportunity to increase the area’s conservation footprint. Current conservation efforts would continue, however conservation will likely become more difficult with anticipated increases in land cost as development pressure grows. Similarly, “do nothing” strategy would result in a missed opportunity to address the anticipated increase in flow volume into the Addicks Reservoir as development occurs.

4.3 Development of Management Strategies

The development of management strategies progressed through three steps. First, a number of conceptual strategies were introduced and discussed with the steering committee. These strategies included both structural concepts, such as the construction of conveyance channels and large-scale reservoirs; and non-structural concepts, such as the identification of regions where restrictions on land use and development could be required. After initial investigation and discussion, some of these were omitted from further consideration, and “bookend” solutions were developed for the remaining concepts. In the bookend solutions, the strategies were generally considered as stand-alone solutions, and were developed in a manner to provide, where possible, a full solution. This facilitated a “biggest case” consideration of the concepts.

The second step was the development of management plans. A workshop was held with the steering committee at which each of these bookend solutions was evaluated and discussed, and ideas were developed for how they might be more effective in combination with other measures. The plans were combined in a manner that attempted to optimize performance in consideration of the objectives and constraints. A total of six management strategies were developed.

Finally, two of the six management strategies were identified as the most desirable and carried forward for additional consideration. For these two, cost estimates were further refined and implementation plans and cost pro forma were developed.

4.3.1 Bookend Solutions

A number of concepts were initially identified and introduced. Structural concepts included conveyance measures that collect and convey the overflow downstream, levee measures that maintain the overflow in the Cypress Creek watershed, diversion measures that divert a portion of Cypress Creek flows to the Brazos River watershed, and storage measures that collect and store the overflow until it can be safely released. Nonstructural concepts involved acquisition and preservation of land subject to the overflow, along with various policy measures to address development in the overflow and/or to protect the Addicks Reservoir. Most of these were carried forward for further consideration; however, the levee along the watershed divide and the diversion to the Brazos River were omitted due to concerns with public acceptability and permitting.

Bookend measures fall under a number of categories, each of which have been assigned a letter category: non-structural (Category "A"), mitigation measures (Category "B"), storage (Category "C"), and conveyance (Category "D"). In addition, the do-nothing alternative described in Section 4.2 was assigned Category "E". The bookend solutions are listed in Table 4.2.

Table 4.2 Bookend solutions

No.	Bookend Solution	Description
A1	Acquisition of Overflow	• Prohibit development of areas in current overflow area • Establish conservation easements or fee ownership of overflow lands
A2	Overflow Development Criteria	• Develop and adopt policy to guide land development activity in the overflow • Establish a master two-dimensional hydraulic model to be utilized by developers in the analysis of proposed

Table 4.2 (Continued) Bookend solutions

No.	Bookend Solution	Description
A3	Overflow Conveyance Zone	• Acquire land (drainage easements or fee) in the primary conveyance area, which is the deepest portion of the overflow – area to be known as the "Overflow Protection Zone" • Define Overflow Protection Zone with two-dimensional model, using encroachments and maximum allowable rise in overflow flood elevation • Allow development in "Overflow Fringe" (the unprotected overflow), but require it to be at elevations above the allowable rise in the Overflow Protection Zone • Acquire land for "training" of overflow
A4	Prairie Restoration	• Undertake prairie restoration initiatives to decrease runoff from green space participating in a restoration program • Research suggests that native prairie vegetation increases the infiltration capacity of soil, including clay soils • This summary sheet assumes 1,000 acres of prairie restoration in the Upper Cypress watershed and 1,000 acres of prairie restoration in the Addicks Reservoir watershed. • This is not a complete solution, and will not eliminate overflow
B1	Upper Cypress Creek Extended Detention	• Develop and adopt policy requiring land development to detain a higher volume of runoff generally equivalent to full retention of 1% event) • Runoff will be drained at a much lower rate than pre-project • This is not a complete solution, and will not eliminate overflow
B2	Addicks Reservoir High Flow Retention	• Develop and adopt policy requiring land development to retain runoff without outfall • Infiltration and Evaporation will be utilized to "drain" basins • Because of prolonged drain time, basins will be designed to only accept high flows
B3	Development Options	• Develop incentives to encourage development to implement measures to reduce runoff volume • Incentives may include reduction in detention requirement • May be used to facilitate small site commercial development • Measures may include Low Impact Development features such as rain gardens, bio swales, rainwater harvesting, and permeable pavement • This is not a complete solution, and will not eliminate overflow
C1	Katy-Hockley N – Cypress Reservoir	• A reservoir with an earthen dam along Longenbaugh Rd and Katy-Hockley Road. • Un-gated outlets to Bear Creek, S. Mayde Creek, and Langham Creek. • Gated outlet to Cypress Creek – operated to duplicate pre-project flow conditions.
C2	Mound Creek Reservoir	• A reservoir with an earth dam downstream of confluence of Mound Creek and Live Oak Creek • Gated outlet to Cypress Creek- operated to prevent discharge that contributes to overflow and to prevent inducing additional flood risk

Table 4.2 (Continued) Bookend solutions

No.	Bookend Solution	Description
C3	JPL Detention	• A lake system is proposed in John Paul's Landing Park. There is freeboard above the permanent water surface available for detention. • A portion of the available detention is reserved for the Langham Creek Regional Plan • Residual detention volume would be used to manage overflows east of Katy-Hockley Road • The detention lakes would connect to Bear Creek via a channel with a control structure that governs flow in each direction
C4	Katy-Hockley Reservoir	• Construct a reservoir with an earth dam along Longenbaugh and Katy-Hockley Roads • Reservoir would have two cells separated by an earth berm to allow for differing stage elevations • Reservoir entirely located in Addicks Reservoir watershed • Un-gated outlet to Bear Creek
D1	Overflow Conveyance Channel	• A widened corridor channel extension of Bear Creek to convey overflow to Addicks Reservoir watershed • Widened corridor channel extends from Cypress Creek watershed divide to West Little York • Conventional channel enlargement and deepening from West Little York into Addicks Reservoir • Attenuation area at collection channels to slightly reduce overflow rate
D2	Overflow Bermed Floodway	• Establishment of a "floodway" contained by berms that define overland flow path along existing Bear Creek channel and extended to collection area • Floodway will transition into existing Bear Creek channel upstream of West Little York • No modification to Bear Creek downstream of West Little York • Training berms will collect overflow south of watershed divide and funnel flow into floodway • Perimeter channels will be constructed on exterior of each berm to collect and convey local runoff
E	Do-Nothing	• When flood flows in Cypress Creek reach a certain threshold flood flows break over the south watershed divide and flow overland to tributaries of Addicks Reservoir (primarily Bear Creek and South Mayde Creek). • This approach describes the status-quo and the impacts of taking no deliberate actions, structural or non-structural, to address the overflow area. • Future development activity within the overflow area and tributary watersheds will be in conformance with Harris County Flood Control District criteria and other relevant criteria

Reservoir storage measures are those that manage the overflow by storing large volumes of runoff in designated reservoir areas. The reservoir will slowly release runoff in a manner that does not result in an overflow. Two primary bookend reservoirs were considered – a reservoir in the Addicks Reservoir and Cypress Creek watersheds that collects overflow waters, known as the Katy-Hockley N - Cypress Reservoir (C1); and a reservoir along Mound Creek (C2), upstream of the overflow that strives to reduce flows and eliminate the overflow. The Mound Creek Reservoir concept requires a small berm along the watershed divide to prevent residual overflows that would occur, even with the reservoir in place. Both of these bookend solutions must adhere to Dam Safety Requirements of the Texas Commission on Environmental Quality (TCEQ), which requires that the facilities adequately and safely store stormwater from a flood resulting from the Probably Maximum Precipitation (PMP) event - an event considered to be the most critical possible rainfall. For this reason, these plans would require the acquisition (fee or drainage easement) of land necessary to contain the pool required to store stormwater generated by this event. In addition to these two larger storage concepts, storage obtained using residual detention capacity in the HCFCD's John Paul's Landing Stormwater Detention Basin may be used to manage flows (C3).

Conveyance measures are those that manage the overflow by concentrating it into reserved or defined corridors that convey it to the Addicks Reservoir. Two bookend conveyance measures were considered: the conveyance of the overflow via an enlarged Bear Creek (D1); and the conveyance of the overflow via a bermed floodway (D2), where floodway is defined as an area designated for high conveyance of floodwaters (not to be defined according to FEMA's very specific definition of a regulatory floodway).

Non-structural measures are those that reduce flood damage and risk in the overflow without physically altering the drainage system or overflow. Four specific non-structural measures were considered: Acquisition (measure A1), Development Criteria (measure A2), an Overflow Protection Zone (measure A3), and Prairie Restoration (measure A4). Two of these – Development Criteria and Prairie Restoration- fall short of the "bookend" concept because they do not provide a full solution, as a full solution is not viable. However, they are still presented in this solution set because they may potentially contribute to a larger combined solution.

Mitigation measures are those measures that strive to offset the potential adverse impacts created by land development. Current policy requires development to install stormwater detention, and this is an example of a mitigation measure commonly employed. However, as noted earlier, traditional mitigation measures do not address the unique phenomena associated with the Cypress Creek Overflow and the Addicks Reservoir. Mitigation measures are generally considered non-structural measures, but for purposes of this study they are categorized separately. Three specific mitigation measures were considered: Upper Cypress Creek Extended Detention (B1), Addicks Reservoir High-Flow Retention (B2), and Development Options (B3). All of these fall short of the "bookend" concept because they do not provide a full solution, as a full solution is not viable. However, they are still presented in this solution set because they may potentially contribute to a larger combined solution.

4.3.2 Management Plans

Six management plans were developed from the various bookend solutions by combining various elements. In addition, some new elements were introduced in the formulation of the six plans. These include the Katy-Hockley Reservoir (C4) and John Paul's Landing Detention (C3). Larger structural bookend elements were reduced in size and combined with other features to present more reasonable and economical measures.

Management Plan 1 – Katy-Hockley Reservoir

This strategy is based upon the Katy-Hockley Reservoir (C4) located entirely in the Addicks Reservoir watershed. The reservoir would capture overflow after it crosses the watershed divide. This measure would be supplemented by storage within John Paul's Landing (JPL) (C3) and Development Criteria (A2). The reservoir would outfall into Bear Creek, which would be enlarged between the reservoir and the downstream development (where the existing channel is larger).

Management Strategy 1 – Katy-Hockley Storage is depicted in Figure 4.3. There would be two cells within the reservoir, referred to as the lower pool and the upper pool. The lower pool is located along Katy-Hockley Road, and the upper pool is located immediately to the west of and adjacent to the lower pool. The purpose of the two cells is to maximize the use of available volume within the reservoir footprint without exceeding the natural ground elevation at the watershed divide, as this is necessary to prevent an influence on the volume of overflow.

The berms would vary in height, with a maximum height of 11feet. They would be constructed using excavated material from within the reservoir. This would be the only excavation within the reservoir.

Bear Creek will be enlarged approximately 22,000 feet, from the outlet of the lower pool near the intersection of Longenbaugh Road and Porter Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel will utilize natural channel design principles within a 500-foot corridor. The channel will be sufficiently deep to accept drainage from lateral channels. In addition, an outlet channel will be located along the perimeter of the dam to provide drainage access for the upper pool.

The two pools will have a combined maximum 1% (100-year) release of 4,500 cfs, which is the maximum capacity of the lower reach of Bear Creek.

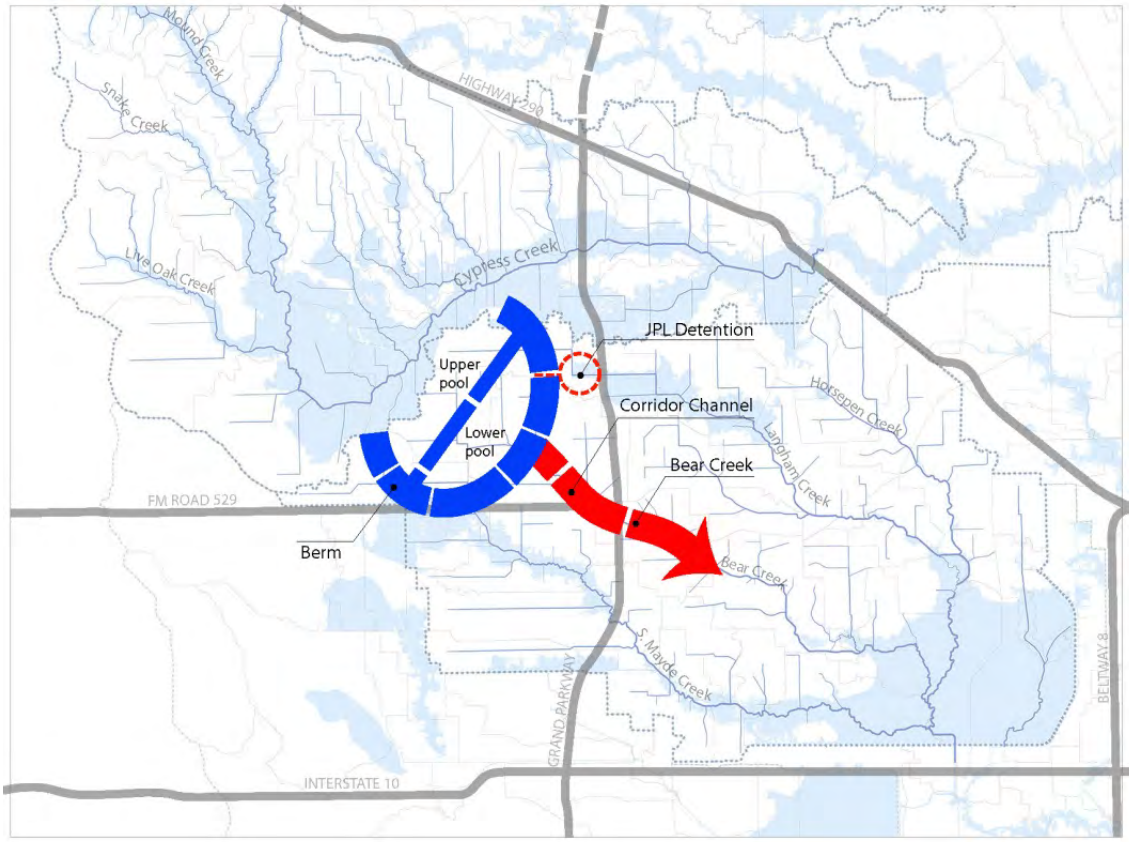


Figure 4.3 Management plan 1 schematic – Katy-Hockley Storage

The lower pool will inundate about 3,300 acres at a 1% (100-yr) pool elevation of 161.9 feet, providing 6,600 acre-feet of storage. It will outfall at a peak rate of 3,000 cfs via a constrained channel section. Not including current channel areas, the average depth is about two feet, and the maximum depth is about five feet. This cell will drain in about two days.

The upper pool will inundate about 2,600 acres at a 1% (100-year) pool elevation of 165.4 feet, providing 4,200 acre-feet of storage. It will outfall at a peak rate of 1,500 cfs via a box culvert conduit into an outlet channel that will run along the perimeter of the dam and ultimately into Bear Creek near the lower pool outlet. The average depth is about two feet, with a maximum depth of eight feet. This cell will drain in about five days.

In both pools, the dam will include a wide spillway that will protect the structure from larger events. During extreme events (those larger than 1% or (100-year), flows may exceed downstream capacity; however, the net impact of the extreme event flow will be less than the existing condition.

In total, 5,899 acres of land will be inundated during the 1% (100-yr) event. This includes 5,425 acres of private land, 245 acres of conservation land, and 230 acres of public land. The current footprint includes Paul Rushing Park; however, this footprint could be revised to avoid the park. This would result in a decrease in storage volume.

Detention would also be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into John Paul's Landing. Approximately 300 acre-feet of storage is required in John Paul's Landing to accommodate the 1% (100-year) overflow east of Katy-Hockley Road.

This strategy includes the adoption of development criteria that prevents the increase in runoff volume into the Addicks and Barker reservoirs as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome based, and developers will determine the approach to managing this runoff.

Management Plan 2 – Mound Creek Reservoir with Overflow Conveyance "A"

This strategy is based on a scaled down version of both the Mound Creek Reservoir (C2) and the Overflow Conveyance Channel (D1). The conveyance channel is reduced in size and capacity to recognize the constraints in flow rate in the lower reach of Bear Creek, and to therefore avoid the need for this channel modification in the developed portion of lower Bear Creek. This measure would be supplemented by John Paul's Landing storage (C3) and Development Criteria (A2). The conveyance channel would include collection channels along the watershed divide (this "collection" configuration is known as Conveyance "A"). Bear Creek would be constructed using natural channel design techniques within a 500-foot corridor.

Management Plan 2 – Mound Creek Reservoir with Overflow Conveyance "A" is depicted in Figure 4.4. The channel will be expanded to convey 4,500 cfs of discharge into the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The channel will utilize natural channel design techniques, and will be sufficiently deep to accept drainage from lateral systems. The overflow will be intercepted by collection channels adjacent to, and south of, the watershed divide that convey flow to the conveyance channel (Conveyance "A").

The existing peak 1% (100-year) overflow of 12,678 cfs will be reduced by the construction of the Mound Creek Reservoir. However, since the reservoir will still allow for a considerable overflow, the required storage volume is substantially smaller. For a 1% (100-year) event, the reservoir will fill to a pool elevation of 188.0 feet and inundate 2,880 acres of land, storing 15,730 acre-feet. The maximum storage depth would be 13 feet, with an average depth of seven feet. The vast majority of the reservoir will drain in 3-4 days, although the lowest areas near the outlet may drain over a week's time. With the reservoir in place, the 1% peak overflow would be reduced from 12,678 cfs to approximately 5,500 cfs. The 1% peak overflow volume would be reduced from 23,000 acre-feet to approximately 17,000 acre-feet into the Addicks Reservoir watershed. The remainder of the overflow balance, 6,000 acre-feet, would be slowly released into Cypress Creek. This reservoir will require 3,765 acres of land, and will provide 15,730 acre-feet of storage during the 1% (100-year) event.

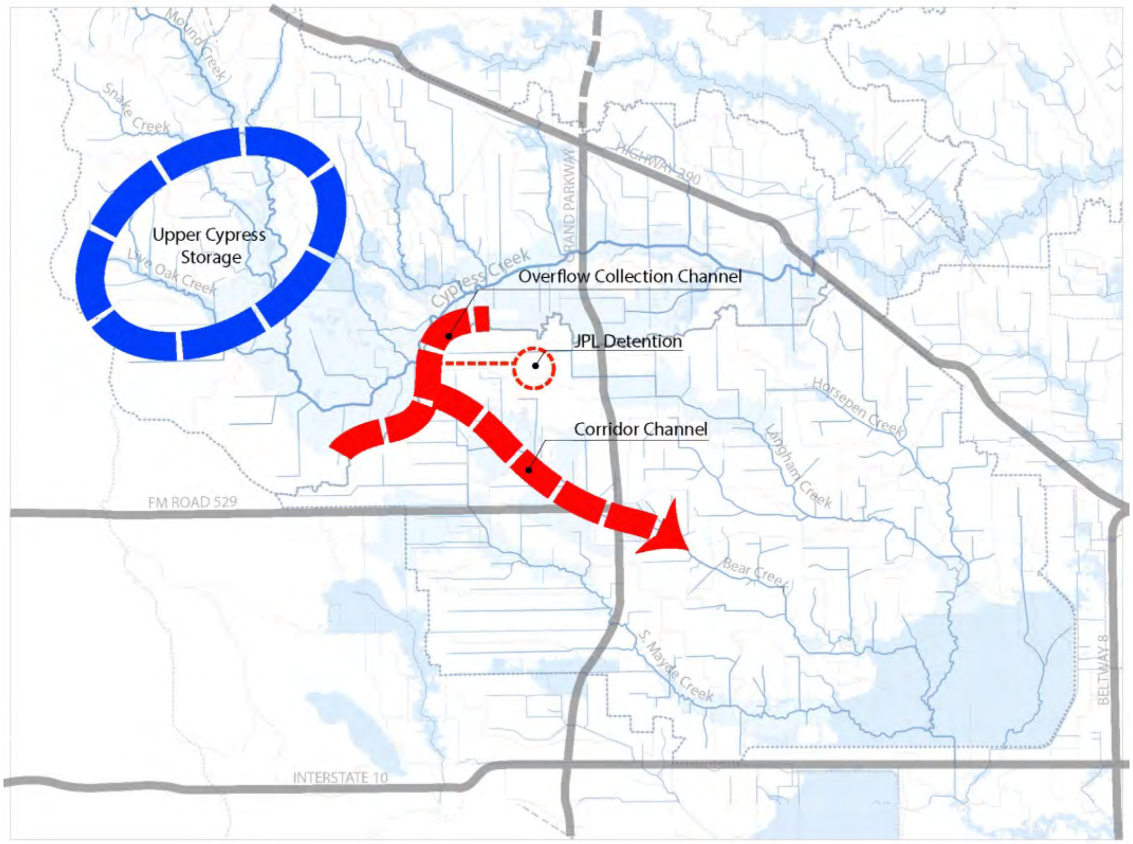


Figure 4.4 Management plan 2 schematic – Mound Creek Reservoir with Overflow Conveyance "A"

The reservoir will be controlled by an earthen dam with a maximum height of 22 feet. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur in the reservoir. The embankment would include a stabilized emergency spillway that would convey stormwater flows in excess of the 1% (100-year) event. Such flows may exceed the design capacity of existing infrastructure, but would not exceed current flow rates for a similar event.

There would be a primary outlet structure to Mound Creek, and a secondary outlet structure to Live Oak Creek. The Mound Creek outlet would be in the form of an armored open channel, while the Live Oak Creek outfall would be via a boxed structure.

The reservoir footprint, which consists of the pool as well as the land necessary for the berm, encompasses 3,765 acres of land. This includes 1,520 acres of private land and 2,245 acres of conservation land, which are private lands with conservation easements and/or protected conservation use.

Detention would also be provided within John Paul Landing. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into

John Paul's Landing. Approximately 300 acre-feet of storage is required in John Paul Landing to accommodate the 1% (100-year) overflow east of Katy-Hockley Road.

This strategy includes the adoption of development criteria that prevents the increase in runoff volume into the Addicks and Barker reservoirs as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome based, and developers will determine the approach to managing this runoff.

Management Plan 3 – Mound Creek Storage with Overflow Conveyance "B"

This strategy is based upon a scaled down version of both the Mound Creek Reservoir (C2) and the Overflow Conveyance Channel (D1). The conveyance channel is reduced in size and capacity to recognize the flow rate constraints in the lower reach of Bear Creek, and to therefore avoid the need for this channel modification in the developed portion of lower Bear Creek. This measure would be supplemented by JPL storage (C3) and Development Criteria (A2). The conveyance channel would be located downstream of an overflow collection and conservation area downstream of the watershed divide. The overflow will be collected in channels that are supplemented by small berms along the perimeter of the overflow collection area (this "collection" configuration is known as Conveyance "B"). Bear Creek would be constructed using natural channel design techniques within a 500-foot corridor. This strategy is similar to that presented previously, with the primary difference being the means of collecting the overflow and conveying it into the channel.

Management Plan 3 – Mound Creek Reservoir with Overflow Conveyance "B" is depicted in Figure 4.5. The channel will be expanded to convey 4,500 cfs of discharge into the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The channel will utilize natural channel design techniques, and will be sufficiently deep to accept drainage from lateral systems. The overflow would continue to inundate about 2,200 acres, 1,580 acres of which is privately held land and the balance is currently being held as conservation land. The 1,580 acres will be preserved as a conservation area, and the collection channels will be located on the south and east perimeter of this conservation area. The conservation area helps assure that the collection will not influence overflow rates and volume, and also provides for additional conservation area. In addition, it will provide some additional attenuation of overflow.

The existing peak 1% (100-year) overflow of 12,678 cfs will be reduced by the construction of the Mound Creek Reservoir. However, since the reservoir will still allow for a considerable overflow, the required storage volume is substantially smaller. For a 1% (100-year) event, the reservoir will fill to a pool elevation of 188.0 feet and inundate 2,880 acres of land during the 1% (100-year) event, and will store 15,730 acre-feet of stormwater. The maximum storage depth would be 13 feet, with an average depth of seven feet. The reservoir would drain in 3-4 days. With the reservoir in place, the peak overflow would be reduced from 12,678 cfs to approximately 5,500 cfs. The peak 1% overflow volume would be reduced from 23,395acre-feet to approximately 17,000 acre-feet.

The reservoir will be controlled by an earthen dam with a maximum height of 22 feet. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur within the reservoir. The embankment would include a stabilized emergency spillway that would convey stormwater in excess of the 1% (100-year) event. Such flows may exceed the design capacity of existing infrastructure, but would not exceed current flow rates for a similar event. This reservoir will require 3,765 acres of land, and will provide 15,730 acre-feet of storage during the 1% (100-year) event.

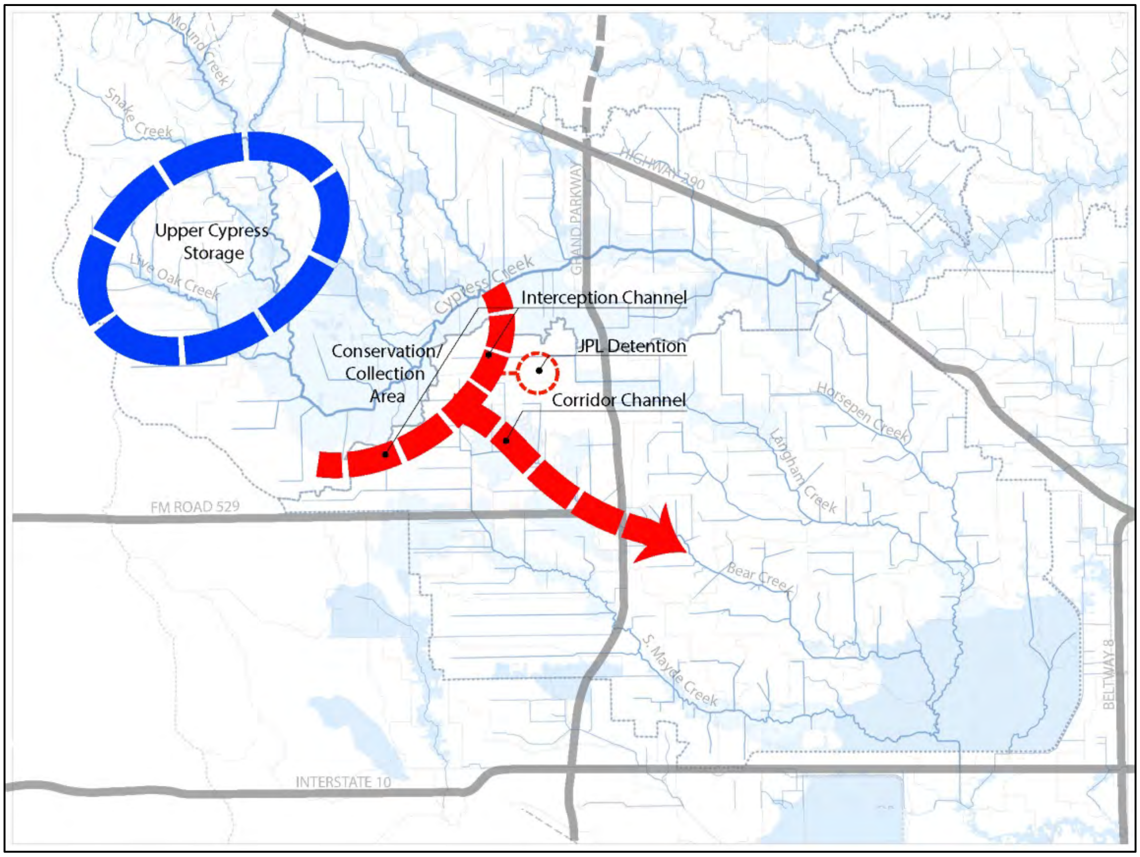


Figure 4.5 Management plan 3 schematic – Mound Creek Reservoir with Overflow Conveyance "B"

There would be a primary outlet structure to Mound Creek, and a secondary outlet structure to Live Oak Creek. The Mound Creek outlet would be in the form of an armored open channel, while the Live Oak Creek outfall would be via a boxed structure.

The reservoir footprint, which consists of the pool as well as the land necessary for the berm, encompasses 3,765 acres of land. This includes 1,520 acres of private land and 2,245 acres of conservation land, which is privately-held land with conservation easements and/or protected conservation use. In addition, the conservation area influences 2,200 acres, including 440 acres of public land (HCFCD Unit No. K700-01-0000) that is being held in conservation.

Detention would also be provided within John Paul's Landing. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into

John Paul's Landing. Approximately 300 acre-feet of storage is required in John Paul's Landing to accommodate the 1% (100-year) overflow east of Katy-Hockley Road.

This strategy includes the adoption of development criteria that prevents the increase in runoff volume into the Addicks and Barker reservoirs as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome-based, and developers will determine the approach to managing this runoff.

Management Plan 4 – Private Sector Strategy w/ Channel Reserve

This strategy is fully based upon the "Do Nothing" Measure (E), but includes the adoption of Development Criteria (A2). In discussions with the steering committee, it was the widely agreed that some development criteria is necessary to recognize the unique nature of the overflow area as well as the Addicks and Barker watersheds, and that the development and adoption of such criteria would occur even without a project. As such, this management strategy adequately serves as a surrogate for the "do-nothing" alternative. The development criteria will require the reservation of a corridor along Bear Creek to maintain the existing overflow and to allow for any future measures or solutions should they be desired.

Management Plan 4 – Private Sector Strategy w/ Channel Reserve is depicted on Figure 4.6. A 1,000-foot corridor will be defined along Bear Creek between the watershed divide and the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. As development occurs, the project will acquire land within the corridor.

Development criteria will be developed and adopted, and guidelines prepared, that establishes requirements and methods for evaluating potential impacts to the overflow area. These criteria will require the use of a two-dimensional flow model similar to the one used to delineate and quantify the overflow. The criteria will also require provisions to manage runoff volume, and the management of the equivalent of two-inches of runoff volume.

Developers may utilize the reserved corridor for their stormwater detention if they can demonstrate that there would be no adverse impact to the system. However, they would be required to dedicate this land to the public in lieu of compensation.

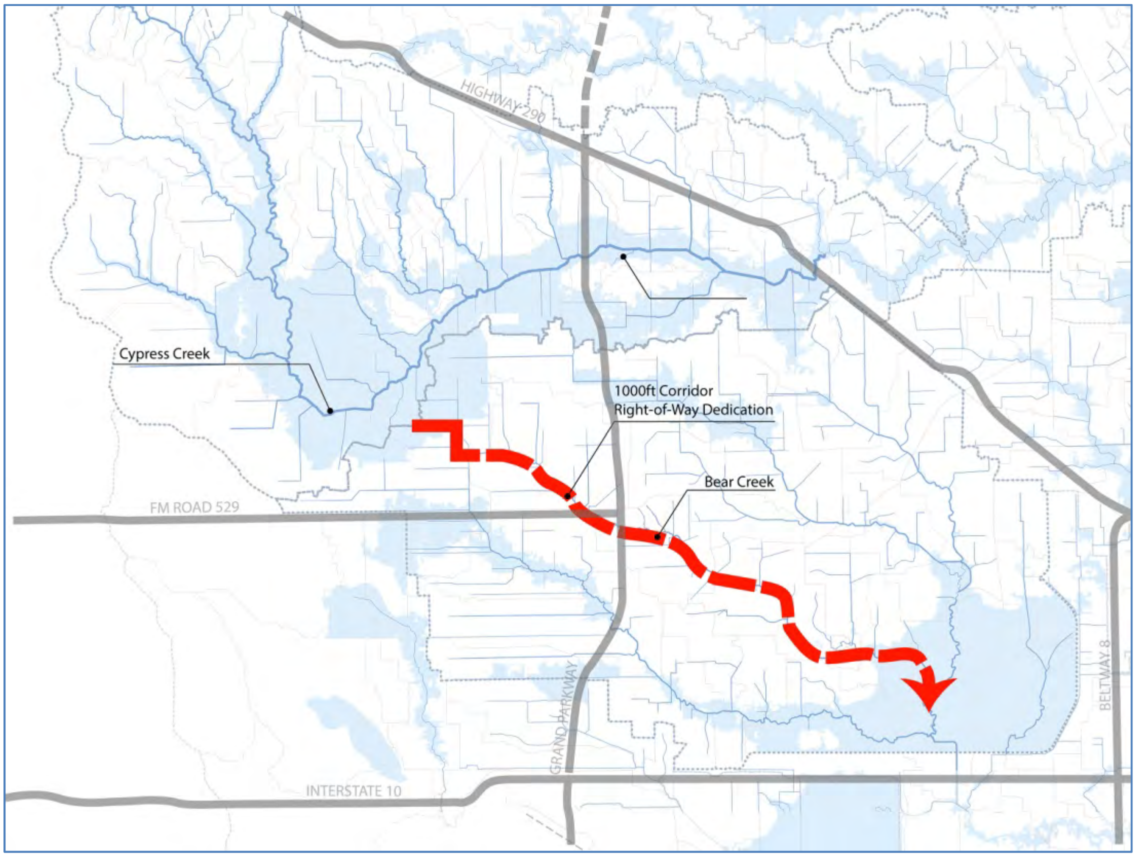


Figure 4.6 Management plan 4 schematic – Private Sector Strategy with Channel Reserve

Management Plan 5 – Katy-Hockley N - Cypress Reservoir

This strategy is based upon the Katy-Hockley N - Cypress Reservoir (C1) located in both the Upper Cypress Creek and Addicks Reservoir watersheds. The reservoir would capture and direct flow along Cypress Creek and the overflow area in one contiguous pool, and includes outlets to Cypress Creek and Bear Creek. Bear Creek would be enlarged between the reservoir and the downstream development (where the existing channel is larger). An internal reservoir balance channel and structure would be constructed to prevent the increase in volume to either Addicks Reservoir or Cypress Creek. This measure would be supplemented by John Paul's Landing storage (C3) and Development Criteria (A2).

Management Plan 5 – Katy-Hockley N - Cypress Reservoir is depicted in Figure 4.7. The reservoir would be formed by an earthen berm or dam that extends along Longenbaugh Road, around and outside of Paul Rushing Park, and northward along Katy-Hockley Road across Cypress Creek. The berms would vary in height, with a maximum height of eight feet. It would be constructed using excavated material from within the reservoir. This is the only excavation that would occur within the reservoir.

Bear Creek will be enlarged for a distance of about 24,000 feet, from the outlet of the lower pool near the intersection of Longenbaugh Road and West Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road).

This enlarged channel will utilize natural channel design principles within a 500-foot corridor. The channel will be sufficiently deep to accept drainage from lateral channels. The outlet to Bear Creek will be restricted to 2,000 cfs via a boxed conduit. This restriction is necessary to prevent the diversion of additional flow volume from Cypress Creek to the Addicks Reservoir during events smaller than the 1% (100-year) event. The outlet to Cypress Creek will be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year) event, the release to Cypress Creek will be restricted to 5,300 cfs. This results in a combined maximum release rate of 7,300 cfs.

The 1% (100-year) reservoir pool elevation is 168, inundating 7,400 acres and providing 26,500 acre-feet of storage. The maximum depth in the basin, excluding existing channels, will be eight feet, with an average depth of four feet. Most of the reservoir will drain in 4-6 days, while the lowest areas near the outfall will drain in about eight days.

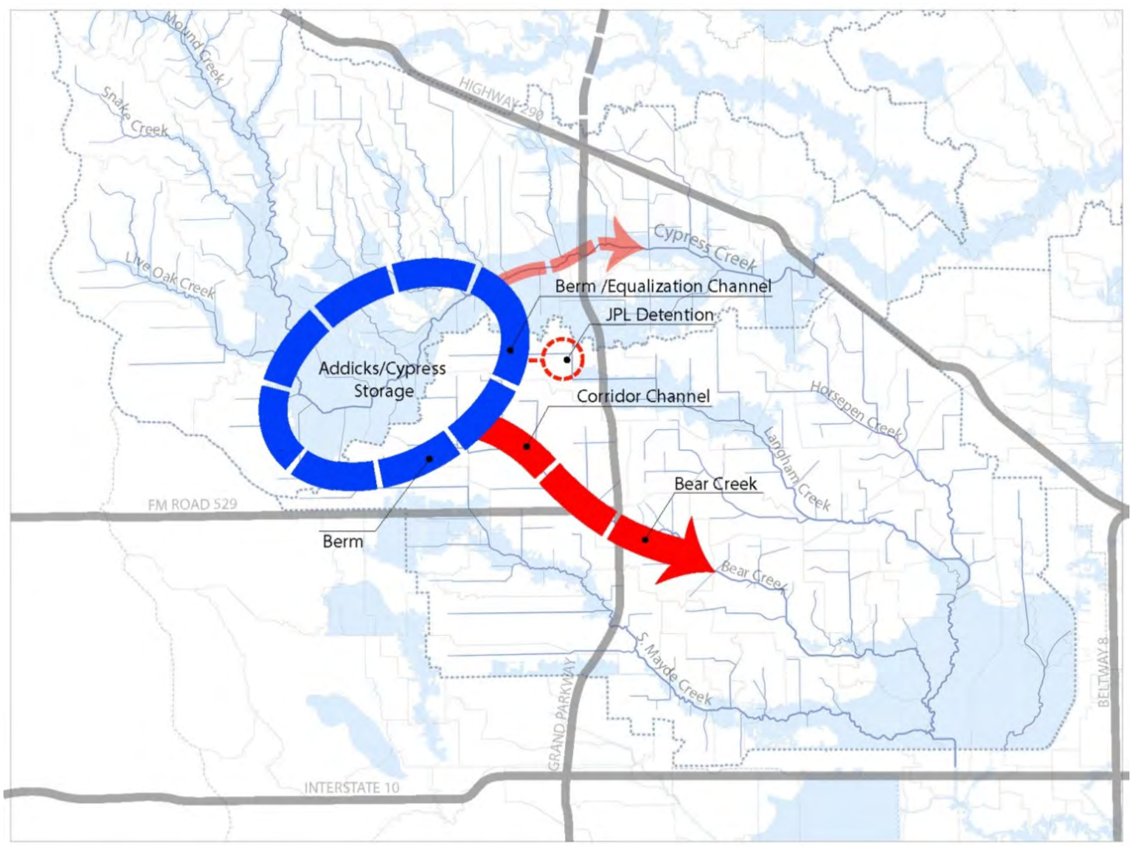


Figure 4.7 Management plan 5 schematic – Katy-Hockley N – Cypress Reservoir

The dam will include wide spillways that will protect the structure during larger events. During extreme events (those larger than the 100-year event), flows may exceed downstream capacity; however, the net impact of the extreme event flow will be less than the existing condition. There will be spillways that allow extreme event flows to discharge into both watersheds.

There will be a small channel inside the reservoir along the south dam that will direct low flows to the outlet to Bear Creek. In addition, there will be a channel inside the east dam that will allow flows to drain back to the Cypress Creek watershed from the Addicks Reservoir watershed. This is necessary because the higher elevations along Cypress Creek created by the dam will result in the diversion of additional volume across the watershed, and this channel is necessary to return volume to Cypress Creek. A backflow prevention structure will be constructed near the watershed divide to ensure the channel does not allow flows from the Cypress Creek watershed to the Addicks Reservoir watershed.

In total, approximately 7,400 acres of land will be inundated during the 1% (100-year) event. This includes 3,540 acres of private land, 3,401 acres of conservation land, and 459 acres of public land (held for conservation).

While 1% inundation will require 7,400 acres of right-of-way to impound 26,500 acre-feet of stormwater, it was assumed that the A2 reservoir would be required to accommodate the Probable Maximum Precipitation (PMP) event. This will require increasing the reservoir right-of-way to 11,260 acres and providing 56,500 acre-feet of stormwater storage.

Detention would also be provided within John Paul's Landing. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into John Paul's Landing. Approximately 300 acre-feet of storage is required in JPL to accommodate the 1% (100-year) overflow east of Katy-Hockley Road.

This strategy includes the adoption of development criteria that prevents the increase in runoff volume into the Addicks and Barker reservoirs as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome based, and developers will determine the approach to managing this runoff.

Management Plan 6 – Frontier Channel w Storage/Conveyance "B"/Storage

This strategy is based on a channel in a wide corridor (also known as a "frontier channel") with Storage/ Conveyance "B" (D1) measure. A wide "frontier" channel would be constructed along Bear Creek downstream to the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The plan would include a conservation area and collection system similar to Conveyance "B" described in Section 5.4. This measure would be supplemented by John Paul's Landing storage (C3) and Development Criteria (A2).

Management Plan 6 – Frontier Channel with Storage/Conveyance "B" is depicted in Figure 4.8. A 2,200 acre conservation area would be established immediately downstream of the overflow. This area would preserve about 1,580 acres of currently privately-held land, and would facilitate the attenuation of flow and interception of runoff into collection channels south and east of the conservation area. The collection channels would vary in width from 300 feet to 1,000 feet, and would provide attenuation of the overflow while conveying it to the "frontier" channel along Bear Creek.

Bear Creek would be widened and deepened as a "frontier" section, using natural channel design techniques and including intermittent structures to maximize storage and assist in the attenuation and reduction of flows. The frontier channel would be located in a 1,000-foot-wide corridor, and will extend for a length of about 24,000 feet. It will originate near the intersection of Katy-Hockley Road and West Road. In total, approximately 2,900 acres of land will be reserved for the project.

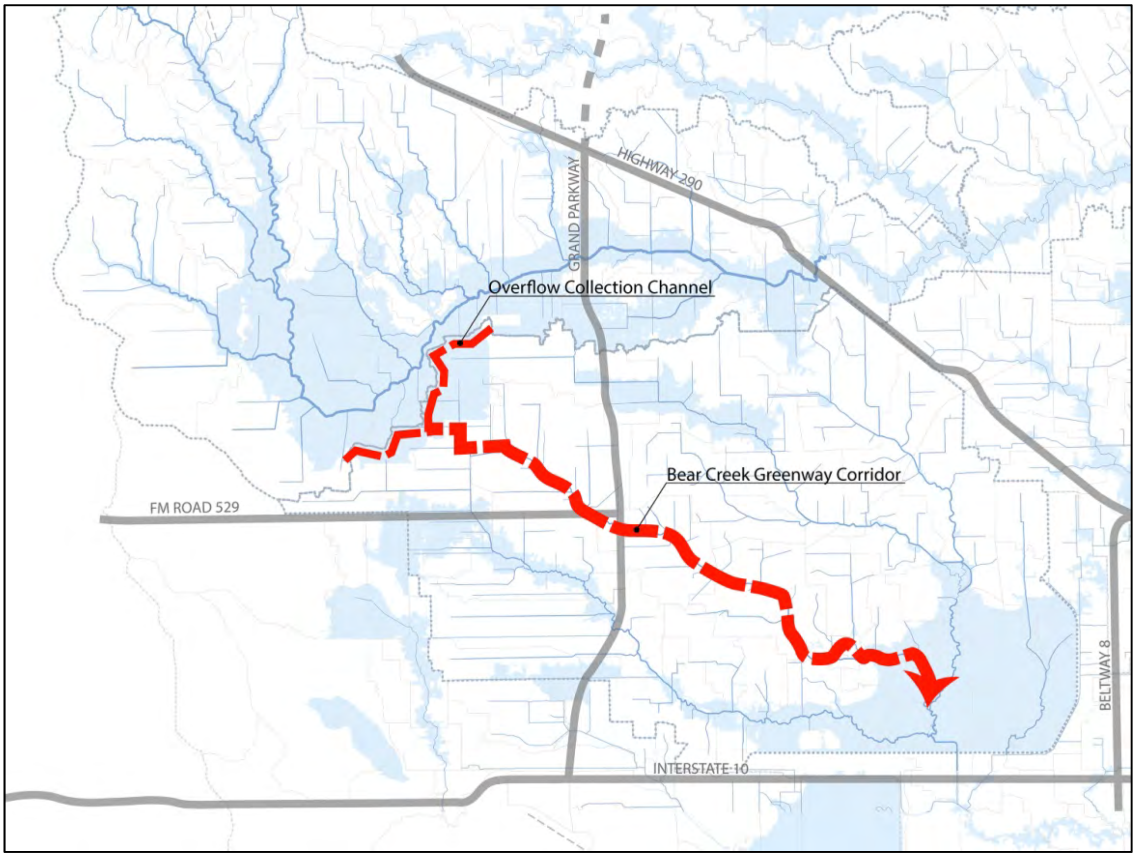


Figure 4.8 Management plan 6 schematic – Frontier Channel with Storage/Conveyance "B"

Detention would also be provided within John Paul's Landing. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into John Paul's Landing. Approximately 300 acre-feet of storage is required in John Paul's Landing to accommodate the 1% (100-year) overflow east of Katy-Hockley Road.

This strategy includes the adoption of development criteria that prevents the increase in runoff volume into the Addicks and Barker reservoirs as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome-based, and developers will determine the approach to managing this runoff.

Evaluation of Management Strategies

The management strategies were presented and discussed with the Steering Committee over the course of several meetings. In the course of the meetings refinements were made to the strategies, and additional strategies were added. The six strategies presented in this section include these refinements.

The six management strategies are summarized in Table 4.3. This table includes relative comparisons of the strategies' various attributes.

In addition, the evaluation included a complete consideration of the full set of planning objectives and constraints. The goal of the evaluation was to gain feedback from the Steering Committee in the evaluation of the objectives and constraints, to identify management strategies that the steering committee could accept and endorse, and ultimately to identify two strategies to carry forward for additional evaluation.

The following bullet points summarize considerations and conclusions of the steering committee and the planning team:

- The high cost and the implementation time associated with the structural solutions is of great concern to land development interests.

- In order to utilize conservation land as part of the solution, the project must in return increase the net value of conservation efforts in the study area.

- Development criteria that address runoff volume from future development must be adopted for both Harris County and Waller County, and it may be necessary to return in kind value back to Waller County in recognition of the county's adoption policy that addresses a problem in Harris County.

- Development criteria is necessary, however outcome-based criteria is preferred over prescriptive criteria.

- A private sector solution should always be considered as a viable option.

There was general consensus among the steering committee regarding these considerations and conclusions; therefore, they provided a framework for and they framed the further evaluation and identification of preferred strategies.

Table 4.3 Comparison of management plans

Plans 1-3

Parameter	**Plan 1**	**Plan 2**	**Plan 3**
	Katy-Hockley Reservoir	**Mound Crk Reservoir w Overflow Conveyance**	**Mound Crk Reservoir w Overflow Conveyance**
Managed Storage			
100yr Pool Elev	161.9 (upper pool)/ 165.4 (lower pool)	188.0	188.0
PMP Pool Elev	n/a	191.7	191.7
PMP+Freeboard (4.5')	n/a	196.5	196.5
100yr Storage (ac-ft)	10,800 (6,600 upper pool + 4,200 lower pool)	15,730	15,730
PMP Storage (ac-ft)	n/a	27,500	27,500
PMP Spillway Length (ft)	4,000	6,000	6,000
Storage/Conservation Land			
Private (ac)	5,424	1,520	3,100
KPC/Conservation (ac)	245	2,245	2,245
Public (ac)	230	0	400
Total (ac)	5,899	3,765	5,745
Collection/Channel Land			
Private (ac)	325	570	650
KPC/Conservation (ac)	0	30	0
Public (ac)	0	0	0
Total (ac)	325	600	650
Excavation/Earthwork			
Volume (cy)	4,600,000	8,200,000	8,900,000
Attributes			
Unit Land Value	Highest	Low	Low/Moderate
Change in Overflow Volume	None	Decrease	Decrease
Permits	Moderate	Most Difficult	Most Difficult
Criteria Change	Yes	Yes	Yes
Storage Area - Inundation Depth	8 ft max, 2 ft avg (upper pool)/5 ft max, 2 feet avg (lower pool)	13 ft max, 7 ft avg	13 ft max, 7 ft avg
Storage Area Drain Time	5 days (upper pool) 2 days (lower pool)	3 days (most)	3 days (most)
Land Removed from	15,000 ac	19,000	18,500
Cost			
Land	$176,000,000	$79,000,000	$117,000,000
Construction	$125,000,000	$128,000,000	$126,000,000
Professional	$27,500,000	$29,000,000	$28,000,000
Total	$328,000,000	$235,000,000	$271,000,000

Table 4.3 (Continued) Comparison of management plans

Plans 4-6

Parameter	**Plan 4**	**Plan 5**	**Plan 6**
	Private Sector with Channel Reserve	**Katy-Hockley N - Cypress Reservoir**	**Frontier Channel w Storage/Conveyance "B"**
Managed Storage			
100yr Pool Elev		168.0	
PMP Pool Elev		170.7	
PMP+Freeboard (4.5')		175.2	
100yr Storage (ac-ft)		26,500	
PMP Storage (ac-ft)		56,636	
PMP Spillway Length (ft)		8,000 (4,000+4,000)	
Storage/Conservation Land			
Private (ac)	0	5,120	1,180
KPC/Conservation (ac)	0	5,725	0
Public (ac)	0	415	400
Total (ac)	0	11,260	1,580
Collection/Channel Land			
Private (ac)	0	420	1,180
KPC/Conservation (ac)	0	0	0
Public (ac)	0	0	0
Total (ac)	0	420	1,180
Excavation/Earthwork			
Volume (cy)	TBD	7,100,000	20,000,000
Attributes			
Unit Land Value	Moderate	Moderate/High	Moderate
Change in Overflow Volume	None	None	None
Permits	Easiest	Difficult	Easy/Moderate
Criteria Change	Yes	Yes	Yes
Storage Area - Inundation Depth	n/a	8 ft max, 4 ft avg	n/a
Storage Area Drain Time	n/a	4-6 days	n/a
Land Removed from Overflow	19,000 (by others)	18,000 ac	18,000 ac
Cost			
Land		$206,000,000	$77,800,000
Construction		$134,000,000	$213,000,000
Professional		$29,000,000	$46,800,000
Total	n/a	$369,000,000	$337,000,000

4.3.3 Preferred Strategies

According to the TWDB Grant, two management plans are to be identified and studied in greater detail. For the reasons described below, it was determined that the two preferred strategies are Management Plan 3 – Mound Creek Reservoir with Overflow Conveyance “B”, and

Management Plan 5 – Katy-Hockley N - Cypress Reservoir. In addition, as a surrogate for the no-action alternative, the Management Plan 4 – Private Sector Strategy with Channel Reserve remains a viable option. Due to its passive nature, it does not warrant further analysis and refinement beyond the identification and adoption of development guidelines.

During the review and discussion of management strategies, the concept of the Mound Creek Reservoir was well received by the steering committee. The reservoir is located furthest away from areas of development pressure, and therefore the land may be less expensive. In addition, the topography of the area, with relatively more relief, results in more efficient storage. The reservoir could also be refined to include provisions for the Waller County Master Drainage Plan, and may afford additional recreation and park opportunities for Waller County. When compared with other structural alternatives, it is the least expensive.

Management Plans 2 and 3 both consider the Mound Creek Reservoir, with the only difference being the means to intercept and collect the overflow. While Management Plan 2 is less expensive, it does not meaningfully contribute to conservation interests. The location of the reservoir requires the use of conservation land, and additional conservation measures are necessary to ensure that the project contributes to the net conservation value in the study area. That is the primary reason for the selection of Management Plan 3 over Management Plan 2. It was further determined that these two strategies were too similar to warrant the selection of both, so Management Plan 2 was omitted from further consideration.

It was determined that Management Plan 5 – Katy-Hockley N - Cypress Reservoir was preferable to Management Plan 1 – Katy-Hockley Reservoir and to Management Plan 6 – Frontier Channel Conveyance "B" Storage. This was decided primarily through the process of elimination. The goal of Management Plan 1 was to maintain the storage within the Addicks Reservoir. This concept was originally conceived for a reservoir located further to the south and east; however known development activity resulted in its alignment closer to the watershed divide. This caused challenges with the allowable pool, eventually resulting in the two reservoir pools. Holding the pool elevation to natural ground elevation at the watershed divide ultimately compromised the effectiveness of the reservoir; therefore, Management Strategy 5 was determined to be more effective and superior.

Management Plan 6 relies upon excavation to provide the necessary storage. The project will require a substantial amount of storage volume to prevent an increase flood risk in downstream channels. The most effective and economical means to obtain a large volume of storage is to utilize the natural topography of land and dams along waterways, as excavation proves to be too costly and difficult to implement. Cost estimates confirmed this supposition, resulting in the elimination of Management Plan 6.

Management Plan 5 is also costly, but provides an extensive conservation footprint, and avoids the prime development activity to the south and east.

Detailed planning level cost estimates and implementation plans are described in Sections 7.0 and 8.0 of this report.

5 Benefits of Prairie Restoration for Flood Control

The study area for the Cypress Creek Overflow Management Plan is mostly undeveloped, with the primary land use being agricultural. However, there are also significant areas of native prairie that were once common to the entire region. There is a generally accepted belief that prairie provides flood control benefits by reducing both the discharge rate and total volume of stormwater runoff. However, the actual study of this is limited and research has not been conducted in areas local to, or similar to, Harris County (Appendix I). As part of the Cypress Creek Overflow Management Plan, a monitoring study was established to assess the impact of prairie vegetation on runoff in terms of infiltration and time of concentration. The purpose of this effort is to increase understanding of the impacts that prairie preservation and restoration may have on stormwater runoff and the potential to reduce downstream flood risk through prairie restoration. This monitoring study will attempt to quantify the benefits of land-use for flood control, with a particular focus on native prairie, agricultural land, and developed urban spaces.

Monitoring was initiated in January 2013 and is planned to continue through January 2019. This timeline is well beyond the extent of the requirements of this grant. As such, this report only provides descriptions of the methodology used to collect and analyze data, along with initial findings established during the first year of the monitoring effort. Given the limited data set, only initial conclusions regarding the data will be offered in this report. The HCFCD will continue to collect and analyze data throughout the duration of the monitoring effort, and conclusions (if any) will be made upon evaluation of the total data set over the six-year time period. During this time, however, as data is acquired it will be applied, with appropriate regard to uncertainty given the limited data set, to specific land cover type values and variables into flood control planning elements, such as engineering calculations and infrastructure design.

5.1 General Background

The relationship between rainfall and runoff is generally understood, and can be quantified through a number of methodologies and numerical models. Rainfall data and gage data are utilized to evaluate these methods. The U.S. Geologic Survey and the HCFCD operate a robust network of rainfall and stream flow gages that allow for the continued evaluation of the rainfall and runoff relationship. HCFCD, in its Hydrology and Hydraulics Manual, specifies parameters for runoff using the Green and Ampt Method. These parameters are based upon calibration of hydrologic models, and are prescribed on a watershed-by-watershed basis as presented in the effective hydrologic models for each watershed.

The determination of the Green and Ampt parameters treat all land as either impervious or pervious. Furthermore, the parameters are applied to all impervious land without recognition of the land use. In other words, lawns, pastures and crops are all treated similarly. While this is generally adequate for determining peak flow rates to support hydraulic models, it does not facilitate a deeper understanding of the relationship between rainfall volume and runoff volume at a specific land-use level.

Variability in vegetation and soil characteristics are hypothesized as having a corresponding effect on volumetric storage and discharge capacities in response to storm event runoff. In particular, native prairie plants are thought to absorb a greater volume of runoff through a higher density of groundcover vegetation, increased depth and density of plant roots, and larger percentage of soil pore spaces (see Figure 5.1). The impact of these root systems is even more prominent in areas of poorly draining soils, such as in Harris County. While this is generally accepted in the hydrology community, the actual study of this is limited and has not focused on areas local or similar to Harris County.

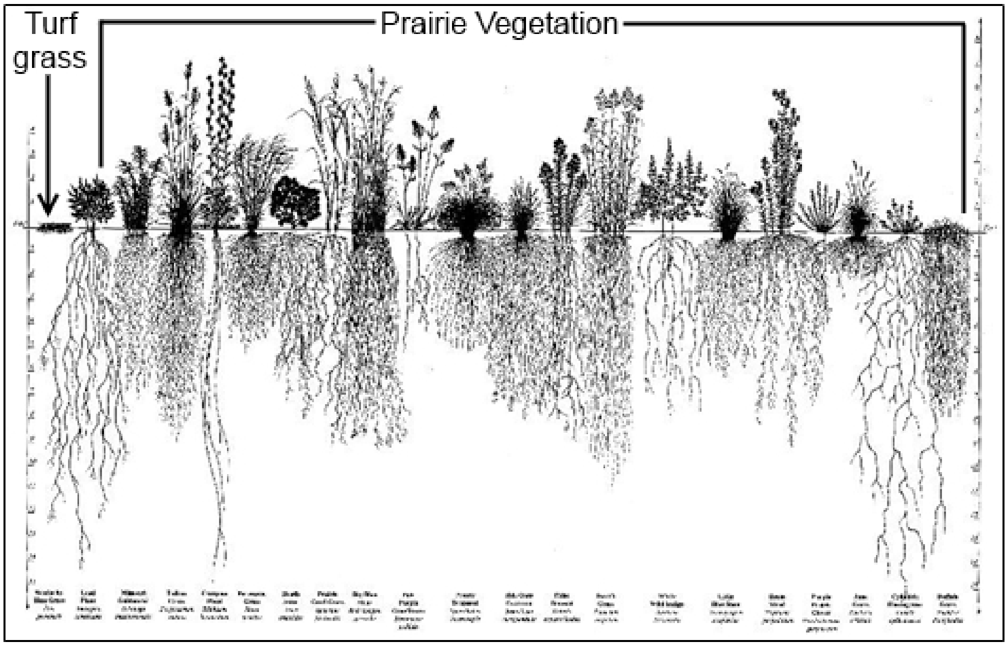


Figure 5.1 Root structure of turf grasses versus prairie vegetation (Source: Heidi Natura for the Conservation Research Institute)

5.1.1 NRCS Methodology

The Natural Resources Conservation Service (NRCS) uses a "Curve Number" (CN) to represent the infiltrative ability of the soil. The CN ranges between 30 and 100, with lower CNs representing soils with higher infiltrative capacities. Undeveloped land in Harris County generally has CN values ranging between 75 and 85, which is reflective of the poorly draining clay soil common to the area. The NRCS CN tables do not recognize a "native prairie" as a land cover type. However, they do have a land use for sage-grass, which is a vegetation type common to native prairie. It is interesting to note that the CN for sage-grass is substantially lower than the other cover types in this table (the cover types were selected because they are consistent with the study area in question). For example, the CN for sage-grass, with a "good" hydrologic condition and soil type "D" is 55 (NRCS categorizes soils as "A," "B," "C," or "D," with "A" soils having high infiltrative capacity and "D" soils having the lowest infiltrative capacity). This is an extremely low number for a "D" soil, and is the same as "B" soils for woods. There are contributing factors to the CN besides the infiltration; however, there would most likely be more interception in wooded areas, suggesting that the difference is mostly in the soils (and perhaps in depression storage that may be more common in some prairie areas). Overall, this seems to support the notion that native prairie substantially reduces infiltration capability.

5.1.2 Rainfall-Runoff Investigations

Past studies and analyses have been performed by HCFCD to better understand the rainfall runoff relationship, and additional analysis was conducted as part of the Cypress Creek Overflow Management Plan. These are described below.

HEC-HMS Analysis

The HCFCD maintains and manages hydrology models for each watershed that utilize the HEC-HMS software developed by the U.S. Army Corps of Engineers. These models apply the Green and Ampt Method, a time-based model that simulates infiltration into the soil based upon hydraulic parameters. Some of these parameters are empirical and difficult to measure and characterize; however, literature provides initial guidance, and the parameters were adjusted during the calibration of the hydrologic models.

A key parameter in the computation of runoff volume from rainfall is the drainage area and the percentage of the area that is impervious. The Green and Ampt parameters are only applied to the percentage of the area that is pervious, as it is assumed that impervious surfaces convert 100% of the rainfall to runoff. A sensitivity comparison was performed by varying the amount of impervious cover in the watershed. The analysis shows that, for a fully pervious watershed, about two inches are lost (via infiltration) during a 50% (2-year) rainfall event, and about 3.5inches are lost during a 1% (100-year) rainfall event. The percentage of rainfall that converts to runoff would vary depending on the amount of rainfall, and this computation shows that it varies between 30% and 60% for large events (defined as those greater than a 50% or 2-year event).

Considering the development of a single-family subdivision with an impervious cover of 50%, about one inch is lost during a 50% (2-year) event, and almost two inches are lost during a 1% (100-year) event. Therefore, based upon the HEC-HMS model using the Green and Ampt method, the development of a single-family subdivision would increase the runoff volume by 1.02 inches during a 50% (2-year) event, and by 1.79 inches during a 1% (100-year) event.

A commercial or industrial development with an impervious area of 90% will have a greater impact. For a 50% (2-year) event, only 0.2 inches are lost; and for a 1% (100-year) event, only about 0.4 inches are lost. Based upon the HEC-HMS model using the Green and Ampt method, the development of a commercial or industrial site would increase the runoff volume by 1.83 inches during a 50% (2-year) event, and by 3.21 inches during a 1% (100-year) event.

HCFCD Rainfall-Runoff Evaluation (R.G. Miller)

In 2012, HCFCD engaged RG Miller Engineers to evaluate observed stream flow data and to compare the resultant runoff volume with the measured precipitation in the upstream watershed. The report is entitled *Rainfall Volume vs. Runoff Volume Evaluation Study*. The goal of this study was “to develop an improved understanding of a relationship between rainfall and runoff for various intensity storm events.”

The results of this analysis are presented in greater detail in Appendix B. The analysis found that the average rainfall to runoff percentage in the Addicks Reservoir, for the full spectrum of events, is 70%. It is difficult to correlate this value to the values in Table D4.1 in Appendix D due to the variability in rainfall amount, percentage of impervious cover, and antecedent moisture condition. However, the results offer no indication of conflict and generally are within expected ranges.

The observed rainfall-runoff relationship in the Upper Cypress Creek watershed is much lower, averaging about 41%. This is not unexpected given the unique topography of the upper Cypress Creek watershed. This is also evident that the areas of remnant native prairie are retaining a much greater percentage of rainfall.

Analysis of Addicks Reservoir Inflow Data, 1992

Daily pool elevation and release data from the Addicks Reservoir was collected and analyzed as part of a study of the reservoirs described in Appendix B. The daily inflow can be reduced from the daily pool elevation and release volume, and this inflow can be compared to measured rainfall in the watershed. Between December 1992 and March 1993 frequent rainfalls during a wet season resulted in the reservoir achieving its record pool elevation.

Section 3.1 of Appendix B summarizes a detailed analysis of the daily data. Among the conclusions from this evaluation is that the rainfall-to-runoff conversion over this period was about 75%. This is slightly higher than the R.G. Miller evaluation of 70%, but within the same order of magnitude. Furthermore, much of the rainfall occurred during a high antecedent moisture condition. As with the R.G. Miller study, there is no indication of conflict with previous studies and understanding.

5.2 The Monitoring Study

Monitoring sites were located at six locations throughout the study area. Each of the monitoring sites was used to collect precipitation, infiltration, and runoff data to attempt to quantify the impact of native prairie vegetation on the rainfall-runoff relationship. Initial data was collected and analyzed as part of the Cypress Creek Overflow Management Study. Additional and more detailed methods for obtaining and calculating the results from this monitoring study can be found in Appendix I.

5.2.1 Study Sites

Initial study activities included the identification of two representative sites for three varying land cover types: 1) Open Space; 2) Native Prairie; and, 3) Developed (Figure 5.2). Following aerial photographic review of candidate sites using Geographical Information Systems (GIS) software, field reconnaissance was conducted to verify photographic signatures and to confirm the sites to be incorporated into the study. As a result, a total of six sites were confirmed.

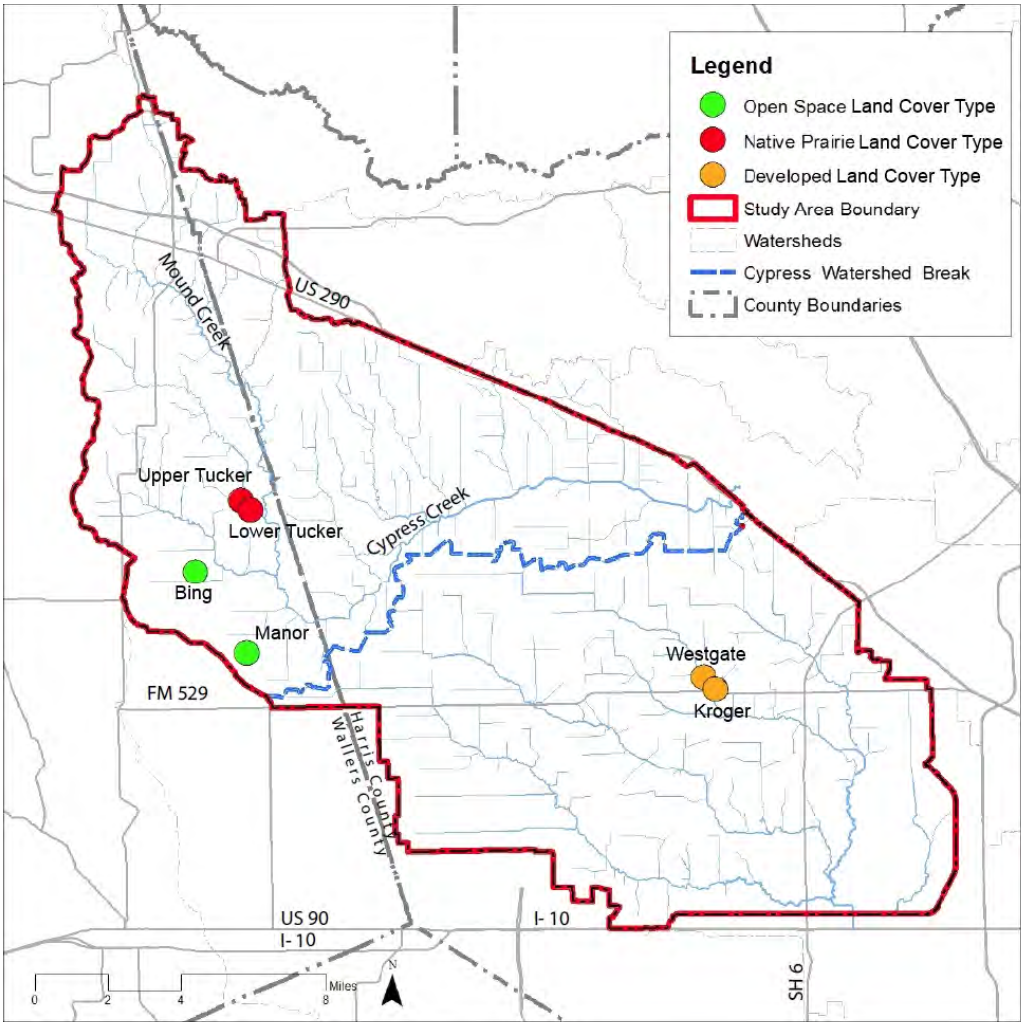


Figure 5.2 Rainfall and runoff monitoring site locations

The open space land cover type, hereby referred to as the Bing and Manor sites, was identified as areas where fallow agriculture/rice crop production has been replaced by cattle grazing, or remains fallow. The native prairie land cover type, hereby referred to as the Upper Tucker and Lower Tucker sites, was identified as sites where native prairie habitat preservation has been performed. The developed land cover type was chosen from a commercial property (hereby referred to as Kroger), and a residential development (hereby referred to as Westgate).

5.2.2 Field Measurements

On-site identification and quantification of vegetation species was conducted for each site (Appendix I). In addition, soil types as provided by the NRCS database were sampled in the field to verify soil descriptions (Appendices I and L).

Monitoring stations at each site were used to record rainfall and water levels (Appendix I). As data was collected for rainfall, depth of water within a storm sewer or culvert, and the depth of water in an adjacent shallow groundwater well, several analytical evaluations were possible, including determination of runoff and storage volumes; initial abstraction (Ia); time of concentration (Tc); time to peak (Tp); and, antecedent moisture condition (AMC). While the calculation of these analytical values may be achieved, as provided herein, the calculations related to storage and runoff volumes for each distinct land cover type would be the focal parameters for this specific research topic (Appendix I).

5.2.3 Results and Discussion

The following narrative provides a discussion of the observed field data in comparison with standard hydrologic techniques primarily incorporated into the TR-55 Manual – Urban Hydrology for Small Watersheds.

Curve Number

Table 5.1 presents a comparison of the CN computed from the observed data and the CN predicted based on land use type. For the open space land use, the observed CN is lower than the TR-55 CN tables suggest. This calculation is based upon only two events, and it is not possible to make conclusions. It is noted that the two events were substantially different in magnitude, with one being about 0.8 inches, and the other 4.9 inches. The larger event equates to about a two-year event, and that is the event used as a basis for the TR-55 tables. For that particular event, there was a closer correlation between observed and expected CN. Another consideration is that the observed CN may be influenced by the recent land-use change from rice farming to cattle grazing, producing the lower than expected CN from the field data.

Table 5.1 Curve number analysis

Land Cover Type	Station Designation	TR-55 Manual Technique	Field Data Computation
Open Space	Bing	88	73
Open Space	Manor	88	N/A[1]
Native Prairie	Upper Tucker	75	N/A[1]
Native Prairie	Lower Tucker	65	53
Developed (Commercial)	Kroger	95	97
Developed (Residential)	Westgate	87	87

[1] Data for Manor site suspect due to equipment malfunction and runoff data for Upper Tucker site incalculably low.

For native prairie, the initial data is returning similar results, with an observed CN lower than the expected CN based upon the TR-55 tables. The expected CN in Table 5-1 is based upon the "open land" designation. As noted previously, the NRCS does not provide a specific value for the native prairie land cover type, but the "sage-grass-sage with an understory of grass" designation was used in lieu of a prairie vegetation designation. In the TR-55 manual, for "Group D" soils (soils with high runoff potential) and "Good Hydrologic Conditions," the NRCS recommends a CN of 55, which correlates to the field data CN of 53. This is just but one plausible explanation of this difference.

The lower calculated CN values from field data may also be a result of direct site reconnaissance and site-specific data collection, whereas TR-55 Manual calculations rely on average conditions for particular land cover type. The low CN from field data may also have been due to the low runoff in the native prairie land cover type, and could be a result of the ability of native prairie land cover types to absorb larger amounts of runoff. In addition, the inherent ability of the native prairie land cover type to store rainfall within its soils may result in lower CN values than the general assumptions provided within the TR-55 Manual techniques. Another factor for dissimilarity may be the reduced accuracy associated with low runoff (<0.5 inches) from the Lower Tucker site.

For the developed land cover type CN, the field data was generally consistent with the TR-55 Manual for both Commercial and Residential land-use

Thus far, the initial field data CN supports the notion that native prairie land cover type substantially increases the infiltrative capacity of the soil. A CN of 53 is extremely low considering the sandy loam soil types found within the proposed study area (Appendix L).

Time of Concentration and Flow Path

The expected time of concentrations (Tc) for each of the open space and native prairie monitoring stations were calculated using the TR-55 Manual techniques. These calculated values are compared with the observed values in Table 5.2. Tc data for the developed land cover type were not considered since their monitoring stations are located at “end of conduit” systems that may have additional interconnectivity with other upstream systems.

Table 5.2 Time of concentration (tc) data

Land Cover Type	Station Designation	TR-55 Technique Tc (hr.)	Calculated Tc (hr.)
Open Space	Bing	1.38	1.75
Open Space	Manor	2.82	1.93
Native Prairie	Upper Tucker	0.65	1.31
Native Prairie	Lower Tucker	0.44	0.97

For the open space land cover type, both computational method results were similar, and the change in land-use from rice farming to cattle grazing did not substantially affect the Tc calculated from field data calculations. For the land cover type, Tc from field data was about twice that calculated. This indication from initial data supports the notion that native prairie influences the overall Tc of the contributing watershed.

Initial Abstraction and Antecedent Moisture Content

The initial data was also utilized to compare the initial abstraction of rainfall, to determine the antecedent moisture condition, and to consider the specific soil and vegetation types. These initial evaluations are presented in greater detail in Appendix I, and are summarized below.

The initial abstraction is the initial portion of rainfall that is removed from the system. TR-55 assumes that this value is equivalent to 20% of the total infiltrative capacity of the soil, although this assumption has never been scientifically validated. An evaluation of the initial data shows that observed initial abstraction was three to five times greater than that assumed by TR-55. While it is premature to generate conclusions, a higher initial abstraction suggests that when the soil is available to absorb rainfall, it will absorb most of the rainfall until it reaches it saturation point, where it will then shed most of the rainfall (in contrast to a more gradual distribution of infiltration and runoff).

Antecedent moisture condition refers to the condition of the soil at the beginning of a rainfall event. TR-55 identifies three conditions: I (dry), II (average), and III (saturated). Absent more information for a specific analysis, TR-55 recommends the use of condition II – and the evaluation of the initial data supports the use of condition II.

Soil and Vegetation Influences

The analysis of the soil and vegetation is an important consideration with respect to the individual land types. The land use classification is “static” in that it represents the current use; however, the actual character of the land is influenced by its past uses. This was noted earlier in the discussion of the open space, as the open space land use has converted from rice farming to cattle grazing. All of the sites were located atop sandy loam Alfisols, which commonly features impermeable subsoil clays and intermittent hydric conditions. The observed infiltration capacity of the native prairie land cover type was determined to be much higher than the open space and developed land cover types, even with the same soil cover (Appendix L). These differences may be due to the roots of species found in the native prairie land cover type, known to extend to deep within the soil (see Figure 5.1). The soils of open space and developed land cover types are generally more highly compacted, which restricts root growth and reduces water infiltration rate (Appendix L). These land cover types are able to support hardy, but shallow-rooted species typically used for sod or forage (Appendix I). In addition, a higher percentage of bare ground exists within open space land cover type compared to the native prairie land cover type, providing fewer water-absorbing roots and pore spaces within the soil (Appendix I).

On a smaller scale, soil biology within the native prairie land cover type was found to be more favorable for flood control reduction as well (Appendix L). Greater soil microbial numbers found in soils of the native prairie land cover type equate to favorable properties such as nutrient retention and nutrient cycling, carbon sequestration, soil moisture-holding capacity, soil structure and porosity, and water infiltration. Since land-use modifications altered the physical and chemical structure of soils within the open space and developed land cover types, these areas cannot support the diverse soil biology found in the native prairie land cover type. These changes in microbial diversity can negatively affect the vegetation composition, and ultimately the ability of the soil to function effectively as a flood reduction tool.

Impact of Prairie Restoration

The existing HEC-HMS subarea models and a sensitivity analysis of NRCS CNs (by HCFCD) were used to determine the potential benefits of native prairie restoration. A spreadsheet was developed to compute potential volume decreases provided by restoration of native prairie land cover type based on the change in the CN. This analysis assumes an existing CN of 85 for areas to be restored to native prairie land cover type. According to the National Engineering Handbook, the appropriate CN for “Group D” soils for “sage-grass-sage with an understory of grass” designation is 55. To be conservative, a reduction to 60 is assumed. The analysis was conducted for a 50% (2-year) 24-hour rainfall, and for a 1% (100-year) 24-hour rainfall.

Presuming that native prairie land cover type would be capable of lowering the CN from 85 to 60, these calculations suggest that substantial benefit would be gained from the restoration of the native prairie land cover type (Table V4.6). For events up to the 2-year event, native prairie land cover type would capture almost 100% of the runoff, and for large events, the establishment of native prairie would be equivalent to 0.29 acre-feet per acre of detention, reducing runoff by 55% (Table 5.3).

Table 5.3 NRCS curve number reduction in volume

	50% (2-yr Event)	**1% (100-yr Event)**
Existing CN	85	85
Existing Precipitation (in.)	2.0 in	12.0 in
Existing Runoff (in.)	0.80 in	10.08 in
Existing Runoff (% Precipitation)	40%	84%
Proposed CN	60	60
Proposed Precipitation (in.)	2.0 in	12.0 in
Proposed Runoff (in.)	0.06 in	6.56 in
Proposed Runoff (% Precipitation)	3%	55%
Additional Losses (in.)	0.74 in	3.52 in
Additional Losses (ac-ft/ac)	0.06 ac-ft/ac	0.29 ac-ft/ac
Additional Losses (ac-ft/1000 ac)	62 ac-ft	293 ac-ft

5.3 Initial Conclusions

The data gathered and analyzed throughout 2013 initially support the hypothesis that the native prairie land cover type has a significant impact on stormwater runoff volume. However, in order to achieve necessary significance, data must be recorded for a period longer than one year. As an interim measure, study efforts throughout the first year were reviewed and initial data was analyzed. Based upon limited data that has been collected and literature review that has been performed, it appears that one acre of prairie would increase the infiltration capacity of undeveloped land by 3.52 inches in a 100-year flood event (Table 5.3). The restoration of one acre of prairie would offset the volume impact of about two acres of a single-family subdivision, or about one acre of commercial or retail development. These changes in hydrology appear to be driven by the theory that native prairie vegetation increases the infiltrative capacity of soil. A reduction in flood control benefits due to the altered soil and vegetation composition are most likely a result of land-use modifications such as agriculture, ranchland, residential or commercial development.

Ideally, conserving existing high-quality native coastal prairie will preserve the flood reduction characteristics of the native prairie land cover type. Unfortunately, few areas of high-quality coastal prairie remain, as the majority of land within the proposed study area has been converted to agricultural or ranch land (Figure 5.3). Furthermore, no additional flood reduction benefits will be achieved by preserving existing high-quality coastal prairie, as these ecological services are currently functioning. The most effective flood reduction benefits will be achieved by the restoration of land parcels that hold the greatest uplift, such as "intermediate" and "low" quality Coastal Prairie (Figure 5.4), or open space land cover type that has been left fallow. Conversion of large amounts of these lands to the native prairie land cover type could significantly slow and absorb runoff during flood events. Preferred areas for prairie restoration are discussed further in Section 6.

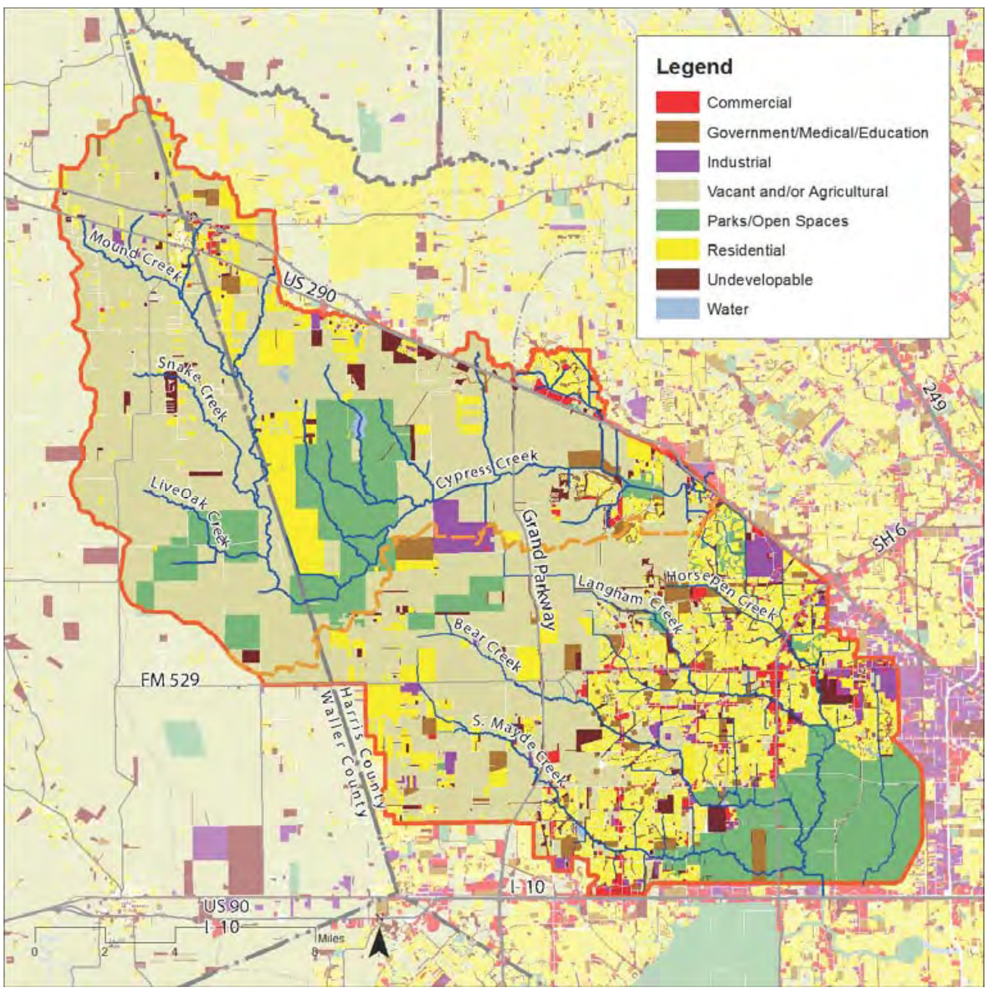


Figure 5.3 Land use in the study area (Source: Houston-Galveston Area Council)

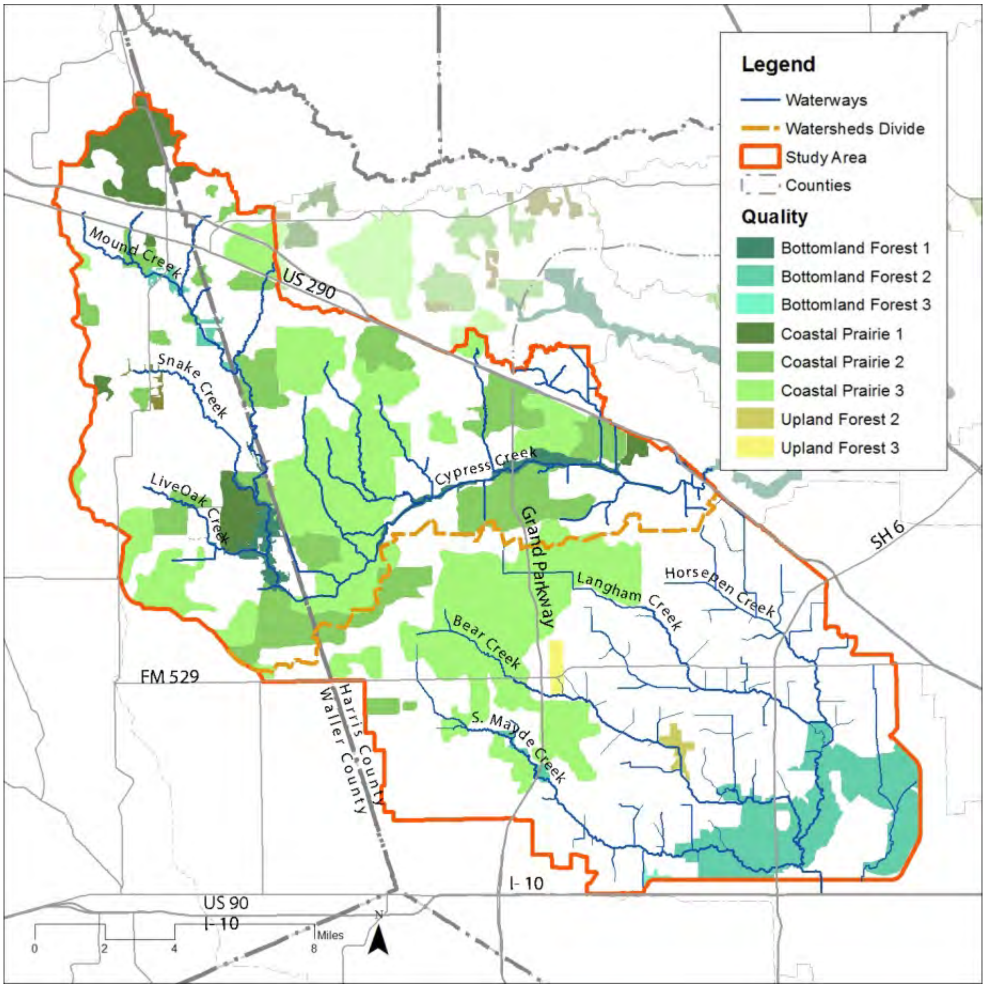


Figure 5.4 Ecological type and quality (Source: Houston-Galveston Area Council)

Modifications to the existing hydrologic models to reflect changing land uses are explored in more detail in Appendix I. The importance of using site-specific field observations in lieu of global assumptions may provide hydrologists with a useful data set for which watershed-based approaches to storage and effective runoff values could be incorporated into future watershed analyses. However, additional field data should be gathered and evaluated prior to their application towards hydrologic modeling. Additional data may provide conclusive results to confidently support the hydrologic principles based upon this concept, which may be achieved with an additional five years of data collection.

6 Identifying Critical Conservation Areas

Based upon the conservation objectives of this study, a list of criteria was developed to aid in the identification of critical conservation areas in the study area. The selection criteria are a combination of interdependent ecological principles and engineering concepts/requirements. The criteria will be used to identify areas that have a high conservation value, and can be used as a guide in the management of land parcels associated with the Cypress Creek Overflow Management Plan.

6.1 Methodology

In order to identify the condition of land parcels the proposed study area, multi-spectral and infrared photography was used for large-scale land cover classification, while field signatures, raster based image analysis, and ground-truthing allowed for classification of soils and land cover differentiation. Light Detection and Ranging (LiDAR) was used to gather topographic information and conveyance zone data about the study area, which was laid over land-use information. Potential wetland areas were mapped using existing data from the National Wetland Inventory and HCFCD databases, while additional mapping of land cover type and ecological quality was accessed through the Houston-Galveston Area Council's GIS database.

Each of the criteria was given a "high" or "moderate" priority ranking based on its conservation potential. A site suitability score was produced for each land parcel, depending on the number of criteria it met and the weight of its priority ranking. A score (0-3 scale) was awarded to each land parcel, with three (3) being the highest score and, zero (0) being the lowest. Land parcels with the highest site suitability score were given priority with regard to the preservation and expansion of existing floodplains, improvement and conservation of ecological quality, and the creation of passive recreation and wetland mitigation bank opportunities.

6.2 Conservation Criteria

The criteria that were developed to identify and prioritize potential critical conservation areas in the study area included:

1. Land Connectivity
2. Ecological Type and Quality
3. Potential for Prairie Restoration
4. Potential for Passive Recreation
5. Potential for Wetland Mitigation Bank
    a. Ability to Support Wetland or Upland Species
    b. Presence of Hydric Soils
    c. Preferable Hydrology
6. Aesthetic Quality
7. Absence of Current Residential or Commercial Development

These criteria, and the basis for their priority ranking, are defined further in Appendix J.

6.3 Results and Discussion

Based on the priority ranking exercise, Management Plans 3 and 5 both have a significant amount of land identified as “critical conservation area.” Approximately 7,800 acres of land within the Management Plan 3 and Management Plan 5 project areas were awarded a site suitability score of 3, which was the score identified with “critical conservation areas.” This means that the land scored high on the majority of the conservation criteria outlined in Section 6.2, and is considered ideally suited for environmental restoration for the purposes of flood control management, preservation of environmental habitat or wetland characteristics, or societal enhancement. Of the 7,800 acres identified as critical conservation areas, approximately 60% (4,690 acres) are currently managed as conservation land or held under conservation easements. The remainder of the identified acreage is not currently utilized for conservation and preservation purposes.

approximately 2,060 acres of land identified as critical conservation area in Management Plan 3 is located in the Mound Creek Reservoir and conservation/collection area described in Section 4.3.2 (Table 6.1). Approximately 1,240 acres is currently managed by the landowner as conservation land or has an existing conservation easement. The critical conservation areas located within Management Plan 3 offer a high potential for a wetland mitigation banking opportunity as well as for passive recreation. High quality coastal prairie and bottomland forest are found within the identified critical conservation area located near and adjacent to this management plan. Figure 6.1 illustrates the identified critical conservation areas and their proximity to the project area identified in Management Plan 3: Mound Creek Reservoir with Overflow Conveyance “B”.

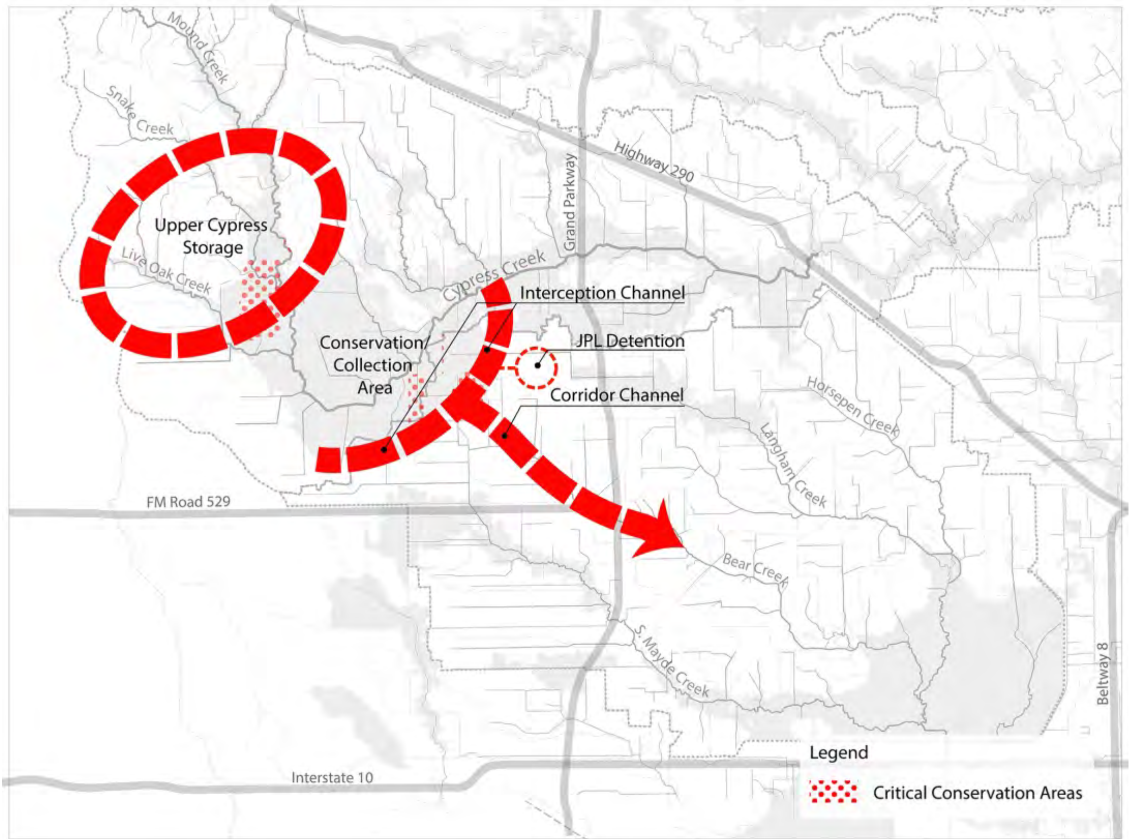


Figure 6.1 Critical conservation area within and adjacent to Management Plan 3: Mound Creek Reservoir with Overflow Conveyance "B"

Table 6.1 Critical conservation areas for Management Plan 3

County	Critical Conservation Area Acreage	Under Current Conservation	Mitigation Bank Ranking	Recreation Potential
Waller	1,212	Yes	High Potential	Yes
Harris	28	Yes	Low Potential	Yes
Harris	803	No	High Potential	Yes
Harris	13	No	Medium Potential	No

Management Plan 5 presents the greatest opportunity for conservation with approximately 5,740 acres of land identified as critical conservation area within the Katy-Hockley N – Cypress Reservoir (Section 4.3.2) (Table 6.2). Approximately 3,440 acres of identified critical conservation areas are currently managed as conservation land or held under conservation easements. Approximately 5,340 acres were identified as having potential for passive recreation, while 2,810 acres are considered to have high or medium potential for a wetlands mitigation bank. Intermediate and lower quality coastal prairie was the most prevalent ecological type and quality; however, this presents the greatest opportunity for prairie restoration, and the potential flood control benefits that the native coastal prairie may possess. Figure 6.2 illustrates the proximity of the identified critical conservation areas and their proximity to the project are identified in Management Plan 5: Katy-Hockley N-Cypress Reservoir.

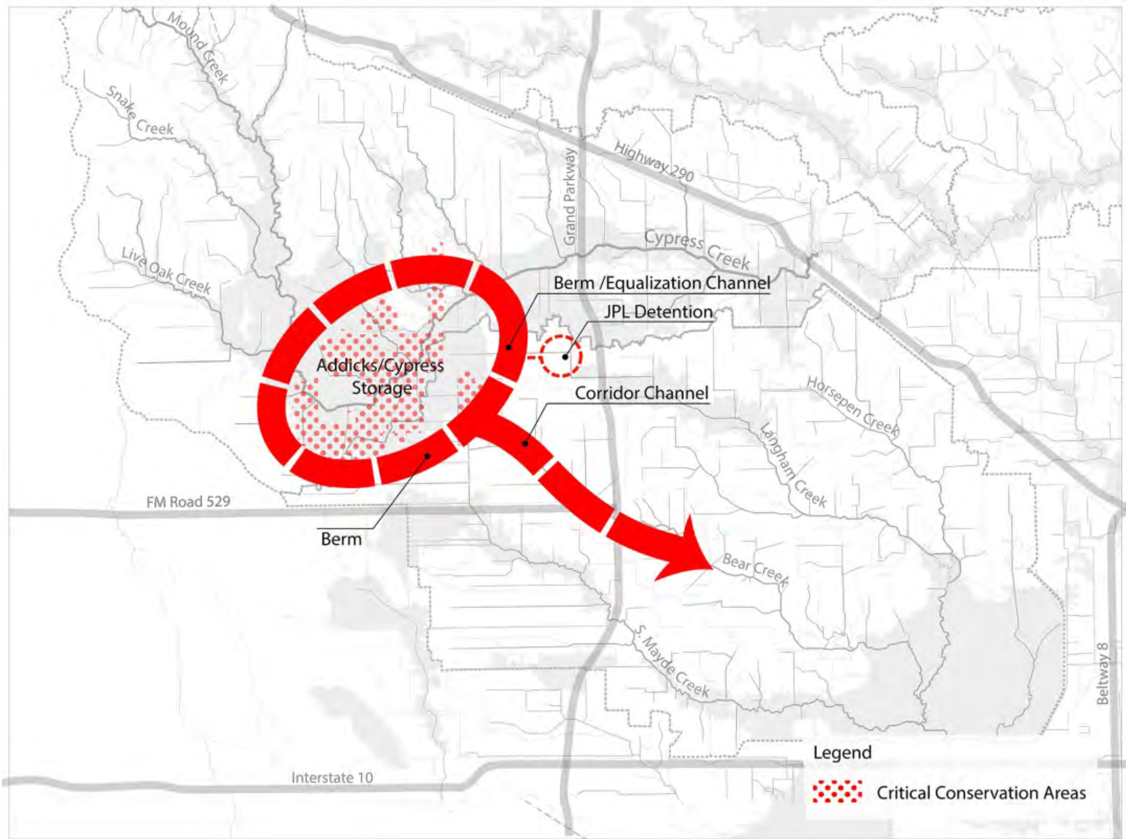


Figure 6.2 Critical conservation area within and adjacent to Management Plan 5: Katy-Hockley N-Cypress Reservoir

Table 6.2 Critical conservation areas for Management Plan 5

County	Critical Conservation Area Acreage	Under Current Conservation	Mitigation Bank Ranking	Recreation Potential
Harris	839	Yes	High Potential	Yes
Harris	8	Yes	Medium Potential	Yes
Harris	2,474	Yes	Low Potential	Yes
Harris	117	Yes	Low Potential	No
Waller	1,092	No	High Potential	Yes
Harris	725	No	High Potential	Yes
Harris	111	No	Medium Potential	Yes
Harris	31	No	Medium Potential	No
Harris	95	No	Low Potential	Yes
Harris	246	No	Low Potential	No

7 Analysis of Costs and Benefits

This section describes and summarizes the development of cost estimates and a benefit-cost analysis for the two alternative management plans developed as part of the Cypress Creek Overflow Management Plan study process. The development of planning level cost estimates for each of these alternatives is summarized, as well as the determination of the benefits provided by each. A benefit-to-cost relationship is also presented for each of the management plans. A comprehensive presentation is provided in Appendix E.

7.1 Cost Estimates

Planning level cost estimates were developed throughout the formulation of the various options presented earlier in this report. Costs were developed for the original “bookend” strategies and six alternative plans described in Appendix C. Cost estimates were developed in slightly greater detail for the final two recommended plans. Those two cost estimates are described below.

7.1.1 Plan 3 Cost Estimates

Two versions of the Plan 3 cost estimate were developed. The initial version is the total cost of the plan. The second version is the total cost of the plan assuming in-kind contributions by conservation interests and through development activity. These in-kind contributions are discussed in Section 8 and in Appendix F.

Plan 3 Total Cost

Plan 3 is estimated to cost approximately $271 million. This includes $117 million in land costs, $126 million in construction costs and $28 million in professional fees. Table 7.1 summarizes the cost estimate by project element.

Table 7.1 Plan 3 cost estimate - full cost

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	215	ac	$22,500	$4,837,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$15,825,000*
E2	Collection Channel Excavation	785,000	cy	$8	$2,335,000	
D5	Backslope Drains	20,000	lf	$25	$500,000	
E2	Daylight/Bear Crk Channel Excavation	739,400	cy	$7.5	$5,545,500	
R3	Katy-Hockley Road	1	ea	$1,500,000	$1,500,000	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$10,650,000*	
	25% Contingency			25%	$2,662,625	
	Total - Construction					*$13,313,125*
	Engineering/Design			8%	$1,065,050	
	Environmental/Permitting/ROW			4%	$532,525	
	Construction Management			10%	$1,331,312	
	Total - Professional					*$2,928,888*
ELEMENT 1 - TOTAL						**$32,067,013**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Land	295	ac	$30,000	$8,850,000	
	Total - Land					*$8,850,000*
E2	Channel Excavation	2,059,800	cy	$7.5	$15,448,500	
R3	Longenbaugh Road	1	ea	$1,500,000	$1,500,000	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
R3	Stockdick School Rd	1	ea	$1,500,000	$1,500,000	
R6	Major Natural Gas Pipelines	5	ea	$1,000,000	$5,000,000	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	180	ac	$7,000	$1,260,000	
S3	Silt Fence	39,000	lf	$2	$78,000	
S4	Care and Control of Water	19,500	lf	$30	$585,000	
S5	Hydromulch	180	ac	$3,000	$540,000	
D5	Backslope Drains	19,500	lf	$25	$487,500	
M1	Stream Mitigation	26,500	lf	$250	$6,625,000	
	Subtotal - Construction				*$37,637,000*	
	25% Contingency			25%	$9,409,250	
	Total - Construction					*$47,046,250*
	Engineering/Design			8%	$3,763,700	
	Environmental/Permitting/ROW			4%	$1,881,850	
	Construction Management			10%	$4,704,625	
	Total - Professional					*$10,350,175*
ELEMENT 2 TOTAL						**$66,246,425**

Table 7.1 (Continued) Plan 3 cost estimate - full cost

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Upper Langham Collection	55	ac	$30,000	$1,650,000	
	Total - Land					*$1,650,000*
E2	Channel Excavation	289,900	cy	$7.5	$2,174,250	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
	Subtotal - Construction				*$8,174,250*	
	25% Contingency			25%	$2,043,563	
	Total - Construction					*$10,530,313*
	Engineering/Design			8%	$842,425	
	Environmental/Permitting/ROW			4%	$421,213	
	Construction Management			10%	$1,053,031	
	Total - Professional					*$2,316,669*
ELEMENT 3 TOTAL						**$14,496,981**

Element 4 - Conservation/Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Collection Channels	90	ac	$22,500	$2,025,000	
L9	Convert Temp Esmt to Permanent	1,580	ac	$16,875	$26,662,500	
L6	County Land	440	ac	$0	$0	
	Total - Land					*$28,687,500*
E1	Excavation	1,573,800	cy	$3	$4,721,400	
D5	Back Slope Drains	13,000	lf	$25	$325,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	230	ac	$7,000	$1,610,000	
S3	Silt Fence	33,000	lf	$2	$66,000	
S5	Hydromulch	230	ac	$3,000	$690,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
	Subtotal - Construction				*$7,527,400*	
	25% Contingency			25%	$1,881,850	
	Total - Construction					*$9,409,250*
	Engineering/Design			8%	$752,740	
	Environmental/Permitting/ROW			4%	$282,278	
	Construction Management			10%	$940,925	
	Total - Professional					*$1,975,943*
ELEMENT 4 TOTAL						**$40,072,693**

Table 7.1 (Continued) Plan 3 cost estimate - full cost

Element 5 - Mound Creek Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	1,520	ac	$22,500	$34,200,000	
L5	Conservation land	2,245	ac	$12,500	$28,062,500	
	Total - Land					*$62,262,500*
E6	Key Trench Excavation	106,950	cy	$7.5	$802,125	
E5	Embankment	1,236,950	cy	$15	$18,554,250	
D2	Mound Crk Outfall Rip-Rap/Slope Paving	15,000	sy	$125	$1,875,000	
D3	Spillway	52,000	lf	$250	$13,000,000	
D1	Live Oak 200 lf 1-6'x6' box	7,200	sf-lf	$15	$108,000	
E2	Live Oak Excavation	267	cy	$7.5	$2,000	
D2	Live Oak Rip-Rap/Slope Paving	1,733	sy	$125	$216,666	
S1	Mobilization	1	ea	$100,000.0	$100,000	
S2	Clear and Grub	190	ac	$7,000	$1,330,000	
S3	Silt Fence	27,500	lf	$2	$55,000	
S5	Hydromulch	190	ac	$3,000	$570,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	1,000	lf	$250	$250,000	
	Subtotal - Construction				$36,878,041	
	25% Contingency			25%	$9,219,510	
	Total - Construction					*$46,097,552*
	Engineering/Design			8%	$3,687,804	
	Environmental/Permitting/ROW			4%	$1,843,902	
	Construction Management			10%	$4,609,755	
	Total - Professional					*$10,141,461*
ELEMENT 5 TOTAL						**$118,501,513**

Plan Totals	
Land	$117,275,000
Construction	$126,396,489
Professional	$27,713,135
TOTAL PLAN COST	**$271,384,624**

Plan 3 Effective Cost (With In-Kind Contributions)

With in-kind contributions from the conservation and development communities, Plan 3 is estimated to cost approximately $178 million. This includes $79 million in land costs, $79 million in construction costs and $20 million in professional fees. Table 7.2 summarizes the cost estimate by project element.

Table 7.2 Plan 3 cost estimate – with in-kind contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	215	ac	$22,500	$4,837,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$15,825,000*
E2	Collection Channel Excavation	785,000	cy	$8	$5,887,500	
E2	Daylight/Bear Crk Channel Excavation	739,400	cy	$8	$5,545,500	
D5	Backslope Drains	20,000	lf	$25	$500,000	
R3	Katy-Hockley Road	1	ea	$1,500,000	$1,500,000	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$14,183,000*	
	25% Contingency			25%	$3,545,750	
	Total - Construction					*$17,728,750*
	Engineering/Design			8%	$1,418,300	
	Environmental/Permitting/ROW			4%	$709,150	
	Construction Management			10%	$1,772,875	
	Total - Professional					*$3,900,325*
ELEMENT 1 - TOTAL						**$37,454,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land Dedicated by Dev	295	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	2,059,800	0	$0.0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
	Subtotal - Construction				*$6,263,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$626,300	
	Environmental/Permitting/ROW			4%	$313,150	
	Construction Management			10%	$782,875	
	Total - Professional					*$1,722,325*
ELEMENT 2 TOTAL						**$9,551,075**

Table 7.2 (Continued) Plan 3 cost estimate – with in-kind contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total - Land					*$0*
D6	JPL Control Structure	1	ea	$250,000	$250,000	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,750*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Conservation/Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Collection Channels	90	ac	$22,500	$2,025,000	
L9	Convert Temp Esmt to Permanent	1,580	ac	$16,875	$26,662,500	
L6	County Land	440	ac	$0	$0	
	Total - Land					*$28,687,500*
E1	Excavation	1,573,800	cy	$3	$4,721,400	
D5	Back Slope Drains	13,000	lf	$25	$325,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	230	ac	$7,000	$1,610,000	
S3	Silt Fence	33,000	lf	$2	$66,000	
S5	Hydromulch	230	ac	$3,000	$690,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
	Subtotal - Construction				*$7,527,400*	
	25% Contingency			25%	$1,881,850	
	Total - Construction					*$9,409,250*
	Engineering/Design			8%	$752,740	
	Environmental/Permitting/ROW			4%	$376,370	
	Construction Management			10%	$940,925	
	Total - Professional					*$2,070,035*
ELEMENT 4 TOTAL						**$40,166,785**

Table 7.2 (Continued) Plan 3 cost estimate – with in-kind contributions

Element 5 - Mound Creek Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	1,520	ac	$22,500	$34,200,000	
L7	Conservation land	2,245	ac	$0	$0	
	Total - Land					*$34,200,000*
E6	Key Trench Excavation	106,950	cy	$7.5	$802,125	
E5	Embankment	1,236,950	cy	$15	$18,554,250	
D2	Mound Crk Outfall Rip-Rap/Slope Paving	15,000	sy	$125	$1,875,000	
D3	Spillway	52,000	lf	$250	$13,000,000	
D1	Live Oak 200 lf 1-6'x6' box	7,200	sf-lf	$15	$108,000	
E2	Live Oak Excavation	267	cy	$7.5	$2,000	
D2	Live Oak Rip-Rap/Slope Paving	1,733	sy	$125	$216,666	
S1	Mobilization	1	ea	$100,000.0	$100,000	
S2	Clear and Grub	190	ac	$7,000	$1,330,000	
S3	Silt Fence	27,500	lf	$2	$55,000	
S5	Hydromulch	190	ac	$3,000	$570,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	1,000	lf	$250	$250,000	
	Subtotal - Construction				$36,878,041	
	25% Contingency			25%	$9,219,510	
	Total - Construction					*$46,097,552*
	Engineering/Design			8%	$3,687,804	
	Environmental/Permitting/ROW			4%	$1,843,902	
	Construction Management			10%	$4,609,755	
	Total - Professional					*$10,141,461*
ELEMENT 5 TOTAL						**$90,439,013**

Plan Totals	
Land	$78,712,500
Construction	$79,467,552
Professional	$19,552,896
TOTAL PLAN COST	**$177,732,948**

7.1.2 Plan 5 Cost Estimates

Two versions of the Plan 5 cost estimate were developed. The initial version is the total cost of the plan. The second version is the total cost of the plan assuming in-kind contributions by potential partners. These in-kind contributions are discussed in Section 8 and in Appendix F.

Plan 5 Full Cost

Plan 5 is estimated to cost approximately $369 million. This includes $206 million in land costs, $134 million in construction costs and $29 million in professional fees. Table 7.3 summarizes the cost estimate by project element.

Table 7.3 Plan 5 cost estimate - full cost

Element 1 - Initial Collection Area						
No	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	285	ac	$22,500	$6,412,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$17,400,000*
E2	Collection Channel Excavation	785,000	cy	$7.5	$5,887,500	
E2	Daylight/Bear Crk Channel Excavation	739,400	cy	$7.5	$5,545,500	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$12,183,000*	
	25% Contingency			25%	$3,045,750	
	Total - Construction					*$15,228,750*
	Engineering/Design			8%	$1,218,300	
	Environmental/Permitting/ROW			4%	$609,150	
	Construction Management			10%	$1,522,875	
	Total - Professional					*$3,350,325*
ELEMENT 1 - TOTAL						**$35,979,075**

Table7.3 (Continued) Plan 5 cost estimate - full cost

Element 2 - Bear Creek Channel						
No	**Item**	**Quantity**	**Uni**	**Unit Price**	**Cost**	**Totals**
L3	Land	295	ac	$30,000	$8,850,000	
	Total - Land					*$8,850,000*
E2	Channel Excavation	2,059,800	cy	$7.5	$15,448,500	
R3	Longenbaugh Road	1	ea	$1,500,000	$1,500,000	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
R3	Stockdick School Rd	1	ea	$1,500,000	$1,500,000	
R6	Major Natural Gas Pipelines	5	ea	$1,000,000	$5,000,000	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	180	ac	$7,000	$1,260,000	
S3	Silt Fence	39,000	lf	$2	$78,000	
S4	Care and Control of Water	19,500	lf	$30	$585,000	
S5	Hydromulch	180	ac	$3,000	$540,000	
D5	Backslope Drains	19,500	lf	$25	$487,500	
M1	Stream Mitigation	26,500	lf	$250	$6,625,000	
S1	Mobilization	1	ea	$100,000	$100,000	
E2	Channel Excavation	80,000	cy	$7.5	$600,000	
D5	Backslope Drains	10,000	lf	$25	$250,000	
S3	Silt Fence	20,000	lf	$2	$40,000	
S5	Hydromulch	28	ac	$3,000	$84,000	
D1	Remove Ex Structure	1	ea	$50,000	$50,000	
R7	Adjust Bridges at Fry and W Little Yk	2	ea	$250,000	$500,000	
	Subtotal - Construction				*$39,261,000*	
	25% Contingency			25%	$9,815,250	
	Total - Construction					*$49,076,250*
	Engineering/Design			8%	$3,926,100	
	Environmental/Permitting/ROW			4%	$1,963,050	
	Construction Management			10%	$4,907,625	
	Total - Professional					*$10,796,775*
ELEMENT 2 TOTAL						**$68,723,025**

Table7.3 (Continued)   Plan 5 cost estimate - full cost

Element 3 - JPL Landing Detention						
No	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Upper Langham Collection	55	ac	$30,000	$1,650,000	
	Total - Land					*$1,650,000*
E2	Channel Excavation	6	cy	$7.5	$2,174,250	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
	Subtotal - Construction				*$8,174,250*	
	25% Contingency			25%	$2,043,563	
	Total - Construction					*$10,530,313*
	Engineering/Design			8%	$842,425	
	Environmental/Permitting/ROW			4%	$421,213	
	Construction Management			10%	$1,053,031	
	Total - Professional					*$2,316,669*
ELEMENT 3 TOTAL						**$14,496,981**

Element 4 - Acquire Land for KH N-Cypress Storage						
No	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	3536	ac	$22,500	$79,560,000	
L4	Conservation land	5,725	ac	$12,500	$71,562,500	
L6	County Land	415	ac	$0	$0	
L9	Land Value B Convert Temp Esmt to Perm	1584	ac	$16,875	$26,730,000	
	Total - Land					*$177,852,500*
	Total - Construction					*$0*
	Engineering/Design			8%	$0	
	Environmental/Permitting/ROW			4%	$0	
	Construction Management			10%	$0	
	Total - Professional					*$0*
ELEMENT 4 TOTAL						**$177,852,500**

Table7.3 (Continued) Plan 5 cost estimate - full cost

Element 5 - Construct KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
	Total - Land					*$0*
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
E6	Key Trench Excavation	89,800	cy	$7.5	$673,500	
E5	Embankment	788,200	cy	$15	$11,823,000	
D2	Cypress Outlet - riprap/slope paving	13,300	sy	$125	$1,662,500	
D3	Cypress Spillway	18,667	lf	$250	$4,666,750	
D3	Bear Creek Spillway	18,667	lf	$250	$4,666,750	
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
D1	S Mayde Crk- 200 lf 1-6'x8' box	9,600	sf-lf	$15	$144,000	
E2	S Mayde Excavation	356	cy	$7.5	$2,667	
D2	S Mayde Rip-Rap/Slope Paving	1,733	sy	$125	$216,667	
D1	Balance Structure 50 lf 9-6x6 box	16,200	sf-lf	$15	$243,000	
D11	Balance Structure Backflow Prevention	6	ea	$300,000	$1,800,000	
E5	Road Emb - Warren Rnch, Hebert	380,000	cy	$15	$5,700,000	
D1	Road Culvert - Warren Rnch, Hebert	180,000	sf-lf	$15	$2,700,000	
L2	Add ROW - Warren Rnch, Hebert	41	ac	$22,500	$922,500	
	Add Pvmt - Warren Rnch, Hebert	120,000	sy	$50	$6,000,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	400	ac	$7,000	$2,800,000	
S3	Silt Fence	53,900	lf	$2	$107,800	
S5	Hydromulch	400	ac	$3,000	$1,200,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	3,000	lf	$250	$750,000	
	Subtotal - Construction				$47,380,933	
	25% Contingency			25%	$11,845,233	
	Total - Construction					*$59,226,167*
	Engineering/Design			8%	$4,738,093	
	Environmental/Permitting/ROW			4%	$2,369,047	
	Construction Management			10%	$5,922,617	
	Total - Professional					*$13,029,757*
ELEMENT 5 TOTAL						**$72,255,923**

Plan Totals	
Land	$205,752,500
Construction	$134,061,479
Professional	$29,493,525
TOTAL PLAN COST	**$369,307,505**

Plan 5 Effective Cost (With In-Kind Contributions)

With in-kind contributions from the conservation and development communities, Plan 5 is estimated to cost approximately $243 million. This includes $124 million in land costs, $98 million in construction costs, and $21 million in professional fees. Table 7.4 summarizes the cost estimate, by project element.

Table 7.4 Plan 5 cost estimate – with in-kind contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	285	ac	$22,500	$6,412,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$17,400,000*
E2	Collection Channel Excavation	785,000	cy	$7.5	$5,887,500	
E2	Daylight/Bear Crk Channel Excavation	739,400	cy	$7.5	$5,545,500	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$12,183,000*	
	25% Contingency			25%	$3,045,750	
	Total - Construction					*$15,228,750*
	Engineering/Design			8%	$1,218,300	
	Environmental/Permitting/ROW			4%	$609,150	
	Construction Management			10%	$1,522,875	
	Total - Professional					*$3,350,325*
ELEMENT 1 - TOTAL						**$35,979,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land	295	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	2,059,800	0	$0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
S1	Mobilization	1	ea	$100,000	$100,000	
E2	Channel Excavation	80,000	cy	$8	$600,000	
D5	Backslope Drains	10000	lf	$25	$250,000	
S3	Silt Fence	20,000	lf	$2	$40,000	
S5	Hydromulch	28	ac	$3,000	$84,000	
D12	Remove Ex Structure	1	ea	$50,000	$50,000	
R7	Adjust Bridges at Fry and W Little Yk	2	ea	$250,000	$500,000	
	Subtotal - Construction				*$7,887,000*	
	25% Contingency			25%	$1,971,750	
	Total - Construction					*$9,858,750*
	Engineering/Design			8%	$788,700	
	Environmental/Permitting/ROW			4%	$394,350	
	Construction Management			10%	$985,875	
	Total - Professional					*$2,168,925*
ELEMENT 2 TOTAL						**$12,027,675**

Table7.4 (Continued) Plan 5 cost estimate – with in-kind contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	289,900	0	$0.0	$0	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,562,500	
	Total - Construction					*$7,812,500*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,7500*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Acquire Land for KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	3536	ac	$22,500	$79,560,000	
L3	Land value C	0	ac	$30,000	$0	
L7	Conservation land	5,725	ac	$0	$0	
L6	County Land	415	ac	$0	$0	
L9	Land Value B Convert Temp Esmt to Perm	1,584	ac	$16,875	$26,730,000	
	Total - Land					*$106,290,000*
	Total - Construction					*$0*
	Engineering/Design			8%	$0	
	Environmental/Permitting/ROW			4%	$0	
	Construction Management			10%	$0	
	Total - Professional					*$0*
ELEMENT 4 TOTAL						**$106,290,000**

Table7.4 (Continued) Plan 5 cost estimate – with in-kind contributions

Element 5 - Construct KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
	Total - Land					*$0*
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
E6	Key Trench Excavation	89,800	cy	$7.5	$673,500	
E5	Embankment	788,200	cy	$15	$11,823,000	
D2	Cypress Outlet - riprap/slope paving	13,300	sy	$125	$1,662,500	
D3	Cypress Spillway	18,667	lf	$250	$4,666,750	
D3	Bear Crk Spillway	18,667	lf	$250	$4,666,750	
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
D3	Spillway	18,667	lf	$250	$4,666,667	
D1	S Mayde Crk- 200 lf 1-6'x8' box	9,600	sf-lf	$15	$144,000	
E2	S Mayde Excavation	356	cy	$8	$2,667	
D2	S Mayde Rip-Rap/Slope Paving	1,733	sy	$125	$216,667	
D1	Balance Structure 50 lf 9-6x6 box	16,200	sf-lf	$15	$243,000	
D11	Balance Structure Backflow Prevention	6	ea	300,000	$1,800,000	
E5	Road Emb - Warren Rnch, Hebert	380,000	cy	$15	$5,700,000	
D1	Road Culvert - Warren Rnch, Hebert	180,000	sf-lf	$15	$2,700,000	
L2	Add ROW - Warren Rnch, Hebert	41	ac	$22,500	$922,500	
	Add Pvmt - Warren Rnch, Hebert	120,000	sy	$50	$6,000,000	
S1	Mobilization	1	ea	100,000	$100,000	
S2	Clear and Grub	400	ac	$7,000	$2,800,000	
S3	Silt Fence	53,900	lf	$2	$107,800	
S5	Hydromulch	400	ac	$3,000	$1,200,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	3,000	lf	$250	$750,000	
	Subtotal - Construction				$52,047,600	
	25% Contingency			25%	$13,011,900	
	Total - Construction					*$69,059,500*
	Engineering/Design			8%	$5,204,760	
	Environmental/Permitting/ROW			4%	$2,602,380	
	Construction Management			10%	$6,505,950	
	Total - Professional					*$143,313,090*
ELEMENT 5 TOTAL						**$79,372,590**

Plan Totals	
Land	$123,690,000
Construction	$97,959,500
Professional	$21,551,090
TOTAL PLAN COST	**$243,200,590**

7.2 Benefit-Cost Analysis

The purpose of the benefit-cost analysis is to identify specific benefits of the respective plans, quantify them monetarily, and compare them to project costs in the form of a benefit-cost ratio. Some benefits, such as flood damages avoided, can be directly determined. However, this can be more difficult with other benefit categories, such as ecological benefits. This section describes the benefit categories and the determination of economic benefits, as well as the computation of a benefit-cost relationship for each plan.

7.2.1 Benefit Categories

Both plans provide benefits by 1) decreasing structural flooding in the overflow area, 2) increasing the economic value of the land manifest in development potential; 3) providing contiguous green space and increasing the conservation footprint; 4) providing protection for Addicks Reservoir via new development policy; and, 5) providing recreational opportunities.

The various benefit sections are described below, along with the quantification for each of the two plans.

Flood Damage Reduction

There are existing flood prone properties in the study area that will be beneficially impacted by the proposed project. These include properties in the existing overflow area, developments along Addicks Reservoir tributaries, and properties along Cypress Creek downstream of the overflow.

<u>Cypress Creek Overflow</u>

The HCFCD Structural Inventory Database was used to evaluate properties in the overflow, and the structures estimated to be subject to flooding are depicted in Figure 7.1. During the 1% (100-year) flood event, it is estimated that 107 structures are subject to flooding. This includes 53 single family homes, 19 mobile homes, 17 warehouses (or industrial/commercial) buildings, 1 government or utility structure, and 17 under the category of home/repair use. This last category primarily refers to toolsheds and/or barns adjacent to single family homes. Table 7.5 summarizes the flood prone structures affected by various studied storm events.

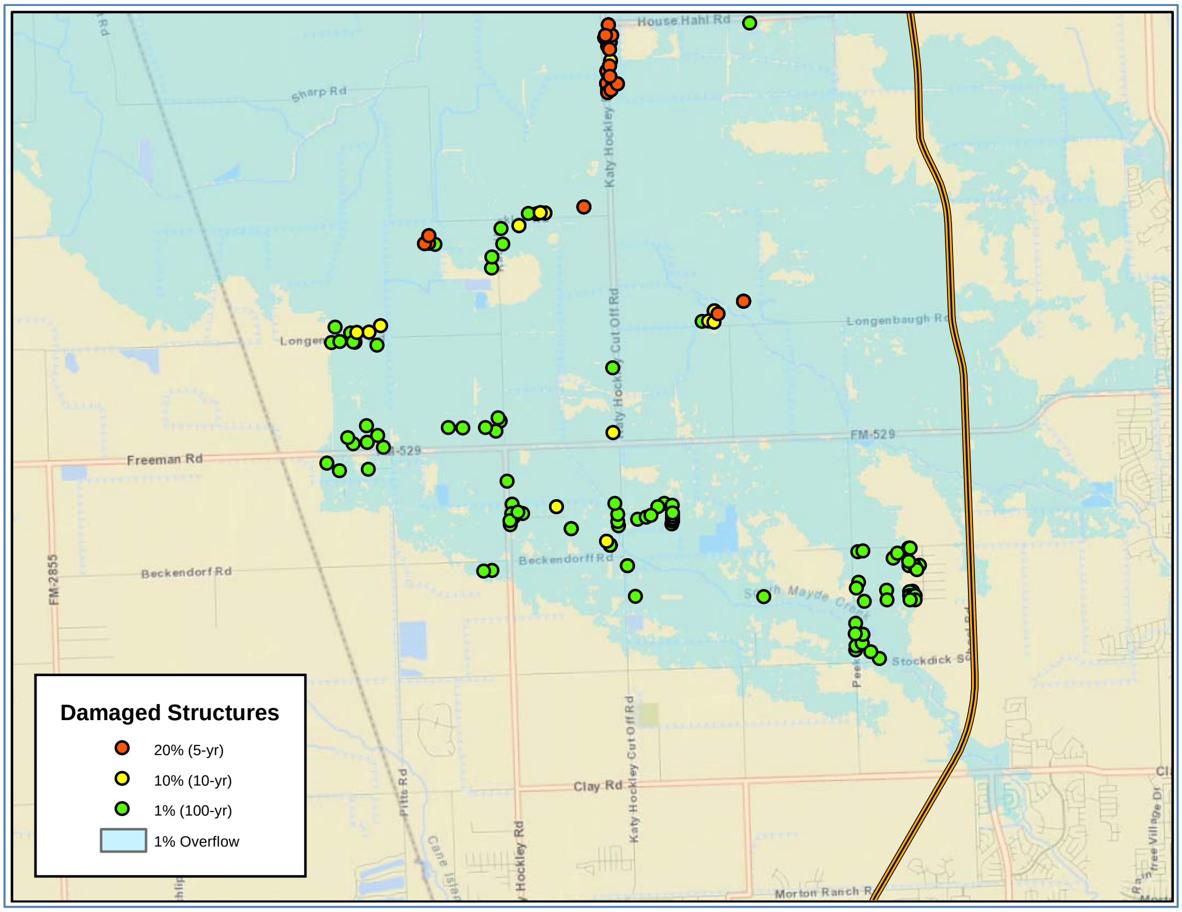


Figure 7.1 Flood prone structures in the cypress creek overflow

Table 7.5 Flood prone structures in overflow

	20% (5-yr)	10% (10-yr)	1% (100-yr)
Single Family House	7	14	53
Mobile Home	4	5	19
Warehouse/Commercial	3	4	17
Government/Utility	0	0	1
Repair/Home Use	0	3	17

Expected damages for the structure and contents were determined by comparing the computed flood elevation at a location with the estimated elevation of the structure, and then applying a damage estimate to the appraised value. The damage estimates were determined by using curves developed by the U.S. Army Corps of Engineers New Orleans District. These damages were converted to annual average damages using the annual exceedance probability for event. The present value was developed using a period of 40 years and a discount rate of 3.9% based on guidance from the Office of Management and Budget (OMB Circular A-94, 2014).

The damage computations are summarized in Table 7.6. A single 1% (100-year) flood event in the overflow area is estimated to cause almost $8 million in damages. Over time, damages are estimated to average just over $300,000 per year, resulting in a present value of about $6.5 million.

Table 7.6 Summary of structural damages in overflow

Storm	Probability	Single Event Damages	Average Annual Damages	Incremental Annual Average Damages
5-yr	20%	$863,636	$173,000	$173,000
10-yr	10%	$1,569,000	$157,000	$71,000
100-yr	1%	$7,716,000	$77,000	$61,000
Total Average Annual Damages				**$305,000**
Present Value of Damages				**$6,552,000**

The analysis of structures summarized in Table 7.6 does not include the potential damage to vehicles. The structural database was utilized in the estimation of vehicle damages. While structures are generally assumed to be one foot above natural grade, it is assumed that vehicles will be parked at natural ground and incur damage when floodwaters are at least 2 feet deep. Therefore, the flood depths utilized in the computation of structure damages were increased by one foot to estimate the cost of vehicle damages.

A cursory survey was developed by driving through the study area. Based on this survey, a breakdown of the type of vehicles owned by residents was assumed for structures in the overflow area, as depicted in Table 7.7. Depth damage curves for vehicles were utilized to evaluate estimated damages, which were then converted to average annual damages and present value damages. Table 7.8 summarizes the computation of vehicle damages. A single 1% (100-year) event is estimated to cause over $1.1 million in vehicle damages. Over time, vehicle damages are estimated to average just over $80,000 per year, resulting in a present value of almost $1.8 million. The present value was developed using a period of 40 years and a discount rate of 3.9% based on guidance from the Office of Management and Budget (OMB Circular A-94, 2014).

Table 7.7 Assumed vehicle values and inventory factor

	Sedans	**Pickups**	**SUV**	**Sports**	**Minivans**
Assumed Value	$10,000	$18,000	$20,000	$22,000	$15,000
Structure Type – No. of Vehicles for Each					
Single Family	0.3	0.9	0.4	0.1	0.3
Public & Semi Public	0.0	1.0	0.0	0.0	0.0
Mobile Home	0.6	0.9	0.3	0.0	0.2
Repairs & Home Use	0.0	1.0	0.0	0.0	0.0
Warehouse & Contractor Services	0.0	2.0	0.0	0.0	0.0

Table 7.8 Summary of vehicle damages in overflow

Storm	**Probability**	**Single Event Damages**	**Average Annual Damages**	**Incremental Annual Average Damages**
5-yr	20%	$338,332	$68,000	$68,000
10-yr	10%	$419,092	$42,000	$8,000
100-yr	1%	$1,126,213	$11,000	$7,000
Total Average Annual Damages				**$83,000**
Present Value of Damages				**$1,783,000**

Both Plan 3 and Plan 5 will eliminate all structural flood damages associated with the overflow. Three mobile homes would be acquired as part of the project, and ultimately most, if not all, flood-prone properties will be acquired by private development interests. Since the cost of the structures was not included in the land cost, the benefit of the flood damage reduction is considered throughout the duration of the project.

Addicks Reservoir Tributaries

There are mapped floodplains along Addicks Reservoir's various tributaries, including Bear Creek, South Mayde Creek, and Langham Creek. Each of these channels carry runoff generated by the surrounding drainage areas in addition to the Cypress Creek Overflow. The local runoff generally reaches these tributaries much more quickly and at higher flow rates than the overflow. Flooding along these tributaries is generally associated with local runoff; the 1% annual chance floodplain mapped on the effective flood insurance rate maps for these tributaries is based on flow generated by the surrounding drainage areas. In some cases, an overflow-only event creates flow rates that result in flooding along these tributaries, but in almost all cases the regulatory floodplain is controlled by the local event.

Plan 5 includes some minor channel modifications along Bear Creek in the vicinity of Fry Road. These improvements will provide a slight reduction in flood elevations. During the 1% (100-year) event, water surface elevations will be reduced by 0.5-1foot. This area was subject to flooding during a recent flood event. The structural inventory does not show any damages for events up to and including the 1% (100-year) event.

There are likely non-quantifiable benefits along Bear Creek as a result of the Plan 5 improvements. These include reduced inundation of neighborhoods' lower-lying areas. Reduced inundation would help improve mobility through neighborhood streets during heavy rainfall events, and would also reduce general nuisance experienced by residents when stormwater inundates a neighborhood, but does not result in structural flooding.

Cypress Creek

There are many flood prone areas along Cypress Creek downstream of the study area. This area, which is commonly known as "Lower Cypress Creek," has experienced more development than Upper Cypress Creek, and is subject to a double peak hydrograph. The channel hydrograph experiences an initial rise from local runoff in the developed areas of lower Cypress Creek that usually recedes before another rise occurs as the flood wave from Upper Cypress Creek makes its way down stream. The actual nature of rainfall determines which of these peaks results in the greatest source of flood damage. Measures that address the local runoff, or the first peak, will not affect the second peak; likewise, upstream measures that address the second peak will not affect the initial first peak.

Both Plan 3 and Plan 5 include storage reservoirs that are similar in character and location to features proposed in the *Cypress Creek Master Drainage Plan*, which was prepared by engineering firm Turner, Collie & Braden and adopted by Harris County Commissioners Court in the 1980's. The measures will reduce, but not eliminate, the peak flow from the Upper Cypress Creek watershed. For rainfall where this event causes the most flooding, both plans will have a noticeable impact. Because of the nature of the dual peak, it is difficult to quantify the benefit to lower Cypress Creek therefore it is considered a non-quantified benefit for this analysis.

Addicks Reservoir

As noted in Appendix B, Addicks Reservoir does not have the capacity to accept additional runoff volume, whether it is from the additional development or from stormwater diversion related to a flood control project. The development policy adopted for both plans will offset and prevent additional runoff, and is a benefit when compared to a most likely future condition that does not include such controls. In addition, securing additional land for conservation, via the large storage reservoirs, prevents that land from being developed and controls existing runoff. This will also positively impact Addicks Reservoir.

In the 1990s, the U.S. Army Corps of Engineers conducted a Section 216 Reconnaissance Study of the Addicks and Barker reservoirs. As part of this study, an economic analysis was conducted. No structural damages were computed within the 1% (100-year) reservoir pool. It should be noted that this study did not consider the impact of anticipated changes in land use in the Addicks and Barker reservoir watersheds.

For the reasons described above, the benefits to Addicks Reservoir are considered a non-quantifiable benefit. The measures introduced by both plans will provide significant relief for a very large, but rare, flood event.

Land Intensification

Land intensification refers to the increase in overall land value and potential use as it relates to a project. Both projects will have direct and significant impacts on the development characteristic of the land which is manifest in the land intensification benefit.

Development within the project area is highly likely. Absent a regional management plan, management of the overflow would be implemented on a case-by-case basis as each new development is constructed. Results would be focused on the individual developments rather than the region. Overflow management will be provided in an ad-hoc manner, which will require substantial detention, and therefore land, to maintain the existing overflow attenuation.

Without Project Mitigation Cost

Two general approaches were utilized to measure land intensification. The initial approach was to estimate the land required for mitigation of the overflow attenuation based upon the total existing “storage volume” of the overflow. Table 7.9 shows the total area for various overflow depths during the 10% (10-year) and 1% (100-year) events. For the 1% (100-year) event, this results in a total area of 20,838 acres and a “storage volume” of 10,938 acre-feet. For these 20,838 acres to develop without impacts, they must either maintain or replace this storage volume. On a prorated basis, this works out to 0.52 acre-feet per acre – in addition to onsite detention and retention requirements. Under current criteria, it is not unusual that new developments within Harris County reserve 10% -12% of the project area for detention facilities to serve primarily residential subdivisions.

Table 7.9 Total area (acres) of overflow, by depth

Overflow Depth (feet)	10% (10-year)	1% (100-year)
0.0 – 0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	**8,606**	**20,838**

The available depth of overflow mitigation is limited by outfall depth. In some cases, development may be able to drain its collected overflow into channel systems. This might be possible when a development is immediately upstream and adjacent to a previously constructed development that provides access to outfall. However, in areas without such outfall capacity, the construction of new outfall would expedite the flow velocity and overflow travel time, and would require significant attenuation in order to mimic the existing hydrology and avoid adverse impacts. This analysis assumes that new development will occur without the availability of outfall. The deepest overflows are about three feet. Assuming that the mitigation measure will maintain a depth of three feet, approximately 17% of a project site would need to be reserved for overflow mitigation, or 3,542 acres in total throughout the overflow area. Assuming a cost of $30,000 per acre for land, the total land cost required for overflow mitigation would be about $106 million. In addition, the storage mitigation area must be excavated. Using an excavation cost of $3 per cubic yard, total mitigation excavation costs in the overflow area would be approximately $117 million. When combined, a total mitigation cost would be approximately $213 million.

Development Yield

A second approach was to evaluate the cumulative development yield for the entire study area. This computation assumed a 1,000-acre single-family master-planned community as its prototype. The "with project" condition represents either Plan 3 or Plan 5. In such a case, the land would develop in a manner consistent with other areas that are not inundated by floodplain or an overflow. The development plan assumes 10% of land for detention, 50% for single family lots, 25% for roads and common areas, 8% for commercial, 4% for schools, and 3% for utilities. Income is produced by single family lots, commercial areas, and school sites. It is assumed that raw land will be purchased for $30,000 per acre, which is the same value used in the project cost estimates. There will be four residential lots per acre of single family land, and they will sell for $20,000 each. Commercial land and school land will sell at $80,000 per acre. Development construction costs are omitted because they will typically be passed on to the municipal utility district.

The "without project" condition is similar; however, the detention commitment is increased from 10% to 27% based upon the computation that 17% of land will be required for overflow mitigation. The resultant acreages for income producing uses are adjusted accordingly.

This calculation and comparison of the "with project" and "without project" conditions is tabulated in Table 7.10. Based on this table, the "without project" condition produces income of about $10,000 per acre, while the "with project" condition produces income of about $19,600 per acre. The difference between these, $9,600, spread over 18,000 acres that would be protected from the overflow if a regional management facility is constructed, results in a value of approximately $175 million. This is similar to the value of $213 million computed using the first method (the value of land required for additional detention).

Table 7.10 Computation of land intensification based on use

Item	Without Plan		With Plan (Plan 3 or Plan 5)	
		Income		Income
Acreage	1000		1000	
Raw Land Price	$(30,000)		$(30,000)	
Land Cost		$(30,000,000)		$(30,000,000)
Single Family Density	4		4	
% for Detention	10%		10%	
% for Overflow Mitigation	17%		0%	
% SF Lots	39%		50%	
% Roads, Common	20%		25%	
% Commercial	7%		8%	
% School	4%		4%	
% Utility	3%		3%	
Summary				
Area for Lots (ac)	390		500	
No. Lots	1560		2000	
Lot Sale Price (per lot)	$20,000.00		$20,000.00	
Lot Income		$31,200,000		$40,000,000
Area for Commercial (ac)	70		80	
Commercial Sale Price	$80,000.00		$80,000.00	
Commercial Income		$5,600,000		$6,400,000
Area for School (ac)	40		40	
School Sale Price (per ac)	$80,000.00		$80,000.00	
School Site Income		$3,200,000		$3,200,000
TOTAL VALUE (1000 AC)		$10,000,000		$19,600,000
TOTAL VALUE/ac		$10,000		$19,600

Conservation

There is an abundance of literature regarding the value of conservation land, including a compilation of studies by the Trust for Public Land. It is difficult to derive a correlation for use in placing a value on conservation land in the project area. There have been a number of deals made to preserve land within the study area; however the financial details of these are unavailable. The HCFCD paid about $2,000 per acre in 2003 for property located within the path of the 1% overflow, downstream of the watershed divide. This equates to $3,100 per acre in 2014 dollars. However, land values have increased considerably in recent years. It is estimated that the property would cost $20,000 - 30,000 per/acre in 2014.

Plans 3 and 5 both present an opportunity to expand the conservation footprint within the area inundated by the 1% annual chance overflow event. However, it would require that some of the land protected by existing conservation easements be included in the regional overflow management plan and provide the dual use of conservation and drainage. Considering the large opportunity costs foregone by various conservation transactions, a value of $12,500 seems reasonable. This is about one-half of the market value, and is the value utilized for conservation land in the cost estimates.

Infrastructure Benefits

The project will provide benefits for existing infrastructure by alleviating flooding problems along public roadways in the study area, and by providing a much needed drainage artery along Bear Creek.

<u>Roads</u>

Every time there is an overflow event, there are costs associated with the impact on public roadways. These include damage to the roads and bridges, lost travel time, cleanup activities and emergency services. A detailed economic study of all of these is beyond the scope of this study, and these potential benefits have minimal impact on the overall benefit. Instead, this benefit is recognized but not quantified.

<u>Drainage</u>

As the study area develops, there will need to be a drainage artery along Bear Creek to provide adjacent developments access to drainage infrastructure. The same goes for, developments that drain to Bear Creek tributaries. The project will provide this artery, so the benefit is the cost of deepening Bear Creek to a 15-foot deep channel, without consideration for additional capacity. The cost would be approximately $6 million.

Park Facilities

The project will reduce flooding in Paul Rushing Park, and will provide a means to excavate a portion of lakes in John Paul's Landing. The John Paul's Landing impact is neutral as it pertains to benefits. The benefit to Paul Rushing Park is difficult to quantify and relatively small; therefore, it is considered a non-quantified benefit.

Green Space

Studies have indicated that parks and green space and increase land values. This relative impact decreases with distance from the park or open space. There are algorithms to compute this. Both Plan 3 and Plan 5 will increase the conservation and green space footprint, and will thus provide a benefit. However, the “without project” condition also has large green space reserves, considering the existence of Precinct 3 parks and conservation land. Therefore, the relative impact is small and is considered a non-quantified benefit.

Other Non-Quantified Benefits

The plans deliver additional benefits that are difficult to quantify but that warrant recognition. These include opportunities to provide or improve wetland mitigation banks, water quality improvement measures, general public recreation facilities, ecosystem services and carbon sequestration.

7.2.2 Comparison of Benefits and Costs

Benefits and costs were assigned throughout the life of the project based on the implementation plan described in Appendix F. Efforts were made to align costs and benefits based on this model. For the evaluation of Plan 3 and Plan 5, it is assumed that development will occur at 800 acres per year for both the “with” and “without project” condition. However, the “with project” condition will reflect the higher development yield made possible by the project.

Project costs for the benefit-cost comparison were based on the Plan 3 and Plan 5 cost estimates that assumed in-kind contributions. This is a valid approach because the in-kind contributions do not represent economic costs incurred by any party. For example, if a conservation organization active in the area allowed the use of conservation land for the project, it would require no expenditure on the organization’s part. The in-kind contributions provided by developers are activities they would perform as part of their normal development activity.

The benefits and costs were distributed over 50 years based on the implementation plans. The annual costs are based upon 2014 dollars. The expenditures over the life of the project were brought to present value using a discount rate of 2.0%, which is the premium over the annual inflation index (1.9%) cited in OMB Circular A-94.

Benefit-to-Cost Ratio - Plan 3

The costs and benefits were distributed over the life of the Plan 3 project, at 2014 present values. This distribution is shown in Appendix E. The total present value cost of Plan 3, with in-kind contributions, is $148 million; while the total benefit is $168 million. The largest benefit category is land intensification, which accounts for $120 million, or 71%, of the total quantified benefit. There are non-quantified benefits as well, such as the value of increasing the conservation footprint in a contiguous manner, that if quantified, would trend the overall benefit upward.

Plan 3’s resultant benefit-to-cost ratio, defined as annualized benefits divided by annualized costs, is 1.14. This does not consider the aforementioned non-quantified benefits. Full consideration of this would result in a slightly higher benefit-to-cost ratio.

Benefit-to-Cost Ratio - Plan 5

The costs and benefits were distributed over the life of the Plan 5 project, at 2014 present values. This distribution is shown in Appendix E. The total present value cost of Plan 5, with in-kind contributions, is $206 million; while the total benefit is $183 million. The largest benefit category is land intensification, which accounts for $114 million, or 62%, of the total quantified benefit. There are other non-quantified benefits as well.

Plan 5's resultant benefit-to-cost ratio, defined as annualized benefits divided by annualized costs, is 0.89. This does not consider the aforementioned non-quantified benefits. Full consideration of this would result in a slightly higher benefit-to-cost ratio.

8 Project Financing and Cost Pro-Forma

The study area lies within a large area that is experiencing immediate development pressure. However, the two preferred management plans include flood control reservoirs that will take years to plan, design, permit and construct. The proposed implementation strategy for each preferred management plan considers this factor, and provides a mechanism to phase in project features over time in a manner that will incrementally address the overflow. It does so in a manner that does not restrict or inhibit land use, whether it be to maintain the status quo or to change land use for the purpose of development, conservation, recreational use, etc.

8.1 Plan Implementation

As mentioned, implementation plans were developed for the two preferred management plans, Plan 3 and Plan 5. The primary purpose of these implementation plans was to determine key activities required to construct components of the preferred management plans, and to develop a strategy for how these activities could be carried out in a series of steps. The implementation plans also consider funding mechanisms and potential partnerships that could be used to help offset costs and to fund the entirety of the projects.

In addition to the project scope, it must be taken into consideration that the environmental investigations and permitting for both management plans may take several years to accomplish. The reservoirs will likely require Individual Section 404 Permits from the U.S. Army Corps of Engineers, and it is possible that an Environmental Assessment will be required in order to conform with the National Environmental Policy Act. For these reasons, it is recommended that initials construction activities be those that would not require extensive permitting processes or environmental investigations.

With that said, the initial implementation steps should include the commencement of the necessary investigations and pursuit of environmental permits that would be required for the longer-term project components. Activities related to permitting will continue throughout project implementation, and should be considered separately from the individual timeline for individual project elements.

8.1.1 Plan 3 Implementation

The Mound Creek Reservoir with Overflow Conveyance “B” (Plan 3) is depicted in Figure 4.5, and is described in Section 4.3.2. The total cost of Plan 3 is estimated to be $271 million; however, with in-kind contributions (see Section 8.2.2) the project cost is reduced to $177 million. It will remove the overflow from about 18,500 acres of land, and has the potential to increase the conservation footprint by 3,100 acres. There are five elements to Plan 3’s implementation, as are described in the following sections.

Plan 3, Element 1 – Initial interception

First, an interim collection channel would be constructed in a north-south orientation along Katy-Hockley Road. Spoil material from this construction activity will be used to construct a small berm on the east bank of the channel. The channel and berm will intercept overflow and convey it to the upper end of Bear Creek, which will be deepened for a distance of about 7,000 feet, at a very minimal slope, until it daylights to the bottom of the existing stream. This element is illustrated in Figure 8.1.

This initial project element will not address overflow west of Bear Creek, but it will remove stormwater inundation from areas immediately east of the channel and berm. Bear Creek does not have the capacity to convey all of the overflow, so the overflow will maintain its current boundaries and patterns downstream of the interim collection channel and north of Bear Creek until channel modifications are constructed along Bear Creek that provide additional channel capacity to accommodate the overflow. However, once this interim collection channel is constructed, along with the incremental construction of measures described in Plan 3, Element 2 (Bear Creek conveyance improvements), and some onsite mitigation, the land east of Bear Creek would be available for development

Permitting and environmental investigations necessary to construct the full Management Plan 3 are anticipated take several years to complete. Therefore, these tasks would be initiated as part of Element 1. The permitting would continue throughout the duration of implementation, and is included in each of the elements as part of "Professional Services."

This interim measure would cost about $37 million. It assumes that temporary flooding easements will be obtained on almost 1,600 acres of private land in the collection area, which is property that is inundated by the overflow under existing conditions.

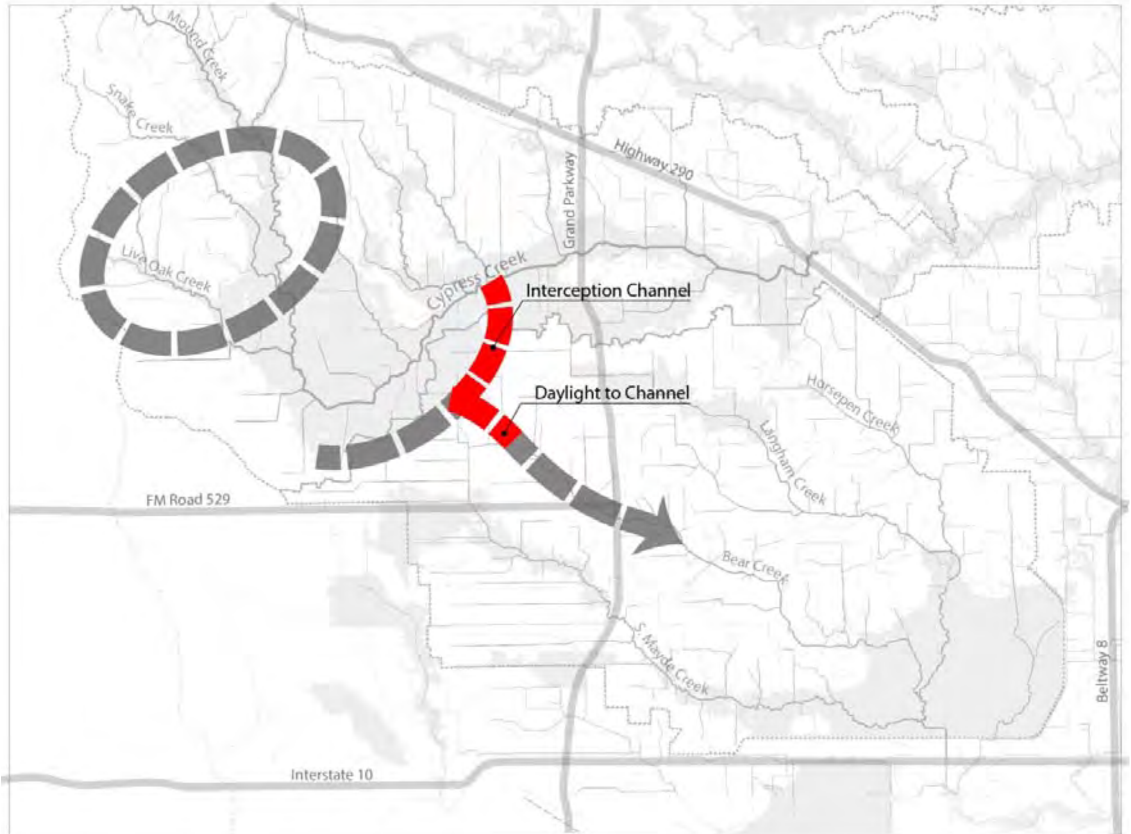


Figure 8.1 Plan 3, element 1: initial interception

Plan 3, Element 2 – Bear Creek Conveyance Improvements

Plan 3, Element 2 is the reservation of the 500-foot Bear Creek corridor and the construction of the modified channel. Coupled with Element 1, this element will protect 5,500 acres from inundation during the 1% (100-year) event. This element is illustrated in Figure 8.2.

These features will be implemented as development progresses along Bear Creek. Individual development activity within the 5,500 acres may occur ahead of full implementation; however, those that occur along the Bear Creek corridor will be required to reserve right-of-way and to construct portions of the channel. This will provide outfall depth to serve drainage infrastructure and fill material for future development, as well as a potential location for limited detention. Depending on the status of the overall project, developments may have to install interim measures to protect against the overflow until the full project is constructed. This may be in the form of fill, levees and channels that protect the development.

Considering in-kind contributions, Element 2 costs approximately $10 million and (coupled with Element 1) will protect approximately 5,500 acres of land from the overflow during a 1% (100-year) storm event.

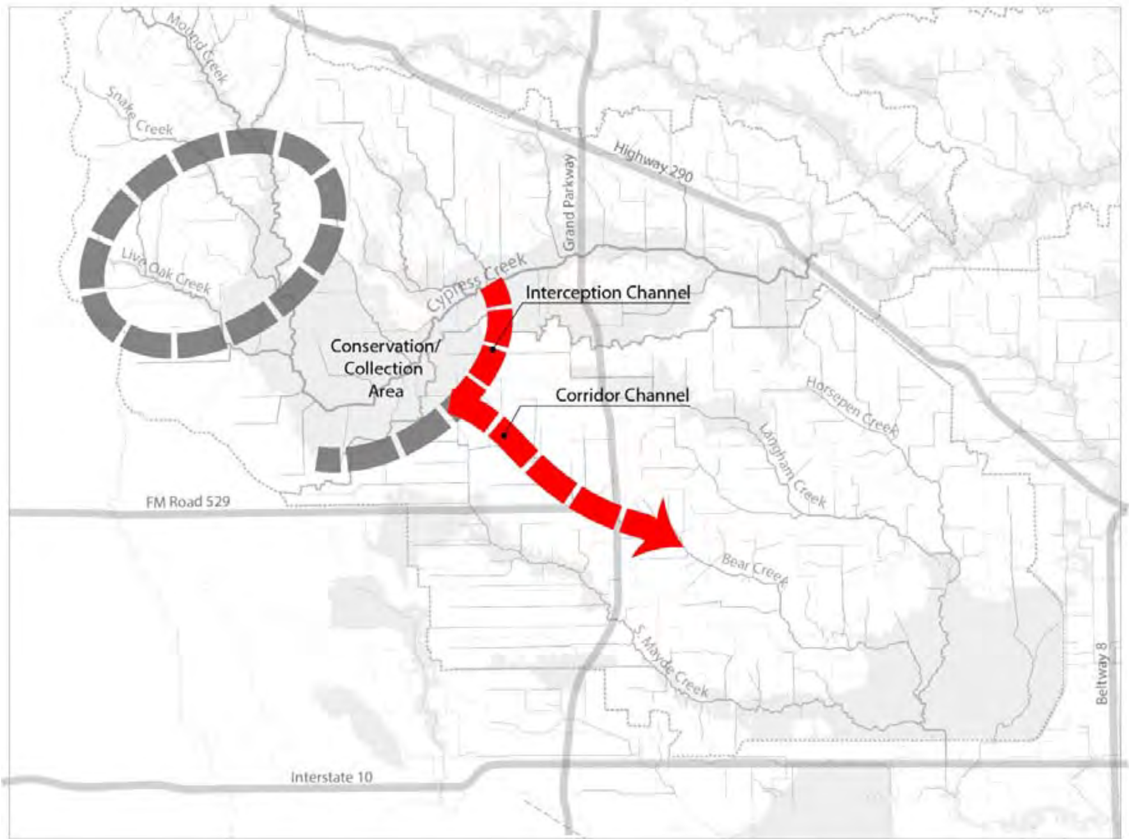


Figure 8.2 Plan 3, element 2: Bear Creek conveyance improvements

Plan 3, Element 3 – John Paul's Landing Detention

John Paul's Landing is a Harris County Precinct 3 park located along the east side of Katy-Hockley Road. Plans for the park include about 400 acres of lakes that would have a permanent water surface about eight feet below natural ground; and, therefore, would have significant detention capacity. The Upper Langham Creek Master Drainage Plan intends to utilize a portion of the available detention storage, with the remaining storage capacity used to collect and store the relatively small volume of overflow east of Katy-Hockley Road. Element 3 involves the excavation of this storage, which is about 500 acre-feet. This element is illustrated in Figure 8.3.

A channel would be constructed north of the park near the watershed divide, and this channel will collect overflow east of Katy-Hockley Road and convey it to the John Paul's Landing detention basins. The implementation of Element 3 will require coordination with park construction and activity associated with the Upper Langham Creek Master Drainage Plan. With in-kind contributions, this element will cost approximately $9 million, and will protect an approximately 3,500 additional acres of land from the 1% (100-year) overflow event.

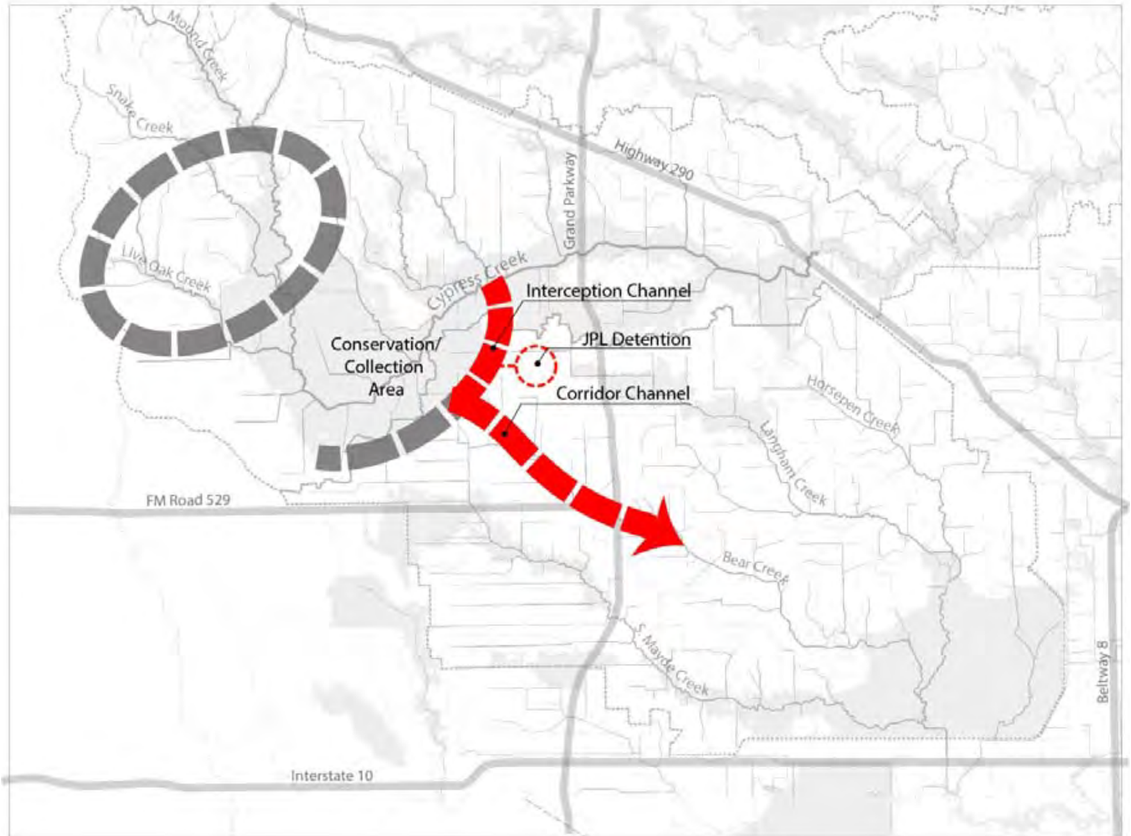


Figure 8.3 Plan 3, element 3: JPL detention

Plan 3, Element 4 – Acquire Conservation/Collection Area

The implementation of Element 1 would require obtaining temporary flood easements across approximately 1,600 acres of land for the collection of the overflow and the construction of the east-west collection channel. Element 4 involves the conversion of these temporary easements into permanent easements or fee ownership. It also includes the construction of an east-west collection channel; however this channel cannot be constructed until Element 5, the Mound Creek Reservoir, is constructed.

Element 4 will cost approximately $90 million. This element does not recover overflow land without the Mound Creek Reservoir (Element 5); therefore, land recovery is discussed in the description of that element.

Plan 3, Element 5 – Mound Creek Reservoir

This element involves the acquisition of land required for the Mound Creek Reservoir, as well the construction of a berm that would occasionally impound water for a short duration. This storage area will decrease the frequency and magnitude of the overflow. Element 5 will cost approximately $90 million, and together with Elements 4 and 5, will protect about 9,500 acres from the overflow.

Figure 8.4 illustrates Elements 4 and 5 for Plan 3.

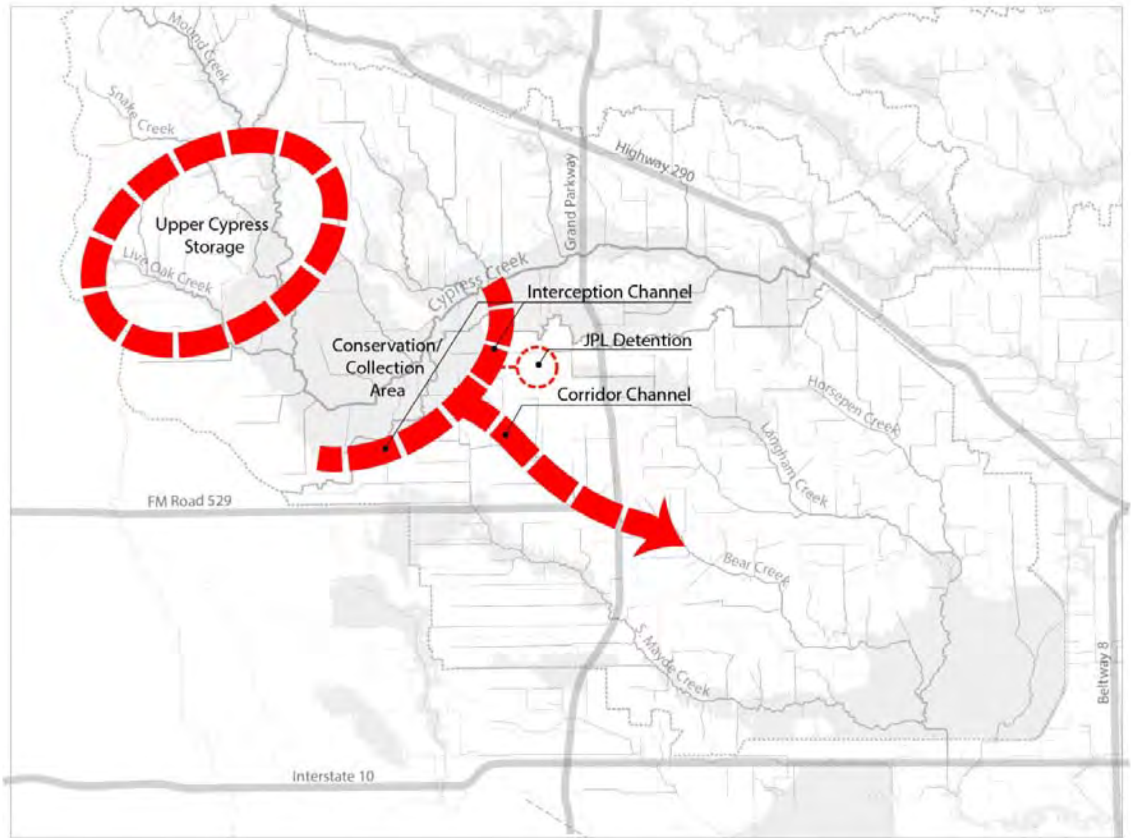


Figure 8.4 Plan 3, elements 4&5: conservation/collection area and Mound Creek Reservoir

8.1.2 Plan 5 Implementation

The Katy-Hockley N – Cypress Reservoir (Management Plan 5) is depicted in Figure 4.7 and is described in Section 4.3.2. The total cost of Plan 3 is estimated to be about $369 million. However with in-kind contributions (described in Section 8.2.2) the project cost is reduced to $243 million. It will remove the overflow from about 18,000 acres of land, and has the potential to increase the conservation footprint by 5,000 acres. There are five elements to Plan 5'simplementation, as are described in the following sections.

Plan 5, Element 1 – Initial interception

An interim collection channel would be constructed in an east-west orientation that will intercept overflow west of Katy-Hockley Road. Spoil material from this construction activity will be used to construct a small berm on the right bank of the channel. The channel and berm will intercept overflow and convey it to the upper end of Bear Creek, which will be deepened for a distance of about 7,000 feet, at very minimal slope, until it daylights to the bottom of the existing stream. This element is illustrated in Figure 8.5.

This initial element will not address overflow east and north of Bear Creek, but it will remove stormwater inundation from areas immediately south of the interim collection channel and adjacent berm. Bear Creek does not have the capacity to convey the flows, so the overflow will maintain its current overflow boundaries and patterns downstream of the interim collection channels until channel modifications are constructed along Bear Creek that provide additional channel capacity to accommodate the overflow.

Permitting and environmental investigations necessary to construct the full Management Plan 5 are anticipated take several years to complete. Therefore, these tasks would be included as part of Element 1. The permitting would continue throughout the duration of implementation, and is included in each of the elements as part of "Professional Services."

This interim measure would cost about $36 million. It assumes that temporary flooding easements will be obtained on almost 1,600 acres of private land in the collection area, which is property that is inundated by the overflow under existing conditions.

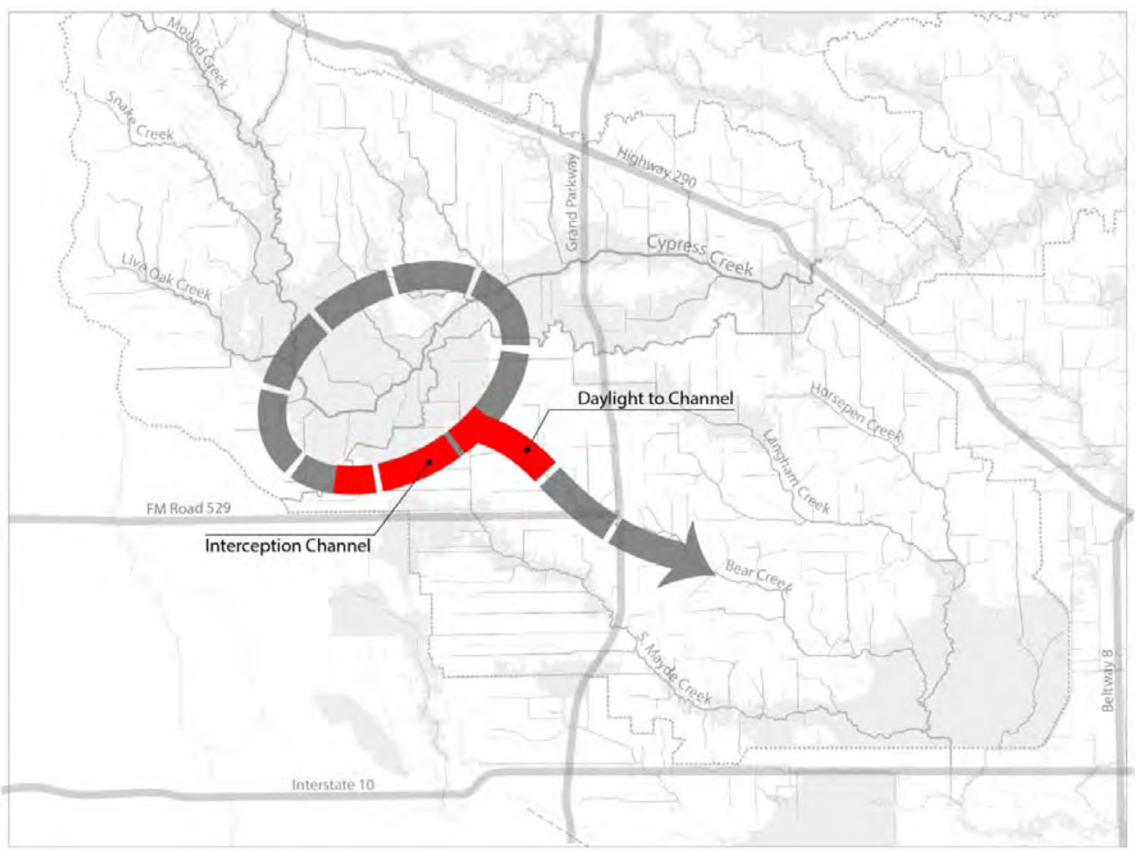


Figure 8.5 Plan 5, element 1: initial collection

Plan 5, Element 2 – Bear Creek Conveyance Improvements

Plan 5, Element 2 is the reservation of the 500-foot Bear Creek corridor and the construction of the modified channel. Coupled with Element 1, this element will protect 9,000 acres from inundation during the 1% (100-year) event. This element is illustrated in Figure 8.6.

These features will be implemented as development progresses along Bear Creek. Individual development activity within the 9,000 acres may occur ahead of full implementation; however those that occur along the Bear Creek corridor will be required to reserve right-of-way and to construct portions of the channel. This will provide outfall depth to serve drainage infrastructure and fill material for future development, as well as a potential location for limited detention. Depending on the status of the overall project, developments may have to install interim measures to protect against the overflow until the full project is constructed. This may be in the form of fill, levees and channels that protect the development.

As the channel enlargements are completed, the peak overflow discharge in the channel may eventually exceed current peak overflow discharges in Bear Creek as it passes through developed areas. While the resultant 1% (100-year) overflow flow rate is less than the 1% (100-year) flow rate from a local rainfall event, this would result in a temporary slight increase in flood risk through this reach. To offset this, Element 2 includes about one mile of channel enlargement, generally between Fry Road and West Little York Road. The channel enlargement would start upstream of the sheet pile transition structure located downstream of Fry Road, and would extend upstream to just past West Little York Road. Minor modifications to the bridge structures may be necessary to accommodate the enlarged and deepened channel. This channel widening would be accommodated within the existing channel right-of-way.

Considering in-kind contributions, Element 2 costs approximately $12 million and (coupled with Element 1) will protect approximately 9,000 acres of land from the overflow during a 1% (100-year) storm event.

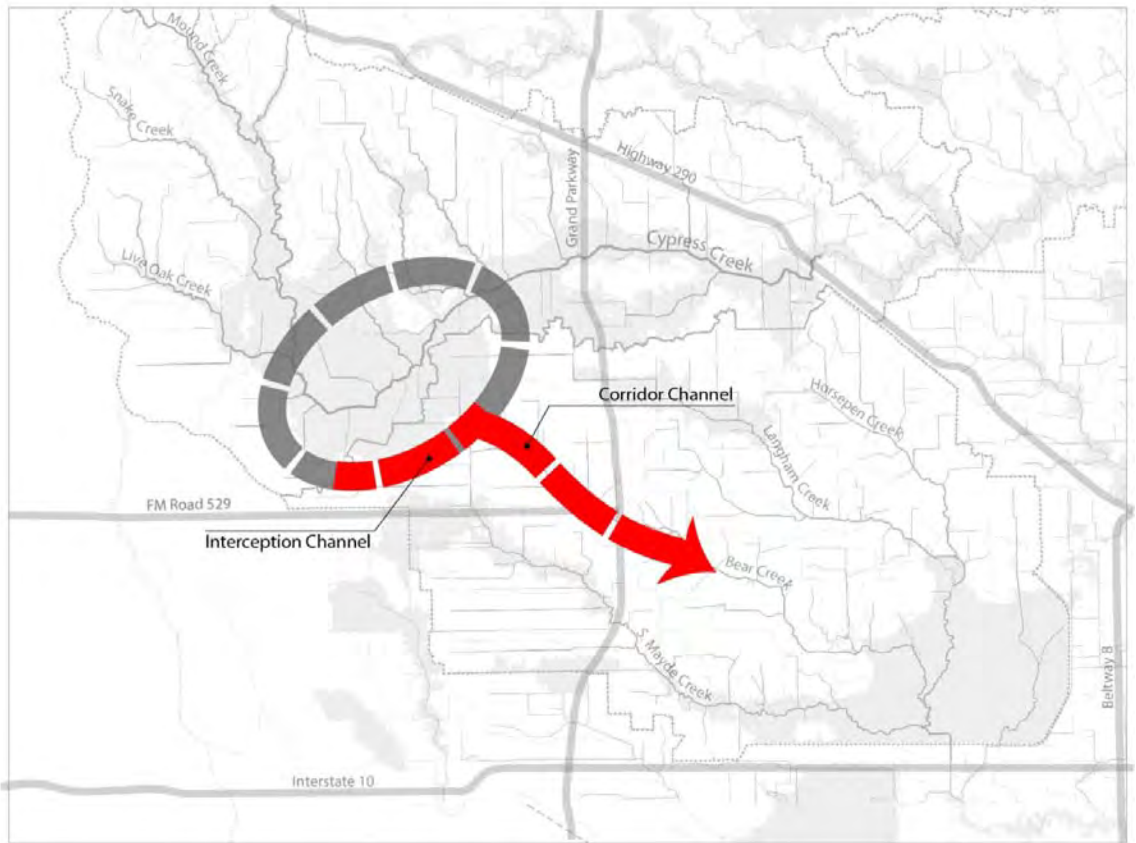


Figure 8.6 Plan 5, elements 2: Bear Creek conveyance improvements

Plan 5, Element 3 – John Paul's Landing Detention

John Paul's Landing is a Harris County Precinct 3 park located along, and east of, Katy-Hockley Road. Plans for the park include about 400 acres of lakes that would have a permanent water surface about eight feet below natural ground; and, therefore, would have significant detention capacity. The Upper Langham Creek Master Drainage Plan intends to utilize a portion of that available detention storage, with the remaining storage capacity used to collect and store the relatively small volume of overflow east of Katy-Hockley Road. Element 3 involves the excavation of this storage, which is about 500 acre-feet. This element is illustrated in Figure 8.7.

A channel would be constructed north of the park near the watershed divide, and this channel will collect overflow east of Katy-Hockley Road and convey it to the John Paul's Landing detention basins. The implementation of Element 3 will require coordination with park construction and activity associated with the Upper Langham Creek Master Drainage Plan. With in-kind contributions, this element will cost approximately $9 million, and will protect an approximately 3,500 acres from the 1% (100-year) overflow event.

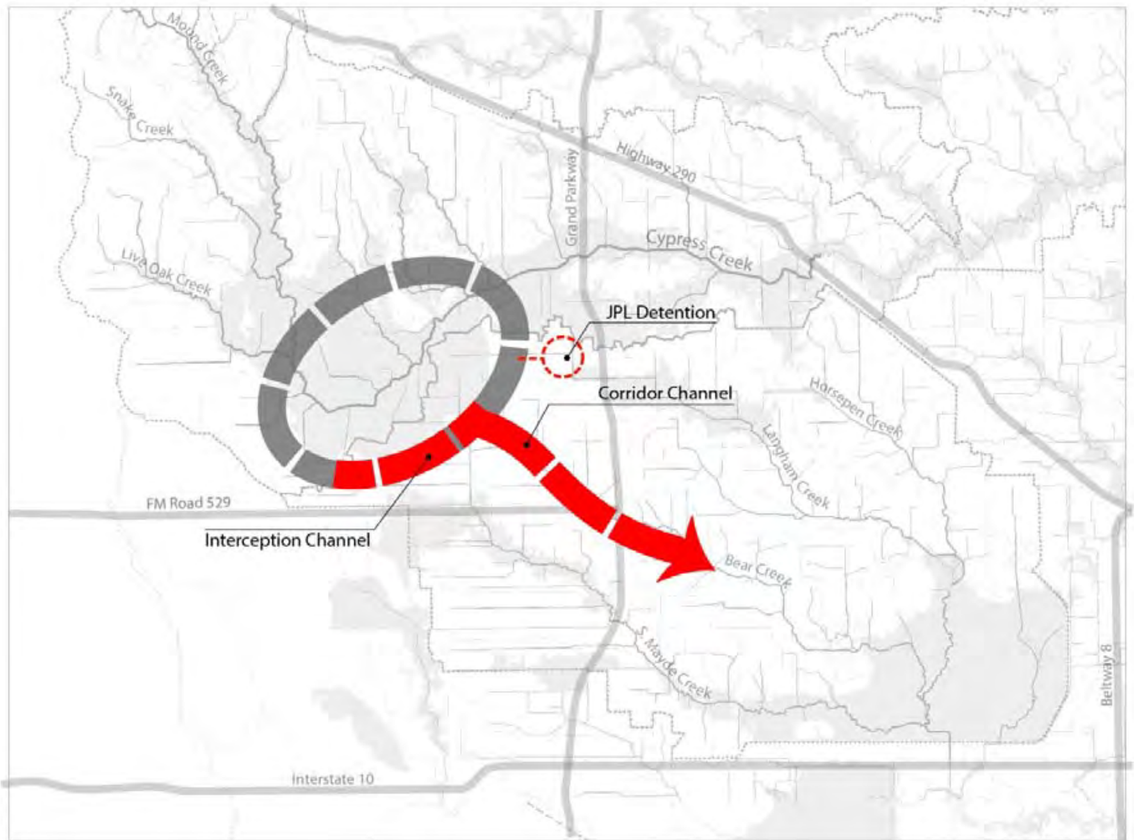


Figure 8.7 Plan 5, element 3:– JPL detention

Plan 5, Element 4 – Acquire Land for Construct Katy-Hockley N – Cypress Reservoir

The implementation of Element 1 would require obtaining flood easements across approximately 1,600 acres of land for the collection of the overflow and the construction of the east-west collection channel. This element requires the conversion of these temporary easements into permanent easements and/or fee ownership, as well as securing additional land for the reservoir.

With in-kind contributions, Element 4 will cost approximately $106 million. There is no land recovery singularly associated with Element 4.

Plan 5, Element 5 – Construct Katy-Hockley N – Cypress Reservoir

This element involves the construction of the berms necessary to occasionally impound water in the Katy-Hockley N – Cypress Reservoir, as well as the outfall and equalization structures.

Element 5 will cost approximately $79 million. Together, Elements 4 and 5 will protect an additional 5,500 acres from the 1% (100-year) overflow event.

Figure 8.8 illustrates Elements 4 and 5 for Plan 5.

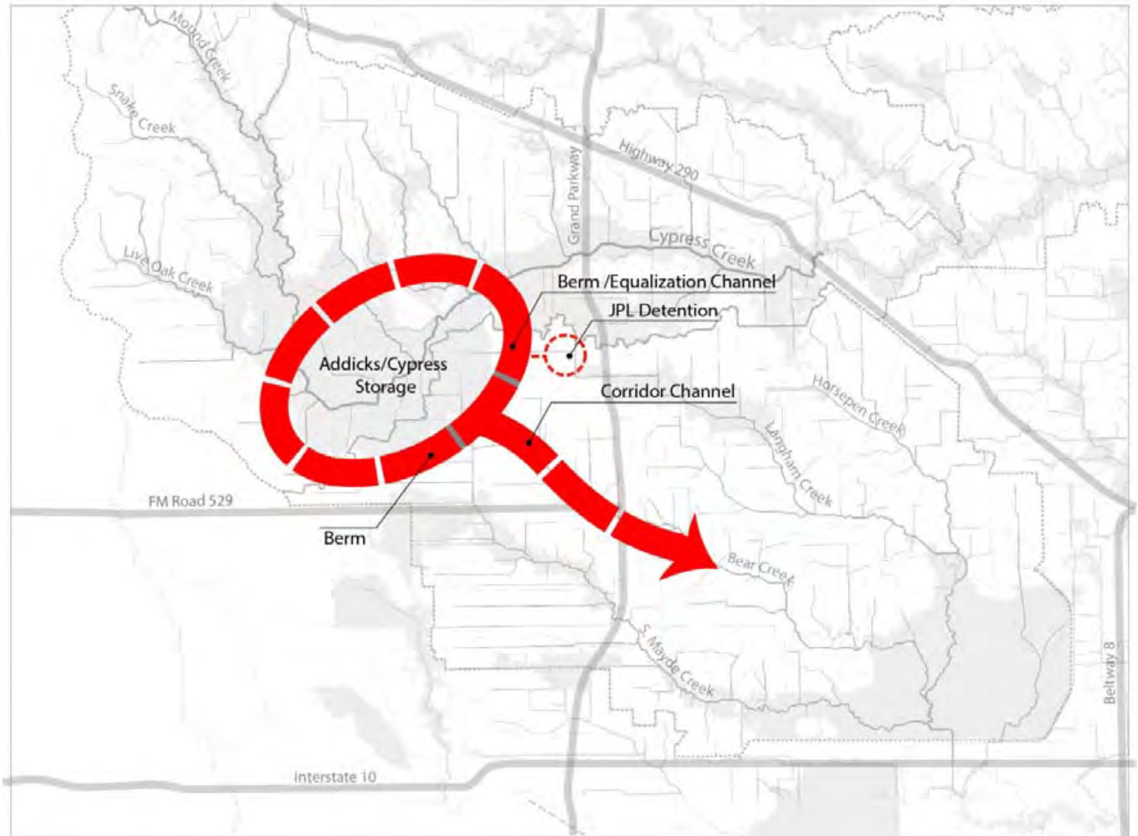


Figure 8.8 Plan 5, elements 4&5: acquire land and construct Katy-Hockley N-Cypress Reservoir

8.2 Funding and Finance Considerations

The development of a funding and financing plan is critical to the potential project's success Elements of a detailed implementation strategy would need to be developed further if a project is pursued. This document presents only a general framework of various options and strategies.

Ultimately, the goals of a funding program are to (1) develop a mechanism whereas the beneficiaries of the project pay an appropriate share of the project; and (2) develop a means to finance the initial project activity.

8.2.1 Funding Mechanism

The State of Texas makes available a number of potential infrastructure funding and financing vehicles. As discussed in Section 7, the primary economic benefit of the plan is the increase to the land value and efficiency of land development activity. Additionally, construction of a regional overflow management plan would eliminate the need for development to incorporate individual overflow management facilities into their overall design. As such, it is reasonable that a considerable share of the project cost will be borne by land interests. A number of finance plans exist that utilize the resultant development as its basis. Many of these, such as special purpose districts, issue debt and retire that debt through ad valorem taxes within the defined district. Impact fees may be collected to offset the cost of infrastructure provided for land development. Local government corporations can be established to oversee various layers of revenue sources, which may include ad valorem taxes in utility districts, one penny of sales tax (if not claimed by other entities in advance of implementing a regional overflow management plan), tax increment reinvestment zones (where tax revenue is derived from a pre-defined portion of the incremental rise in ad valorem tax values), and impact fees. In any of these, one party must act as the project sponsor and banker – in that they oversee the construction and operation of the project, secure the initial investment, and recover the investment through various revenue streams.

The cost and cast-flow model developed in support of this study has the ability to consider various financial mechanisms. Parameters can be adjusted to consider a range of funding scenarios, impacts to tax base, bond finance and recovery, effects on property values over time, and the rise in project costs over time. The most basic approach involved the determination of the cost per affected acre for the land development share of the cost. While this is presented in a manner consistent with an impact fee, and can be thought of in that manner, the primary purpose is to establish a project cost per acre of developed land. However, the model can then be utilized in the consideration of various funding and finance mechanisms.

8.2.2 In-Kind Contributions

In addition to contributions by land interests, there are opportunities for in-kind contributions. Development of land presents opportunities for the acquisition of the Bear Creek corridor, whereby developers will dedicate the 500-foot right-of-way required for the channel as part of their development platting. Because developers would typically prefer to deepen Bear Creek, and to excavate it as a source of material, the channel construction would be provided by developers as they work along the corridor. In addition, the corridor provides an opportunity for on-line detention and/or excavated detention.

Both Plan 3 and Plan 5 have the potential to substantially increase the area’s conservation footprint. The reservoirs both encompass land adjacent to existing conservation land, and they propose occasional and short duration inundation of existing conservation land. This inundation would not be significantly different than currently occurs, and would not affect the ultimate ecology or health of the land. In particular, the inundation associated with Plan 5 is very infrequent, as the existing conservation land is almost entirely outside of the 1% (100-year) pool, and the land that is within this pool would be subject to very shallow inundation. If adjacent land interests would allow the project to occasionally inundate this land, as described, in exchange for an addition to the area’s conservation footprint, this would substantially reduce the land cost associated with the plan.

Harris County Precinct 3 would benefit by gaining construction of lakes in John Paul’s Landing, as well as a potential water source from Bear Creek and the interceptor channel to the north. Their contribution to the plan is the allowance of a portion of John Paul’s Landing for detention.

8.2.3 Harris County Flood Control District (HCFCD)

HCFCD, as the recipient of the TWDB grant, supported the project and contributed funding to the overall study. The role of HCFCD in the ultimate implementation of a management plan is not certain. There is a need for an overall project sponsor to oversee the implementation the management plan; this role may be fulfilled by HCFCD or by another party, such as a special purpose district.

The project requires initial seed funding of about $50 million to implement the initial plan element. Once this initial element is constructed, land will be recovered for development, allowing for the land interest's contribution as described in Section 3.1. HCFCD benefits by providing a higher standard of flood risk reduction and watershed management by reducing flood damages to existing property, and by potentially reducing flood flows in Cypress Creek and Bear Creek.

The TWDB provides funding to communities through low interest loans to support various water resources development activities. The TWDB may be a viable source of funding for the project

8.2.4 Other Interests

The U.S. Army Corps of Engineers benefits from the proposed development policy that manages runoff volume to Addicks Reservoir, and also from the additional conservation footprint that protects land from future development. Funding support from the Corps is possible; however, it would likely require a Congressional appropriation.

Waller County benefits by the removal of some overflow in Cane Island Branch, as well as the certainty that comes with an established management plan in the Cypress Creek watershed. Plan 3 would provide opportunity for county park facilities in the portion of the reservoir land (Plan 3) that is not already dedicated to conservation. Waller County could contribute to the plan by adopting the development criteria recommended as part of both plans.

8.2.5 Pro Forma

A cash flow model was developed to assist in the evaluation of the two plans. This model establishes a funding basis, computes a per-acre cost basis, tracks an implementation schedule, and develops different charts that assist in evaluating the project. The model presented in this section assumes the in-kind contribution described in Section 8.2, and assumes that 70% of the remaining project cost would be borne by land interests and 30% would be borne by the project sponsor. However, these assumptions can easily be modified in the model input.

The model, as developed, provides a useful planning tool and could also be utilized throughout implementation. The model is in the form of an MS Excel spreadsheet. It is described in greater detail in Appendix F. The model outputs for each plan are presented in the following sections. These outputs demonstrate a viable implementation program for each plan. The actual parameters can be adjusted within the model to recognize changes in development rate, impact fee, funding mechanisms, and other constraints.

8.2.6 Implementation Schedule

Table 8.1 shows an implementation schedule for Plan 3, and Table 8.2 shows an implementation schedule for Plan 5.

The schedules shown depict an 18- to 20-year implementation timeline for both management plans. Ultimately, the schedule depends on the time needed to complete the engineering, permitting, land acquisition, and construction processes. Additional considerations available funding and include available cash flows.

Table 8.1 Plan 3 – implementation schedule

Component	Description	Start (BOY)	Duration	End (BOY)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		1	4	5																				
	Professional	1	2	3																				
	Real Estate	2	1	3																				
	Construction	3	2	5																				
2		5	14	19																				
	Professional	7	7	14																				
	Real Estate	5	3	8																				
	Construction	8	11	19																				
3		3	7	10																				
	Professional	3	7	10																				
	Real Estate	4	3	7																				
	Construction	7	2	9																				
4		2	13	15																				
	Professional	2	11	13																				
	Real Estate	2	11	13																				
	Construction	13	2	15																				
5		8	12	20																				
	Professional	8	6	14																				
	Real Estate	12	4	16																				
	Construction	16	4	20																				

Table 8.2 Plan 5 – implementation schedule

Element	Activity	Start (BOY)	Duration	End (BOY)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		1	4	5																				
	Professional	1	2	3																				
	Real Estate	2	1	3																				
	Construction	3	2	5																				
2		5	14	19																				
	Professional	7	7	14																				
	Real Estate	5	3	8																				
	Construction	8	11	19																				
3		6	10	16																				
	Professional	6	3	9																				
	Real Estate	7	3	10																				
	Construction	10	6	16																				
4		2	13	15																				
	Professional	2	13	15																				
	Real Estate	2	13	15																				
5		10	9	19																				
	Professional	10	6	16																				
	Real Estate	16	0	16																				
	Construction	16	3	19																				

8.2.7 Land Recovery

Figure 8.9 depicts a chart that illustrates the estimated land recovery rate versus development demand in the overflow area over time for Plan 3. Figure 8.10 depicts the same for Plan 5. These charts are based upon the development rate provided as part of the input data required to develop the chart. The implementation schedule presented was based on an average development rate of 800 acres per year, which was determined by investigating trends in other large developments such as The Woodlands in south Montgomery County as well as in the Katy-Fulshear corridor west of SH 99. The schedule also takes into account the population growth forecast for the region.

To be effective, the management plan must be able to recover land at a rate necessary to meet the overall development demand. During implementation, the model allows for the adjustment of the implementation schedule to meet this demand, within the constraints of the engineering, permitting, land acquisition and construction processes.

The models indicate that the implementation of the initial elements would satisfy this demand in a manner that allows for the time needed to engineering, permitting, land acquisition, and construction phases.

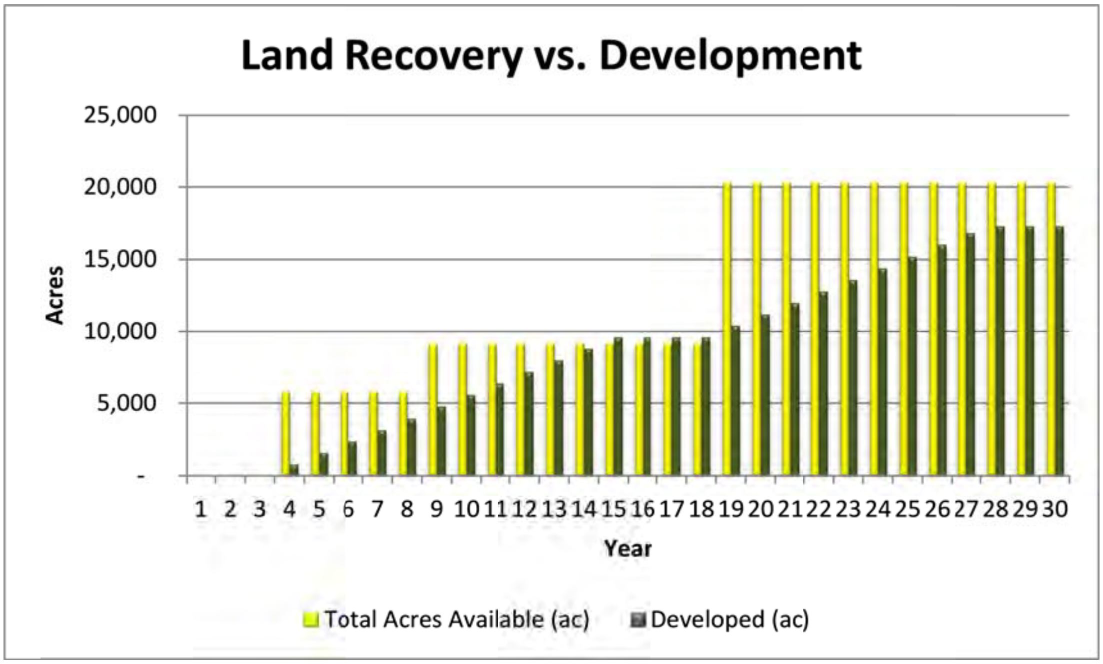


Figure 8.9 Plan 3 – Land Recovery vs. Development Demand

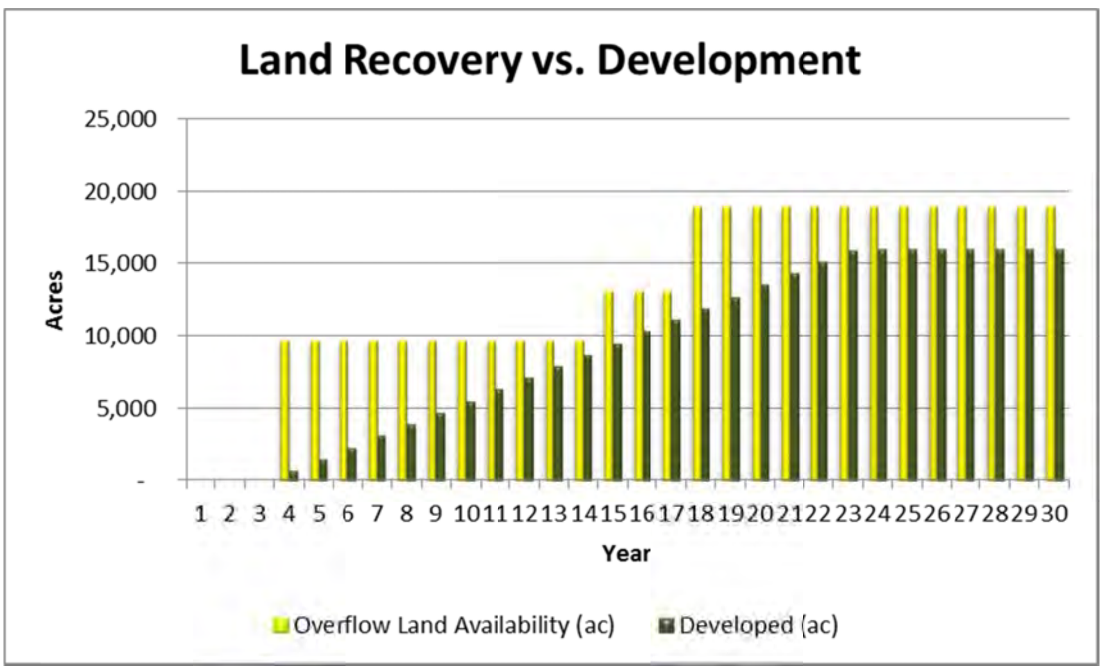


Figure 8.10 Plan 5 – land recovery vs. development demand

8.2.8 Annual Project Cost by Element (Component)

Figure 8.11 and Figure 8.12 illustrate, respectively, Plan 3 and Plan 5's annual project cost by element over the span of the proposed implementation schedule. The implementation schedules were developed in a manner that attempts to maintain a level cost throughout the implementation process. There is a higher cost in the second year because of the need to secure land in the initial collection area associated with Element 1 in both plans. This represents a portion of the initial investment that must be made in the project.

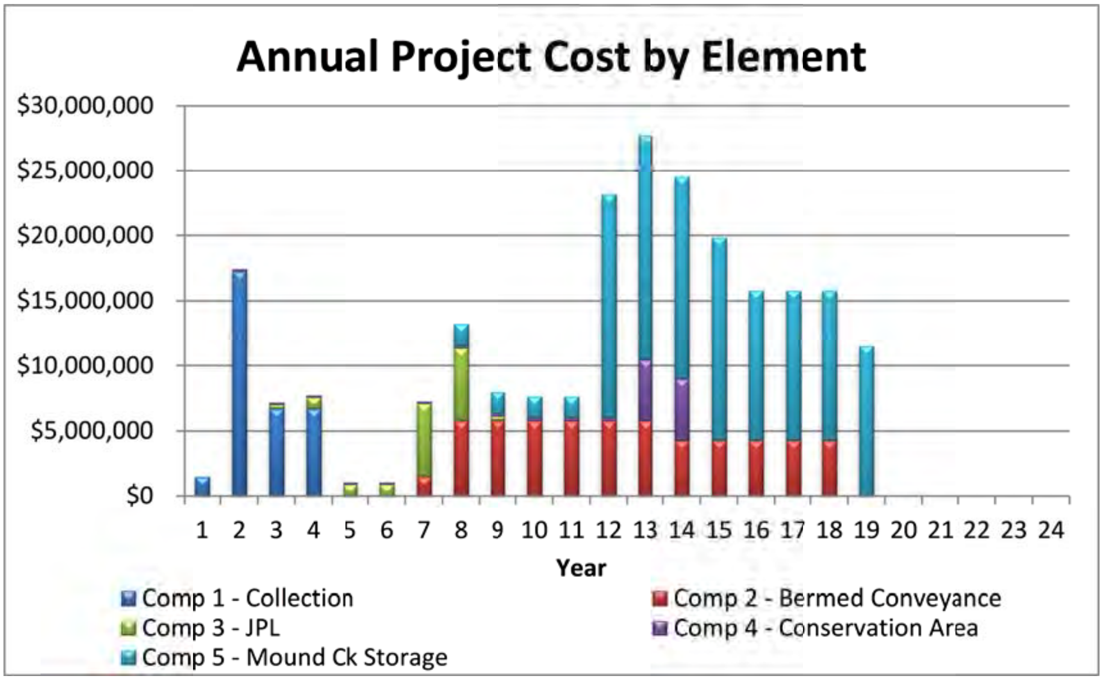


Figure 8.11 Plan 3 – annual project cost by element

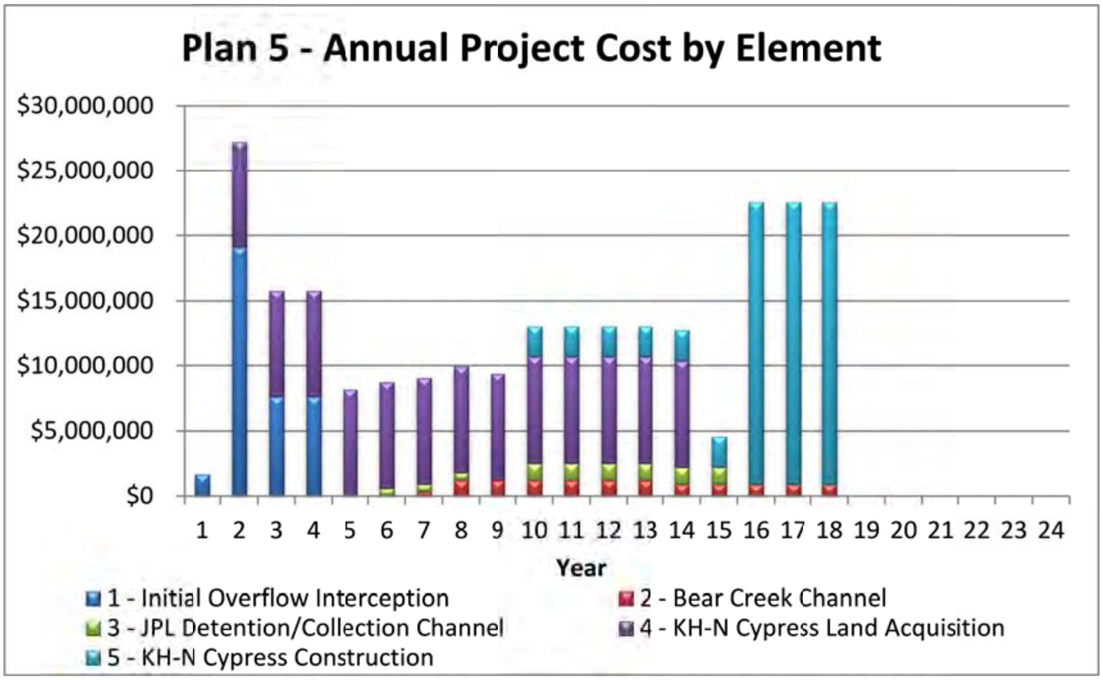


Figure 8.12 Plan 5 – annual project cost by element

8.2.9 Project Cost vs. Land Revenue

The management plans will provide a regional management strategy and eliminate the need for development to construct individual onsite overflow management facilities; therefore as the land develops it will contribute to the project cost. There are various methods for this to occur, and the basic input allows for the consideration of various funding mechanisms. This section presents the results of an impact fee model, which considers development impact fees paid as land develops. The model determines an impact fee from the basic input parameters. For Plan 3, the computed impact fee is $9,454 per acre; and for Plan 5, the computed impact fee is $11,708 per acre.

Figure 8.13 shows Plan 3's annual project cost compared to the annual project revenue, based on an impact fee model. Figure 8.14 shows the same for Plan 5. The revenue stream from the project will change based on the rate of development and the impact fee.

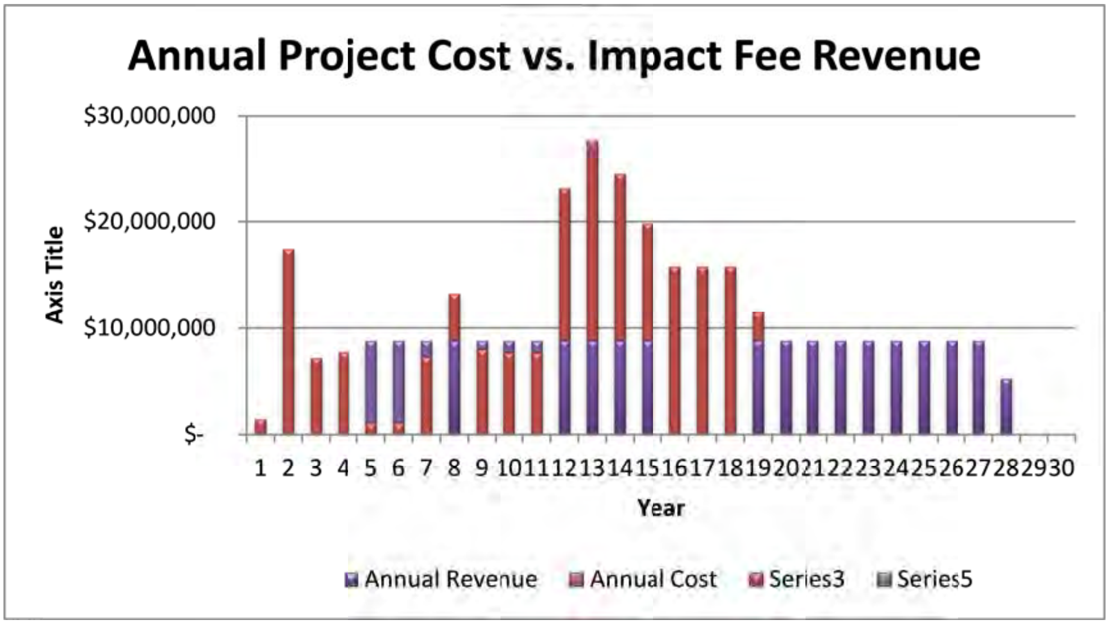


Figure 8.13 Plan 3 – annual project cost vs. land revenue (impact fee model)

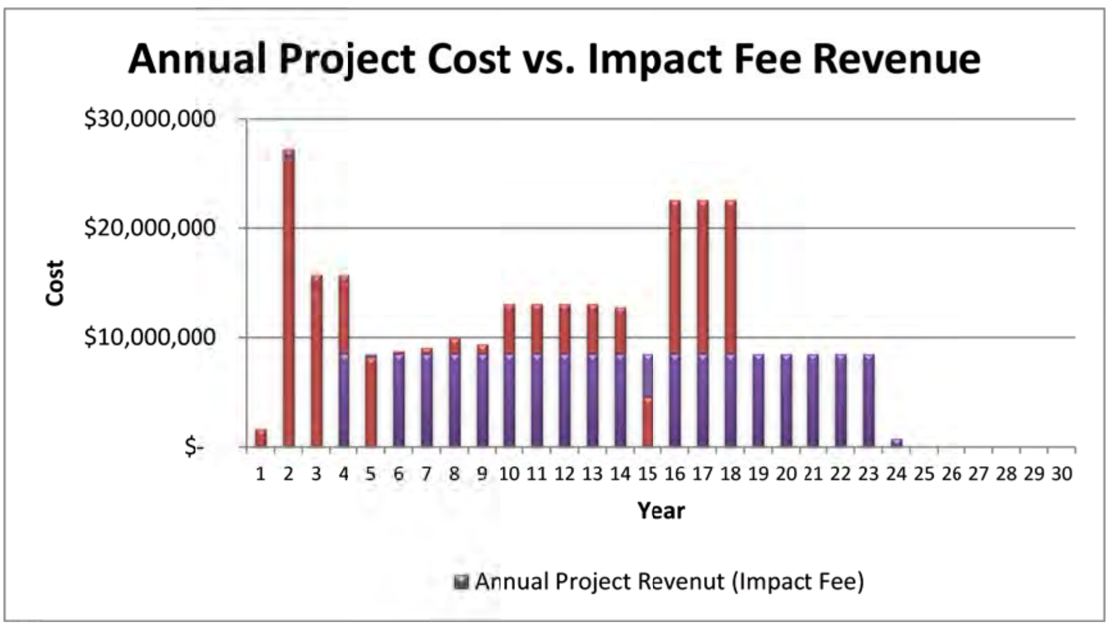


Figure 8.14 Plan 5 - annual project cost vs. land revenue (impact fee model)

The comparisons presented in Figures 8.5 and 8.6 provide insight into annual costs and revenue, however they do not clearly reflect the overall financial structure of the implementation plan. Figures 8.7 and 8.8 compare the cumulative annual costs and revenue of both plans. The red bars in both graphs represent the project costs in excess of the revenue that would be borne by the project sponsor. This includes the initial investment in addition to the funds needed to complete the project once the land is fully developed and revenue streams cease.

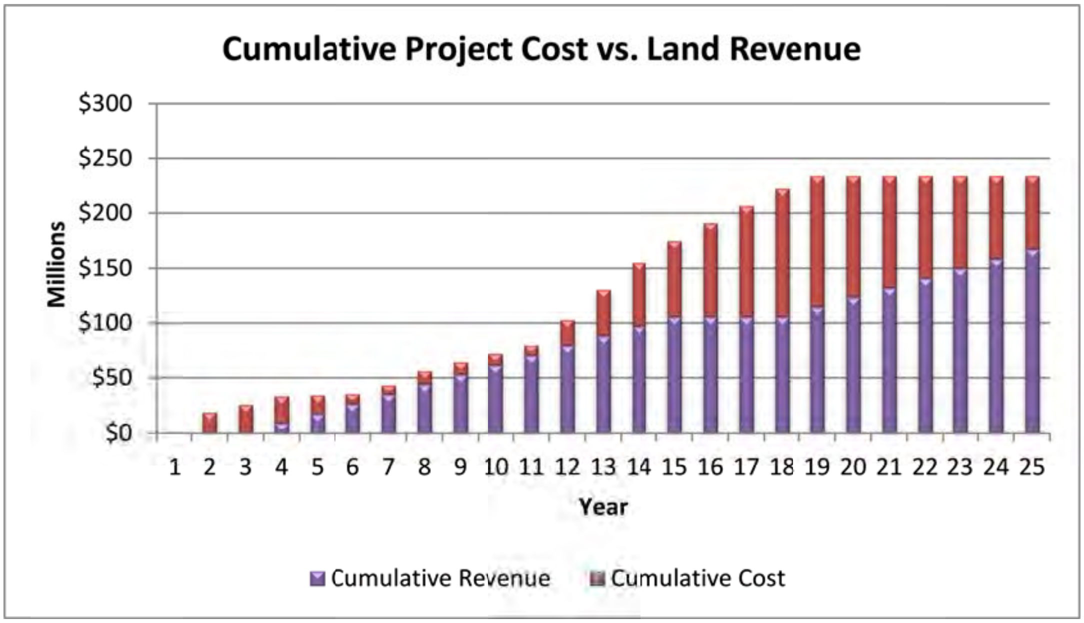


Figure 8.15 Plan 3 – cumulative project cost vs. land revenue (impact fee model)

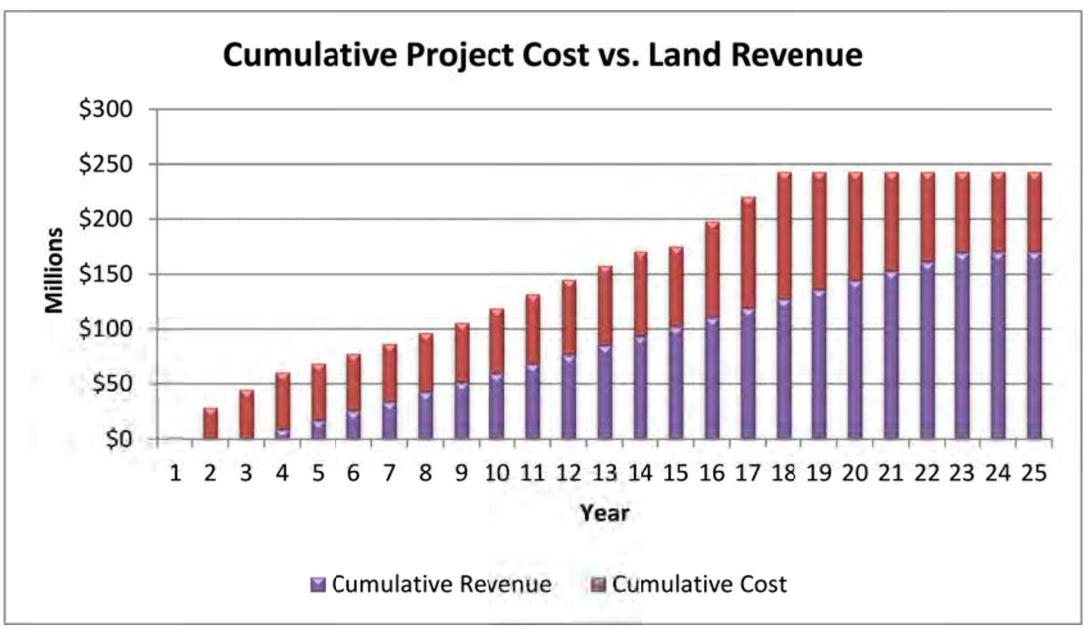


Figure 8.16 Plan 5 – cumulative project cost vs. land revenue (impact fee model)

8.2.10 Ad Valorem Tax Revenue

The management plans will open up land for development that is currently encumbered by the overflow floodplain. The total tax base created by the proposed management plan and project will influence future Harris County tax revenues. Figure 8.17 depicts the anticipated annual tax revenue to Harris County, for Plan 3, from development in the overflow area, assuming a tax rate of $0.658 per $100 valuation. Figure 8.18 depicts the anticipated annual tax revenue to Harris County for Plan 5.

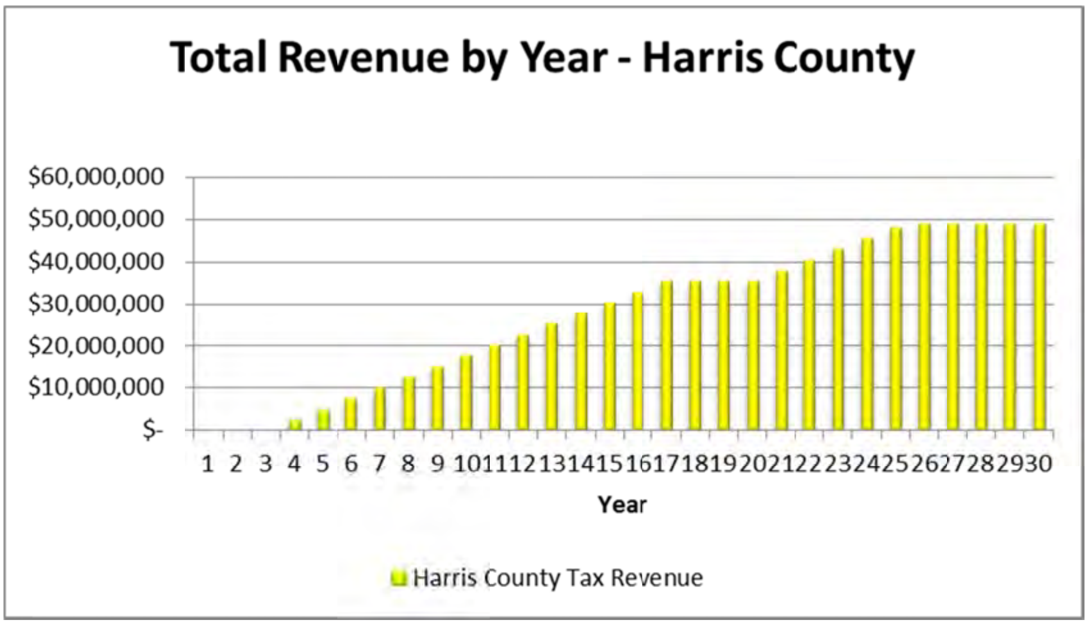


Figure 8.17 Plan 3 – annual Harris County tax revenue – development in overflow area

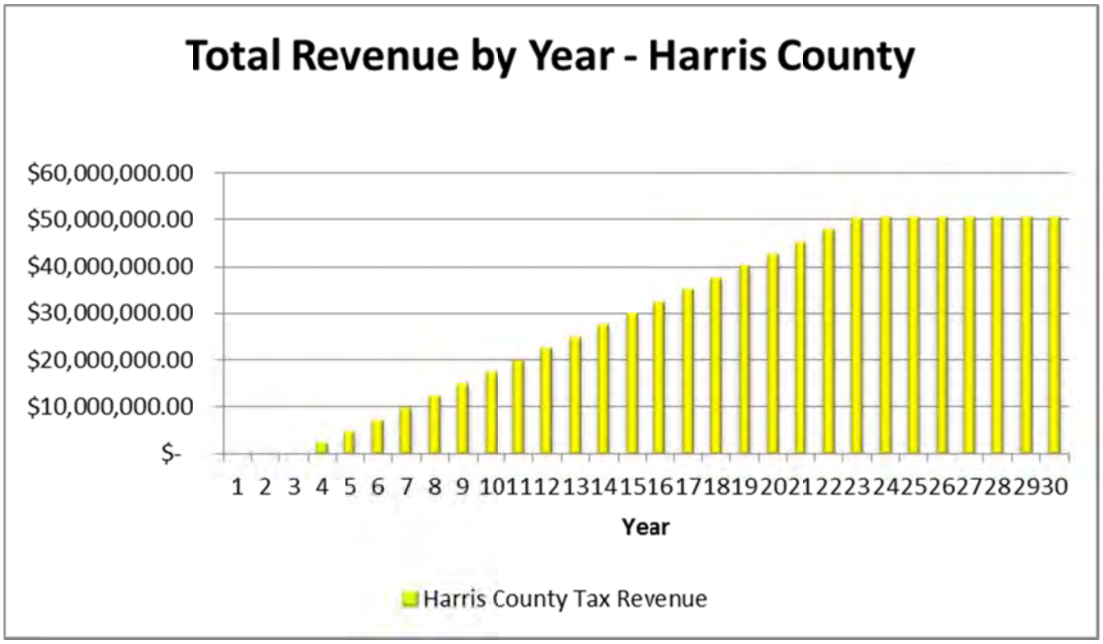


Figure 8.18 Plan 5 – annual Harris County tax revenue – development in overflow area

8.2.11 Summary

The cash flow model has additional outputs that could be used to consider impacts to tax revenue and other potential funding scenarios; however these outputs were not developed for this plan.

The various charts presented in this report indicate the implementation viability of each alternative assuming the provision of land revenue and in-kind contributions. The charts also demonstrate how the "Schedule Input" can be adjusted to balance the annual costs, meet the land development demand, and manage overall implementation.

9 Public Outreach Program

The goals of the Cypress Creek Overflow Management Plan study's public outreach program have been to communicate to the public the scope of activities being considered, and to solicit suggestions that might be incorporated into the planning effort. This purpose complements the Harris County Flood Control District's overall communications strategy to inform, educate and engage the public in its flood damage reduction activities. It also reflects the District's mission statement: **To provide flood damage reduction projects that work with appropriate regard for community and natural values. The District accomplishes its mission by devising the flood damage reductions plans; implementing the plans; and maintaining the infrastructure.**

9.1 Background

As HCFCD began to conceptualize this effort in late spring 2011, a steering committee comprised of key stakeholders was established to assist in identifying the array of issues associated with competing land interests and drainage concerns in the study area. The steering committee encouraged HCFCD to apply to the Texas Water Development Board for funds to conduct this planning effort, and has been central to the development of a possible regional overflow management plan. The steering committee's membership and its meetings are described in Section 9.2.

Three public meetings were held during the course of the study. They are detailed in Section 9.5.

As the study progressed, additional interested groups and individuals were identified, and meetings were held with a broader stakeholders group. Section 9.3 describes those meetings.

Meetings were also held with individuals and groups who had a stake in the outcome of the planning effort. These meetings are listed in Section 9.4.

HCFCD used multiple communications tools to reach the individuals and groups during the public outreach effort, including public notifications, direct mail, written materials, public presentations and information posted on the HCFCD website. Sections 9.6 through 9.10 delineate the various public outreach tools, the settings in which they were applied and the groups that were addressed.

The study team has worked to provide information to the interested public, and to public officials who ultimately will decisions about the future course of a regional plan to manage the Cypress Creek Overflow.

9.2 Overflow Steering Committee

In June 2011, the Flood Control District organized a steering committee of key stakeholders to identify the array of issues associated with the competing land interests and drainage concerns in the study area. The steering committee included representatives from Harris County Precincts 3 and 4, City of Houston, Katy Prairie Conservancy, U.S. Army Corps of Engineers, West Houston

Association, Harris County Public Infrastructure Department and HCFCD. These are individuals and entities that have some or all of the following characteristics in common:

- Have major investments in the study area
- Are responsible for or can influence development
- Construct major public infrastructure projects
- Were willing to work in a collaborative environment
- Were willing to dedicate time to an 18-plus month study and meet twice monthly.

One of the first questions addressed by the steering committee was whether additional members were needed to adequately identify the issues and fairly represent the various interests in the study area. As a result, representatives from Waller County and the Bayou Preservation Association were added to the group.

Although the steering committee's membership was drawn from several political subdivisions, this study's objective has been (1) to establish guidelines for development in Harris County that are appropriate for the unique hydrologic environment in the overflow area; and (2) to develop a regional plan to reduce flooding from the Cypress Creek Overflow that could gain support of all the interests in the study area.

Procedurally, the steering committee's meeting format generally has been to have fact-sharing and interest-identifying presentations, followed by round table discussions. As the study proceeded, many meetings were devoted to discerning consensus on potential strategies or alternative plans for managing the Cypress Creek Overflow. The committee worked through a reasonably long list of management strategies to identify a short list of promising alternative overflow management plans for further analysis.

In January 2013, the steering committee met in a workshop format to discuss the relative merits of alternative strategies, and how these strategies would affect the various interests represented. The committee also discussed how information might be communicated with area interests. This served as an aid to developing presentations and written materials for a meeting of area stakeholders that was held the following month.

From its inception through September 2014, the steering committee met, considered information and provided input to the project team at 35 separate meetings. Table 9.1 presents a list of the steering committee meetings and the primary topics on the agenda. Presentations made by HCFCD staff at the steering committee meetings are considered to be working documents. Several steering committee members gave presentations that contained material that contained confidential or proprietary information; therefore, those presentations are not reproduced here. The steering committee continues to exist and was, and will be, a critical component of the public outreach effort for this study.

Table 9.1 Cypress Creek Overflow Management Plan Steering Committee meeting chronology

Date	Agenda
2011 28 June	Organizational Meeting Pres. on Concepts by Alan Potok, HCFCD Discussion: Beginning to Define Issues
2011 12 July	Pres.: Flooding by Jeff Lindner, HCFCD Pres.: Floodplains by Gary Bezemek, HCFCD Pres.: Addicks/Barker by Richard Long, USACE Discussion: Beginning to Define Issues
2011 26 July	Pres.: Addicks Mapping Update by David Randolph, HCFCD Pres.: Langham Creek Plan by Potok and David Saha, HCFCD Discussion: Magnitude, Boundaries of Overflow Area
2011 9 August	Discussion: Issues identified at the June 28 meeting.
2011 23 August	Pres.: Katy Prairie Conservancy by Mary Anne Piacentini, KPC Pres.: Waller County Interests by S. Reiter and Yancy Scott, Waller Co. Pres.: West Houston Assn. Interests by Roger Hord, WHA Discussion: General
2011 13 September	Discussion: Items for Consultant Scope of Work Discussion: Desirable Criteria for Consultant
2011 27 September	Pres.: Internal Committee Communication Pres.: 2004 Overflow Study by Carl Woodward, HCFCD Pres: Overflow 2007-08 Studies by Costello Inc. Pres.: Addicks and Cypress Studies by Brown & Gay Engineers, Inc. by Lee Lenard, BGE Discussion: Mapping Conceptual Mitigation Scenarios
2011 11 October	Discussion: Mitigation Alternatives from Previous Studies
2011 25 October	Discussion: Internal Committee Communications Techniques

Table 9.1 Cypress Creek Overflow Management Plan Steering Committee meeting chronology

Date	Agenda
2012 24 January	Pres. by Alan Potok, HCFCD, on (1) Grant Appl. to TWDB; (2) Additional scope of service items not covered in Grant; (3) Consultant Team
	Discussion: General
2012 26 June	Introduce Consultant Team: Mike Talbott, HCFCD
	Pres.: Addicks Reservoir Repairs by Richard Long, USACE
	Pres.: Waller County Drainage Criteria Update by Stephen Reiter, Halff Assoc.
	Discussion: Summary of Issues and Goals of the Members
2012 10 July	Pres.: Prairie grass Study Update by Mary Anne Piacentini, KPC
	Pres.: Addicks Reservoir Repairs Update by Richard Long USACE
	Discussion: Mapping Areas of Special Concern
2012 24 July	Pres.: CC Overflow Hydrology by Burton Johnson, Baker
	Pres.: July 2012 Flood Event on CC, by Alan Potok, HCFCD
	Pres.: Constraints on Widening Channels into Addicks Reservoir, by Kevin Shanley, SWA
	Pres.: Planning Concepts for Overflow Storage in Upper Addicks, by Kevin Shanley, SWA
	Discussion: Steering Committee Feedback on Presented Material
2012 14 August	Pres.: Task 4 Environmental Issues, by Stephen Benigno, HCFCD
	Pres.: Waller County Drainage, by Halff Associates. for Waller County
	Pres.: Prairie Inundation, by Mary Anne Piacentini, KPC
	Pres.: Overview of Upcoming Public Meeting, A. Potok, HCFCD
	Discussion: Steering Committee Structure
2012 28 August	Discussion: Project Schedule
	Pres.: Mound Creek Base Plan Scenario
	Discussion: Base Plan Scenario
	Discussion: Next Conceptual Plan for Analysis
	Discussion: Outcome of Public Meeting held on August 16, 2012
2012 11 September	Discussion: Acquisition in the AO Zone
	Discussion: Bear Creek Conveyance Corridor
	Discussion: Next Conceptual Plan to Analyze
	Discussion: Outcome of August 16 Public Meeting
2012 25 September	Discussion: Alternate Bear Creek Conveyance Channel Concept
	Discussion: Katy-Hockley Storage Reservoir Concept
	Discussion: Objectives for Comparing Conceptual Plans

Table 9.1 (Continued) Cypress Creek Overflow Management Plan Steering Committee meeting chronology

Date	Agenda
2012 9 October	Discussion: Planning Objectives for Evaluating the Strategies Discussion: Cost Estimates for Katy-Hockley Storage Strategy Discussion: Improved Cost Estimate for Mound Creek Strategy Discussion: Hydrology and Hydraulic Considerations for Channel Conveyance Strategy Considering Ultimate Development Conditions
2012 13 November	Discussion: Project Schedule Discussion: Formation of Stakeholder Group and Stakeholder Meeting Pres.: Environmental Tasks Update Pres.: Refined Cost Estimates Pres.: 2-Dimensional Hydraulic Model Pres.: Draft Strategy Evaluation Objections
2013 22 January	Steering Committee Workshop Pres.: Background Information and Basic Options: Store It; Move It; Manage It Two Group Breakout for Discussion Summaries of Group Findings Discussion: Path Forward
2013 26 March	Pres.: Concept of a Complete Management Plan Pres.: Plan Evaluation Criteria List Pres.: Project Team Proposed Plan #1 Discussion: How the Plan Addresses the Interests of the Steering Committee Members
2013 9 April	Pres.: Summary of Meetings with Corps of Engineers; West Houston Association representatives; Waller County representatives; Katy Prairie Conservancy representatives Discussion: Steering Committee Interests and Concerns
2013 24 April	Pres.: Summary of April 12, 2013 Meeting with the Corps of Engineers Galveston District Discussion: Continued Review of Management Plan #1 Pres.: Introduction of Proposed Management Plan #2 Pres.: Environmental Mitigation Limitations with the Addicks and Barker Project Area
2013 14 May	Pres.: Summary of Preliminary Data from Rainfall Test Sites Discussion: Management Plan #2 Discussion: Differences in Drainage Requirements between Plan #1 and Plan #2 Discussion: Cost Estimates for Management Plans #1 and #2
2013 11 June	Discussion: Management #2 Revisions Discussion: Management Plans #3, #4, #5

Table 9.1 (Continued) Cypress Creek Overflow Management Plan Steering Committee meeting chronology

Date	Agenda
2013 25 June	Pres.: Review of Management Strategy Options, by B. Johnson Discussion: How to Evaluate as Thumbs Up, Thumbs Down, or Neutral
2013 23 July	Pres.: Addicks Reservoir Watershed Update Pres.: Review of Management Strategy Alternatives Pres.: Stormwater Runoff Volume Assessment Discussion: Prioritize Management Strategies Discussion: Choose Two Strategies for Further Study
2013 13 August	Pres.: Analysis of Future Conditions Discussion: Evaluating Alternative Strategy Scenarios Discussion: Implementation Strategy
2013 10 September	Discussion: Implementation Strategy/Phasing Discussion: Cash Flow Analysis Discussion: Completion of a Plan
2013 24 September	Discussion: Conservation and Environmental Mitigation Discussion: Implementation Strategy and Cash Flow Analysis (Management Plan #5)
2013 8 October	Discussion: Bear Creek Overflow Conveyance Corridor Discussion: Community Value of the Regional Management Plans Discussion: Cash Flow Analysis Alternative Participation Scenario
2013 23 October	Discussion: Cash Flow Analysis and Alternative Participation Scenario led by Burton Johnson Discussion: Alternative Funding Strategy led by Kevin Shanley and James Vick
2013 26 November	Discussion: Preparing a Draft Pathway for Implementation Discussion: Cash Flow Analysis Discussion: Inundation Depth and Duration Considerations
2014 4 February 2014 8 September	Pres.: Study Schedule Update by Dena Green, HCFCD Discussion: Consensus for a Regional Plan Pres.: Review of Preferred Regional Management Plans by Dena Green and Burton Johnson Discussion: Study Update; Moving Forward with a Regional Plan

9.3 Stakeholder Meetings

At the introductory public meeting for the Cypress Creek Overflow Management Plan, attendees were asked if they wanted to participate in additional meetings as an interested stakeholder. A number of individuals indicated that they would like to do so in order to receive updated information about progress of the study. Materials were developed and a stakeholders meeting was held on February 12, 2013 at HCFCD's North Service Center Pavilion Meeting Room. Invitations to the meeting were mailed to all who had indicated at the public meeting that they wanted to be included, as well as to established groups with known interests that might intersect with overflow management planning.

Approximately 30 meeting participants heard presentations, received handout materials and engaged in a question-and-answer session with project team members, including the study manager and the Director of the Flood Control District. *[See Appendix H Section 3.1 for meeting materials, the PowerPoint presentation, list of invitees and list of attendees.]*

During the question-and-answer period, the study team was questioned about future meetings. Stakeholders were told that another meeting would be held, either just before or after the second public meeting. A second stakeholders meeting was held on May 20, 2014, to provide an update as the study neared completion. Topics discussed included options for the expected recommended regional management strategy and the recommended Guidelines for Development in the Upper Cypress Creek and Addicks Reservoir watersheds. *[See Appendix H Section 3.2 for the agenda, PowerPoint presentation, list of invitees and list of attendees.]*

9.4 Group and Individual Meetings

Throughout the study process, meetings and briefings were held with individuals and groups who are important to the outcome of the planning effort. Some of these are organizations with representatives on the steering committee; others are organizations whose mission makes them important to the success of a management plan. They include:

- West Houston Association
- Katy Prairie Conservancy
- Bayou Preservation Association Board of Directors,
- U.S. Army Corps of Engineers, Galveston District
- Waller County
- Cypress Creek Flood Control Coalition Board of Directors

Meetings also were held with staff of Harris County Precincts 3 and 4 and with representatives of the Harris County Public Infrastructure Department.

9.5 Public Meetings

The first of three public meetings scheduled for this study was held on August 16, 2012. The meeting was held at the Harris County Precinct 3 Bear Creek Community Center, which is physically located within the Addicks Reservoir footprint and is a popular and well-used meeting place. The study area is large and some meeting attendees faced extended travel time, so the meeting was held at 3:30 p.m. to accommodate those who could attend during the day, and those who were excused from work to attend. There were approximately 140 individuals attendees at the meeting.

A PowerPoint presentation of study material was presented at the meeting, and questions were taken after the presentation. Computer-Assisted Real Time Translation (CART) technology was used to record the meeting and it provided a transcript (see Appendix H Section 4.1). Meeting materials, including the presentation and transcript, were placed on the Cypress Creek Overflow Management Plan study page on the HCFCD website.

The second public meeting was held on November 7, 2013 at the Harris County Precinct 3 Bear Creek Community Center.

As with most public meetings, turnout estimates can be very imprecise. To provide some assurance that the facilities would accommodate all who wanted to attend, two sessions were held, one at 2 pm and one at 7 pm. As it turned out, the facility was adequate, with about 100 attending the afternoon meeting, and about 45 attending the evening meeting.

The same presentation was provided at each meeting, and questions were taken afterward. Computer-Assisted Real Time Translation (CART) technology was used to record the meeting and it provided a transcript (see Appendix H Section 4.2). Meeting materials were placed on the HCFCD website.

A third public meeting was held on September 25, 2014 from 6-8 p.m. at the Harris County Precinct 3 Bear Creek Community Center.

Members of the Flood Control District study team provided details of the Cypress Creek Overflow Management Plan study, the final two concept plans (Plan 3 and Plan 5) and information about study findings that was included in the draft study report (posted on the Flood Control District's website at www.hcfcd.org/cypressoverflow). The presentation was followed by a question-and-answer period.

A summary of meeting details follows:

- 94 total attendees:
    - 74 members of the public
    - 20 staff (HFCFD study team plus employees who volunteered to work at the meeting)
- 39 organizations/government agencies/firms were represented:
    - Energy Corridor District, West Houston Association, Cypress Creek Flood Control Coalition, Cypress Creek Greenway Coalition, Hearthstone Flood Coalition, Katy Prairie Conservancy (6)
    - City of Waller, City of Katy, Katy ISD, Morton Road MUD, Harris County MUD 127, Chimney Hill MUD, Harris County MUD 208, Harris County Public Infrastructure Department, Harris County MUD 64, Texas Water Development Board, Barker Cypress MUD, Harris County Precinct 4, City of Houston, Ricewood MUD, Jackrabbit Road PUD, Chimney Hill MUD, Harris County MUD 136 (17)

  - Walter P. Moore, Gracious Engineering, Brown & Gay Engineering, Costello Engineering, 5engineering, Halff Associates, Brewer Escalante, Charter Development, EHRA Engineering, Freese & Nichols, Dannenbaum Engineering, Michael Baker International, R. G. Miller Engineers, Lario Land Consultants, Jones & Carter, LSA Engineering (16)
- 3 reporters (media) covered the meeting:
  - Shawn Arrajj, reporter, Community Impact News
  - Bryan Kirk, reporter, Houston Chronicle
  - Karen Zurawski, editor, Houston Chronicle

The majority of attendees appeared to have prior knowledge of the study, and most likely, had attended at least one of the two previously held public meetings or one of the two stakeholder meetings. A question-and-answer session was held at the end of the public presentation. It was announced that the draft report was available to download from the website, and that public comments on the draft report were due to the Flood Control District by October 25, 2014.

9.6 Public Notifications

Newspaper

Many people still rely on legal advertisements in local newspapers to monitor the actions of government agencies. In a metropolitan area as large as Houston, a major general circulation newspaper provides a venue for notices of public meetings. For each Cypress Creek Overflow public meeting, notice was placed in the Houston Chronicle, well in advance of the meeting. See Appendix H, Sections 4.1.1 and 4.2.1 for copies of the following notices:

- Newspaper Notice, Houston Chronicle, July 26, 2012
- Newspaper Notice, Houston Chronicle, October 4, 2013
- Newspaper Notice, Houston Chronicle, September 3, 2014

Commissioners Court

Harris County Commissioners Court meeting agendas are posted with the Harris County Clerk's office and advertised the Harris County website at least three days before the meeting. Items involving the Harris County Flood Control District are an identified subgroup of actions on the Commissioners Court agenda. Public comments are received on agenda items.

Permission to apply for a grant from the Texas Water Development Board was received from Commissioners Court on January 10, 2012, and the awarded grant was accepted on August 21, 2012. If the Cypress Creek Overflow Management Plan study results in a recommendation for new or revised guidelines for development, those policies will be placed on a Commissioners Court agenda for action.

Signs

HCFCD casts a wide net to inform the public about opportunities to learn about its activities and to comment on them, particularly in the surrounding area of a project or study. Outdoor signs are placed strategically near meeting locations as an aid to the public in locating meeting sites and to attract meeting attendees. Prior to the Cypress Creek Overflow Management Plan study public meetings held at the Bear Creek Park Community Center, Harris County Precinct 3 (Hon. Steve Radack, Commissioner) contributed two movable signs, which were placed on major roadways (Eldridge Parkway and SH 6) near the meeting location.

9.7 Direct Mail

Grant Application

Direct mail notification of the application for a grant from the Texas Water Development Board was made to local elected officials and to more than 400 local utility and water districts in the study area on January 11, 2012 (See Appendix H, Section 5.1 for Letter to Elected Officials).

Other

- Letters were mailed to government and nonprofit agencies on July 20, 2012, announcing the initial public meeting to be held on August 16, 2012 (See Appendix H, Section 5.2). Elected officials were also sent a letter on July 26, 2012, advising them of the public meeting (See Appendix H, Section 5.3).

- Letter invitations were sent to interested parties announcing the stakeholder meeting in January 2013 (See Appendix H, Section 5.4). The list of interested parties included individuals who had indicated their interest at the first public meeting, as well as established groups or agencies who could be affected by an overflow management plan.

- In April 2014, letter invitations were sent to interested parties announcing a stakeholders meeting to be held on April 29, 2014 (See Appendix H, Section 5.5). The interested parties list was similar to that of the stakeholders meeting held in 2013.

9.8 Written Materials

Collateral Materials for Meetings

- The grant application was distributed to local elected officials and municipal utility districts in the study area.
- The HCFCD watershed fact sheets for the Addicks Reservoir Watershed and for the Cypress Creek Watershed were available to the public at all three meetings. *[See Appendix H, Section 6.1 and 6.2 for copies of the watershed fact sheets.]*

- A briefing book was developed for the January 2012 stakeholder meeting.
- The U.S. Army Corps of Engineers supplied an Addicks Reservoir Fact Sheet for use at all meetings*. [See Appendix H, Section 6.3.]*

Reports

- A draft final report was made available to the public for review and comment.
- When it is available, the final report will be posted on the HCFCD website.

9.9 HCFCD Website

The HCFCD website has a Cypress Creek Overflow Management Plan study page, which provides general study information as well as information presented at the public meetings. Additionally, the site provides a mechanism for questions and comments to be transmitted to HCFCD. Appendix H, Section 7.1 presents a screen shot of the CCOMP webpage, which can be found at www.hcfcd.org/cypresscreekoverflow. Appendix H, Section 7.2 shows the form for submitting comments to HCFCD via email at the website. Materials located at the website include:

- Grant application
- Meeting notices
- Meeting transcripts
- Comments received
- Public comment submittal form

9.10 Moving To Implementation

Responding to Comments

Throughout the study process, response to comments has been largely informal; more focused on sharing information, constructive dialogue and working toward a solution than arguing the fine points of a particular proposal. All meetings have incorporated time for questions and answers, either during or after presentations, or both. The objective has been to bring public questions and comments into the planning process so that potential solutions developed by the project team could accommodate public concerns and suggestions. A summary of comments received was prepared and posted on the HCFCD website after each of the public meetings *(*See Appendix H, Section 4).

Finding Acceptability

The Flood Control District has sought acceptability of a proposed regional overflow management plan through several efforts. The first and central focus of these efforts has been through discussions with the steering committee. Since this body represents a spectrum of interests that must be accommodated in a successful management plan, many months of meetings were spent defining a plan that would effectively manage the overflow itself while addressing the needs of area businesses and communities. The steering committee narrowed the potential management plan alternatives by conducting a “thumbs up/thumbs down” exercise, and then refining options that were potentially acceptable to the majority of the membership. The reduced number of options were closely scrutinized, and finally narrowed to two. The study team ultimately decided upon the most feasible option that was most likely to be accepted by the broader community.

At two points in the process, stakeholders were brought together to learn about the study's progress. In addition, study team members met with a number of groups that had a strong interest in solutions proposed by the study.

Study team members also met individually with members of the steering committee outside of the committee setting. Comments received at these meetings about the recommended Cypress Creek Overflow Management Plan, and Interim Guidelines for Development in the Upper Cypress Creek and Addicks Reservoir Watersheds, were key to helping determine the general level of community acceptability of the proposed plan.

Building for the Long Term

It is clear that for a regional management plan to be accepted, HCFCD must have broad community support that is strong enough to sustain at least two decades. That is the period of time that it will likely take to implement the regional management strategy that is recommended by the study team, both for engineering reasons and (mostly) for financial reasons. Maintaining public support through that period will be critical.

Fortunately, the growth imperative that is making a regional management plan necessary also is a long-term phenomenon. While development is imminent, and most striking because it is occurring in an area that is largely undeveloped, it also will take many years to fully play out. If an acceptable regional overflow management plan is defined, and is funded starting in the near term, a phasing strategy can make implementation possible in the next two decades.

10 Conclusions and Recommendations

The western edge of the Houston metropolitan area is currently one of the fastest growing sectors in the region and this growth is now encroaching on land impacted by the Cypress Creek Overflow. If unmanaged, the growth in the Addicks Reservoir and Barker Reservoir watersheds, and in the Upper Cypress Creek watershed will create challenges for both public and private entities to create safe, sustainable communities. For example:

a) The U.S. Army Corps of Engineers will have to respond to higher volumes of runoff, and during larger or more sustained rainfall events, additional properties will be at risk of flooding either within the maximum pool footprint of the reservoirs or in the watershed downstream of the dams.

b) The Harris County Flood Control District may have to allocate additional capital and operational dollars to respond to increased flood risks in the drainage area.

c) Property owners will find it increasingly difficult to design and develop safe communities if the overflow is not managed on a regional basis.

The mission of the Harris County Flood Control District seeks to reduce or avoid flood risks and damages, with due regard for community and natural values. In pursuit of these goals, the District is recommending the following implementation steps to manage the periodic overflow events:

1. Update the Harris County Drainage Criteria to include mitigation for changes in runoff volume due to changes in land use in the reservoir watersheds and in the Upper Cypress Creek watershed. Development guidelines that satisfy this recommendation will be presented to Harris County Commissioners for their consideration.

2. Prepare detailed environmental analysis and engineering design of Management Plan 5. The design will include guidelines for interim work that may be performed or funded by entities other than the HCFCD, but will be part of the overall plan.

3. Initiate appropriate funding structures to most expeditiously implement the plan, and to most appropriately allocate the capital and operational expenses to the parties that will benefit from the plan.

4. Acquire necessary right-of-way for the plan and construct the berms, channels and control structures that are a part of the plan.

5. Begin long-term management of the new facilities, including management of the storage area, in order to increase its stormwater runoff reduction characteristics through prairie restoration practices.

11 References

Root System Prairie Plants, Heidi Natura for the Conservation Research Institue, 1995

Houston-Galveston Area Council topography data set:
http://www.h-gac.com/rds/gis-data/gis-datasets.aspx

Houston-Galveston Area Council environmental data set:
http://www.h-gac.com/rds/gis-data/gis-datasets.aspx

Houston-Galveston Area Council transportation data set:
http://www.h-gac.com/rds/gis-data/gis-datasets.aspx

Houston-Galveston Area Council land use data set:
http://www.h-gac.com/community/socioeconomic/land-use-data/default.aspx

City of Houston Major Thoroughfare Plan data set:
http://www.houstontx.gov/planning/mobility/MTFP.html

FEMA effective flood hazard area data set:
http://www.fema.gov/floodplain-management/flood-insurance-rate-map-firm

Appendix A

Hydrologic and Hydraulic Modeling Analysis

August 18, 2015

Table of Contents

1.0 Introduction

This appendix describes the hydrologic and hydraulic analysis of the overflow from the Cypress Creek watershed into the Addicks Reservoir watershed during larger flood events, which is anticipated to occur during hypothetical storm events equal to or greater than a 20% (5-year) annual chance event. When such an overflow occurs, a very large portion of land is inundated by shallow, slowly moving water that flows towards the southeast across much of the upper Addicks Reservoir watershed as it makes its ways into the tributaries of Addicks Reservoir and ultimately into Addicks Reservoir itself. Limited overflow is also anticipated to drain into the Barker Reservoir as well; however, the volume of overflow estimated to reach the Barker Reservoir is insignificant compared to the storm water storage volume provided by Addicks Reservoir. For this reason, the assessment focusses on the overflow into the Addicks Reservoir watershed. Furthermore, the preferred overflow management plans identified as part of this study would effectively manage the overflow such that overflow that currently flows to Barker Reservoir during a 1% design storm event would be eliminated; all of the overflow would be directed towards Addicks Reservoir. In addition to the overflow, this appendix describes the analysis of various management measures considered as part of the Cypress Creek Overflow Planning Study.

The study utilized a coupled 1D/2D model to simulate the overflow and the management measures. The development of the models, and results, are presented in this appendix.

1.1 Study Area Description

The study area is depicted in Exhibit A1.1. It consists of the Addicks Reservoir watershed as well as the Upper Cypress Creek watershed, which for this study is defined as the portion of the Cypress Creek watershed that contributes to drainage along Cypress Creek as it passes US 290. Exhibit A1.2 shows the floodplains depicted on the effective Flood Insurance Rate Maps (FIRMs), including the Zone AO area associated with the overflow (FIRM Panel Nos. 48201C0160L, 48201C0190L, 48201C0595L, 48201C0605L, 48201C0610L, 48201C0615L, 48201C0620L, 48201C0630L, and 48201C0640L, all dated June 18, 2007; 48201C0170M, 48201C0360M, 48201C0370M, 48201C0380M, 48201C0385M, 48201C0390M, 48201C0395M, 48201C0405M, 48201C0410M, 48201C0415M, 48201C0420M, 48201C0580M, and 48201C0585M, all dated October 16, 2013; and 48473C0175E, 48473C0275E, 48473C0375E, all dated February 18, 2009). The total study covers 277 square miles, with the Addicks Reservoir watershed contributing 136 square miles, and the Upper Cypress Creek watershed contributing 141 square miles. Within this study area, the overflow analysis described in this appendix focuses on the areas subject to overflow as well as flow rates along the channels within the study area.

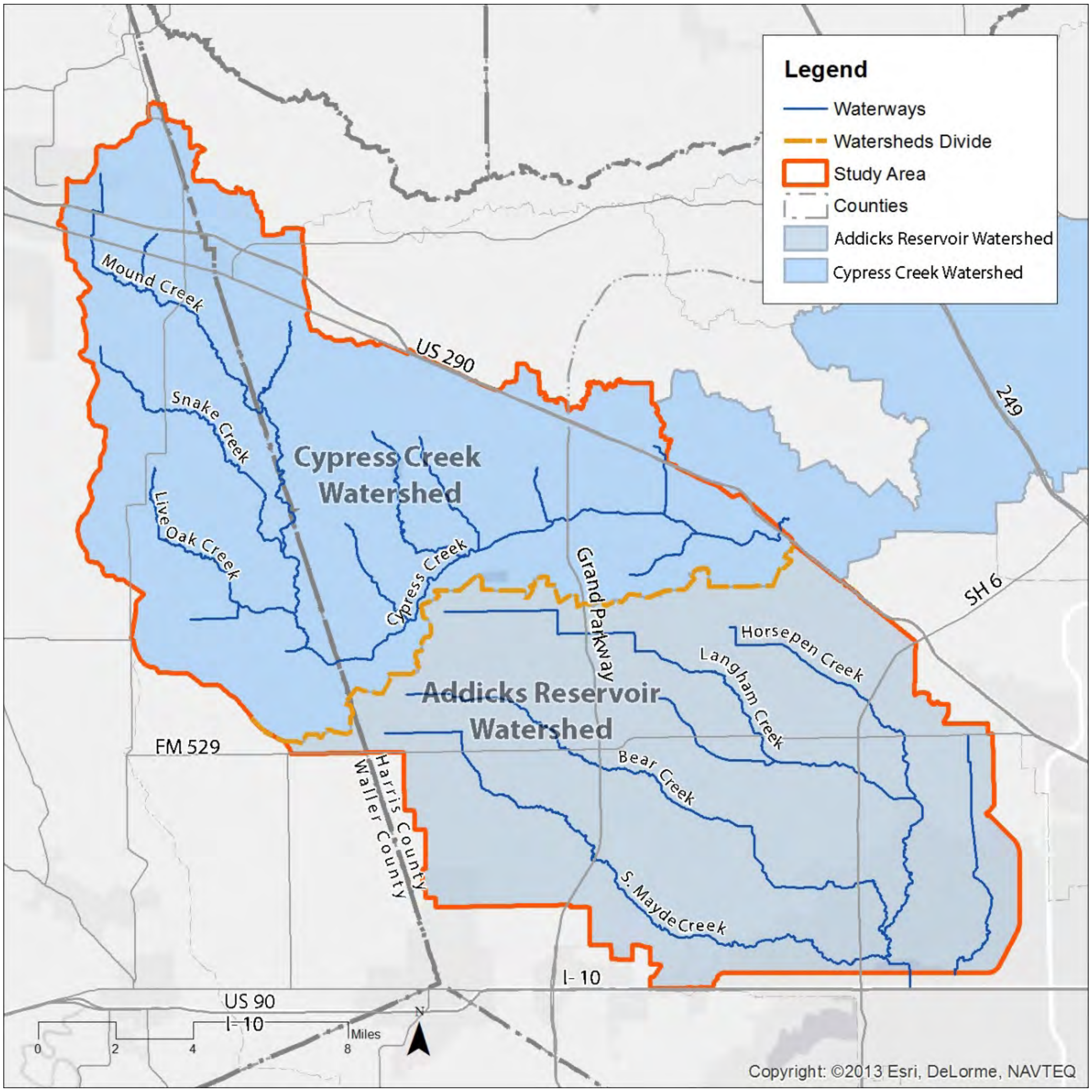


Exhibit A1.1 - Study Area

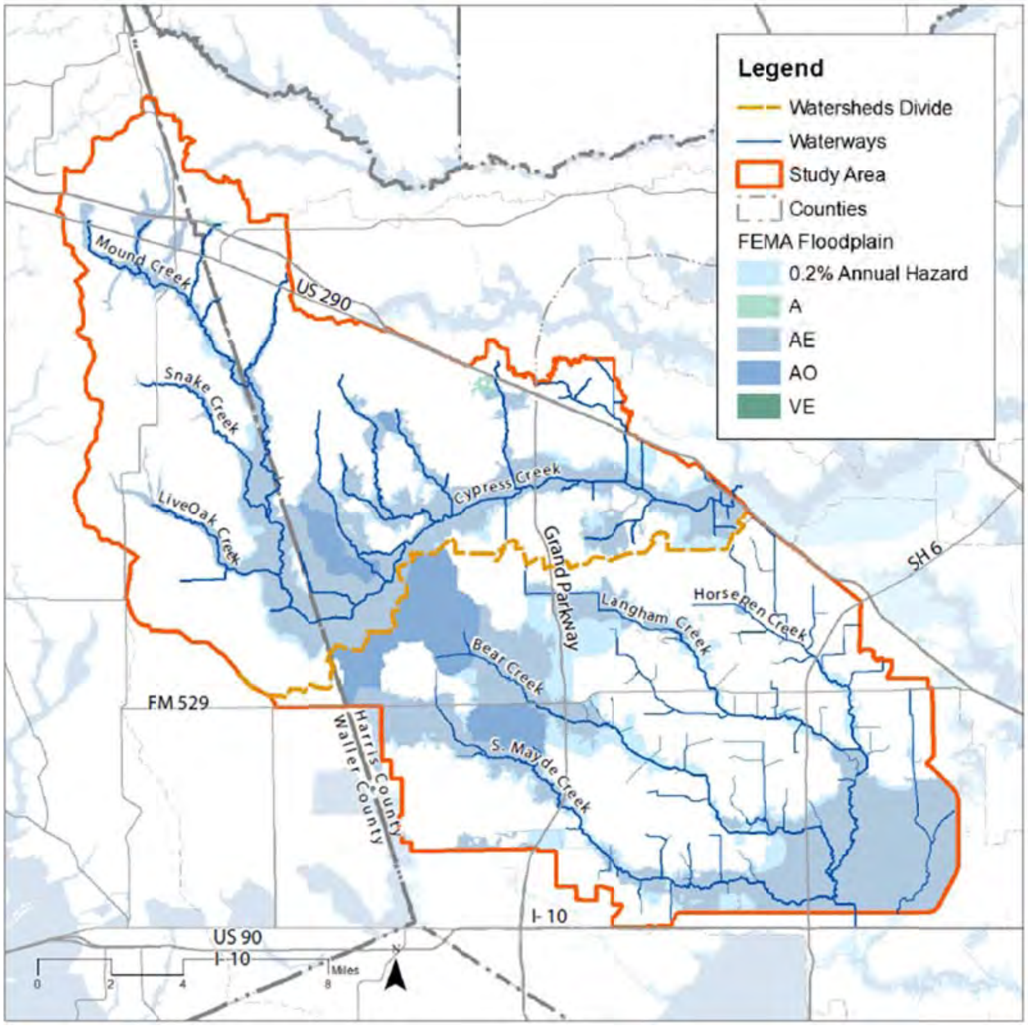


Exhibit A1.2
Effective Special Flood Hazard Areas (from FIRM Panels effective as of April, 2014))

The natural topography of the study area is primarily flat, and generally drains from the northwest to the southeast. However, the northern one-third of the study area– the portion of the Upper Cypress Creek watershed that includes Mound Creek – has steeper topography than the rest of the study area. Exhibit A1.3 depicts the topography, with elevations as high as 300 feet above mean sea level in the upper portion of the Cypress Creek watershed in Waller County, and as low as 80 feet in Addicks Reservoir. In the northern third of the study area natural land slopes approximately 10-20 feet per mile, while the remainder of the study area slopes approximately 4-6 feet per mile.

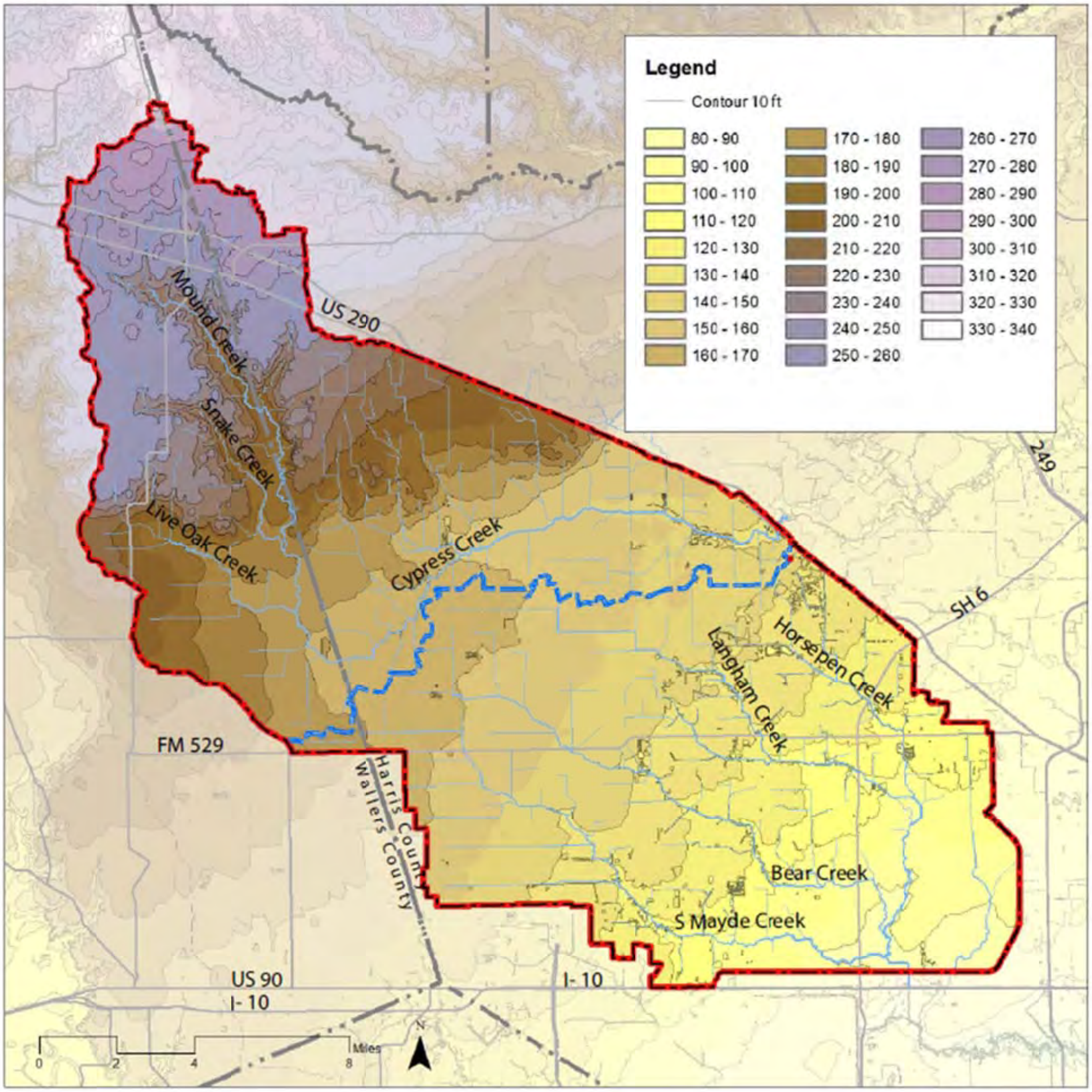


Exhibit A1.3
Topography

The location of the main channels in the study area is shown on Exhibit A1.4. Most of the channels in the Cypress Creek watershed are natural, although the main channel of Cypress Creek was channelized in the mid 1900's. Since that time, it has become incised and unstable, has re-vegetated, and appears natural. Most of the channels in the Addicks watershed, particularly those in the developed portion of the watershed, have been deepened and straightened. A bypass was constructed along Bear Creek to divert flow around a large meander and increase capacity as it flows into Addicks Reservoir. Within Addicks Reservoir, much of the channel system remains natural.

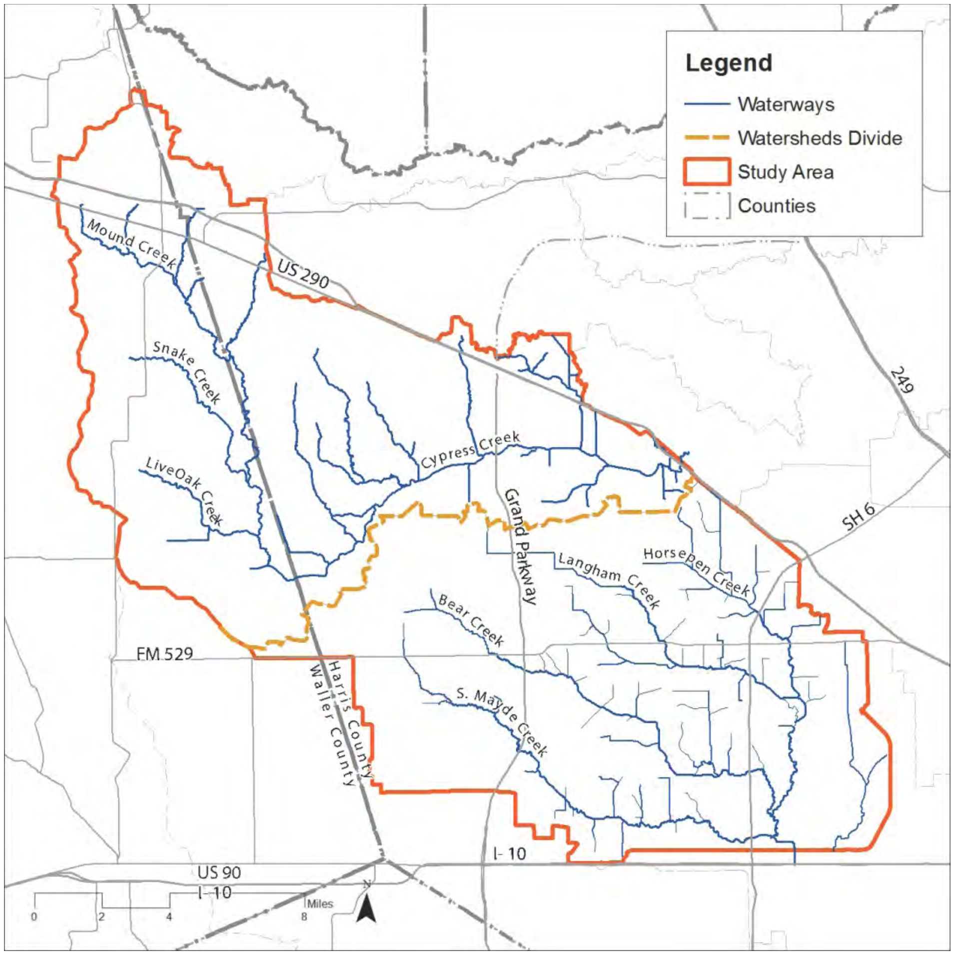


Exhibit A1.4
Channels in the Study Area

Exhibit A1.5 depicts the land use as of 2013 in the study area. The majority of the study area is undeveloped, although about 55 square miles are developed. Most development is concentrated in the eastern and southern portion of the study area, in areas closer to the urbanized portion of the Houston metropolitan area. Most development is single family residential, with commercial and retail along the primary corridors. The undeveloped land is primarily agricultural, with a combination of ranch land and row crops, as well as limited areas with native prairie cover. Historically, much of the area was used for rice farming, however much of this agricultural use has converted to corn in the past twenty years. Rice farming required the construction of agricultural berms to facilitate flooding of the rice fields. As these farms have converted away from rice, some of the berms have been removed, or at least the berms have been "broken" in places.

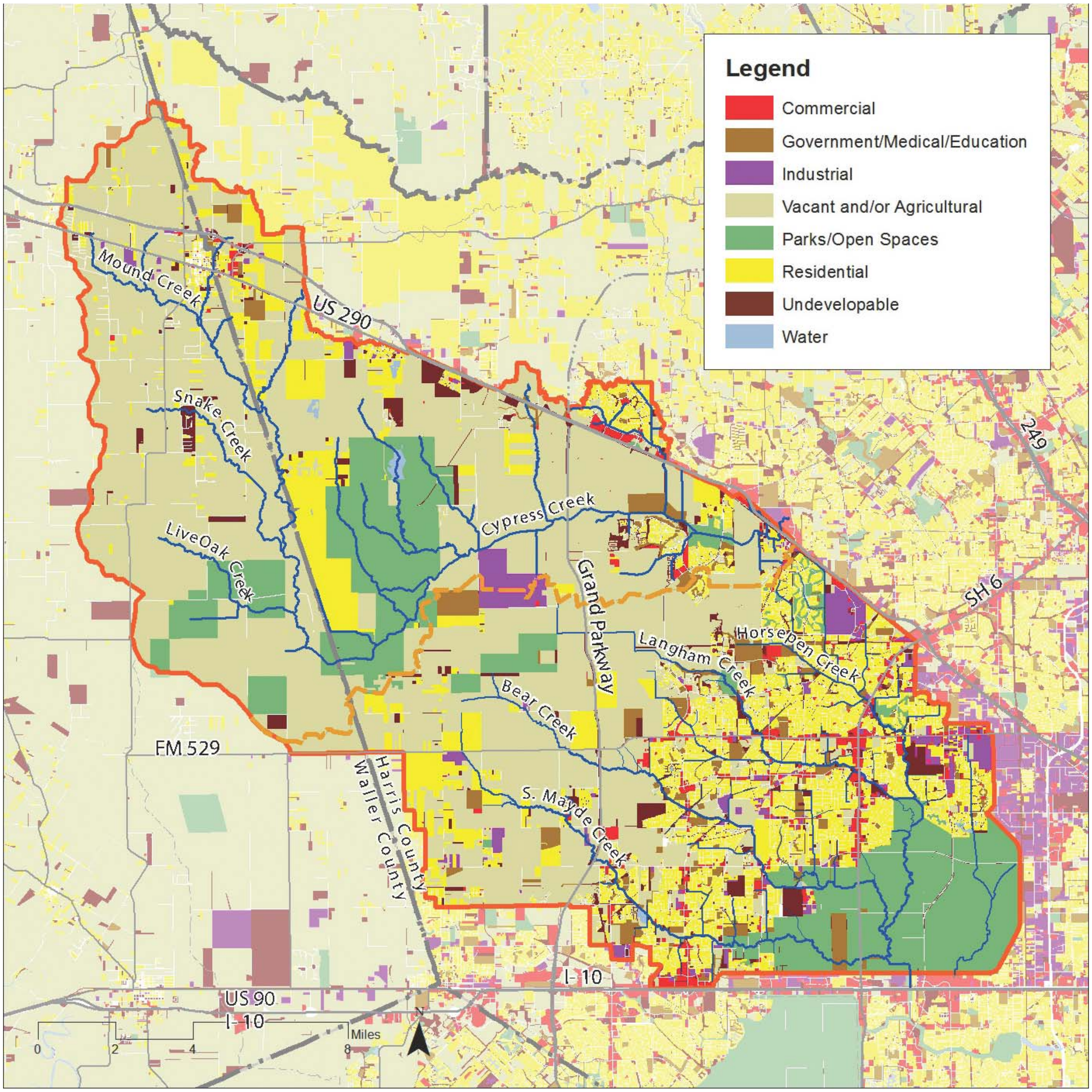


Exhibit A1.5
Existing Land Use (Source: Houston-Galveston Area Council)

1.2 Observations of the Cypress Creek Overflow

Although the overflow from Cypress Creek into the Addicks Watershed has not been well documented over time, there has been knowledge of the overflow. In fact, the original plan for Addicks and Barker Reservoirs, developed by the U.S. Army Corps of Engineers (USACE) in the 1930's, included a levee along the watershed divide to ensure that the overflows remained in the Cypress Creek watershed. This levee was never constructed, and the resultant plan was revised to include the purchase of additional land behind Addicks Dam to accommodate the overflow. According to the USACE, approximately one-third of the volume of Addicks Reservoir on government land is relegated to overflows from the Cypress Creek watershed.

The overflow is predicted to occur about once every 5-10 years. The total number of times the Cypress Creek overflow has occurred has not been well documented; however, the overflow has been recorded five times in the past 30 years. Two of the largest overflow events were observed in October 1994 and October 1998; smaller overflow events were also recorded in 2002, 2003 and 2012. Exhibit A1.6 shows photographs taken from the air by the Harris County Flood Control District (HCFCD) during the overflow event in 2003. As the photographs indicate, the inundation from the overflow is vast. It typically last about one day, and is relatively shallow.

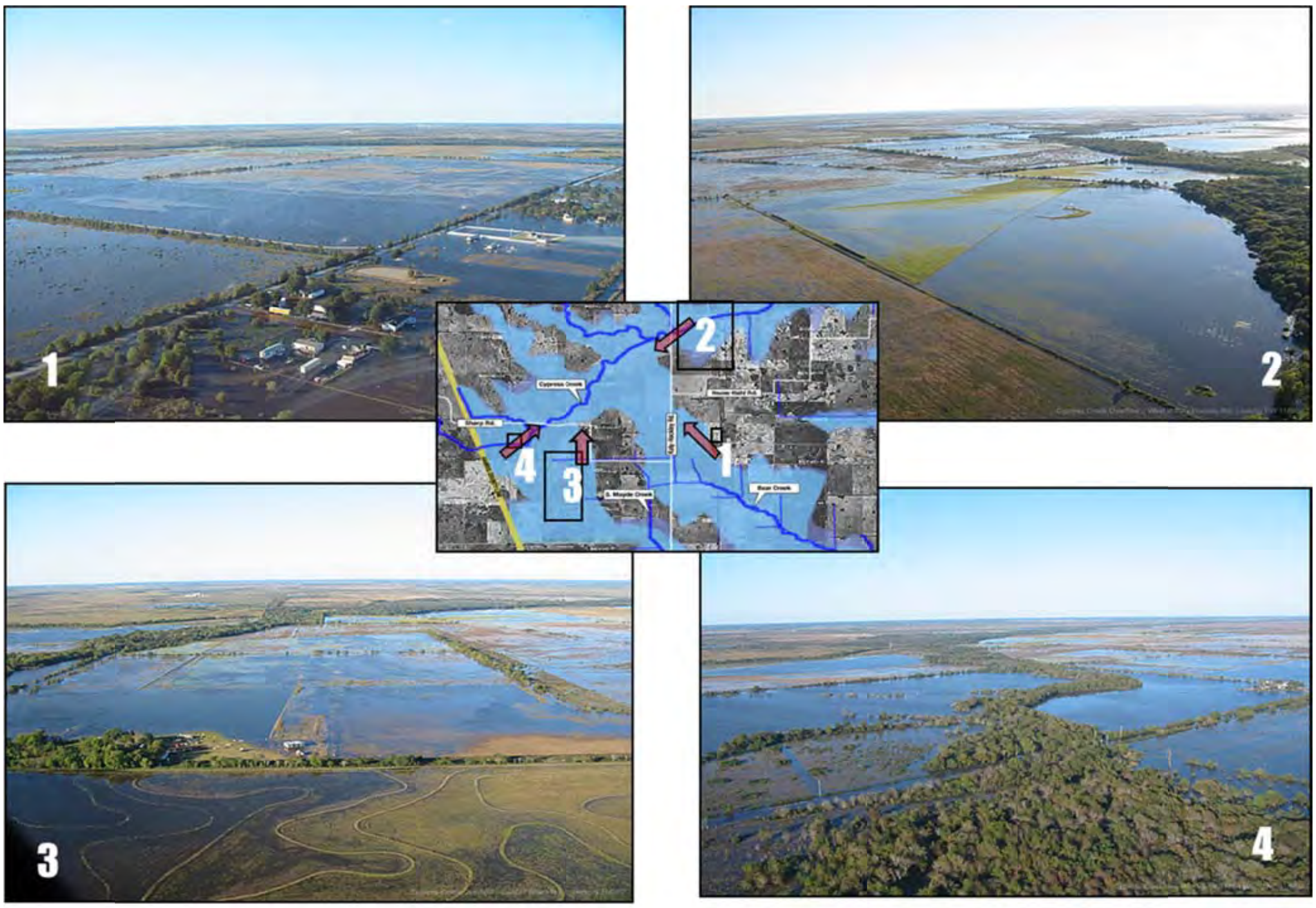


Exhibit A1.6
November 2002 Event

1.3 Previous Studies and Modeling

Floodplains in Harris County have historically been computed, mapped, and analyzed using a combination of models developed by the USACE, Hydrologic Engineering Center (HEC). A software program known as HEC-HMS (Hydrologic Modeling System), and before that, HEC-1, have been utilized to develop computer models that simulate the runoff of rainfall from particular rainfall events. The output of the HEC-HMS model is a series of hydrographs, which track the flow rate from an upstream watershed over the course of the event.

Peak flow rates from these computed hydrographs, at various locations along streams, are then input into a second software program known as HEC-RAS (River Analysis System), and before that, HEC-2. HEC-RAS computes water surface elevations at defined cross sections along a stream or river for a given flow rate. A basic assumption of the model is that water flows from cross section to cross section (the software does not consider that water may flow "away" from the channel, or that it may flow up or down). Because of this assumption, HEC-RAS is known as a *one-dimensional* model. While imperfect, one-dimensional models have proven to be effective at computing flood elevations along defined water courses such as streams and rivers. HEC-RAS computes water surface elevations along the stream or river for the given discharge, and facilitates the determination of flood elevations and floodplain delineations.

HEC-RAS has the capability to compute water surface elevations using both a steady flow routine and an unsteady flow routine. Historically, steady flow has been primarily utilized in Harris County, and the historic computations in the study area are based upon a steady flow routine, which means that only the peak discharge is computed along the channel. An unsteady model considers discharges over time, and computes at a specified time interval. As such, the hydrograph, and not just the peak discharge, is transferred from the HEC-HMS to HEC-RAS.

1.4 Overflow Modeling

While the HEC-HMS and steady flow HEC-RAS models are sufficient to model the riverine flow along the channels and streams in Harris County, they are not well suited to consider the overflow that occurs over a vast area when flood flows exceed the watershed divide and overflow toward Addicks Reservoir. Historically, the overflow was approximated by taking rough cross sections across the sparsely developed land in the upper Addicks Reservoir watershed near the Cypress Creek watershed divide. While this facilitated a rough depiction of the overflow, it does not provide a true understanding of the character and nature of the overflow.

The Cypress Creek Overflow Planning Study utilized a two-dimensional model to simulate the overflow. While a one-dimensional model utilizes cross sections along a channel, a two-dimensional model utilizes a grid. This allows the simulation of flow to and from a grid cell to its neighboring cells, and therefore considers two potential directions. Two dimensional models have been around for some time; however they are computationally intense and require vast volumes of storage. The advent of faster processors and more economical storage media have resulted in a significant expansion of two-dimensional modeling. Furthermore, the availability of digital elevation models, such as those developed from LiDAR (Light Detection and Ranging) technology, has facilitated the use of two-dimensional modeling software.

The two-dimensional component was utilized to represent the overflow, and was "coupled" to a one-dimensional representation of the following defined streams: Cypress Creek, Bear Creek, and South Mayde Creek. Consequently, the model utilized in this study is known as a "coupled 1D/2D" model. This model is described in more detail in this appendix.

2.0 Existing Condition Model Development

This section describes the development of the existing condition coupled 1D/2D model that describes and quantifies the overflow.

2.1 Software

The modeling utilized software developed by XP Solutions known as xpstorm. This software package utilizes multiple modules. The channels were modeled using the basic channel capability in xpstorm, while the two-dimensional component was considered using the xp2D module. The xp2D module utilizes a computational engine developed by Tuflow and used in their highly regarded two-dimensional model. The channel modeling is based upon a link-node concept, and is an unsteady model. The hydrographs developed in HEC-HMS are utilized as a boundary condition.

2.2 Source Data

The model was developed from readily available data sources, including existing models, GIS data sets, LiDAR elevation data, survey data, and field inspection. These are described below.

2.2.1 Source Models

The Cypress Creek FEMA effective HEC-HMS model (2012) model produced hydrographs for the 1% event in the Upper Cypress Creek watershed. The FEMA effective Addicks Watershed HEC-HMS model (2008) produced hydrographs for the 1% in the Addicks watershed. Both of these HEC-HMS models are based upon 2001 levels of development.

The FEMA effective HEC-RAS models for Cypress Creek (2012) and for the Addicks Reservoir tributaries (2008) were made available, and provided representation of roadway and pipeline crossings and the location of cross sections. However, for Langham Creek, HCFCD is in the process of submitting a Physical Map Revision (PMR). The HEC-RAS model utilized for the PMR submittal was utilized in this study.

2.2.2 Topography

Elevation data was developed from airborne LiDAR based digital elevation data. LiDAR is a remote sensing technology that measures distance by illuminating a target with light and analyzing the reflected light. LiDAR flights accumulate a vast amount data, and this data is converted to usable elevation data through a process that first removes extraneous points, adjusts the data to a benchmarked elevation, and then converts a mass of point to a grid, with elevations represented by grid cells at a particular resolution.

In 2008, the Houston-Galveston Area Council (HGAC) obtained LiDAR data for the region. This dataset produced a digital elevation model at a five-foot resolution, and included Harris and Waller counties. This dataset is based upon the NAVD 1998 vertical datum.

In Harris County, the dataset was further adjusted to the NAVD 2001 vertical datum adjustment, which reflects subsidence. However, no such adjustment was made to the Waller County data. Although there has been minimal subsidence in Waller County, this difference resulted in a "seam" at the county line, and necessitated the adjustment of the Waller County dataset. The adjustment process included converting the two datasets into the State Plane coordinate system and establishing the adjustment factors to be incorporated into the Waller dataset. Utilizing GIS processes four distinct areas were defined an adjusted, with adjustment factors ranging from 0.20 to 0.30 feet as shown in Exhibit A2.1.

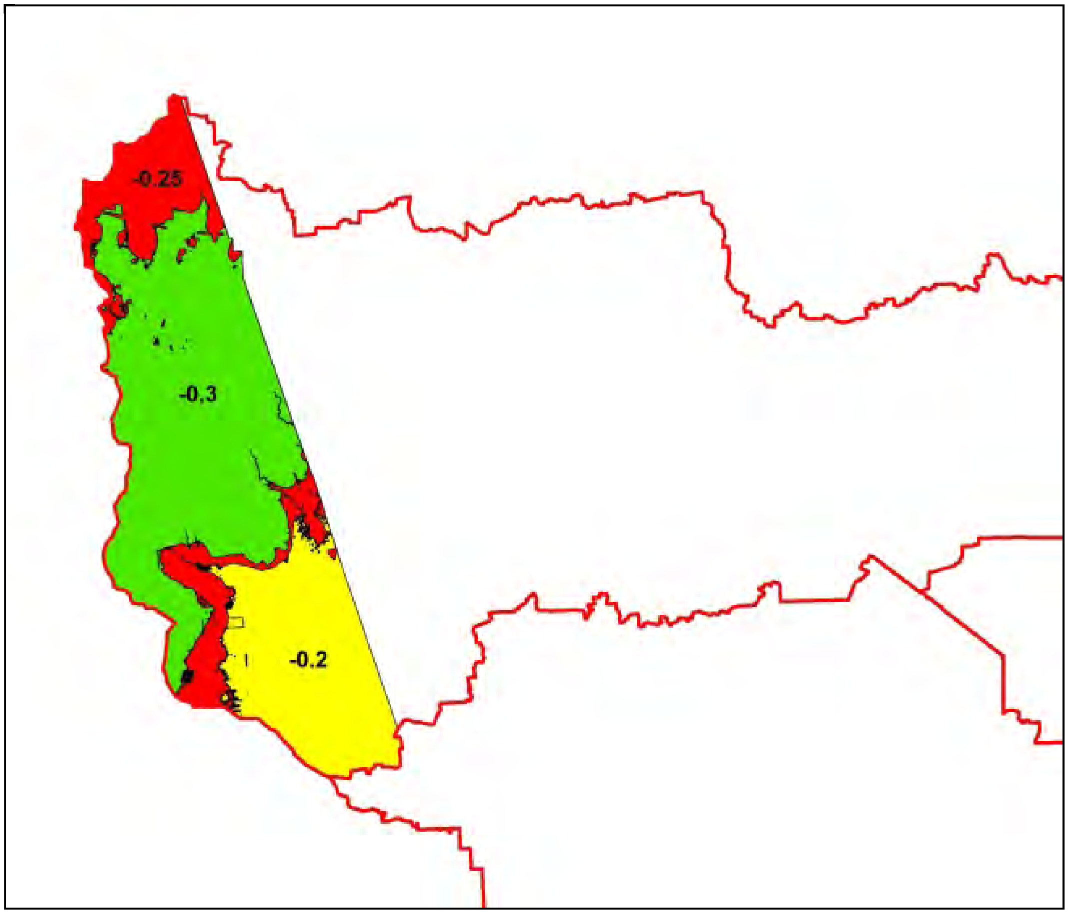


Exhibit A2.1
Waller County LiDAR Adjustment

2.2.3 Agricultural Berms and Features

There are a substantial number of agricultural berms and elevated roadways, along with an abandoned railroad trestle, that have the potential to influence overflows. While the LiDAR based elevation data captures these features, the conversion of the data into a five-foot grid can result in the loss of detail regarding the peak elevation of these features. In addition, the LiDAR is not as accurate as field survey because LiDAR can result in some error in recognizing these critical features

HCFCD provided a shapefile with the location of known agricultural berms in the study area. These berms were carefully evaluated to ensure elevations were appropriately recognized. In addition, HCFCD provided additional field survey data of features. Exhibit A2.2 shows the agricultural berms and other topographic features in the overflow area.

2.2.4 GIS Data

A number of existing datasets were obtained and utilized in this study. Land use datasets were obtained from HCFCD and HGAC. The HCFCD Channel Assessment Program shapefile was obtained for stream centerline data. Additional coverages provided locations of roadways, political boundaries, sub-watershed boundaries.

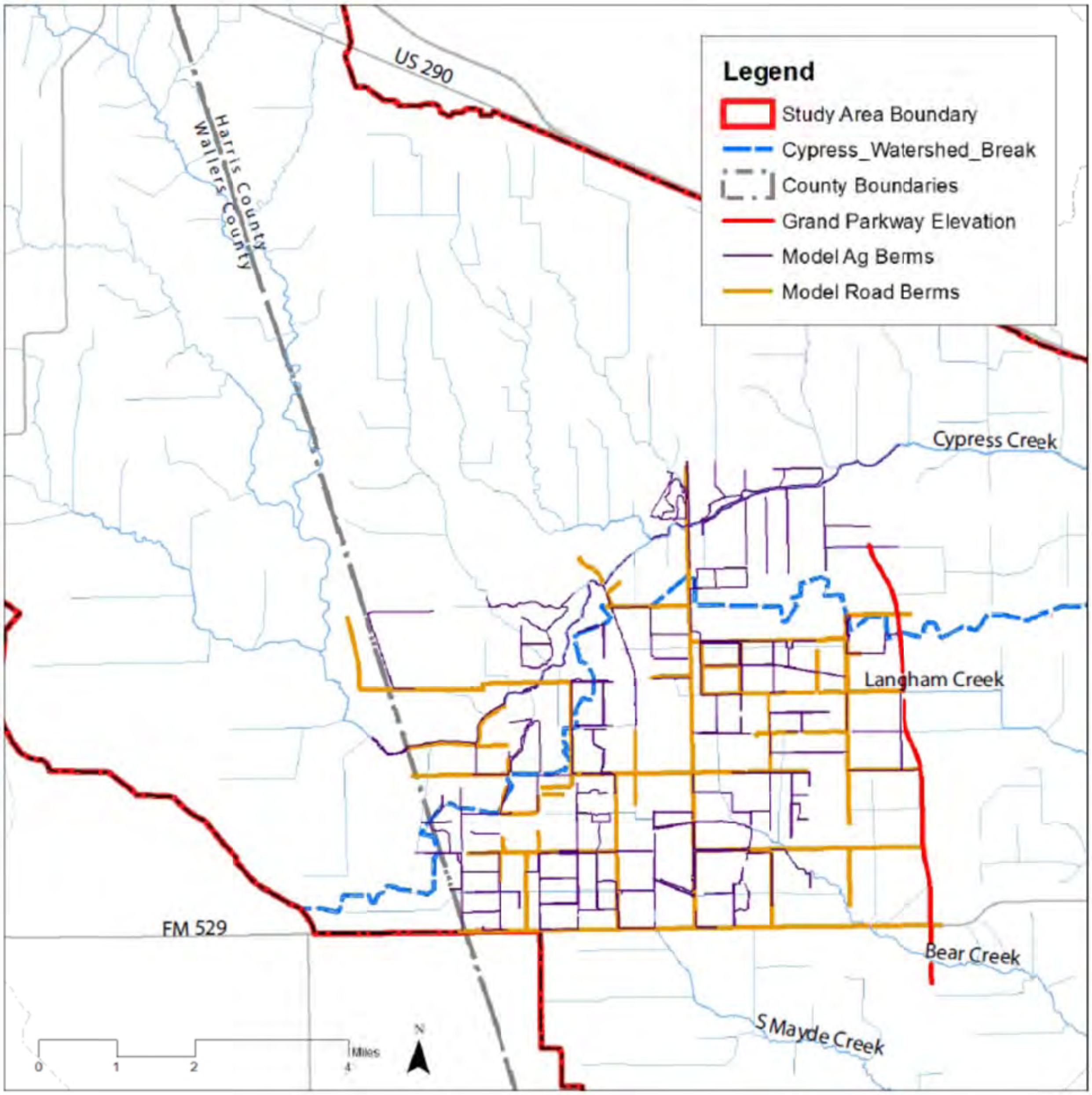


Exhibit A2.2
Berms and Features

2.3 Model Development

The model consists of both one-dimensional components and two-dimensional components. The one-dimensional component is used to represent the main channel flows along Upper Cypress

Creek, Langham Creek, South Mayde Creek, and Langham Creek. The two-dimensional component is used to represent the land located beyond the channel banks, where the overbank floodplain and overflow occur.

2.3.1 One-Dimensional Component

The one-dimensional development features were developed in xpstorm. For each of the channels, the stream centerline was imported into the model as a series of links connecting nodes, where the nodes are the respective cross sections. Cross sections were generally defined in the same locations as those used in the FEMA effective HEC-RAS model, however cross section data was obtained solely from the LiDAR based DEM. The cross sections are approximately 300-feet wide, which is sufficient width to capture the channel high bank on all streams. The resultant cross sections were compared to the surveyed cross sections, which were used to develop the effective HEC-RAS model, as a quality control measure, and refinements were made if necessary.

As a naming convention, cross section nodes were given a prefix representative of their steam, followed by a station number consistent with the approach used in the HEC-RAS model. Table A2.1 lists the channels and their respective prefix. Links were given the same name as the upstream node, but with the “L” suffix.

Table A2.1
Streams and Model Naming Convention

Stream Name	Prefix	HCFCD Unit Number	HEC-RAS model
Cypress Creek	CC	K100-00-00	Cypress Creek FEMA effective model
Langham Creek	LC	U100-00-00	Addicks Watershed PMR model
South Mayde Creek	SM	U101-00-00	Effective M3 Model
Bear Creek	BC	U102-00-00	Effective M3 Model

The xpstorm software, as with all node-link software packages, does not have a robust routine to simulate bridges. Therefore rating curves were developed from the HEC-RAS model and utilized to represent bridges. XP-Storm simulates culverts and storm sewer systems better than HEC-RAS; therefore culvert data was taken from the HEC-RAS model and entered into the XP-Storm model for analysis.

In total, the one-dimensional component of the model has 331 nodes and 321 links. All culverts were coded into the model using data from HEC-RAS models. Bridges were modeled using rating curves developed from the HEC-RAS models.

2.3.2 Two-Dimensional Component

Along the channels, the overbanks beyond the 300-foot channel cross-section corridor are modeled using the two-dimensional xp2D module. These areas are represented by a DEM, which is a grid with assigned elevations at each cell. In addition, Mound Creek was fully modeled as a two-dimensional surface rather than a 1D/2D coupled model. The coverage of the DEM was established wide enough to capture the full floodplains along each channel as well as any overflows. At each time increment, the software computes a flow depth at each cell as well as each cell boundary and assigns flow accordingly, resulting in a new computation at the subsequent time step. The end result is a flow depth or elevation at each location in the study area at each time increment during the simulation.

The grid cell resolution is an important consideration in two-dimensional modeling. Small grid cell sizes increase accuracy, but require additional computation times; while larger grid sizes compromise accuracy but increase computation time. The determination of grid size requires a trade-off to ensure a workable model without compromising satisfactory accuracy. For this study, it was determined that a 70-foot grid cell for the overbanks and overflow area produced highly accurate models with a reasonable run time. For Mound Creek, a 60-foot grid cell was used to ensure adequate capture of elevation changes in the channel. The resulting model completed a five-day rainfall hydrograph simulation, with a computation time-step of five seconds, in 12.5 hours.

The overflow area has numerous elevated features such as agricultural berms, major roads and abounded railroad. These structures should have a significant influence on the overflow and would not be accurately represented in a 70-foot resolution grid. Hence, all of these features were manually digitized in GIS and reintroduced into the model as elevation shapes, ensuring that the true elevations of these features are captured in the model topographic data.

2.3.3 Manning's "n" Values

Manning's "n" values represent the resistance to flow from various surfaces. In the one-dimensional regime, Manning's "n" values were assigned across each cross section, with values similar to those used in previous studies. In the two-dimensional regime, xp2D uses a Land Use Land Coverage (LULC) depiction to assign "n" values to land uses. The source land use datasets were utilized to develop this coverage, and the resultant LULC dataset has nine classifications. It was observed that some of the areas classified as agricultural were no longer being used for cultivation, resulting thick over growths in these areas. The "n" values for these areas were adjusted accordingly. The roughness values varied from 0.22 in dense undeveloped areas to 0.08 for open lands.

2.3.4 Inflow Hydrographs

Existing condition hydrographs from the existing HEC-HMS models were utilized, and were read into the coupled 1D/2D model at appropriate locations. With the exception of hydrographs computed upstream of the study area, the hydrographs represent only runoff and not in-stream routing, as losses from routing are developed within the two-dimensional model.

2.3.5 Boundary Conditions

A normal depth boundary condition was used at the downstream end of the Addicks Reservoir tributaries (Langham Creek, South Mayde Creek, and Bear Creek). Normal depth was chosen to prevent the consideration of any downstream condition upon the overflow behavior. The overflow area is substantially upstream of any potential downstream influence, including influence from Addicks Reservoir.

2.4 Calibration

The model was executed using hydrographs developed from HEC-HMS models simulating events in 1994, 1998, and 2012. For these events, high water marks were taken along Cypress Creek and within the overflow. The locations of these high water marks are shown in Exhibit A2.3. Marks 1 and 2 are along Cypress Creek, and therefore depict riverine flood elevations. Marks 3 and 4 are in the overflow, and represent elevations from the overflow event.

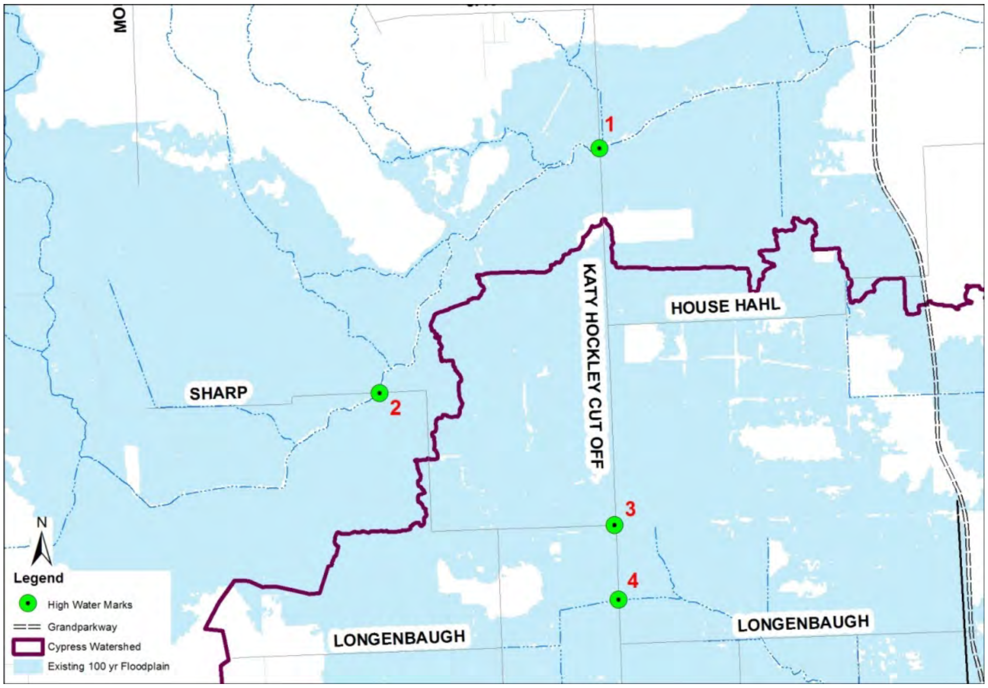


Exhibit A2.3
Location of High Water Marks

It should be noted that there have been some changes to the study area between the 1994 and 1998 events and current time. A comparison of the aerial imagery in 1994 and 1998 to the 2008 LiDAR datasets along with comparison of the 2001 and 2008 LiDAR datasets was performed to identify any major structural additions or deletions to be considered during calibration runs. The exercise identified two areas with changes as shown in Exhibit A2.4. These changes were incorporated into the calibration model runs.

The results of the simulations are compared with observed high water marks in Table A2.2. Mark 1 is at Katy-Hockley Road, and the observed high water marks are about two feet lower than the elevations recorded in 1994 and 1998. Historically, it has been difficult to replicate these high water marks with computer simulations. The HEC-RAS model produced by HCFCD as part of the Cypress Creek Physical Map Revision (PMR) was able to achieve a closer match to this mark. Even though the coupled 1D/2D model shows two-foot difference, the 1D component of the model closely duplicates the profile from the PMR model between Katy-Hockley Road and Sharp Road. Mark 2, located near Sharp Road, shows a much closer match, with a difference within one foot.

Marks 3 and 4 are in the overflow. Mark 3 was taken after the 1994 event, and the simulation shows a water surface just over one-half foot lower than observed. This is a reasonable match. Mark 4 was taken after the 1998 event. The simulation predicts a substantially higher water surface, with a difference of over seven feet. The elevation for the high water mark is well below the LiDAR based topography in the area, and is likely an incorrect elevation.

With only one overflow high water mark, it is difficult to make a conclusion regarding the overflow from observed data and simulations of events. However, the one mark supports the modeling results. The water surface elevations along Cypress Creek show a close match at Sharp Road. The Katy-Hockley Road marks show a larger departure than desired, however as noted above, this mark has been difficult to confirm.

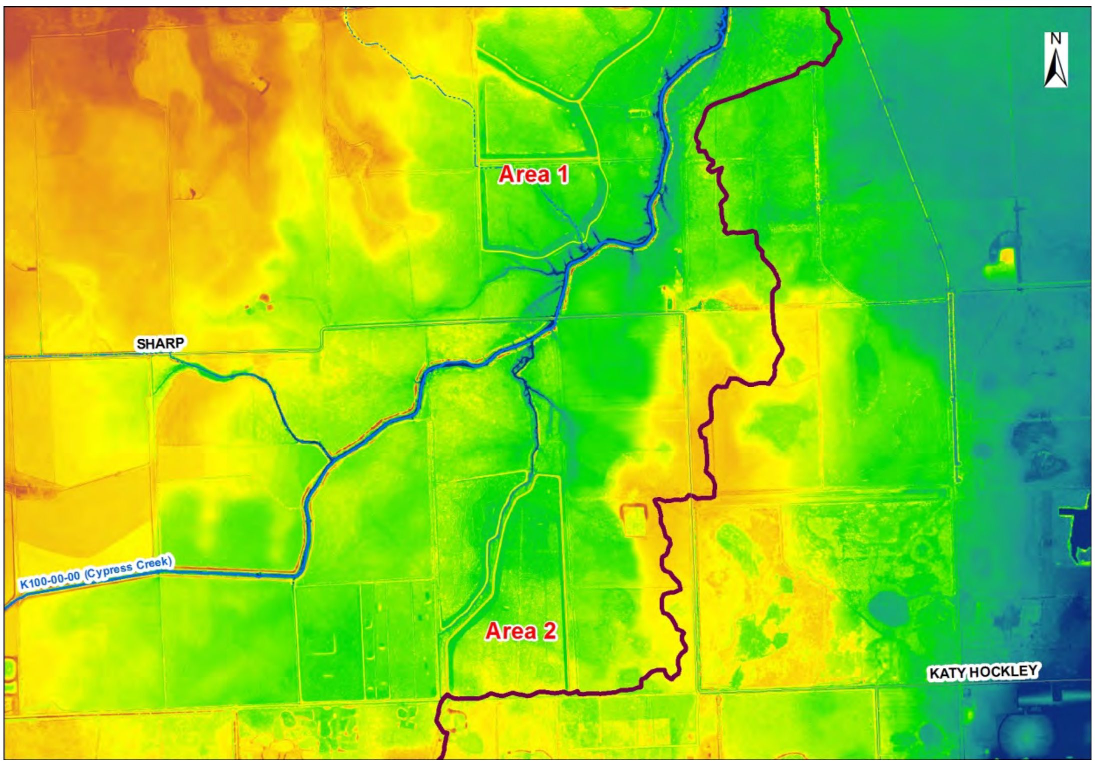


Exhibit A2.4
Adjustment to 1994/1998 Conditions

Table A2.2
Calibration Summary

HWM No.	Location/Event	HWM (ft)	Xpstorm (ft)	Difference (ft)
1	*Cypress Creek at Katy-Hockley Rd*			
	October, 1994	163.0	160.96	-2.04
	October, 1998	162.9	160.46	-2.44
	July, 2012	-	161.14	-
2	*Cypress Creek at Sharp Road*			
	October, 1994	168.9	168.09	-0.81
	October, 1998	166.8	166.96	0.16
	July, 2012	-	168.21	-
3	*Overflow near Unit U102-14-00 and Sharp Rd*			
	October, 1994	160.7	160.13	-0.57
	October, 1998	-	159.20	-
	July, 2012	-	160.14	-
4	*Overflow near Katy-Hockley Rd/Bear Creek*			
	October, 1994	-	165.71	-
	October, 1998	157.9	165.19	7.29
	July, 2012	-	165.76	-

3.0 Existing Condition Model Results

This section summarizes the results of the xpstorm simulation of the overflow from the Cypress Creek watershed. The results consider the existing condition overflow associated with a standard 24-hour 1% rainfall. The model facilitates the estimation of the overflow hydrograph at various locations along the overflow path, the overflow travel time, the volume of overflow, and the depth of overflow. The overflow was simulated for the 1% annual probability event (100-year), the 4% (25-year), the 20% (5-year) event, and the 50% (2-year). All of these simulations consider existing development levels and a 24-hour rainfall distribution.

3.1 Hydrographs

Runoff hydrographs were initially determined in HEC-HMS, using the model from the Cypress Creek Physical Map Revision. Hydrographs were injected at appropriate points in the simulation. It was determined that runoff from rainfall over the Addicks Reservoir does not impact the overflow event, as it occurs a day prior to the overflow. Therefore, the Addicks Reservoir watershed hydrographs were not included in the overflow simulation in xpstorm.

Within the xpstorm software, the user may define “lines” where hydrographs are computed during the simulation. The user must specify the computation lines prior to executing the model. Exhibit A3.1 shows an aerial depiction of the study area, and highlights key areas where hydrographs are computed and reported. Table A3.1 summarizes these key locations.

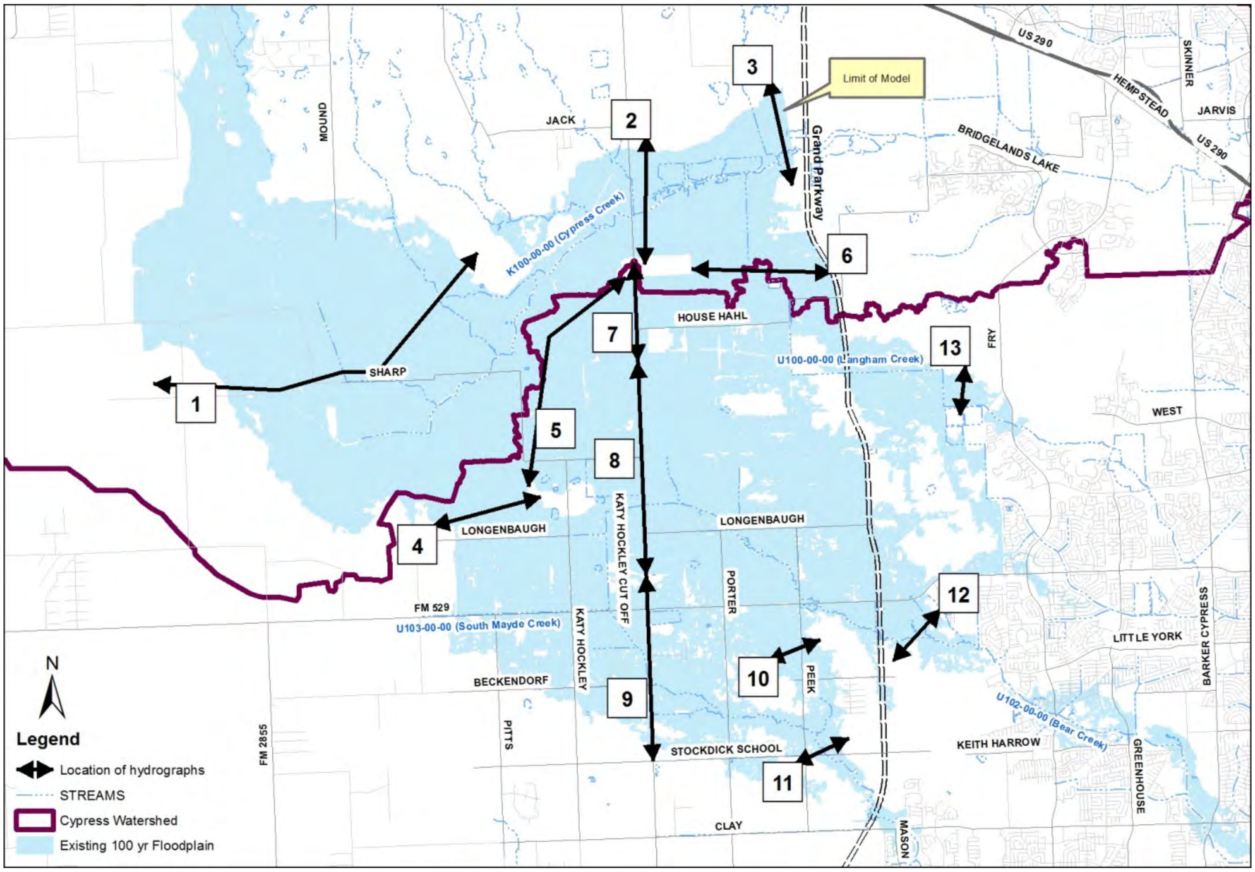


Exhibit A3.1
Hydrograph Computation Locations

Table A3.2 presents the computed peak discharges and Table A3.3 presents the computed volumes at these key locations.

Table A3.1
Hydrograph Locations

No	Location	Description
1	Mound Creek/Little Mound Creek	Represents Cypress Creek flow upstream of the overflow the line crosses Cypress Creek tributaries downstream of where the overflow begins.
2	Cypress Creek downstream of Katy-Hockley Rd	Represents Cypress Creek flow at the Katy-Hockley Rd gage
3	Cypress Creek upstream of Grand Parkway	Represents Cypress Creek flow downstream of the overflow
4	Overflow "1" – west (toward South Mayde Creek)	Represents overflow that flows toward South Mayde Creek
5	Overflow "2" – middle (toward Bear Crk)	Represents overflow that flows toward Bear Creek
6	Overflow "3" – east (toward Langham Creek)	Represents overflow that flows toward Langham Creek
7	North Overflow at Katy-Hockley Rd (to Bear Creek)	Represents overflow that flows across JPL to Bear Creek about hallway across the overflow
8	Middle Overflow at Katy-Hockley Rd (to Bear Creek)	Represents overflow that flows south of JPL to Bear Creek about halfway across the overflow.
9	South Overflow at Katy-Hockley Rd (to S. Mayde Creek)	Represents flow along South Mayde Creek about halfway across the overflow.
10	Diversion from Bear Creek to South Mayde Creek	Overflow that is diverted from Bear Creek to South Mayde Creek
11	Flow entering South Mayde Creek development area	Represents overflow in South Mayde Creek as it enters the developed reach
12	Flow entering Bear Creek development area	Represents overflow in Bear Creek as it enters the developed reach
13	Flow entering Langham Creek development area	Represents the overflow in Langham Creek as it enters the developed reach

Table A3.2
Computed Peak Discharges

No	Description	1% (100-yr)	10% (10-yr)	20% (5-yr)	50% (2-yr)
1	Mound Creek/Little Mound Creek	18,419	7,424	4,681	2,233
2	Cypress Creek downstream of Katy-Hockley Rd	5,231	1,711	1,189	871
3	Cypress Creek upstream of Grand Parkway	5,138	1,675	1,111	802
4	Overflow "1" – west (toward South Mayde Creek)	3,258	569	117	0
5	Overflow "2" – middle (toward Bear Creek)	8,590	2,476	1,297	349
6	Overflow "3" – east (toward Langham Creek)	829	232	58	0
	Total Overflow at Watershed Divide (4, 5, & 6)	**12,678**	**3,278**	**1472**	**349**
7	North Overflow at Katy-Hockley (to Bear Creek)	2,858	1,161	614	112
8	Middle Overflow at Katy-Hockley (to Bear Creek)	4,221	633	263	34
9	South Overflow at Katy-Hockley (to S. Mayde Crk)	1,958	83	0	0
10	Diversion from Bear Creek to South Mayde Creek	589	0	0	0
11	Flow entering South Mayde Creek development area	1,918	62	0	0
12	Flow entering Bear Creek development area	2,593	459	214	23
13	Flow entering Langham Creek development area	394	55	7	0
	Total Overflow Entering Addicks Reservoir	**4,905**	**576**	**214**	**0**

TableA3.3
Computed Flow Volumes

No	Description	1% (100-yr)	10% (10yr)	20% (5yr)	50% (2yr)
1	Mound Creek/Little Mound Creek	28,846	12,281	8,319	4,972
2	Cypress Creek downstream of Katy-Hockley Rd	19,916	9,850	6,015	5,215
3	Cypress Creek upstream of Grand Parkway	29,861	13,162	6,428	5,393
4	Overflow “1” – west (toward South Mayde Creek)	5,192	783	160	0
5	Overflow “2” – middle (toward Bear Creek)	16,583	5,263	2,699	541
6	Overflow “3” – east (toward Langham Creek)	1,580	394	73	0
	Total Overflow at Watershed Divide (4, 5, & 6)	**23,355**	**6,439**	**2,933**	**541**
7	North Overflow at Katy-Hockley Rd (to Bear Creek)	6,856	2,744	1,275	187
8	Middle Overflow at Katy-Hockley Rd (to Bear Creek)	8,852	1,567	444	27
9	South Overflow at Katy-Hockley Rd (to S. Mayde Crk)	3,302	193	0	0
10	Diversion from Bear Creek to South Mayde Creek	747	0	0	0
11	Flow entering South Mayde Creek development area	5,939	783	160	0
12	Flow entering Bear Creek development area	15,836	5,263	2,699	541
13	Flow entering Langham Creek development area	1,580	394	73	0
	Total Overflow Entering Addicks Reservoir	**23,355**	**6,439**	**2,933**	**541**

The computed flows and volumes are discussed in the following sections.

3.1.1 Total Overflow

The computed 1% (100-year) peak discharge along Cypress Creek upstream of the overflow is 18,419 cfs. The peak 1% overflow discharge is 12,678 cfs. The computed 1% (100-year) discharge along Cypress Creek downstream of the overflow is 5,138 cfs.

The total volume that overflows from the Cypress Creek watershed to the Addicks Reservoir watershed during the 1% (100-year) event is computed to be 23,355 acre-feet, which is 83% of the stormwater volume flowing through Cypress Creek upstream of the overflow. The majority of the overflow drains into Addicks Reservoir. It is estimated that for a 1% (100-year) event, approximately 650 acre-feet of the 23,355 acre-feet (less than 3%) leaving the Cypress Creek watershed drains into the Addicks Reservoir watershed and then overflows into the Barker Reservoir watershed. For the purpose of this study, the overflow reaching Barker Reservoir is considered negligible.

For the 10% (10-year) event, the peak discharge along Cypress Creek upstream of the overflow is 7,424 cfs, and the peak 10% overflow discharge is 3,278 cfs. The total volume that overflows from the Cypress Creek Watershed to the Addicks Reservoir Watershed during the 10% (10-year) event is computed to be 6,439 acre-feet, which is 56% of the volume flowing in Cypress Creek upstream of the overflow.

Exhibit A3.2 shows the hydrographs in Cypress Creek, along with the overflow hydrograph and the hydrograph in Cypress Creek downstream of the overflow for the 1% (100-year) and 10% (10-year) storm events.

As the calculations indicate, during a flood event a substantial amount of the Upper Cypress Creek flows divert into the Addicks Watershed.

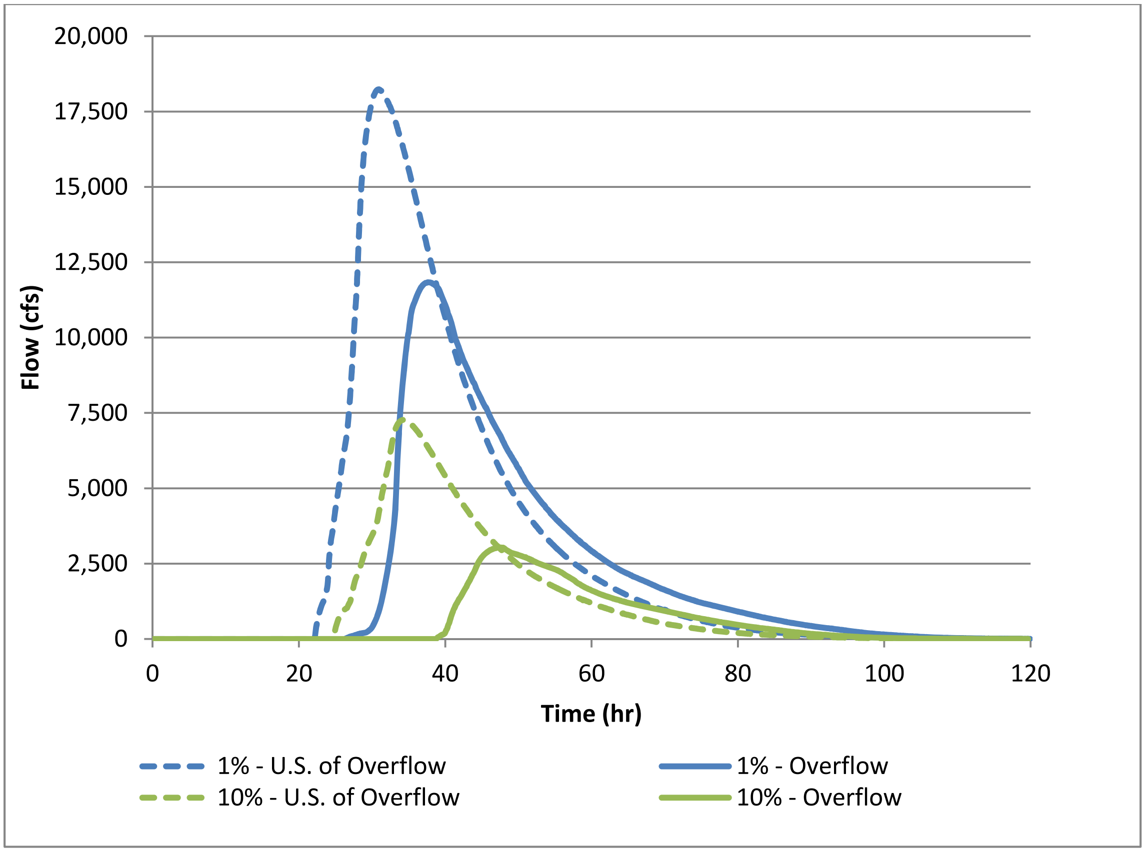


Exhibit A3.2
Cypress Creek and Overflow Hydrographs

3.1.2 South Mayde Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper portion of South Mayde Creek is 3,258 cfs, with a total volume of 5,192 acre-feet.

In addition, a portion of the overflow that reaches Bear Creek eventually overflows into South Mayde Creek. During a 1% (100-year) event, the peak overflow rate from Bear Creek is 589 cfs, and the total overflow volume is 747 acre-feet. South Mayde Creek ultimately receives about 20% of the total overflow volume during the 1% (100-year) event. See Exhibit A3.1 for location reference.

The peak discharge is substantially attenuated as the overflow flows across open land. The peak 1% flow rate from the overflow along South Mayde Creek at the Grand Parkway (where South Mayde Creek begins to flow through existing development) is reduced to 1,918 cfs. It takes about 38 hours for the peak flow to move from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate from a local rainfall event (without the occurrence of the overflow) is 4,473 cfs. This event would typically peak much more quickly than the overflow event - by approximately two days. Consequently, the local event will dissipate prior to the overflow event. The 1% peak flow rate for the local event is much higher than the peak 1% peak flow rate from the overflow, however the total volume for each event is similar. The total 1% volume for the local event along South Mayde Creek at the Grand Parkway is 6,627 acre-feet, while the total 1% volume for the overflow event is 5,939 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of South Mayde Creek is 569 cfs. During this event there is no further overflow from Bear Creek to South Mayde Creek. This flow rate is attenuated to 62 cfs near the Grand Parkway. The total 10% (10-year) overflow volume into South Mayde Creek is 783 acre-feet.

Exhibit A3.3 shows the 1% (100-year) and 10% (10-year) overflow hydrographs at upper extent of South Mayde Creek and at the Grand Parkway.

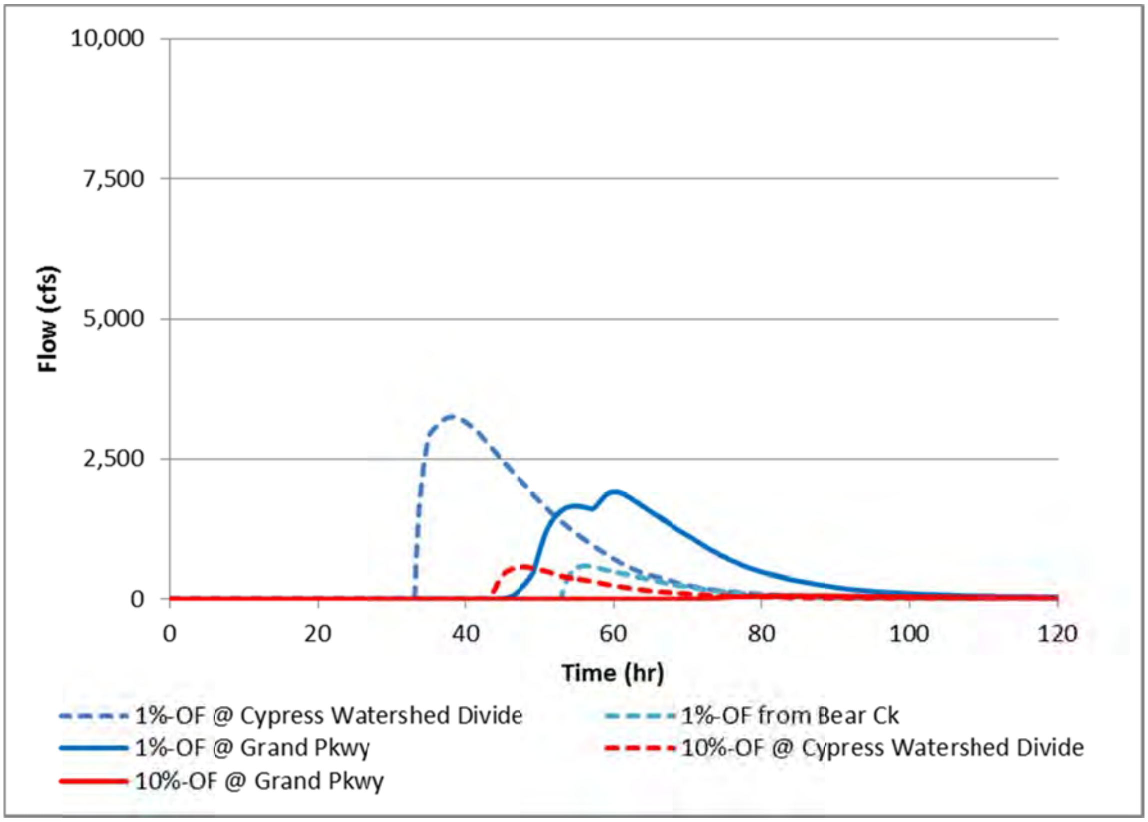


Exhibit A3.3
South Mayde Creek Overflow Hydrographs

3.1.3 Bear Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper extent of Bear Creek is 8,590 cfs, with a total volume of 16,583 acre-feet. As noted in the previous section, a portion of this volume (747 acre-feet) overflows to South Mayde Creek. Bear Creek receives about 75% of the total overflow volume during the 1% (100-year) event.

The peak discharge is substantially attenuated as the overflow conveys across the open land. As the overflow passes Katy-Hockley Road (see Exhibit A3.1 for location), the 1% peak discharge has been reduced to 7,079 cfs; and by the time it reaches the developed area just upstream of Fry Road, the 1% peak discharge has been reduced to 2,593 cfs (see Exhibit A3.1 for location). It takes about 40 hours for the peak flow to convey from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate at this location from a local rainfall event (without overflow) is 6,031 cfs. This event would typically peak much quicker than the overflow event, assuming that rainfall occurs simultaneously across the upper Cypress Creek Watershed and the Addicks Reservoir watershed, the peak runoff rate from the local event is anticipated to occur about two days before the overflow reaches Bear Creek and would dissipate prior to the overflow event. While the 1% peak flow rate for the local event upstream of Fry Road is much higher, the computed volume for the overflow event is significantly higher than the local event. The total 1% volume for the local event along Bear Creek upstream of Fry Road is 8,514 acre-feet, while the total 1% volume for the overflow event at the same location is 15,836 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of Bear Creek 2,476 cfs. During this event there is no further overflow from Bear Creek to South Mayde Creek. This flow rate is attenuated to 459 upstream of Fry Road. The total 10% (10-year) overflow volume into Bear Creek is 5,263 acre-feet.

Exhibit A3.4 shows the overflow 1% (100-year) and 10% (10-year) overflow hydrographs along Bear Creek at upper extent of the watershed and just upstream of Fry Road.

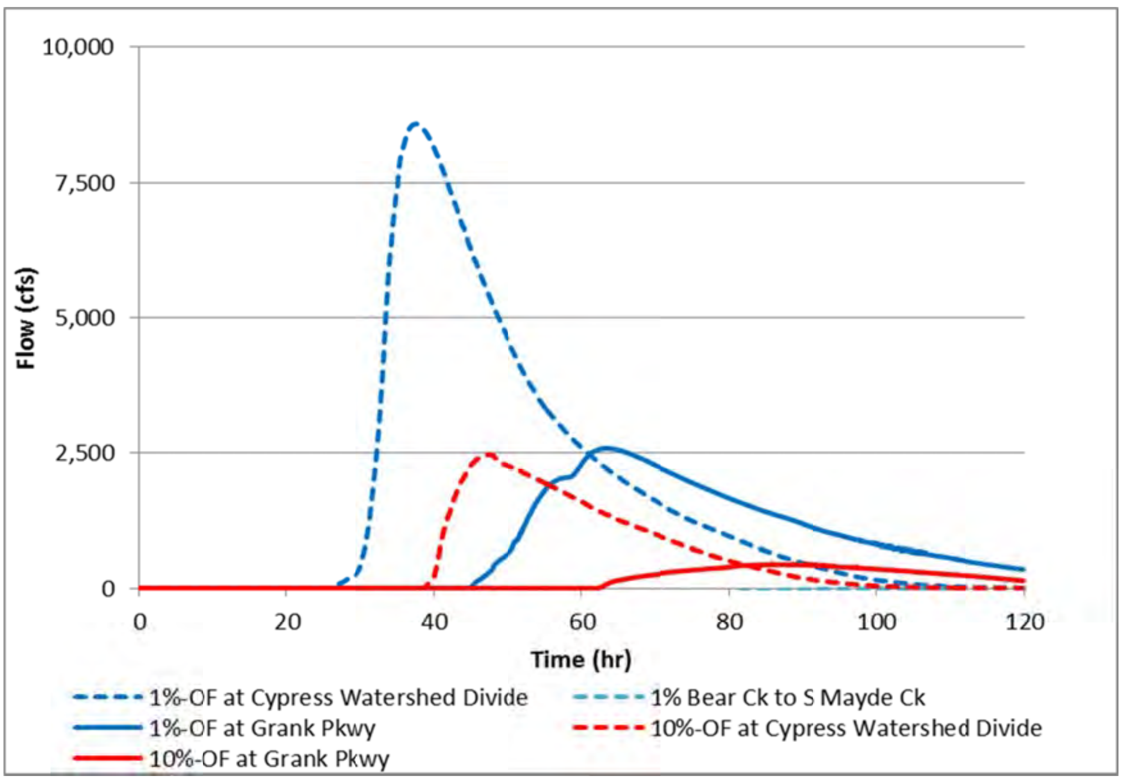


Exhibit A3.4
Bear Creek Overflow Hydrographs

3.1.4 Langham Creek

During the 1% (100-year) event, the peak overflow from Cypress Creek into the upper portion Langham Creek is 829 cfs, with a total volume of 1,580 acre-feet. Langham Creek receives about 5% of the total overflow volume during the 1% (100-year) storm event.

The peak discharge is substantially attenuated as the overflow moves across open land. By the time it reaches the developed area near Fry Road, the 1% peak discharge has been reduced to 394 cfs. It takes about 40 hours for the peak flow to move from the watershed divide to this point. For comparison, the peak 1% (100-year) flow rate at this location from a local rainfall event (without overflow) is 1,980 cfs. This event would typically peak more quickly than the overflow event – by approximately two days. Consequently, the local event will dissipate prior to the overflow event. The total volume for the local event is much higher than the overflow event. The total 1% volume for the local event along Langham Creek upstream of Fry Road is 3,143 acre-feet, while the total 1% volume for the overflow event at the same location is 1,580 acre-feet.

The 10% (10-year) peak overflow from Cypress Creek into the upper extent of Langham 232 cfs. The total 10% (10-year) overflow volume into Langham Creek is 394 acre-feet.

Exhibit A3.5 shows the 1% (100-year) and 10% (10-year) overflow hydrographs along Langham Creek in the upper portion of the watershed near Fry Road.

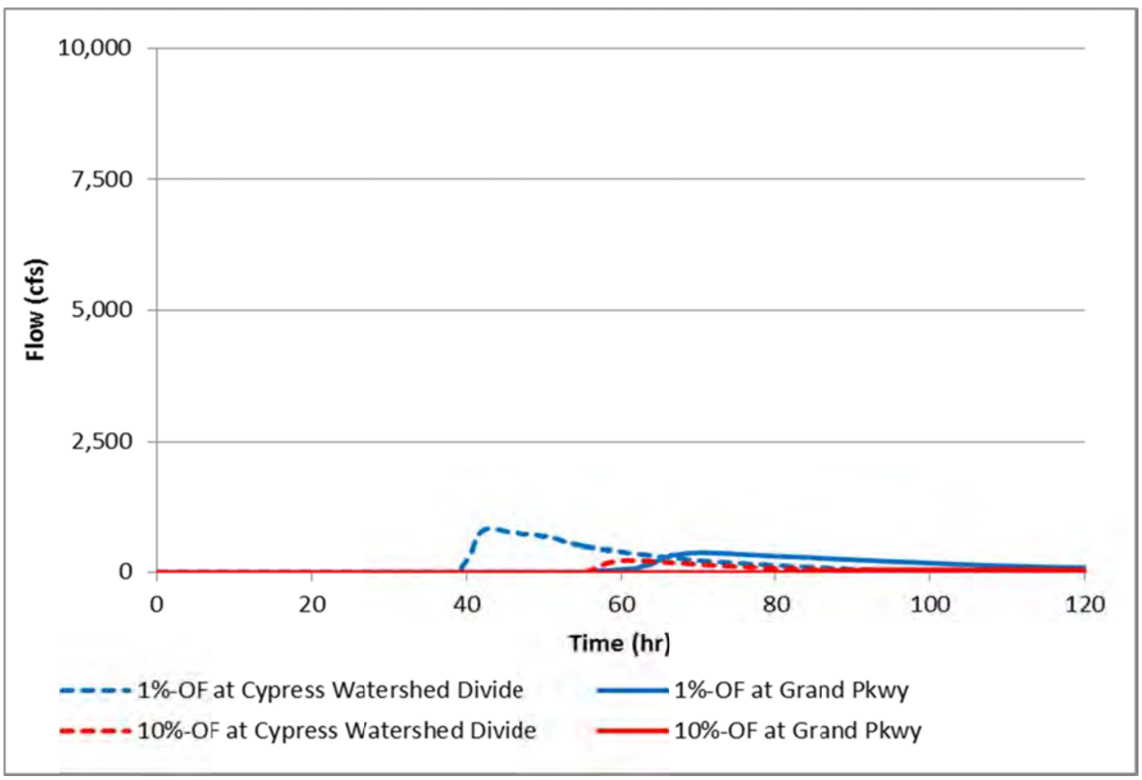


Exhibit A3.5
Langham Creek Overflow Hydrographs

3.1.5 Addicks Reservoir

During a local 24-hour 1% (100-year) event, the Addicks Reservoir watershed is expected to deliver 67,005 acre-feet of runoff volume to the reservoir (under current development conditions). The resultant 1% peak discharge into the reservoir, considering all of the tributaries, is 42,731 cfs.

For a similar overflow event, with current development conditions, Cypress Creek is expected to contribute 23,355 acre-feet of overflow volume at a peak discharge of 4,905 cfs. This peak discharge is anticipated to occur about two days later than the local event.

For a combined 24-hour 1% (100-year) rainfall event over both the Addicks Reservoir watershed and the Upper Cypress Creek watershed, the peak flow rates would remain unchanged. The total runoff volume under current development conditions is estimated to be 90,360 acre-feet. Of this, 74% is from rainfall over the Addicks Reservoir watershed, and 26% is from rainfall over the Upper Cypress Creek watershed.

The peak flow rates and total volumes from the 1% (100-year) rainfall event for Addicks Reservoirs and the three tributaries are summarized in Table A3.4

Table A3.4: Peak 1% Flow rates and Flow Volumes Along Addicks Tributaries

Parameter	**Addicks Watershed Rainfall (Local)**		**Upper Cypress Watershed Rainfall (Overflow)**	
	Peak Flow (cfs)	**Volume (ac-ft)**	**Peak Flow (cfs)**	**Volume (ac-ft)**
Langham Creek				
At Fry Rd	1,980	3,143	394	7,941
Entering Addicks Reservoir	8,701	13,568	394	7,941
Bear Creek				
At Katy-Hockley Rd	N/A*	N/A*	4,221	10,252
At Fry Rd	6,031	8,514	2,593	9,505
Entering Addicks Reservoir	7,959	11,899	2,593	9,505
South Mayde Creek				
At Katy-Hockley Rd	N/A*	N/A*	1,772	5,162
At The Grand Parkway	4,473	6,627	1,918	5,909
Entering Addicks Reservoir	11,508	17,123	1,918	5,909
Addicks Reservoir				
Total Addicks Reservoir	42,731	67,005	4,905	23,355

An additional hydrologic analysis was conducted to consider the potential increase from development in the Upper Cypress Watershed. This analysis assumes that (1) all land will develop at a typical single family rate with the exception of existing lands held in conservation, which will remain undeveloped; (2) current detention policies are in place; and (3) current detention policies are adequate to offset the potential increase in peak flow rate.

The analysis indicates that the peak flow rates of the overflow would not be impacted, and would remain the same. However, Cypress Creek would stay at flood stage for a slightly longer duration as the detention basins empty, resulting in a 15% increase in the overflow volume. With full development and current policy, it is estimated that the overflow volume would increase from 23,355 acre-feet to 26,267 acre-feet. Exhibit A3.6 presents a comparison of the Upper Cypress Creek hydrographs and overflow hydrographs for both the existing and ultimate development during the 1% (100-year) storm event.

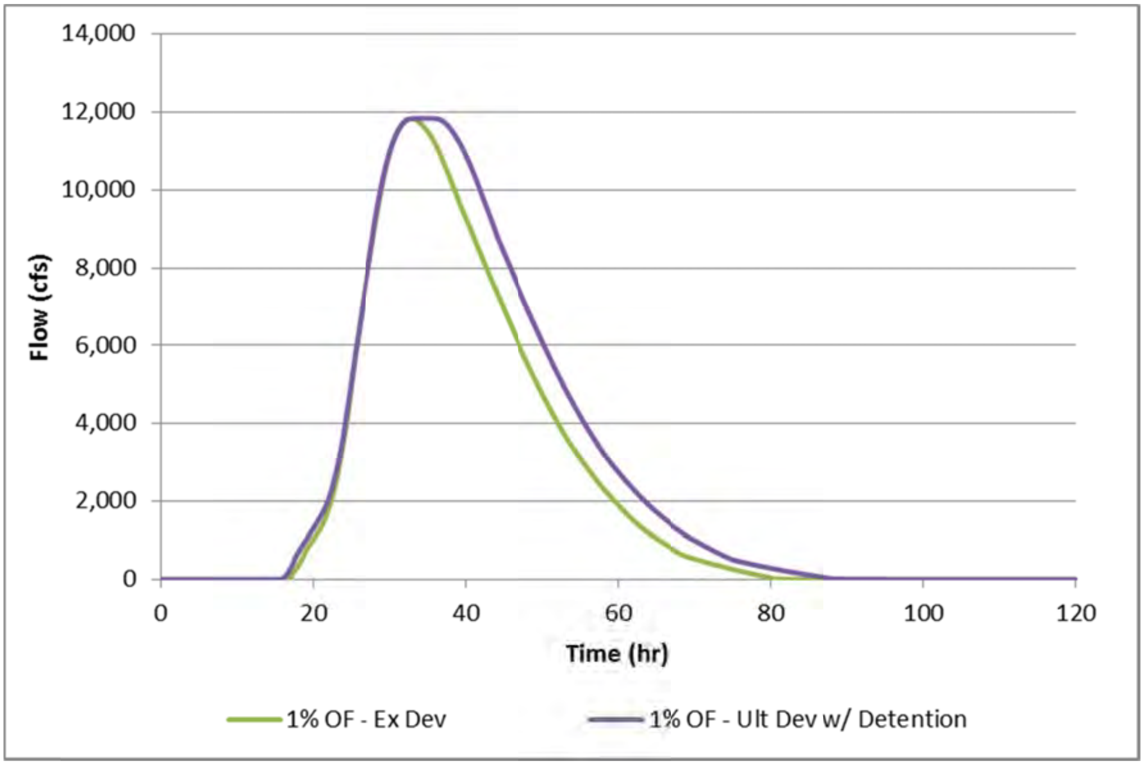


Exhibit A3.6
Existing and Full Development Overflow Hydrographs

3.2 Overflow Inundation

The xpstorm model facilitated the determination of areas that would be inundated by the overflow for various events. Furthermore, the model allowed the development of a depth-grid depicts overflow depths across the overflow area. Lastly, lines of equivalent water surface elevation were developed for the 1% (100-year) event.

3.2.1 Inundation Mapping

The area inundated by the 1% (100-year) overflow is depicted in Exhibit A3.7, while the area inundated by the 10% (10-year) overflow is depicted in Exhibit A3.8 and the area inundated by the 20% (5-year) overflow is depicted in Exhibit A3.9. These maps also display the peak depth of inundation throughout the overflow area, which are also summarized in Table A3.5.

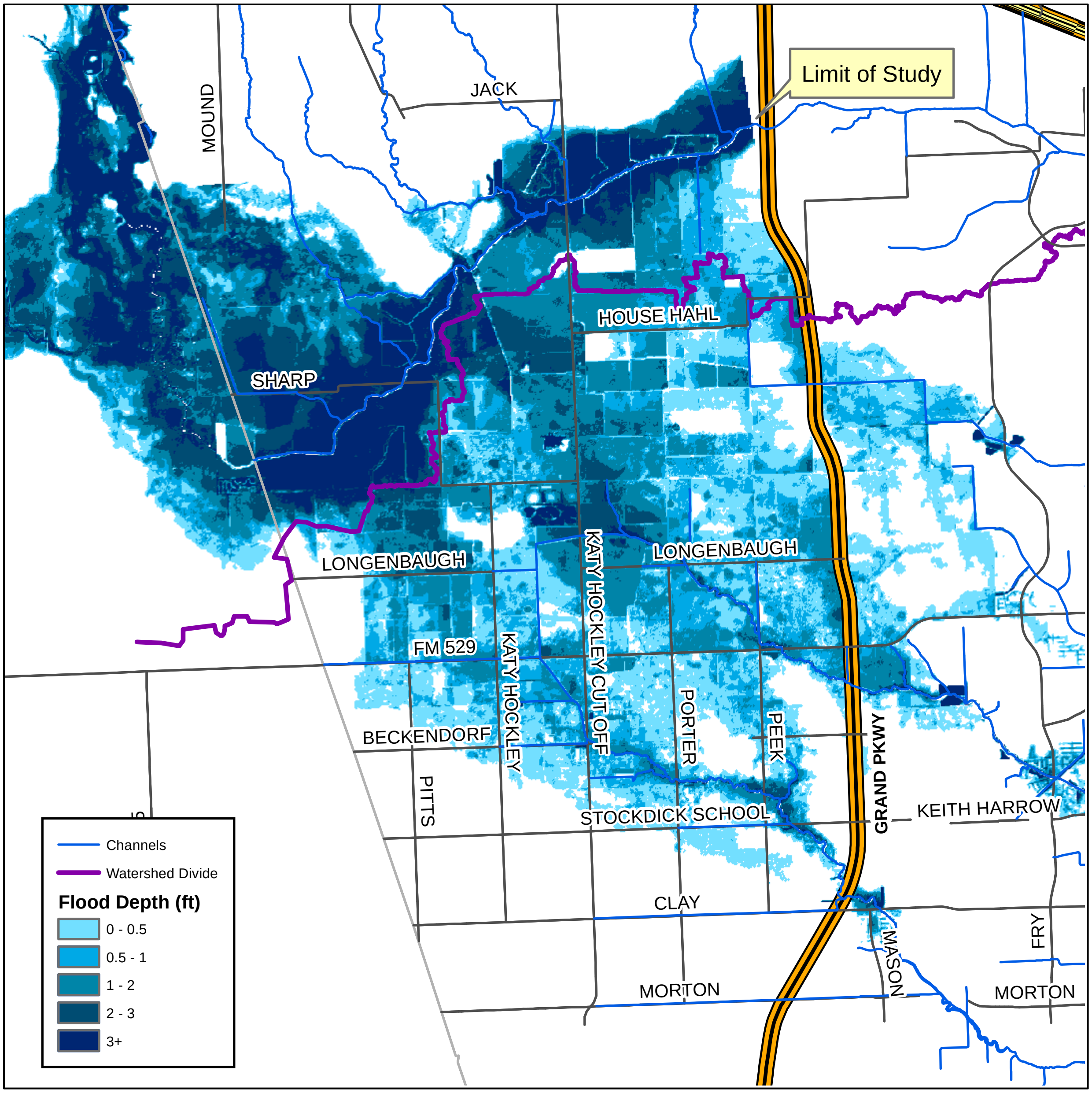


Exhibit A3.7
1% (100-year) Overflow Inundation
(Riverine Floodplains Not Depicted)

Table A3.5: Total Area (Acres) of Overflow, by Depth

Overflow Depth (feet)	10% (10-year)	1% (100-year)
0.0-0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	8,606	20,838

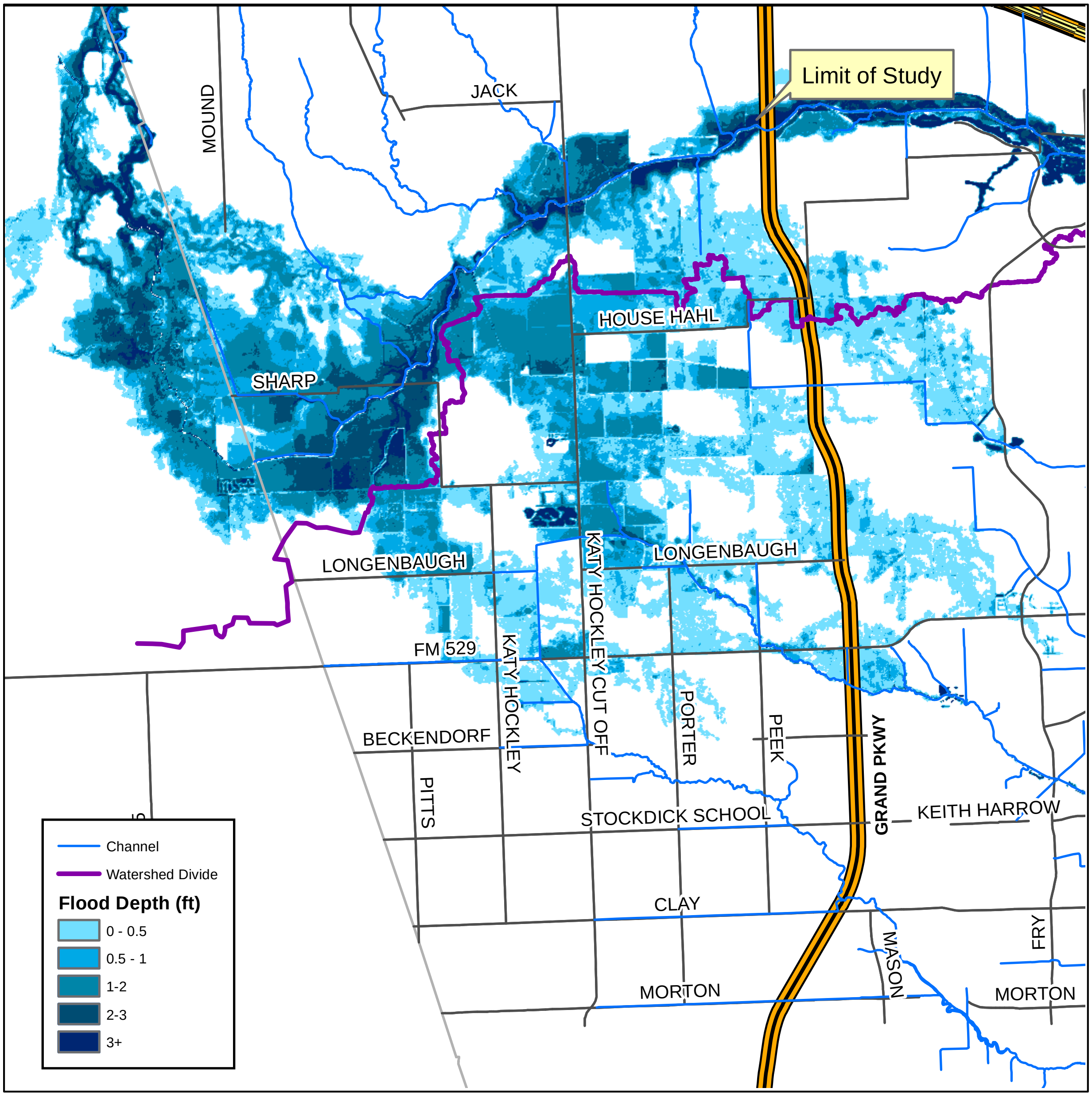


Exhibit A3.8
10% (10-year) Overflow Inundation
(Riverine Floodplains Not Depicted)

As the table indicates, the total area inundated by the 1% (100-year) overflow event is 20,838 acres. Of this, over one-half (12,730 acres) has an inundation depth of less than one foot, and the overwhelming majority (almost 90%) of the area has an overflow depth of less than two feet.

During the 10% (10-year) event, 8,606 acres would become inundated. Most of this, 6,356 acres, inundates at a depth of one-foot or less.

The deeper overflow areas are generally those located within or near existing drainage courses, such as along or near Bear Creek.

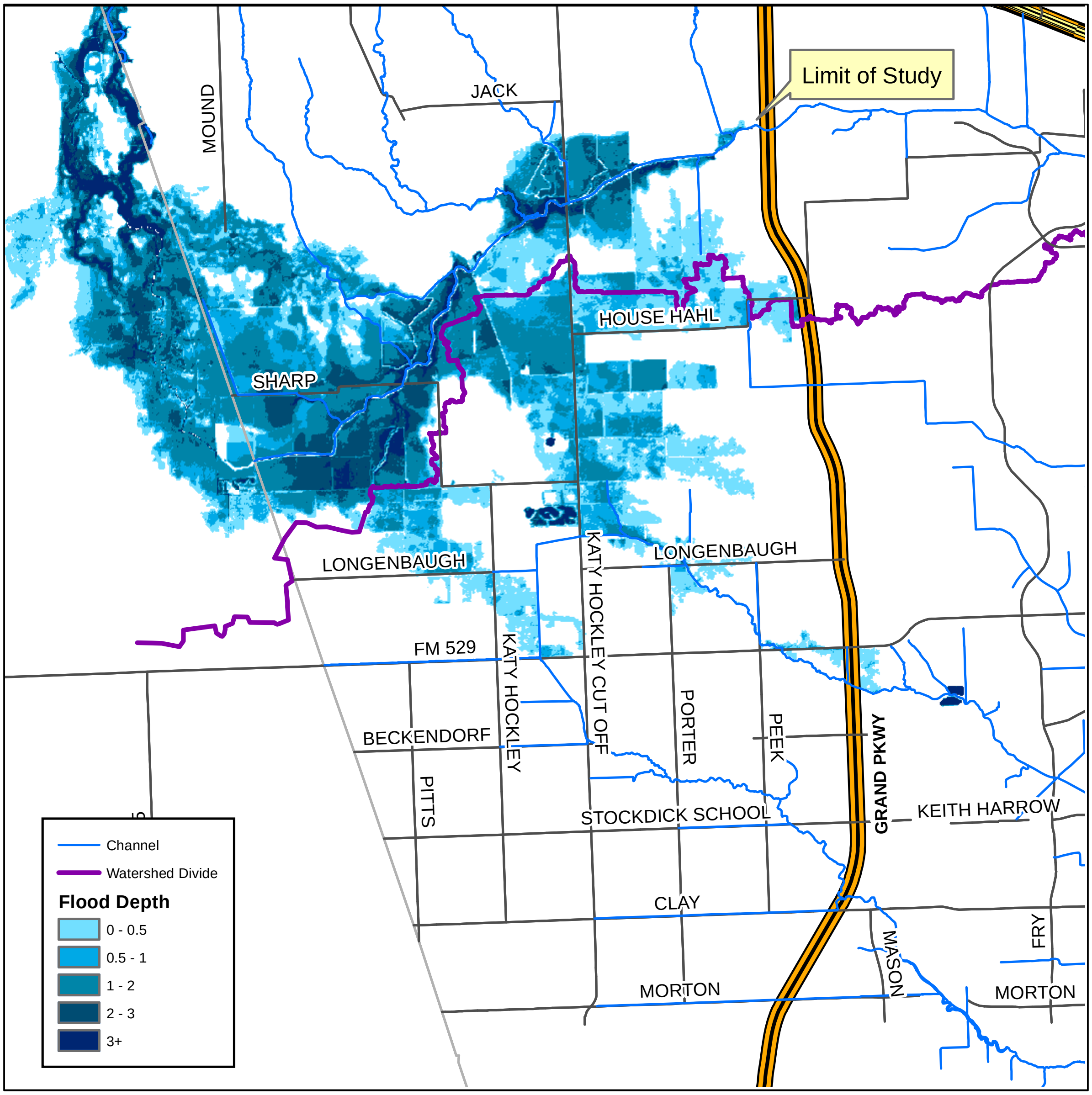


Exhibit A3.9
20% (5-year) Overflow Inundation
(Riverine Floodplains Not Depicted)

4.0 Management Measures

This section describes the hydrologic and hydraulic modeling of the two management measures, and provides key information regarding the measures. In addition, the implementation phasing is considered, with an emphasis on the initial phase of implementation.

4.1 Management Plan 3 – Mound Creek Reservoir plus Conveyance "B"

Management Plan 3 - Mound Creek Reservoir plus Conveyance "B" is depicted in Exhibit A4.1. The plan includes a large reservoir located along Mound Creek upstream of the overflow, a conservation and collection area that will be used to intercept and collect the residual overflow, and a 500-foot corridor along Bear Creek and modifications to Bear Creek to convey the overflow. The plan also includes detention within John Paul's Landing (JPL), a Harris County Precinct Three facility that proposes to build amenity lakes, and additional development criteria. When fully implemented, the plan will fully manage the overflow.

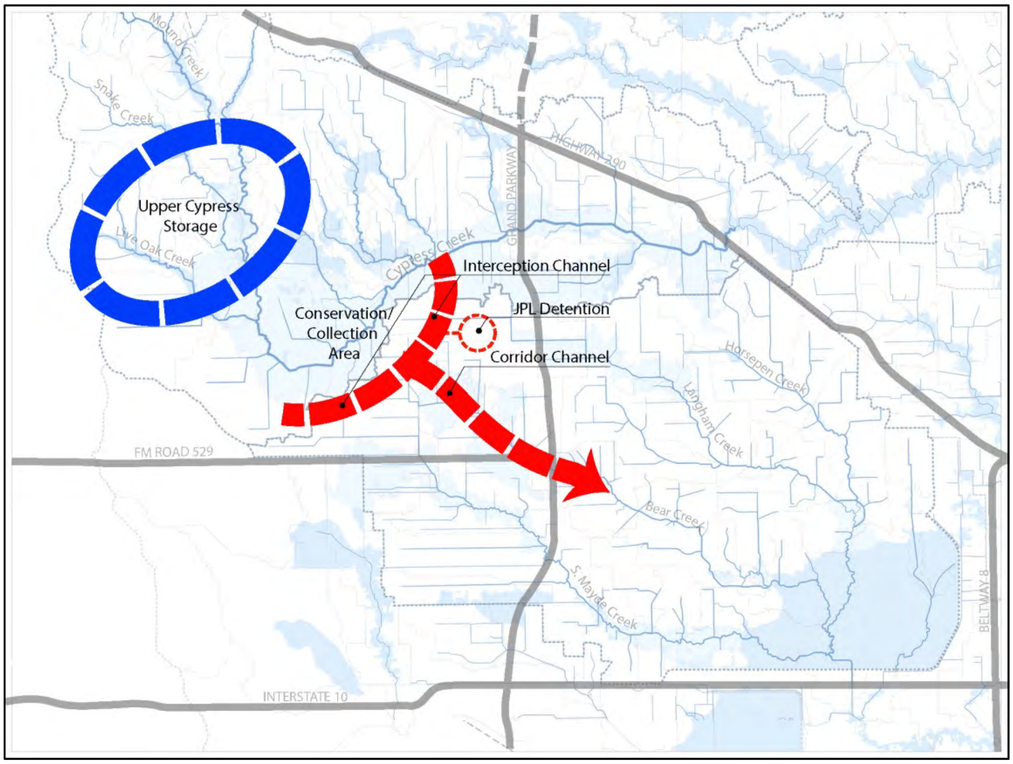


Exhibit A4.1
Management Plan 3 – Mound Creek Reservoir Plus Overflow Conveyance "B"

4.1.1 Modeling of Mound Creek Reservoir

The Mound Creek Reservoir is located upstream of the overflow along Mound Creek. It is also beyond the gridded mesh used in the two-dimensional analysis. However, HEC-HMS is sufficient to simulate the reservoir, and was therefore used in this study. The reservoir was depicted with an elevation vs. storage volume relationship developed from the LiDAR based Digital Elevation Model. The outfall was modeled as a conduit, although in reality an open channel conduit would be designed in a fashion that mimics the necessary outfall behavior. Exhibit A4.2 shows the 1% (100-year) hydrograph at the outfall of Mound Creek. Both the existing (without the reservoir) and Plan 3 condition are depicted. The reservoir will have an ungaged free outlet, and will provide very short duration storage of the overflow, as the shape of the hydrograph indicates.

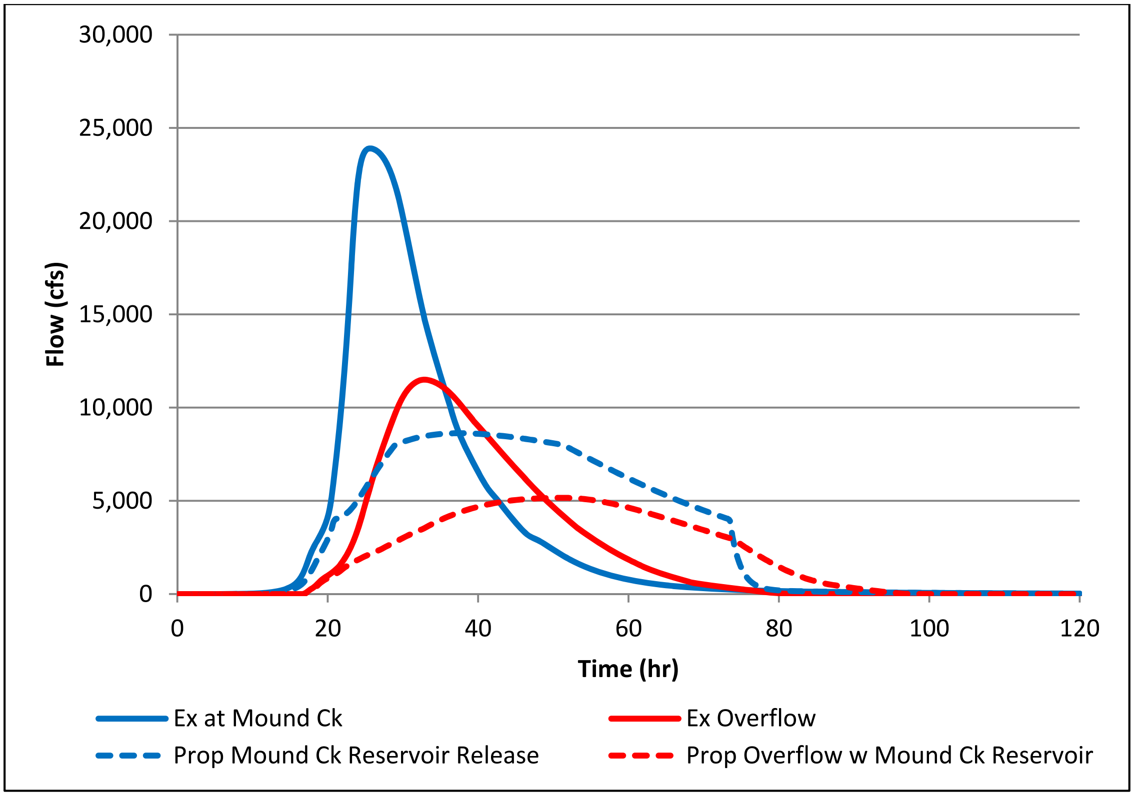


Exhibit A4.2
Mound Creek Reservoir 1% (100-year) Hydrograph Comparison

During the 1% (100-year) event, the reservoir will reduce peak discharges along Mound Creek from about 24,000 cfs to about 8,600 cfs. The 1% (100-year) peak pool elevation within the reservoir is 188.0. During such an event, 2,880 acres will become inundated, and the reservoir will store approximately 15,730 acre-feet. The maximum depth of this inundation is 13 feet, with an average inundation depth of 7 feet. Most of the reservoir will drain in about four days.

TCEQ Dam Safety Permit criteria require the reservoir provide structural protection for events up to the Probably Maximum Precipitation (PMP), which is the maximum precipitation that could occur. For the Mound Creek Reservoir, it was determined that the critical storm duration was 24 hours, resulting in a PMP event of 44.8 inches. In order to accommodate and pass the PMP, the total land required for the Mound Creek Reservoir is about 3,765 acres.

The dam will be constructed to the PMP elevation plus additional height too account for wave setup and run-up. A 4,000 foot wide overflow spillway will be constructed at the 1% (100-year) pool elevation of 188.0. When elevations exceed this, flow will exit the reservoir over this controlled spillway, which will be designed to protect the integrity of the structure. It is estimated that the top of the dam will be at elevation 196.0, which provides the necessary depth to accommodate the PMP event along with provisions for wave setup and run-up.

Exhibit A4.1 shows a schematic of the management plan.

4.1.2 Duration of Inundation

As noted above, the vast majority of the Mound Creek Reservoir will drain within four days during a 1% (100-year) event. Much of the area occupied by the reservoir is within the existing floodplain of Mound Creek, and would be subject to a considerable duration of flooding even without the reservoir.

Comparison depth hydrographs were presented for various locations in the reservoir. Exhibit A4.3 shows the location of these comparisons, and depth hydrograph comparisons are presented for the 50% (2-year), 20% (5-year), 10% (10-year), and 1% (100-year) events in Exhibits A4.4, A4.5, A4.6, and A4.7. The comparisons confirm that the net change in inundation time for most locations is relatively small, and even those locations that are not currently subject to inundation would see very short and shallow inundations.

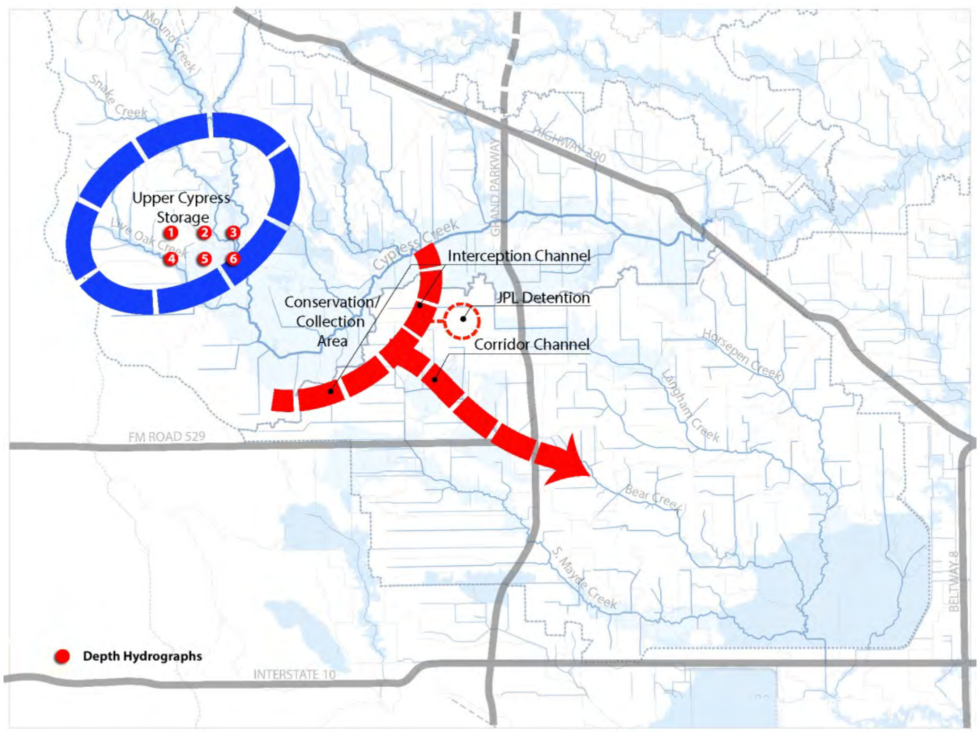


Exhibit A4.3
Plan 3 - Depth Hydrograph Locations

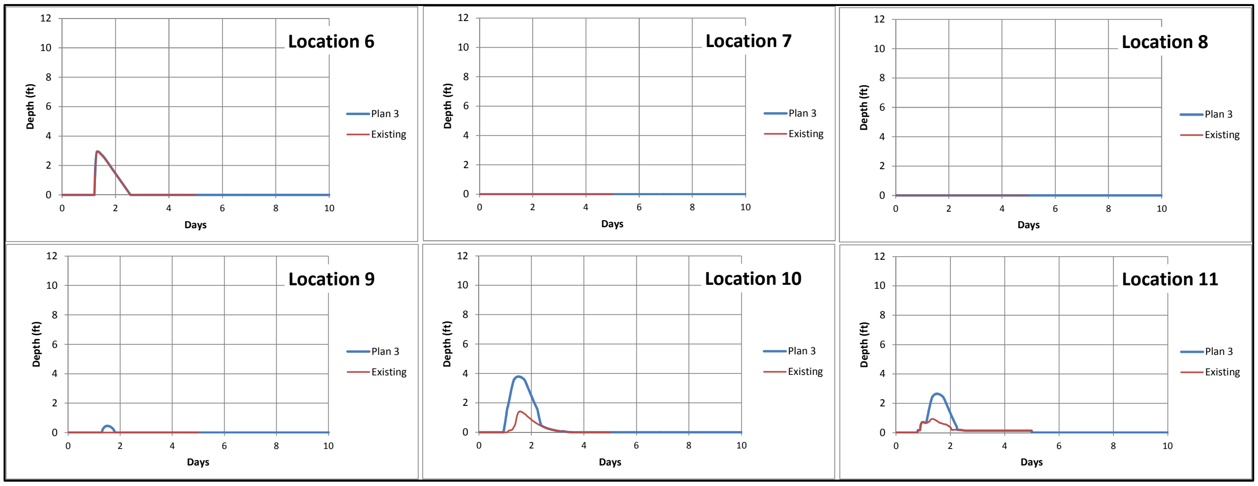


Exhibit A4.4
Plan 3 Depth Hydrographs – 50% (2-year) Event

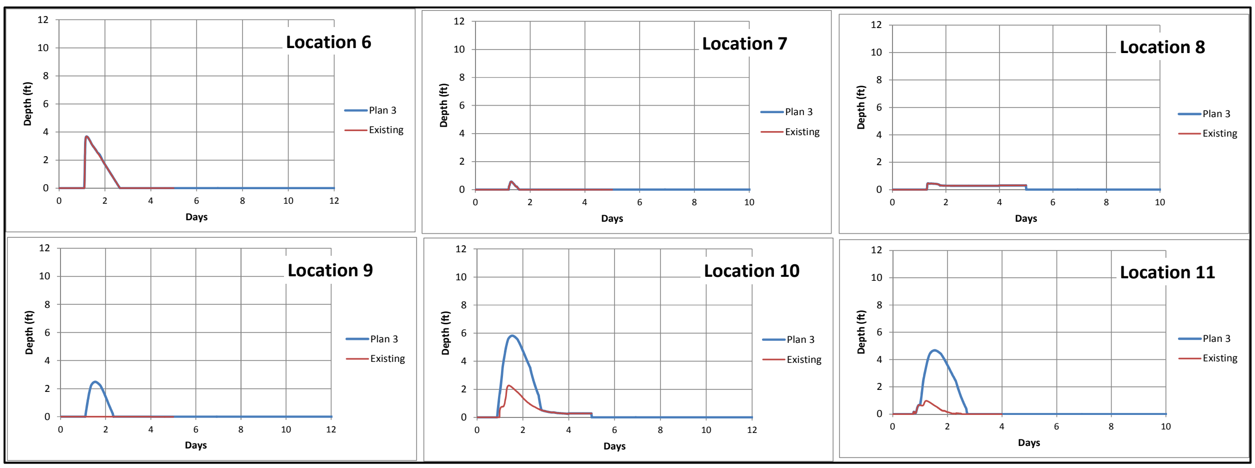


Exhibit A4.5
Plan 3 Depth Hydrographs – 20% (5-year) Event

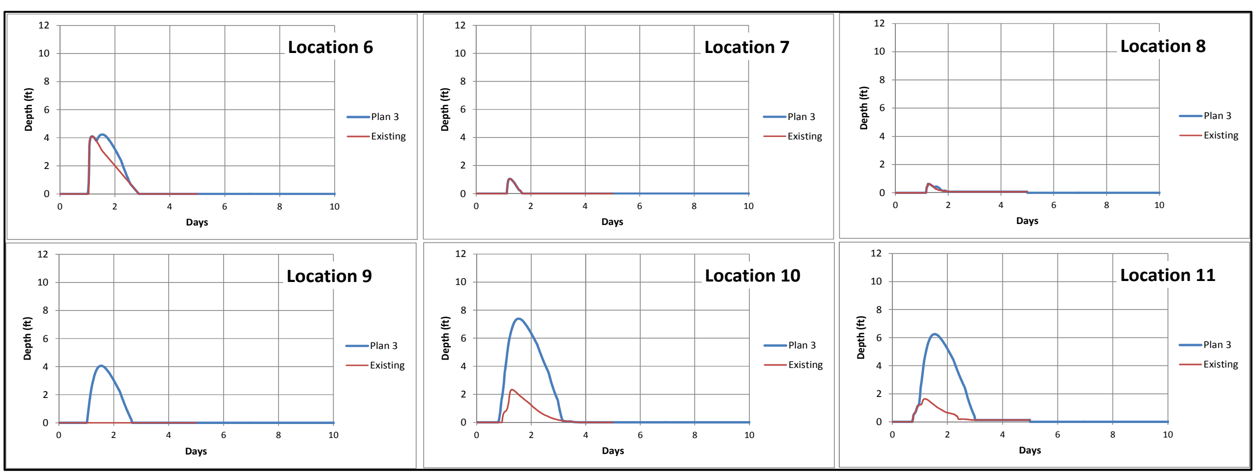


Exhibit A4.6
Plan 3 Depth Hydrographs – 10% (10-year) Event

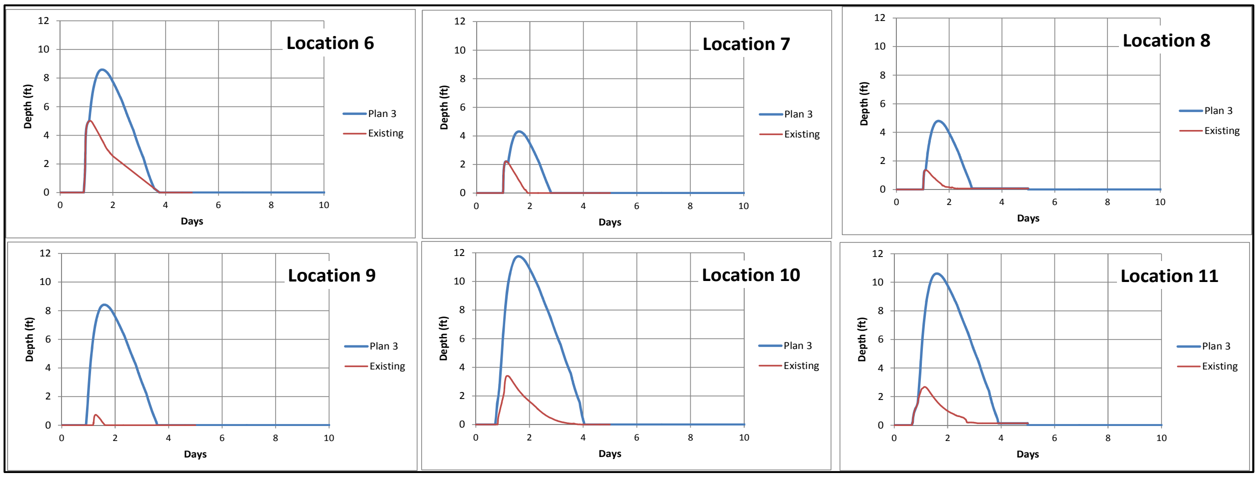


Exhibit A4.7
Plan 3 Depth Hydrographs – 1% (100-year) Event

4.1.3 Overflow Collection and Conveyance, and JPL Detention

The Mound Creek Reservoir will significantly reduce the peak overflow, as indicated on Exhibit A4.2, but will not eliminate the overflow. There will also be a slight reduction in overflow volume. The xpstorm model was revised to include the upstream hydrograph that results with the Mound Creek Reservoir in place, allowing for the computation of a revised overflow hydrograph. Exhibit A4.2 also shows the existing and Plan 3 overflow hydrograph for the 1% (100-year) event. As the hydrographs indicated, the reservoir will reduce the overflow by approximately 6,700 cfs, from approximately 11,500 cfs to approximately 5,200 cfs. The total overflow volume will be reduced by about 3,100 acre-feet, from 23,350 to 20,250 acre-feet.

The digital elevation data was modified to include the collection channels and modified Bear Creek. Because of the limitations of the model, the models were simplified and the channels were represented as rectangular channels. Since the channels, in general, are wide and flat, this was considered an adequate simulation. Once the basic configuration was developed, the channels were sized using Manning's Equation for open channel flow using the flow rates determined in the xpstorm analysis. The DEM was also modified to reflect 1,800 acre-feet of storage volume in JPL.

The north-south oriented collection channel along the east side of the area that will continue to be inundated by the overflow during a 1% event will vary in size. At the south, near Bear Creek, it will convey about 3,000 cfs and have a total top-width of 200 feet. The collection channel that runs east-west along the overflow inundation area will convey about 3,500 cfs during the 1% (100-year) event. Its size will also vary, but at the east end near Bear Creek it will have a top-width of about 230 feet.

During a 1% (100-year) overflow event, Bear Creek will convey a peak flow of about 4,500 cfs downstream of its connection with John Paul Landing. This channel will also convey local runoff, however the local event would be conveyed down to Addicks Reservoir prior to the overflow event. The modified channel section will utilize natural channel design techniques in order to minimize the need for mitigation credits, and to allow for the attenuation of flow as it flows downstream.

4.1.4 Future Development

Current development criteria require the use of detention to mitigate the potential increase in peak discharges. However, detention will not offset the increase in volume, which could impact the behavior of flows in the Mound Creek Reservoir. An analysis was conducted that considered ultimate development, with current detention policy, and it did slightly increase the computed stage elevations in the reservoir. However, this relative impact was small and does not affect the conclusions of this planning level study.

In addition to the structural measures described above, Management Plan 3 does include the adoption of additional development criteria as a means to offset the increase in volume from new development.

4.1.5 Initial Phases

Management Plan 3 also includes an implementation plan. A key part of this plan are the two initial phases, which strive to utilize the conveyance and collection area as an interim means to protect a portion of the study area from the overflow. Specifically, the initial phase of Management Plan 3 calls for the construction of the north-south oriented collection channel near Katy-Hockley Road, and the construction of modifications along Bear Creek for about 7,000 feet downstream in order to daylight the deepened channel. The channel would intercept overflow and convey it to the Bear Creek corridor. The captured overflow conveyed by Bear Creek would be "released" and permitted to spread out downstream of the initial channel enlargements, as the overflow currently does under existing conditions. Individual developments, as part of the second phase, would construct the improved Bear Creek channel and implement interim measures, as necessary, to protect their property from the overflow.

When these two phases are fully implemented, the modified Bear Creek Channel would extend all the way down to a portion of lower Bear Creek that was previously enlarged during earlier periods of development. The existing channel enlargements begin upstream of Fry Road. This resultant configuration was simulated in the xpstorm model, without the Mound Creek Reservoir in place. During simulations, it was determined that additional widening of the collection channel was necessary in order to obtain some necessary attenuation and to ensure the capacity of the lower Bear Creek channel (4,500 cfs) is not exceeded. In addition, it was found that it is necessary to construct a berm on the east side of the collection channel in order to ensure that overflows are intercepted, and to provide additional attenuation. The berm would have a maximum height of about four feet. The collection channel would have an average width of 500 feet, but it would be smaller at the lower end to control discharges into the Bear Creek system.

The resultant analysis determined that the 1% (100-year) flow rate along Bear Creek upstream of Fry Road would be about 4,500 cfs. While this is slightly higher than the existing 1% (100-year) overflow of about 2,600 cfs into Bear Creek from the overflow, it is below the local 1% (100-year) flow rate and does not exceed the capacity of the existing Bear Creek channel.

4.2 Management Plan 5 – Katy-Hockley N – Cypress Reservoir

Management Plan 5, Katy-Hockley N – Cypress Reservoir is depicted in Exhibit A4.6. The plan includes a large reservoir that encompasses much of the overflow. The reservoir would be formed by a dam that extends across both Cypress Creek and Bear Creek. The reservoir would outfall into both Cypress Creek and a modified Bear Creek. Bear Creek would be modified in a 500-foot corridor. There would be an internal channel within the reservoir to ensure that volume will not divert from Cypress Creek to Addicks Reservoir. In addition, the plan proposed detention in JPL and development criteria, both similar to those described for Management Plan 3. When fully implemented, the plan will fully manage the overflow.

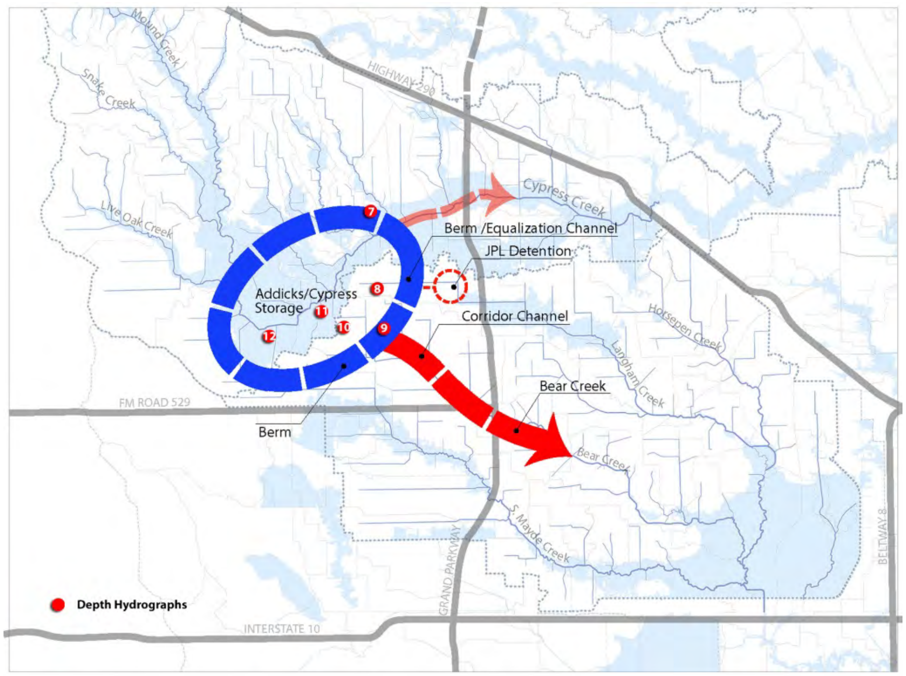


Exhibit A4.6
Management Plan 5 – Katy-Hockley N – Cypress Reservoir

4.2.1 Modeling of the Katy-Hockley N – Cypress Reservoir

The Katy-Hockley N – Cypress Reservoir is located fully within the xpstorm grid mesh, so the two-dimensional model could be was utilized to simulate the reservoir. This was simply done by adjusting the elevation grid to reflect a dam, and by providing rating curves to reflect the outlets. However, a HEC-HMS simulation was also performed to facilitate certain design considerations, such as the potential to increase the overflow from Cypress Creek to Addicks Reservoir. This analysis required numerous iterations, which would be time consuming using the two dimensional model. To construct the HEC-HMS model, the Addicks and Upper Cypress HEC-HMS models were merged into a single model. The reservoir was depicted with an elevation vs. storage volume relationship developed from the LiDAR based Digital Elevation Model. The outfalls were modeled as conduits. The reservoir will have ungaged free outlets, and will provide very short duration storage of the overflow, as the shape of the hydrograph indicates.

During the 1% (100-year) event, the reservoir will have a total discharge of 7,300 cfs. This includes 5,300 cfs to Cypress Creek, and 2,000 cfs to Bear Creek. Along Cypress Creek, the peak discharge will not exceed existing peak discharges. During the 1% (100-year) event, 7,400 acres will become inundated, and the reservoir will store 26,500 acre-feet. The 1% (100-year) pool elevation would be 168. The maximum depth of this inundation is eight feet, with an average inundation depth of four feet. Most of the reservoir will drain in four-to-six days, while the lowest areas will drain in about eight days.

TCEQ Dam Safety Permit criteria require the reservoir provide structural protection for events up to the Probably Maximum Precipitation (PMP), which is the maximum precipitation that could occur. For the Katy-Hockley N – Cypress Reservoir, it was determined that the critical storm duration was 24 hours, resulting in a PMP of 42.7 inches. The dam will be constructed to the PMP elevation plus additional height too account for wave setup and run-up. Two 4,000 foot wide overflow spillway will be constructed at the 1% (100-year) pool elevation of 170.7. One spillway will direct flow to Cypress Creek and the other will direct flow to Bear Creek. When elevations exceed this, flow will exit the reservoir over this controlled spillway, which will be designed to protect the integrity of the structure. It is estimated that the top of the dam will be at elevation 174.0, which provides the necessary depth to accommodate the PMP event along with provisions for wave setup and run-up.

Exhibit A4.6 shows the Katy-Hockley N – Cypress Reservoir, along with key parameters.

4.2.2 Duration of Inundation

As noted above, the vast majority of the Katy-Hockley N – Cypress Reservoir will drain within three days during a 1% (100-year) event. Much of the area occupied by the reservoir is within the existing overflow floodplain or the existing floodplain of Cypress Creek, and would be subject to a considerable duration of flooding even without the reservoir.

Comparison depth hydrographs were at various locations in the reservoir. Exhibit A4.7 shows the location of these comparisons, and depth hydrograph comparisons are presented for the 50% (2-year), 20% (5-year), 10% (10-year), and 1% (100-year) events in Exhibits A4.8, A4.9, A4.10, and A4.11. The comparisons confirm that the net change in inundation time for most locations is relatively small, and even those locations that are not currently subject to inundation would see very short and shallow inundations.

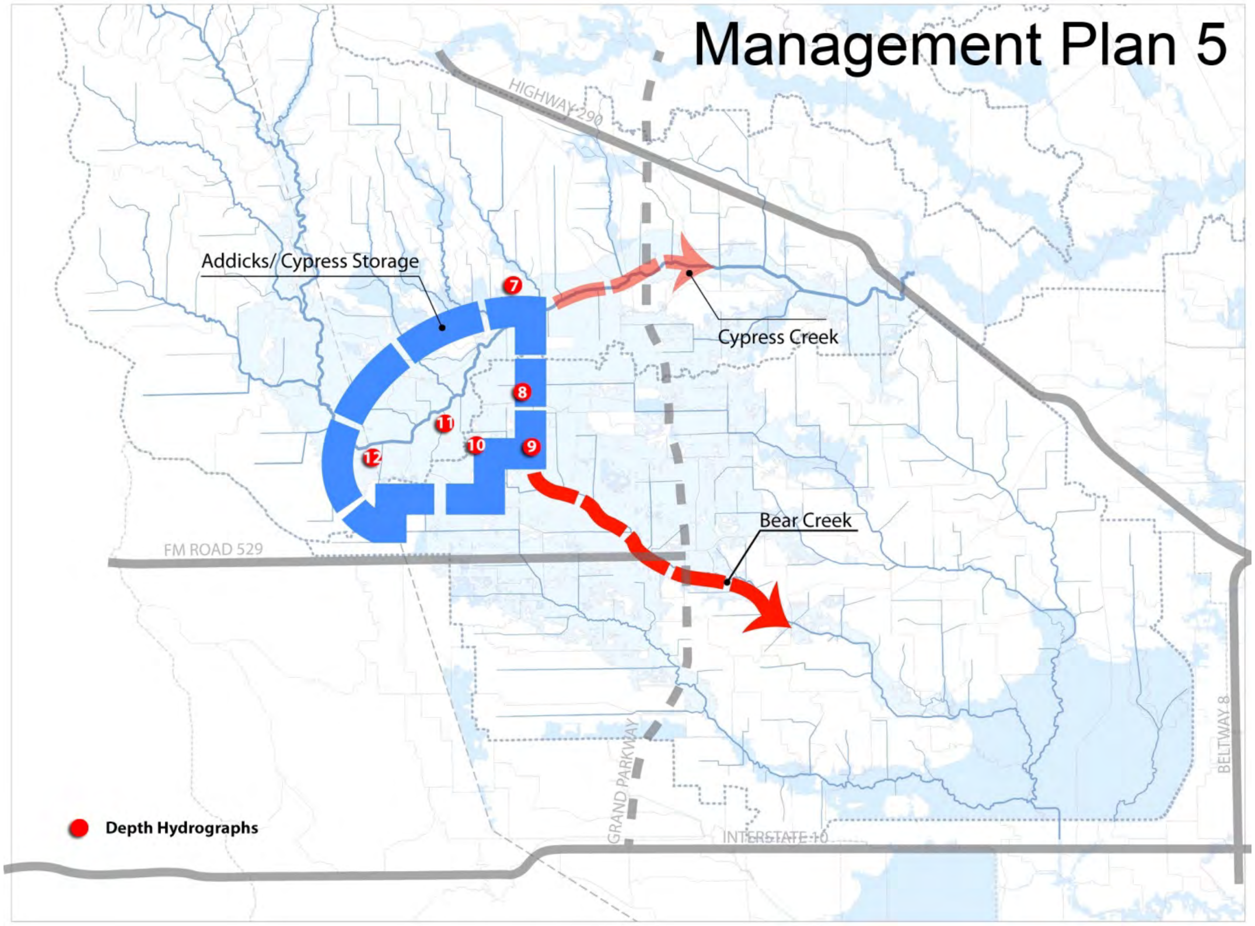


Exhibit A4.8
Plan 3 - Depth Hydrograph Locations

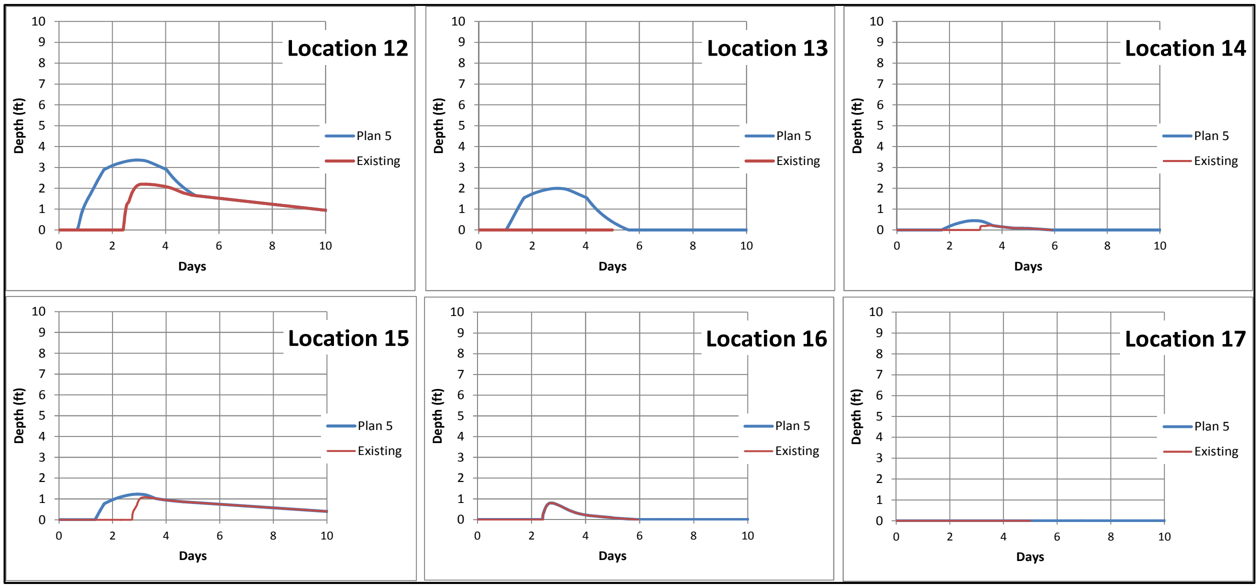


Exhibit A4.9
Plan 5 – 50% (2-Yr) Depth Hydrograph Comparisons

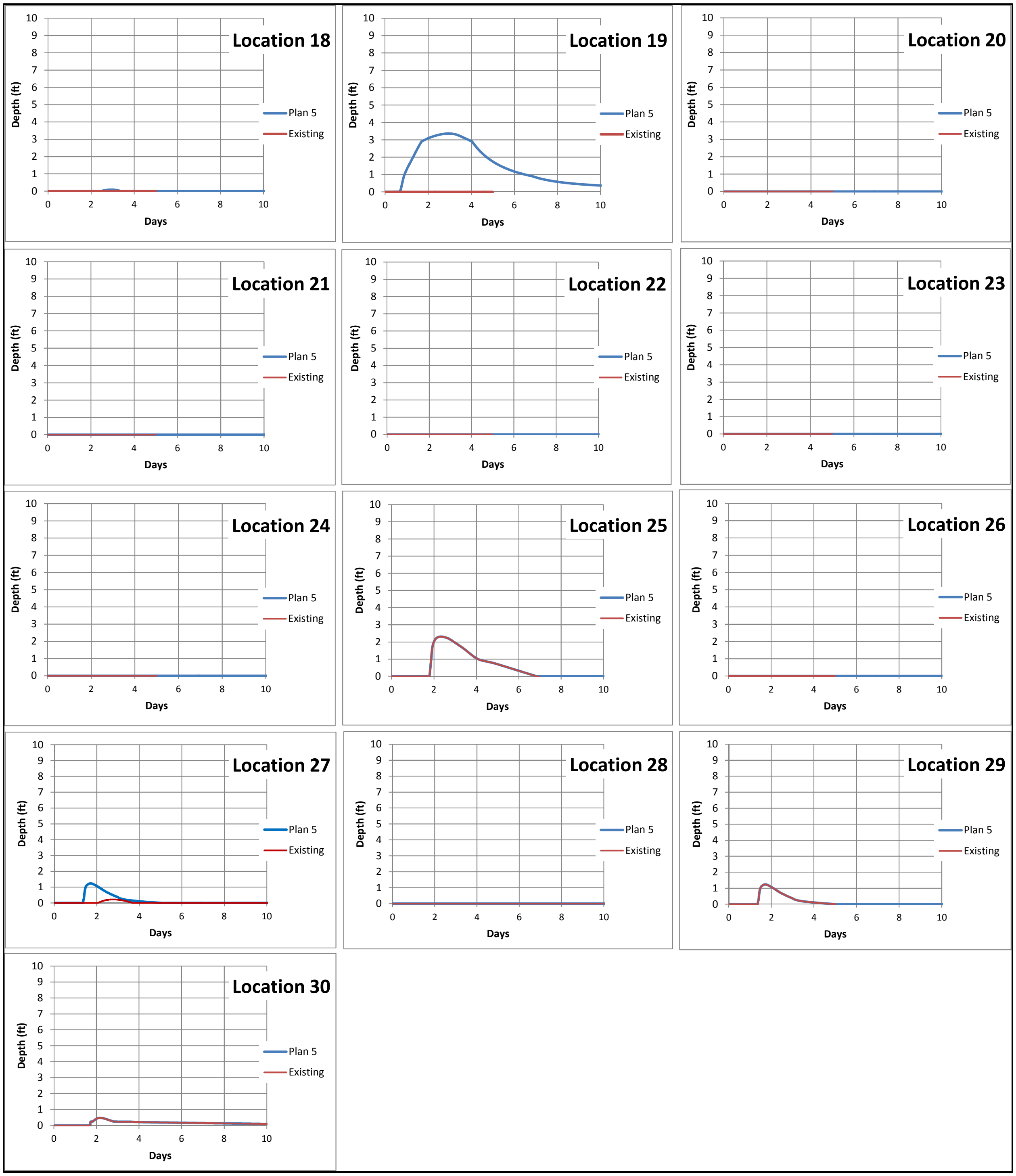


Exhibit A4.9 (Continued)
Plan 5 – 50% (2-Yr) Depth Hydrograph Comparisons

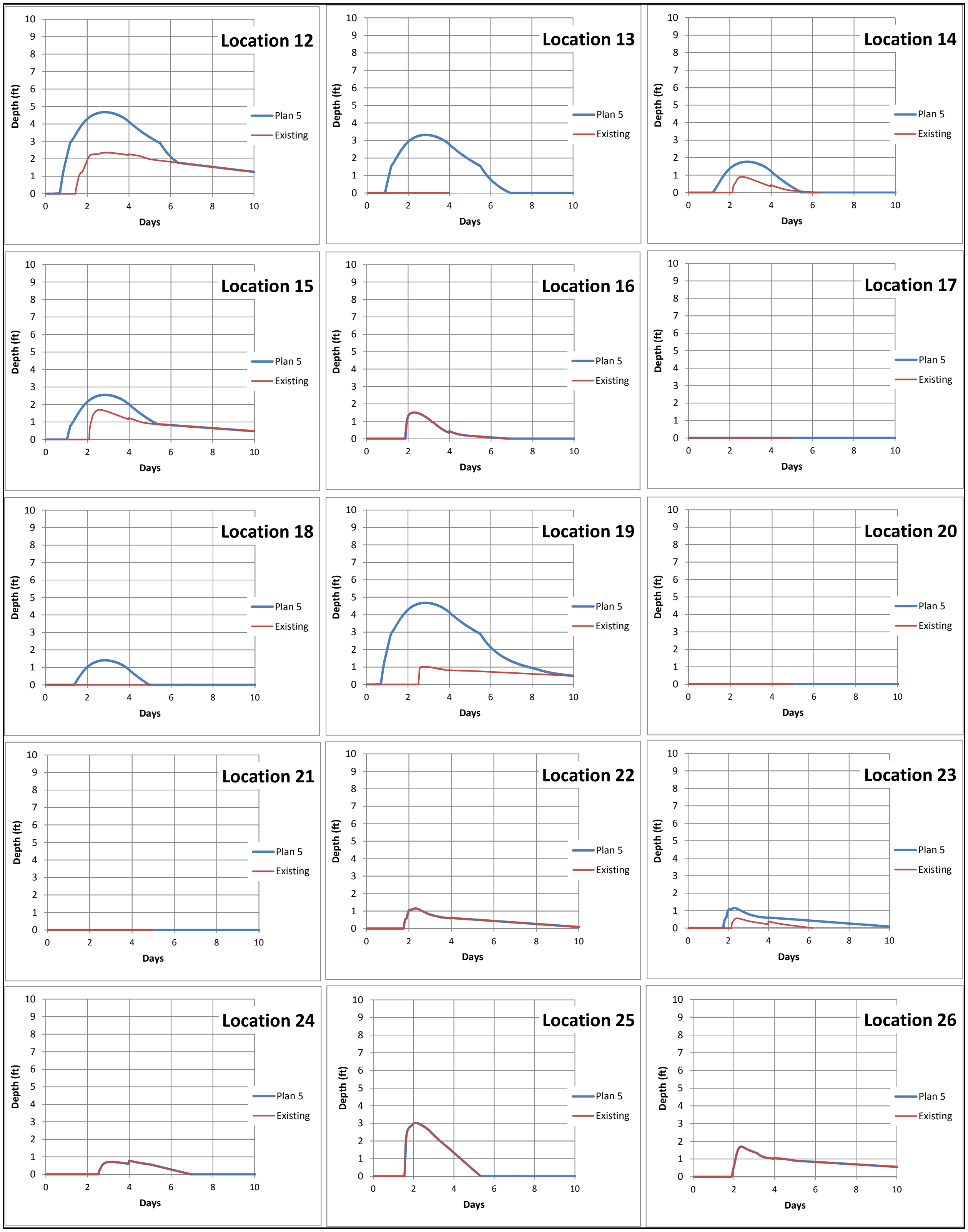


Exhibit A4.10
Plan 5 – 20% (5-Yr) Depth Hydrograph Comparisons

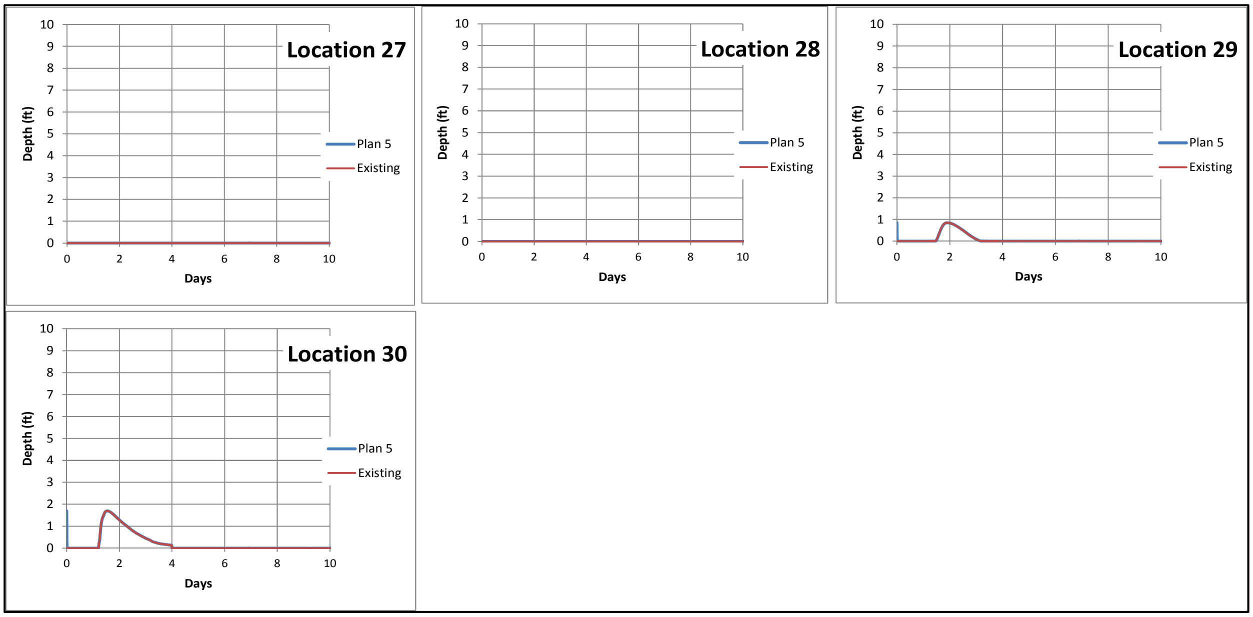


Exhibit A4.10 (Continued)
Plan 5 – 20% (5-Yr) Depth Hydrograph Comparisons

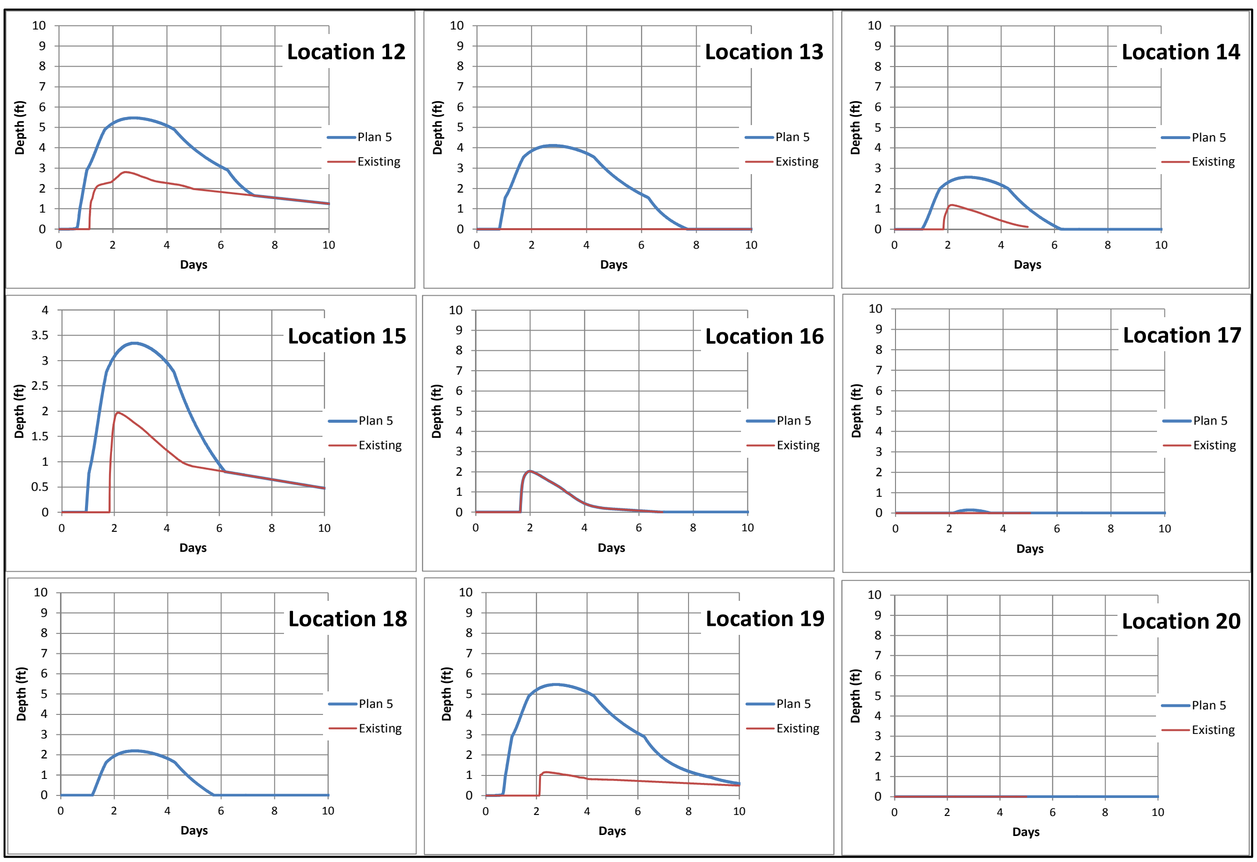


Exhibit A4.11
Plan 5 – 10% (10-Yr) Depth Hydrograph Comparisons

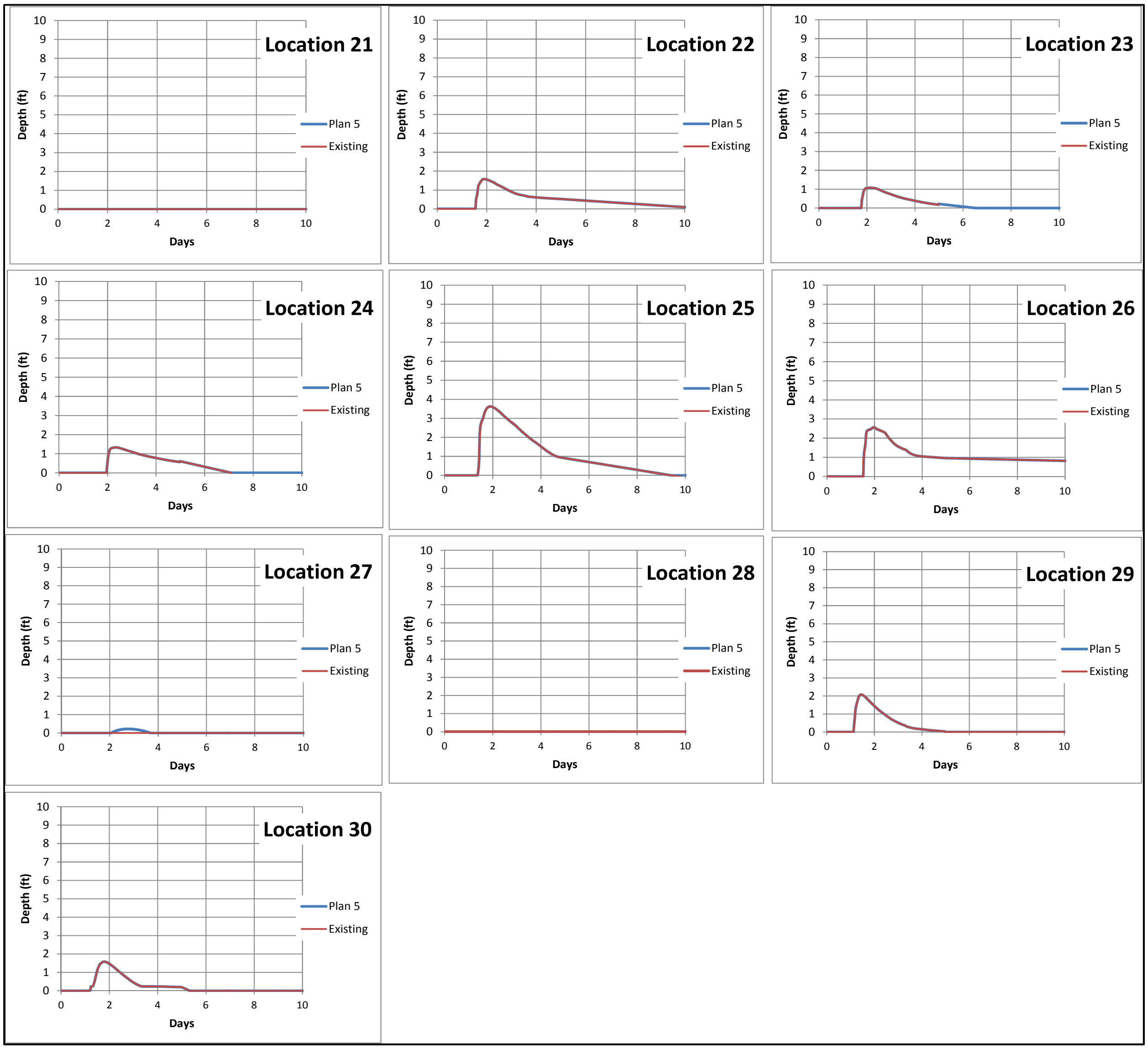


Exhibit A4.11 (Continued)
Plan 5 – 10% (10-Yr) Depth Hydrograph Comparisons

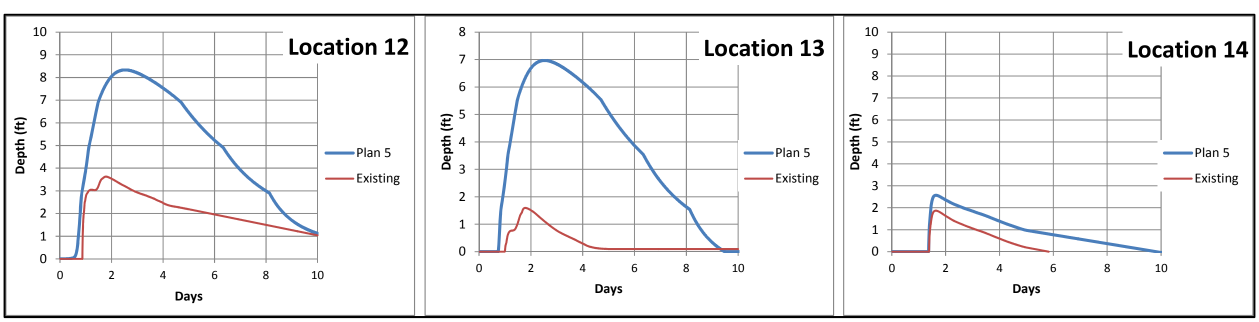


Exhibit A4.12
Plan 5 – 1% (100-Yr) Depth Hydrograph Comparisons

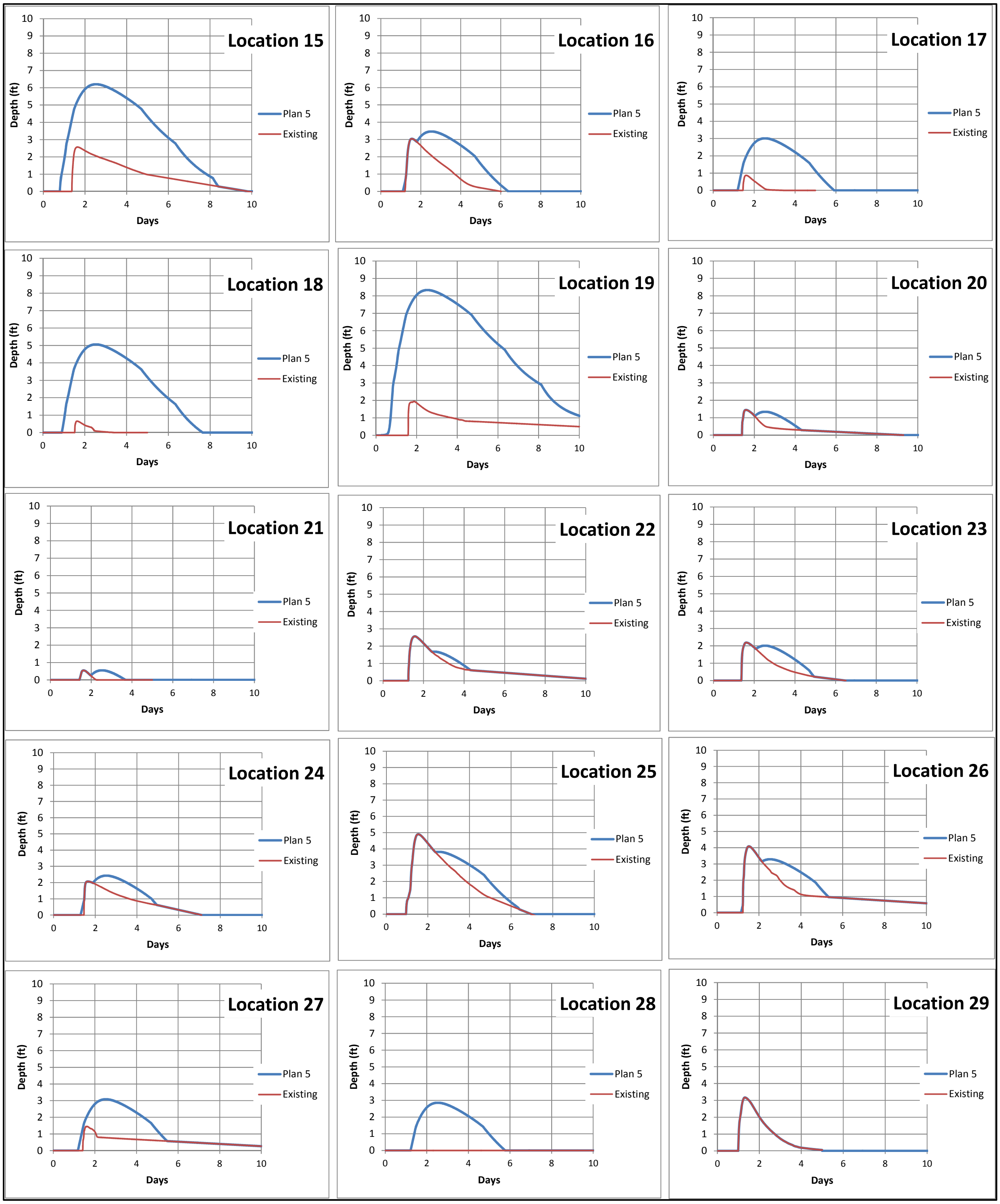


Exhibit A4.12 (Continued)
Plan 5 – 1% (100-Yr) Depth Hydrograph Comparisons

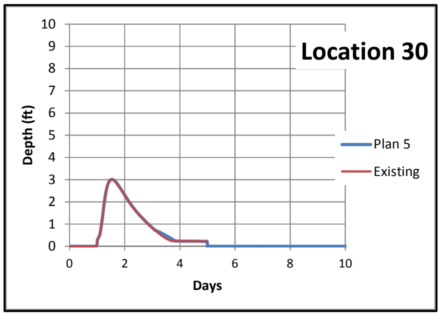


Exhibit A4.12 (Continued)
Plan 5 – 1% (100-Yr) Depth Hydrograph Comparisons

4.2.3 Watershed Volume Balancing

The dam along Cypress Creek will create a rise in water surface elevation along Cypress Creek upstream of the berm, which could result in additional volume being conveyed across the watershed boundary. In order to evaluate that, the combined watershed HEC-HMS model was modified to separate the portion of the reservoir in the Cypress Creek Watershed and the Addicks Reservoir watershed. The reservoirs were connected in a manner that balanced the water surface elevation in each. This facilitated a determination of volume transfer to each watershed.

Initially, the outfalls limitations on each reservoir were established based upon peak flow criteria in each watershed. The peak 1% (100-year) discharge in Cypress Creek was limited to the existing rate of about 5,000 cfs, and the peak rate to Bear Creek was limited to the existing local runoff rate of about 4,500 cfs. During the simulation, it was found that additional volume would "escape" the Cypress Creek watershed and flow to the Addicks Reservoir watershed, since there is substantially more storage capacity south of the watershed divide. To offset this, a return channel is proposed to convey storage back into the Cypress watershed. This return channel would have a backflow prevention structure at the watershed divide to ensure that it does not facilitate additional diversion to the Addicks Reservoir watershed.

The analysis found that during a 1% (100-year) event, outflows to Bear Creek had to be slightly reduced to prevent the diversion of volume from Cypress Creek to Addicks Reservoir. However, it was found that even when a volume balance was achieved during the 1% event, the analysis indicated a volume diversion during smaller events. Ultimately, it was determined that the outfall to Bear Creek must be restricted to 1,984 cfs in order to prevent the diversion of volume from the Cypress Creek watershed to the Addicks Reservoir watershed during all events up to the 1% (100-year) event.

During a 1% (100-year) event, Bear Creek will be sized to convey a minimum flow of 2,000 cfs near Katy-Hockley Road. The modified channel section will utilize natural channel design techniques in order to minimize the need for mitigation credits, and to allow for the attenuation of flow as it flows downstream.

4.2.4 Future Development

Current development criteria require the use of detention to mitigate the potential increase in peak discharges. However, detention will not offset the increase in volume, which could impact the behavior of flows in the Cypress – Katy Hockley North Reservoir. An analysis was conducted that considered ultimate development, with current detention policy, and it did slightly increase the computed stage elevations in the reservoir. However, this relative impact was small and does not affect the conclusions of this planning level study.

In addition to the structural measures described above, Management Plan 5 does include the adoption of additional development criteria as a means to offset the increase in volume from new development.

4.2.5 Initial Phases

Management Plan 5 also includes an implementation plan. A key part of this plan are the two initial phases, which strive to utilize the conveyance and collection area as an interim means to protect a portion of the study area from the overflow. Specifically, the initial phase of Management Plan 5 calls for the construction of an east-west oriented collection channel and berm near Longenbaugh Road, and the construction of modifications along Bear Creek for about 7,000 feet downstream in order to daylight the deepened channel. The channel would intercept overflow and convey it to the Bear Creek corridor. Even though the captured overflow would be "released" and permitted to spread out, individual developments, as part of the second phase, would construct the improved Bear Creek channel and implement interim measures, as necessary, to protect their property from the overflow.

When these two phases are fully implemented, the modified Bear Creek Channel would extend all the way to the enlarged development channel upstream of Fry Road. This resultant configuration was simulated in the xpstorm model, without the Cypress – Katy Hockley North Reservoir in place. During simulations, it was determined that additional widening of the collection channel was necessary in order to obtain some necessary attenuation and to ensure the capacity of the lower Bear Creek channel is not exceeded. In addition, it was found that it is necessary to construct a berm on the south side of the collection channel in order to ensure that overflows are intercepted. The berm would have a height of about four feet. The width of the collection channel will vary, but will have an average width of 500 feet. The width will be smaller at the downstream end in order to control flow into the Bear Creek system.

The resultant analysis determined that the 1% (100-year) flow rate along Bear Creek upstream of Fry Road would be 5,500 cfs. While this is slightly higher than the capacity of Bear Creek, it was found that there is a particular choke point upstream of Fry Road, and that the channel capacity is much higher along the remainder of Bear Creek. Therefore, Phase 1 was revised to include minor channel work along lower Bear Creek to increase its capacity. It should be noted that this work will also increase the capacity of Bear Creek during local rainfall events. This work involved widening within the existing right-of-way upstream of the drop structure located about 2,000 feet downstream of Fry Road.

Appendix B
Addicks Reservoir Hydrology

August 18, 2015

Table of Contents

1.0 Introduction

Addicks Reservoir and its adjacent reservoir, Barker Reservoir, combine to protect the City of Houston from flooding along Buffalo Bayou. These reservoirs were constructed, and are currently operated by, the U.S. Army Corps of Engineers (USACE). They were constructed in the early 1940's, after devastating floods in 1927 and 1935. Addicks Reservoir occupies 12,460 acres of land north of Interstate 10 and west of Beltway 8. The reservoir is bisected by State Highway 6, which runs north south through the reservoir. The location of Addicks Reservoir and Barker Reservoir are shown in Exhibit B1.1.

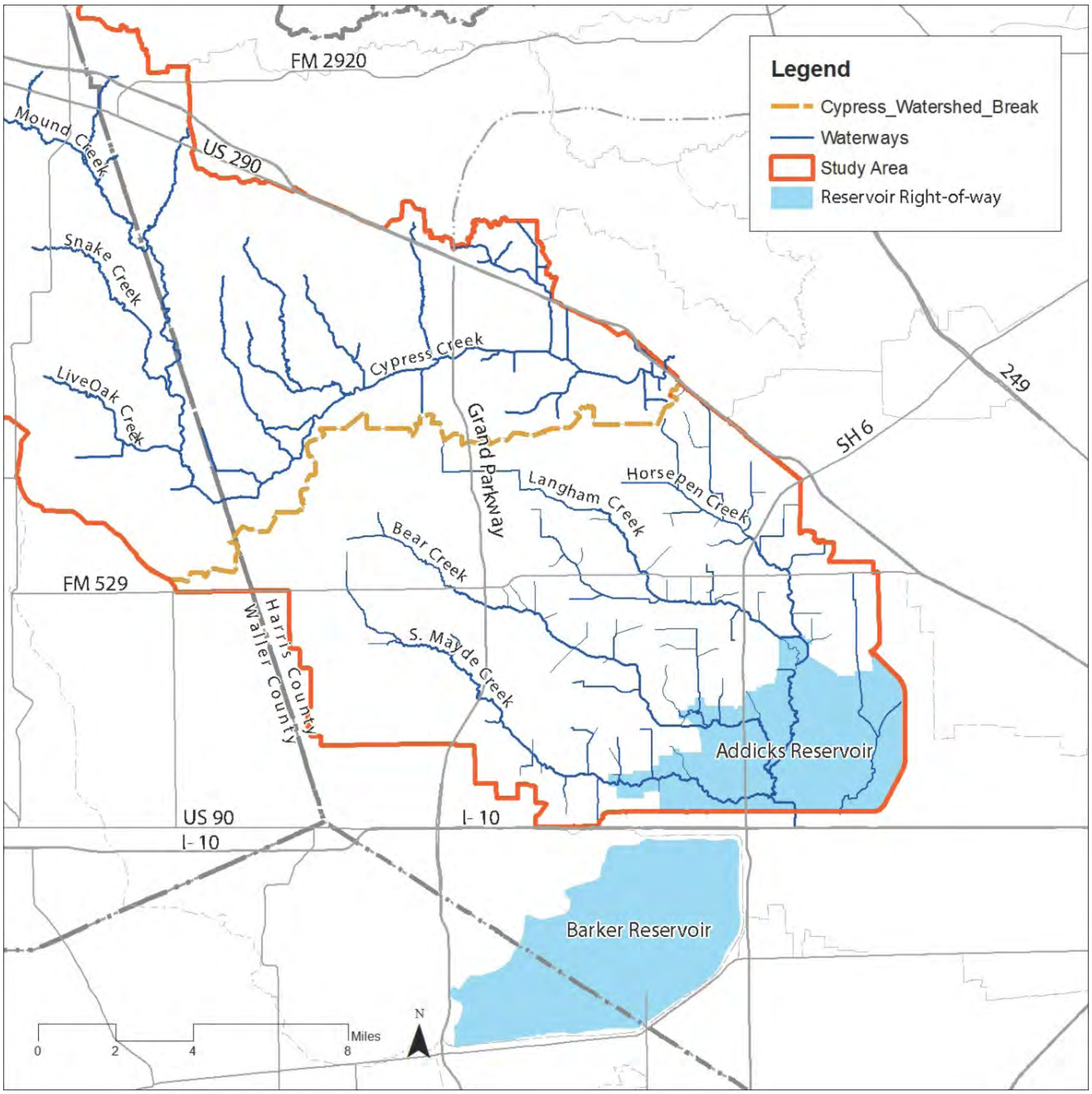


Exhibit B1.1
Addicks and Barker Reservoirs

Addicks and Barker Reservoir were components in a larger flood control plan developed by the USACE in the 1930's. However, due to changing conditions throughout Harris County such as rapid development and increased land costs, the original design was modified. Modifications included adding additional capacity to the Addicks Reservoir to accommodate the overflow from Cypress Creek instead of constructing a levee along Cypress Creek to prevent the overflow, as well as reducing the combined discharge rates from the two reservoirs down to 2,000 cfs or less to avoid damages downstream along Buffalo Bayou. Changes have resulted in a higher expected pool elevation during rainfall events. Addicks Reservoir still has capacity to accommodate the 1 % annual chance (100-year) event within the limits of the government owned right-of-way for the reservoir, however a similar event in Barker Reservoir will slightly exceed the limits of the government owned right-of-way. Furthermore, land development has occurred adjacent to the reservoirs. While there is sufficient right-of-way within the government owned land for the 1 % pool elevation within the reservoirs, there is little if any capacity to accommodate increases in the 1% pool elevation if the inflow into the reservoirs is increased, or discharge from the reservoirs is further restricted in the future.

The Cypress Creek Overflow Management Planning Study considered the current operations of Addicks Reservoir as it relates to future development and potential management measures. The purpose of this consideration was to determine what measures and/or policies are desirable within the study area pertaining to flood risk upstream of Addicks Reservoir. This appendix describes the analysis in support of this. Ultimately, this appendix concludes that Addicks Reservoir does not have the capacity to accept additional runoff volume anticipated from land development activities in the Addicks Reservoir Watershed and the Cypress Creek watershed and Upper Cypress Creek watershed, and recommends that development policy include mitigation measures to prevent the increase in runoff volume that may exasperate flood risk within Addicks Reservoir. Additionally, mitigation measures to prevent increased runoff volume from draining to Barker Reservoir as development occurs upstream of the Barker Reservoir.

1.1 Addicks Reservoir History

Addicks and Barker Reservoirs were constructed by the USACE in the 1940's. The reservoirs were a component of the Buffalo Bayou, Texas Flood Control Project authorized by the Rivers and Harbors Act of 1938 and modified by the Flood Control Acts of 1939 and 1954.

The Buffalo Bayou and Tributaries, Texas, Flood Control Project was a federal response to major flood events in 1929 and 1935 that inundated downtown Houston and closed the Ship Channel, and consequently the plan was designed for the flood protection of downtown Houston and the Houston Ship Channel. The plan included the construction of three detention reservoirs (Addicks, Barker, and White Oak Reservoirs), a south canal to convey releases from the Addicks and Barker Reservoirs to Galveston Bay, and north canal to convey releases from White Oak Reservoir to the San Jacinto River, and a levee between the Buffalo Bayou and Cypress Creek watershed divide so as to prevent overflows from Cypress Creek from entering Addicks Reservoir.

The dams along the downstream periphery of Addicks and Barker Reservoirs were to each have four uncontrolled outlet conduits and one controlled outlet conduit, resulting in a maximum combined uncontrolled release of 15,700 cfs. The USACE purchased all the property within the

Addicks and Barker Reservoir areas with ground elevations up to three feet above the predicted pool elevation which would be caused by a storm similar to the 1935 flood event. This left privately owned property with ground elevation above this design stage and below the maximum pool elevation of the reservoirs (determined by their spillway elevations: 114.0 feet for Addicks and 107.0 feet for Barker). These privately owned lands are commonly referred to as the reservoir “fringe".

The levee separating the Cypress Creek and Addicks Reservoir watersheds was abandoned during preconstruction planning, as it was determined to be more economical to increase the capacity of Addicks Reservoir to accommodate the overflow. Consequently, additional storage capacity was included in the Addicks Reservoir through the purchase of property up to 3.6 feet above the elevation of the previously purchased property. Furthermore, the post-World War II rapid development in the Houston area delayed and eventually eliminated the ability to construct the relief canals due to cost constraints that prohibited purchasing the necessary land. In their place, gated structures were added to two of the four outlet conduits for both Addicks and Barker Reservoirs, limiting combined uncontrolled flows into Buffalo Bayou to 7,900 cfs. The USACE abandoned the White Oak Bayou Reservoir concept in the early 1950's. At that time the USACE re-evaluated the entire project concept and formulated an alternate plan for regional flood control which included rectification of White Oak, Brays, and Buffalo Bayous.

In 1960, the USACE completed a report addressing the feasibility of gating all of the outlet conduits on the two reservoirs. That report concluded that the reservoirs could contain the standard project flood with only minor flanking of the dams and minimal associated damages. The channel rectification projects on White Oak Bayou and Brays Bayou were undertaken and completed in accordance with the alternate regional plan. Local opposition to the rectification of Buffalo Bayou along with encroaching development along the Buffalo Bayou channel caused that project to be canceled. In 1963, the USACE installed gates on all of the remaining outlet structures, thereby establishing manual control of the discharges from the reservoirs.

Throughout the time of the changing structural facilities and operational changes on the reservoirs, the non-damaging flow rate along Buffalo Bayou downstream of the dams has been re-evaluated. The original combined uncontrolled outflow from Addicks and Barker Reservoirs was to be 15,700 cfs. After the reservoirs became fully controlled in 1963 the USACE operated the gates such that the maximum combined outflow from the reservoirs was 6,000 cfs. In the mid-1970’s, this combined outflow from the reservoirs was reduced to 2,000 cfs, although there is no documentation of the basis for this decision. Subsequent studies have indicated that this is the approximate level where structural damages along Buffalo Bayou begin to occur. Thus they adopted a policy of operating the reservoirs such that the peak combined downstream discharge, on “dry” days, would not exceed 2,000 cfs as measured at the U.S. Geological Survey (USGS) gage at Piney Point. In addition, on days where rainfall is anticipated, outfalls are restricted because of uncertainty regarding potential flows from local rainfalls in the downstream Buffalo Bayou watershed. The travel time from the reservoirs to Piney Point is about eight hours, so the USACE operators have to consider rainfall over about a one day period.

In accordance with current operational procedures, the 2,000 cfs outfall cannot be exceeded unless potential dam breaching or overflow of the dam is imminent.

1.2 U.S. Army Corps of Engineers Reservoir Design Considerations – General

There are four important definitions in understanding reservoir designs by the USACE – the Probable Maximum Flood (PMF), Spillway Design Food (SDF), the Standard Project Flood (SPF), and the 100-year flood. These are defined as follows:

Probable Maximum Flood (PMF) - the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.

Spillway Design Flood (SDF) – the largest flood that a project is designed to pass safely.

Standard Project Flood (SPF) – flood resulting from the most severe flood-producing rainfall depth-area-duration relationship and isohyetal pattern of any storm that is considered reasonably characteristic of the region in which the drainage basin is located, giving consideration to the runoff characteristics and existence of water regulation structure in the watershed.

100-Year Flood – flood expected to be equaled or exceeded, on average, once every 100-years. Also known as the 1% flood, as the 100-year flood event has a 1% chance of being equaled or exceeded in a given year.

The USACE does not typically consider the 100-year even in reservoir designs. They have historically utilized the SPF as their design even, using this SPF to determine property acquisition requirements and basic operations of the reservoir. They have also considered the larger SDF in their public safety considerations, as reservoirs are designed to safely pass the SDF without creating a downstream flood hazard. The selection of the SDF is based upon the consequences of exceedance or failure, and for larger and higher hazard dams the PMF is used as the SDF.

The SPF does not have a uniform frequency (such as the 100-year or 200-year), but is a site specific determination made on the basis of flood frequency, damage potential, and cost of construction. It is generally understood that a SPF ranges in the vicinity of a 200-year to 500-year event.

When the National Flood Insurance Program developed a standard for flood protection they chose the 100-year flood event. This was seen as a compromise between the Corps of Engineers' SPF and the event used in the design of most local drainage systems (5-year to 20-year). However the design event utilized in any project should be aligned with the consequences of failure or exceedance – where there is higher risk a higher design standard is warranted. The Corps of Engineers continues to apply the SPF and SDF based upon this premise, although there is a move toward more holistic risk-based approaches.

Current policy and law (Federal Register CFR Chapter V, Section 644.4) requires the USACE to purchase land in fee up to the SPF.

1.3 Previous Hydrologic Studies of Reservoirs

A number of relevant studies have been prepared that establish the design and operating parameters within the reservoir, or that further consider flood risk in the reservoir. These are described in this section.

1. 3.1 Original USACE Study (1940)

Spillway Design Flood (SDF) – The 1899 Hearne, Texas storm. The total rainfall for the SDF was 30 inches, and the total runoff volume to Addicks Reservoir was computed to be 190,000 acre-feet, assuming 90% of the runoff converted to volume.

Standard Project Flood (SPF) – The 1935 rainfall event over Houston, Texas with rainfall depths increased by 50%. The total rainfall for the SPF event was 21 inches, and the total runoff volume to Addicks Reservoir was computed to be 146,000 acre-feet, assuming 90% of the rainfall converted to runoff. The resultant stage elevation in Addicks Reservoir is 102.9. This is equivalent to a storage volume of 79,600 acre-feet – considerably less than the runoff volume of 146,000 acre-feet because the reservoirs were to be ungated.

Neither of these calculations considered overflow runoff from Cypress Creek, since at the time of the study the plan still included the levee at the watershed divide.

1.3.2 Updated USACE Study (1977)

In 1977, the USACE conducted an in-depth hydrologic study of the reservoirs, updating past hydrologic studies to consider the current reservoir operational status at that time. This study is described in a report entitled *Buffalo Bayou and Tributaries, Texas, Addicks and Barker Reservoirs, Hydrology, Corps of Engineers, August 1977.*

Spillway Design Flood (SDF) – A Spillway Design Storm (rainfall) was determined based upon probable maximum precipitation using the method described in Hydrometeorological Report No. 51, dated September 1976, subject: *Probable Maximum Precipitation Estimates, United States East of the 105th Meridian.* The SDF was computed by centering this event over the Addicks Reservoir watershed. The resultant SDF is based upon an average of 43.5 inches of rainfall over the 136 square mile Addicks Reservoir watershed, with 92% of rainfall converted to runoff; plus the overflow from Cypress Creek from a similar event. The total runoff volume from the Addicks Reservoir watershed is about 292,000 acre-feet, while the total runoff volume from Cypress Creek overflow is about 170,000 acre-feet – about one-third of the overall runoff volume. The resultant storage volume 462,000 acre-feet would exceed the spillway elevations at the end of the dams. The spillways are at elevation 112.0 feet, with a corresponding storage capacity of 200,800 acre-feet.

Standard Project Flood (SPF) – Utilized about 50% of rainfall from the SDF rainfall. Specifically, 21.0 inches of rainfall was utilized, with 86% of the rainfall converted to runoff; plus the overflow from Cypress Creek from a similar event. The total runoff volume from the Addicks Reservoir watershed is about 131,000 acre-feet, while the total runoff volume from the Cypress Creek overflow is about 63,000 acre-feet – about one-third of the overall runoff volume.

Based upon the Addicks Reservoir stage-storage relationship, the resultant storage volume of 194,000 acre-feet would produce a stage elevation of 111.6 feet.

Frequency Analysis/100-yr – Because the gated operations may result in an extended duration event, it is not possible to determine a true stage-frequency relationship from a single hypothetical rainfall event. The Corps of Engineers determined the stage-frequency relationship, including a 100-year stage elevation, by simulating the Addicks and Barker Reservoirs over an extended time period. This simulation utilized the recorded daily inflows into both reservoirs from 1945 to 1976 (daily inflows were recorded since the completion of construction) along with the recorded flows downstream in Piney Point. The USACE developed a FORTRAN computer program to simulate the present day operations, and performed statistical analysis of these simulations to determine a stage-frequency relationship. According to their calculations, the computed 100-year water surface elevation in Addicks Reservoir is 104.1 feet allowed for the establishment of pool elevations for various frequencies.

The maximum design water surface elevation represents the upper extreme of the worst flooding conditions that could occur. The elevation was set based on the hypothetical premise of the probable maximum flood (PMF) occurring directly after the occurrence of the standard project flood (SPF). The design storm for the PMF incorporates a probable maximum precipitation (PMP) of 43 inches occurring over a 72-hour period. The SPF reflects 21 inches of precipitation in 72 hours. The peak inflow rate for the PMF is 295,000 cfs and 256,000 cfs for Addicks and Barker Reservoirs, respectively. At the maximum design water surface, the outflow capacity of the five outlet conduits is 7,850 cfs and 8,730 cfs, respectively, for Addicks and Barker. Thus, for the maximum design water surface condition, most of the outflow would be over the uncontrolled natural-ground spillways.

1.3.3 USACE Section 216 Reconnaissance Study

In 1995, the USACE completed a Section 216 Reconnaissance Study to determine if there is federal interest in further flood control solutions regarding Addicks and Barker Reservoirs. That study utilized the 1977 hydrologic study, with minor revision to recognize the addition of the emergency spillways and the raising of the embankment. Table B1.1 shows the results of the hydrologic analysis. Incidentally, the Section 216 did not identify a federal interest, and no further feasibility studies were pursued by the USACE.

Table B1.1
Key Reservoir Parameters – Section 216 Reconnaissance Study (USACE)

	Addicks Reservoir	**Barker Reservoir**
Watershed area (square miles)	136	130
Elevation (1973 adj. of 1929 datum) (feet)		
Top of dam	122.7	114.7
Standard project flood (approx. a 1,000 yr frequency for Addicks Res. and a 500-yr frequency for Barker Res.)	110.6	100.4
Natural ground at ends of dam	112.0	106.0
Government owned land	106.1	97.3
1% (100-Year)	104.1	97.8
March 1992 flood (Barker flood of record)	100.6	95.9
Conduit invert	71.1	73.2
Storage Capacity (acre-feet)		
Standard project flood	178,556	123,653
Natural ground at ends of dam	200,800	209,000
Government owned land	116,263	83,410
March 1992 flood of record	57,956	66,910
Surface area (acres)		
Natural ground at ends of dam	16,423	16,739
Government owned land	12,460	12,060

1.3.4 HCFCD Addicks Watershed Master Plan

The Harris County Flood Control District (HCFCD) has completed additional hydrologic studies in support of the development of a watershed master plan for the Addicks Reservoir watershed. In the 1990's, Bernard Johnson, Inc. (BJI), and later Lockwood Andrews and Newnam, Inc. (LAN), were engaged to develop watershed master plans for Addicks Reservoir, and they utilized HEC-5 to update the 1977 USACE Hydrologic Study. However, the HEC-5 software had limitations pertaining to the operation of the reservoirs which compromised the ability to complete the study, and the reservoir simulations were never completed.

1.3.5 HCFCD Addicks and Barker Reservoir Feasibility Study

In 1996, HCFCD engaged Costello, Inc. to conduct a Feasibility Study of Addicks and Barker Reservoir. This was partially in response to record flood stages in 1992, as well as potential partnering opportunities available due to the pending reconstruction of the Katy Freeway. There was specific concern related to a phenomenon known as the “ratcheting effect”, where a long rainy season, absent a single significant event, would result in the reservoir pool levels slowly rising due to the requirement to close the gates when rain is forecast. Furthermore, there were allied concerns regarding erosion in the Buffalo Bayou due to the opening and closing of the gates, as well as general drainage and flooding concerns in the Buffalo Bayou watershed downstream of the reservoirs. Areas of concern included the Memorial Villages, Spring Branch, and the new Katy Freeway.

Costello, Inc. engaged Dr. Ralph Wurbs from Texas A&M to perform a hydrologic analysis of the reservoirs. Similar to the USACE, the Wurbs study utilized daily inflows into the reservoirs and gage data at Piney Point to simulate current operating conditions. In addition, this study had the benefit of approximately 20 years of additional data, including the rainfalls of 1992 that resulted in the flood of record. As with the BJI study, the Wurbs study utilized HEC-5, however the USACE had updated HEC-5 since the BJI study, with the updated version having the ability to properly simulate operations (specifically, there is an option to specify the outflow rate if the reservoir inflow is decreasing or increasing).

The Wurbs study predicted slightly lower pool elevations in Addicks Reservoir when compared to previous USACE studies. For example, the USACE study predicted a 1% (100-Year) pool elevation in Addicks Reservoir of 104.1 feet, while the Wurbs study predicted a 1% (100-Year) pool elevation of 102.6. Conversely, the Wurbs study predicted slightly higher elevations in Barker Reservoir. For example, the USACE study predicted a 1% (100-Year) pool elevation of 97.0 feet in Barker Reservoir, while the Wurbs study predicted a 1% (100-Year) pool elevation of 97.7 feet.

As a supplement, and as a follow to Wurbs’ own recommendations, Dr. Wurbs was asked to evaluate the development impacts in the reservoirs upon stage elevations given the current operations of the reservoirs. Dr. Wurbs modified the observed inflows to simulate the full development (the assumption is that the entire upstream watershed would consist of commercial and high density residential development – a somewhat extreme case that represents a worst case) of the Addicks and Barker Reservoir watersheds (by using the National Resources Conservation Services (NRCS) Curve Number (CN) methodology). As expected, this study indicated that the full development of the watersheds would result in higher pool elevations, but the increase was considered to be relatively minor. According to the study, full development of the Addicks Reservoir watershed would increase the 1% (100-Year) pool elevation in Addicks Reservoir by 1.5 feet; and full development of the Barker Reservoir watershed would increase the 1% (100-Year) pool elevation in Barker Reservoir by 0.1 feet.
The Wurbs study elevations are summarized in Table B.1.2

Table B1.2
Key Reservoir Elevations – Wurbs Study (HCFCD)

	Addicks Reservoir	Barker Reservoir
Study – 1% (100-Year) Pool Elevation (feet)		
1. USACE 1977 Hydrology	104.1	97.0
2. Wurbs (from Stage-Frequency)	102.6	97.7
3. Wurbs (Plan 7)	103.1	97.7
4. Wurbs Ultimate Development (Plan 7)	104.6	97.8
Study – 0.5% (200-Year) Pool Elevation (feet)		
1. USACE 1977 Hydrology	105.7	99.1
2. Wurbs (from Stage-Frequency)	103.4	98.5
3. Wurbs (base condition for Ultimate Dev)	104.1	98.8
4. Wurbs Ultimate Development (Plan 7)	106.0	99.0
Reference Elevations (feet)		
Government owned land	106.1	97.3
Standard project flood	110.6	100.4
Natural ground at ends of dam	112.0	106.0

1.4 Review of Previous Work

The studies referenced in the previous section were reviewed and evaluated in order to further the understanding of flood risk associated with the reservoir pools. A number of observations regarding these studies were made, and are presented in the following sections.

1.4.1 Evaluation of the Simulation of Reservoir Operations

The determinations of the stage-frequency relationships by the Corps of Engineers and by Dr. Wurbs are worthwhile and valued attempts to ascertain the relative level of risk associated with the pool elevations of Addicks and Barker Reservoirs. However, there is a significant challenge in simulating the operations of the gated structures, as there are numerous factors that influence the operation of the outlet. Some of these factors, such as the respective pool elevation in each reservoir and the current inflow condition, were ascertainable from the data. Others, such as the weather forecast, were not. Furthermore, the simulations were conducted on a daily basis, while operational decisions may be made numerous times throughout the day. The uncertainty associated with that is best illustrated in the Wurbs analysis of the March 1992 event. According to historical record, Addicks Reservoir achieved a pool elevation of 100.58, while Dr. Wurbs' Plan 6 and Plan 7 simulations produced a stage elevation of 109.35 feet and 105.82 feet, respectively. For perspective, the Plan 7 simulation, considered the most representative, computes a peak storage volume over twice what was recorded. This illustrates the challenges with attempting to replicate operational decisions, and introduces some uncertainty into the calculations.

1.4.2 Stage-Frequency Analysis

Both the USACE study and the Wurbs' study developed stage-frequency relationships from peak annual data. The USACE utilized methods described by Leo Beard in Statistical Methods in Hydrology, dated January 1962. This document recommends the utilization of reservoir volume data in the determination of frequency. The USACE report on Addicks and Barker does not explicitly describe what data was analyzed, but it is assumed that they analyzed peak storage volumes in the determination of frequency, and related that back to stage elevations using the rating curve. Dr. Wurbs utilized HEC-FFA, which is a USACE software package that applies the same methods recommended in Statistical Methods in Hydrology. However, he performed the analysis using the annual peak stage elevation in Addicks Reservoir. This is relevant because stage elevations are not linear when compared to volume, as incrementally higher stages gain more volume due to wedge storage. While the logarithmic distribution accounts for that, the more appropriate measure of a reservoir is storage. To review this, Dr. Wurbs stage data was duplicated in HEC-SSP, which is the modern successor to HEC-FFA. After a match was confirmed, a similar analysis was performed using peak storage volumes from Wurbs' Combined Plan. After the 100-year storage volume was determined, the Addicks Reservoir rating curve was utilized to determine a 100-year stage. The resulting calculation yielded a 100-year pool elevation of 103.6 feet (recall, the USACE predicted a 100-year stage elevation of 104.1, while the Wurbs report predicts a 100-year stage elevation of 102.6 feet). Based upon this, it is believed that Wurbs is under-predicting the 100-year elevation, and the USACE 100-year elevation is more appropriate.

The HEC-FFA (and HEC-SSP) software also computed a 90% confidence interval. According to the Wurbs report, the 100-year water surface elevation is 102.6, with 5% and 95% confidence limits of 101.0 feet and 104.7 feet, respectively. The storage volume based calculation of Wurbs Combined Plan yielded a 100-year water surface elevation of 103.6 feet, with 5% and 95% confidence limits of 101.0 feet and 107.6 feet. The larger confidence interval is likely due to the effect of the wedge storage, as higher disparities in recorded volume cluster around a comparatively smaller range of stage elevations, again due to the wedge storage effect.

1.4.3 Wurbs Study on the Effect of Development on Reservoir Stages

Dr. Wurbs utilized the NRCS CN method to attempt to simulate the effect of various development levels on runoff volumes. As noted in the Wurbs report, the NRCS CN method is widely used and accepted, as it uses empirical relationships to consider different land use and soil types. It has also been criticized for its simplicity and lack of theoretical basis. The runoff CN is a dimensionless parameter between 0 and 100 that represents runoff characteristics relative to precipitation. A CN of 100 would be a fully impervious condition where all precipitation is converted to runoff, while conversely a CN of 0 would be a condition were no precipitation is converted to runoff. While simplistic, the NRCS calculations are quite robust, and recognize that as rainfall increases, losses will decrease.

The NRCS has published tables to facilitate the determination of CN. They provide different land uses for four different soil types – A, B, C, D. Soil type D represents poorly draining soils, such as clays, that are predominate in Harris County. The NRCS also recognizes three different antecedent moisture conditions. Condition I represents dry soils, condition II is an average condition, and condition III is a saturated condition (heavy rainfall in the last five days). The NRCS tables provide CN values based upon condition II. They also provide guidance for adjusting the CN for condition I and III. These adjustments can be substantial – for example, a CN of 80 for condition II is reduced to 63 for condition I, and increased to 94 for condition III. So for a watershed with land use and soils that suggests a CN of 80, the actual effective CN is between 63 and 94, depending on the antecedent moisture condition. Based upon land use in 1998 and soil type, Wurbs computed the CN for the Addicks watershed to be between 83 and 87 assuming an antecedent moisture condition of II (and between 96-97 for condition III, if there was significant rainfall in the past five days). This calculation assumed the reservoirs were inundated, and therefore assigned a CN for 100 for the reservoirs. In addition, Wurbs computed a pre-development CN representative of the 1940's and 1950's, and determined the pre-development CN to be between 80 and 85 for antecedent moisture condition II.

Wurbs also computed calibrated CNs based upon the observed daily inflows and annual precipitation for the City of Houston. CNs were adjusted, and predicted rainfall amounts were determined from the NRCS rainfall-runoff equations using a program developed by Dr. Wurbs. The resultant rainfall was compared over a long time period with the mean annual rainfall for that period, and the exercise was iterated until the method predicted rainfall that was consistent with what was observed. The analysis was conducted for three distinct time periods – 1946 to 1965, 1966 to 1985, and 1986 to 1987. The computed CNs for the Addicks Watershed for these three periods were 91.8, 91.5, and 87.7. Over the full time horizon, the average CN calibrated to 91.0, and Wurbs utilized this value to represent 1997 conditions.

For ultimate development conditions, Wurbs assumed a CN of 96. According to the report, this value represents an extreme level of development (this value is more indicative of commercial and business districts with a higher level of impervious cover).

In reviewing this approach, there is concern regarding the higher than anticipated CN used for both existing and ultimate development conditions. It is clear from the review of Wurbs' report that CN is much more sensitive to antecedent moisture condition than it is to actual land use, which is concerning since the purpose of the exercise was to evaluate changes from land use. Furthermore, according to Wurbs, larger events show less impact from development because of the eventual saturation of soils, and this explains the higher calibrated CN. While true, the CN is applied to the Addicks watershed in determining precipitation amounts. No consideration was provided for occasional overflows from Cypress Creek, and these overflows would tend to skew the CN upward.

The over-riding conclusion of this review is the CN approach has significant uncertainties related to antecedent moisture condition and the treatment of the Cypress Creek overflow. While this does not invalidate Wurbs' conclusion, these uncertainties must be considered in contemplation of the results.

The same concerns exist regarding the frequency analysis. The ultimate condition analysis utilized Plan 7 for both existing development and ultimate development. According to the Wurbs report data, the computed existing condition 100-year stage is 103.1 feet (slightly higher than the combined plan elevation of 102.6 feet), with 5% and 95% confidence limits of 101.0 feet and 105.8 feet, respectively. The ultimate condition 100-year stage is 104.6 feet, with 5% and 95% confidence limits of 102.6 feet and 107.3 feet, respectively. Using the rating curve, the computed increase in 100-year storage volume is 16,581 ac-ft, with 5% and 95% confidence limit increases of 15,520 ac-ft and 19,056 ac-ft. Unlike the Combined Plan, using a volume based frequency analysis yielded only slightly different results. The volume based existing condition Plan 7 analysis results in a 100-year stage elevation of 103.2 feet, with 5% and 95% confidence limits of 100.2 feet and 107.9 feet, respectively; while the ultimate condition Plan 7 analysis results in a 100-year stage elevation of 104.7 feet, with 5% and 95% confidence limits of 101.9 feet and 109.0 feet, respectively. While the stages are nearly the same as with Wurbs' calculation, the confidence interval is larger.

1.4.4 General Summary Regarding Previous Study

The hydrologic studies conducted to quantify the flood risk in Addicks and Barker Reservoirs requires the consideration of observed data and the simulation of reservoir operations. There are inherent challenges in simulating past operating decisions that introduce uncertainty into the results. However, uncertainty exists to some degree in all simulations, and it is generally believed the current understanding of flood risk in the reservoirs is valid and within appropriate confidence.

A major consideration in the Cypress Creek Overflow Management Plan is the capacity of Addicks Reservoir to receive additional volume from anticipated land development activity in the contributing watersheds (the Addicks Watershed and the Upper Cypress Creek Watershed). Dr. Wurbs attempted to quantify the potential impact in his study, however the approach relied upon a methodology to quantify the rainfall-runoff relationship is heavily influenced by an independent variable – the antecedent moisture condition. For that reason, it is difficult to derive conclusions for that study that have use and relevance in the Cypress Creek Overflow Management Plan.

2.0 Rainfall-Runoff Relationship

The rainfall-runoff relationship is paramount to understanding potential changes to flood risk associated with new development in the Addicks Watershed. While the rate of rise within the reservoir is of interest as it relates to existing facilities within reservoir, such as Bear Creek Park and state and county roads, the primary determination of risk is associated with total volume. As land use transitions, the total volume of runoff may increase. Discharge policies related to reservoir releases likely will not change over time. Traditional methods of development control include detention, where increases in peak runoff rates are temporarily stored in detention basins, which then meter flows out at pre-development rates. The objective of these detention basins is to ensure that new developments do not increase peak flowrates downstream. New development also typically introduces impervious cover, and therefore increases the overall percentage of rainfall converted to runoff. While detention offsets the potential increase in peak flowrate downstream, it is widely recognized that detention has minimal, if any, mitigating impact on runoff volume.

Consequently, peak stage elevations in Addicks Reservoir can be expected to gradually increase over time as development occurs, even with current detention policy. Exhibit B2.1 shows the peak storage volume in Addicks Reservoir for every year between 1973 and 2012. These peak volumes vary based upon the largest rainfall event in each particular year. However, if this graph is converted into a moving 5-year average peak storage volume, a trend becomes more apparent. Exhibit B2.2 illustrates this, and also presents a trend line determined from a linear regression analysis.

Exhibit B2.2 shows a clear upward trend in peak pool storage volumes, even as there has been a detention requirement in the watershed since 1980. However, there has been no similar upward trend in rainfall. Exhibit B2.3 depicts the annual rainfall between 1973 and 2012, and as the graph indicates there is not a discernible trend in rainfall.

As noted previously, the Wurbs' study attempted to ascertain the potential impact of land development activities on runoff volume and reservoir flood stages using the NRCS CN technique. However, this technique was limited in effectiveness, primarily due to uncertainty related to the antecedent moisture condition. This section looks at a few other investigations, and considers some general calculations, related to the rainfall-runoff relationship.

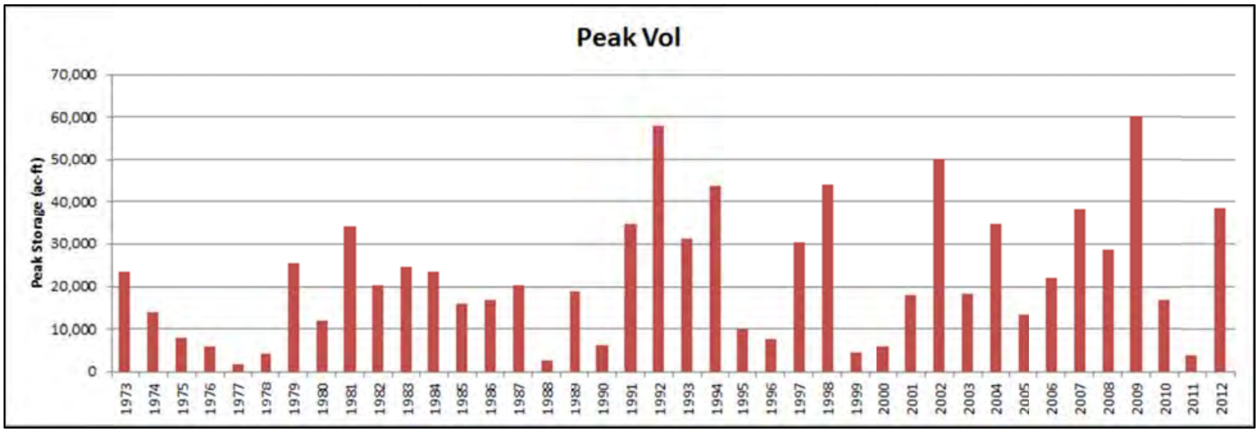


Exhibit B2.1
Addicks Reservoir Annual Peak Volumes (ac-ft), 1973-2012

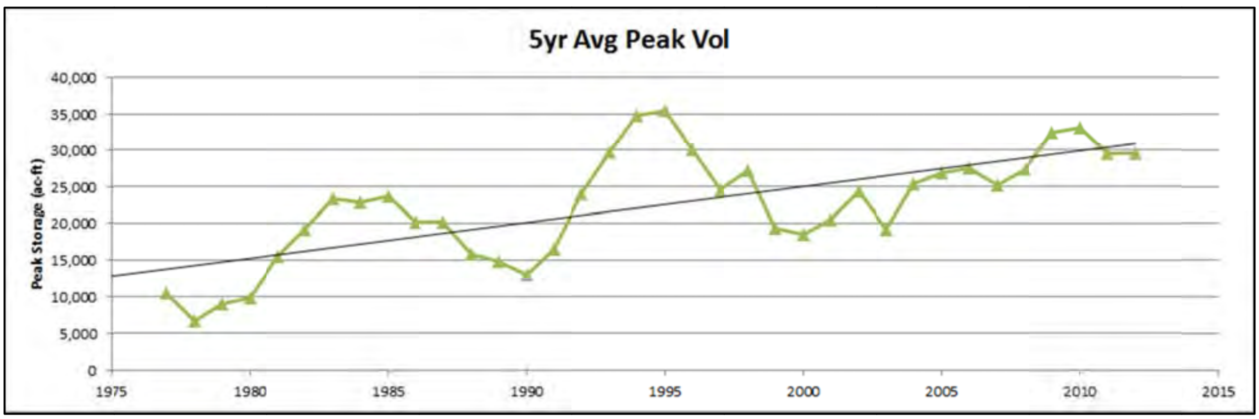


Exhibit B2.2
Addicks Reservoir Annual Peak Volume - Five Year Moving Average with Trend Line (1975-2012)

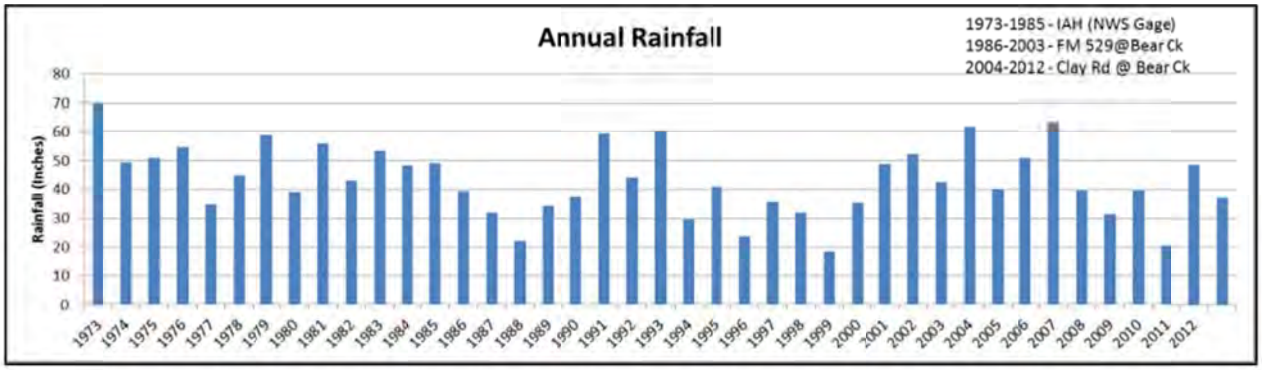


Exhibit B2.3
Annual Rainfall (1973-2012)

2.1 USGS – Johnson-Sayre Study (1973)

In 1973, the USGS, in cooperation with the City of Houston, published a report entitled Effects of Urbanization on Floods in the Houston, Texas Metropolitan Area (WRI 3-73). This report, widely referred to as the Johnson-Sayre report, analyzed stream-gage data from 33 gaging station in the Houston area in order to ascertain relationships between drainage area, impervious cover in order to provide relationships for study of ungaged areas, and to better understand the relationship between urbanization and flooding.

The Johnson-Sayre study primarily involved flowrates, but did consider overall runoff volume. They demonstrated the effects of urbanization on runoff by comparing the runoff from a relatively undeveloped basin (Cypress Creek, near Westfield) to the runoff from a developing basin (Brays Bayou at Houston/Main St.). At the time of the study, development in the Brays Bayou watershed had increased rapidly in the previous fifteen years, from an impervious cover of 2% in 1955 to 15% in 1969.

No conclusions were made regarding percentage of rainfall converted to runoff. In 1969, Brays Bayou was not yet fully developed, but had undergone substantial development. If it was assumed that Brays Bayou, in 1969, has a rainfall-to-runoff ratio of 90%, then based upon Figure 6 in Johnson-Sayre, Brays had a total runoff volume of about 310 inches (345 inches X 90%). Assuming the same rainfall in the Cypress Creek watershed results in a runoff of 150 inches, which equates to a runoff rate of 43%.

The Johnson-Sayre report also considers the relationship between annual runoff and impervious cover from various gages in a dry year (1968) and a wet year (1969). In plotting the resultant data, they noticed separate clusters of data for watersheds north of Buffalo Bayou and south of Buffalo Bayou for the wet year. The watersheds north of Buffalo Bayou showed a lower runoff volume than areas south of Buffalo Bayou. Maps provided by the Soils Conservation Service (which became the NRCS) show that the soils north of Buffalo Bayou are generally more permeable. They concluded that this effect did not occur during the dry year because cracks will open in all soil types and infiltration will be very high. It is unknown if there was a greater rainfall amount south of Buffalo Bayou in 1968.

The Johnson-Sayre report relates peak discharge to rainfall, storm duration, and antecedent moisture condition. They used a modification of the soil moisture index (M) method of Linsley, Kohler, and Paulhus to track the antecedent moisture condition during the period of record for the study. The modification involved the use of a constant soil-moisture depletion factor; they used a variable factor throughout the year based upon the average monthly temperature in Houston.

2.2 Tropical Storm Allison Recovery Project (TSARP) – 2004

Green and Ampt Method. The hydrologic study in support of the TSARP project was conducted between 2001 and 2003. This study represented a new study to replace the FHS, and utilized the new generation of USACE hydrology software known as HEC-HMS. At the time of the study, HEC-HMS did not have the capability to apply the exponential method. The Green and Ampt method was chosen because it is based on physical properties (although it is an empirical relationship) and it allows for the decay of losses and rainfall increases. Green and Ampt loss parameters were calibrated against gage data for each watershed.

Subareas from the Upper Cypress Creek watershed and the Addicks Reservoir watershed were evaluated for a range of rainfall amounts and impervious cover using the Green and Ampt method. The results are presented in Tables B2.1-B2.4.

Table B2.1
Runoff Amounts (inches) for Upper Cypress Creek Watershed
Green & Ampt

Impervious	Rainfall Amount (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
0%	0.27	2.02	3.96	5.94	7.92	9.91	11.90
20%	0.51	2.32	4.27	6.25	8.24	10.23	12.22
40%	0.76	2.61	4.58	6.56	8.55	10.55	12.54
60%	1.01	2.91	4.88	6.87	8.87	10.86	12.86
80%	1.25	3.20	5.19	7.19	9.18	11.18	13.18
100%	1.50	3.50	5.50	7.50	9.50	11.50	13.50

Table B2.2
Runoff Amounts (inches) for Addicks Watershed
Green & Ampt

Impervious	Rainfall Amount (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
0%	0.37	2.19	4.15	6.13	8.12	10.12	12.11
20%	0.63	2.49	4.46	6.44	8.44	10.43	12.43
40%	0.90	2.79	4.76	6.75	8.75	10.74	12.74
60%	1.16	3.09	5.07	7.06	9.06	11.06	13.05
80%	1.42	3.38	5.38	7.37	9.37	11.37	13.37
100%	1.68	3.68	5.68	7.68	9.68	11.68	13.68

Table B2.3
Runoff Amounts (% of rainfall) for Upper Cypress Creek Watershed
Green & Ampt

Impervious	Rainfall Amount (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
0%	14%	51%	66%	74%	79%	83%	85%
20%	26%	58%	71%	78%	82%	85%	87%
40%	38%	65%	76%	82%	86%	88%	90%
60%	51%	73%	81%	86%	89%	91%	92%
80%	63%	80%	87%	90%	92%	93%	94%
100%	75%	88%	92%	94%	95%	96%	96%

Table B2.4
Runoff Amounts (% of rainfall) for Addicks Reservoir Watershed
Green & Ampt

Impervious	Rainfall Amount (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
0%	19%	55%	69%	77%	81%	84%	87%
20%	32%	62%	74%	81%	84%	87%	89%
40%	45%	70%	79%	84%	88%	90%	91%
60%	58%	77%	85%	88%	91%	92%	93%
80%	71%	85%	90%	92%	94%	95%	96%
100%	84%	92%	95%	96%	97%	97%	98%

The calculations suggest a pre-development runoff percentage between 14% (for 2 inches of rainfall) and 87% (for 14 inches of rainfall). The relative amount of runoff progressively increases because of the gradual saturation of the watershed. For a six-inch rain, the Green and Ampt method predicts pre-development runoff rates of 66% in Cypress Creek watershed and 69% in the Addicks Reservoir watershed.

2.3 NRCS Methods

NRCS CN methods were discussed earlier in the summary of the Wurbs report. As noted, the methodology utilizes a dimensionless parameter known as the Curve Number (CN) to represent the rainfall-runoff characteristics.

The runoff was computed for a range of CNs (which incorporates impervious cover and other factors related to land use and soil type) and a range of rainfall amounts. The results are presented in Tables B2.5 and B2.6.

Table B2.5
Runoff Amounts (inches) - NRCS Method

CN	Rainfall (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
70	0.24	1.33	2.81	4.46	6.22	8.05	9.91
75	0.38	1.67	3.28	5.04	6.88	8.76	10.67
80	0.56	2.04	3.78	5.63	7.52	9.45	11.39
85	0.80	2.46	4.30	6.21	8.16	10.11	12.08
90	1.09	2.92	4.85	6.81	8.78	10.76	12.75
95	1.48	3.43	5.41	7.40	9.40	11.39	13.39
100	2.00	4.00	6.00	8.00	10.00	12.00	14.00

Table B2.6
Runoff Amounts (% of rainfall) - NRCS Method

CN	Rainfall (in)						
	2.00	4.00	6.00	8.00	10.00	12.00	14.00
70	12%	33%	47%	56%	62%	67%	71%
75	19%	42%	55%	63%	69%	73%	76%
80	28%	51%	63%	70%	75%	79%	81%
85	40%	61%	72%	78%	82%	84%	86%
90	55%	73%	81%	85%	88%	90%	91%
95	74%	86%	90%	93%	94%	95%	96%
100	100%	100%	100%	100%	100%	100%	100%

The existing Addicks Watershed has a CN of approximately 85 assuming an antecedent moisture condition of II. This corresponds to a predicted runoff rate between 40% and 86%, with a rate of 72% for a six-inch rain. For a dry condition (condition I), the corresponding CN can be as low as 70, resulting in a runoff rate of 47% for a six-inch rain; and for a saturated condition (condition III) the CN may be as high as 97, resulting in a runoff rate of about 98% for a six-inch rain. The undeveloped Cypress Watershed has lower CN due to the soil type and the prominence of prairie vegetation in portions of the watershed. Runoff rates are likely lower, particularly for condition I and II.

2.4 Evaluation of May and June 1989 Floods in Harris County, Texas.

After two devastating floods in two months in 1989, HCFCD engaged LJA & Associates, Inc. to evaluate the two events with a particular focus on the performance of the hydrologic and hydraulic models developed from the 1984 Flood Hazard Study. The study compared observed hydrographs with computed hydrographs from simulations of the rainfall events. The flood event was mostly centered on the north and east sides of Harris County, so the Addicks Reservoir watershed was not strongly impacted, and thus was not evaluated. However the Cypress Creek watershed was studied. The rainfall event was not that significant in the upper watershed, as each event had less than four-inches of precipitation at the Katy-Hockley gage. However, the analysis of the rainfall event in the middle portion of the watershed, which was still predominately undeveloped at the time of the event, may lend some insight. There was substantially greater rainfall at the gage at Huffmeister. This size of rainfall is appropriate for considering the rainfall-runoff analysis because the resultant downstream hydrograph is not influenced by an overflow event.

For the May, 1989 event, there was an average of about 2.5 inches of rainfall in the watershed that contributes to the gage at Katy-Hockley, and about 4 inches of rainfall in the watershed that contributes to Huffmeister. The event measured a total runoff volume of 0.24 inches at Katy-Hockley Road and 0.49 inches at Huffmeister. The resultant runoff percentage is about 10%.

For the June, 1989, there was an average of about two inches of rainfall in the watershed that contributes to the gage at Katy-Hockley, and about 3 inches of rainfall in the watershed that contributes to Huffmeister. The event measured a total runoff volume of 0.08 inches at Katy-Hockley and about 0.15 inches at Huffmeister.

It is difficult to derive specific conclusions of the appropriate rainfall-runoff value to use from this analysis. However, the results support the notion that there is a large initial abstraction in the upper Cypress Creek watershed. There are a number of factors that may contribute to this – the soils types, the antecedent moisture condition, the lack of drainage infrastructure, and the predominance of agricultural features that retain runoff.

2.5 HCFCD Rainfall-Runoff Evaluation (R.G. Miller)

In 2012, HCFCD engaged RG Miller Engineers to evaluate observed streamflow data and to compare the resultant runoff volume with the measured precipitation in the upstream watershed. The report is entitled *Rainfall Volume vs. Runoff Volume Evaluation Study.* The goal of this study was to "to develop an improved understanding of a relationship between rainfall and runoff for various intensity storm events."

The study considered a number of events throughout Harris County. For each event, the categorized the antecedent moisture condition as Low Saturation (less than 0.5 inches of rainfall in preceding seven days), Medium Saturation (0.5 to 1.5 inches of rainfall in the preceding seven days), or High Saturation (more than 1.5 inches in the preceding seven days). Contributing areas were classified as having high, medium, or low urbanization based upon the level of development in the watershed.

Table B2.7 presents the results of the evaluation of the Langham Creek sub-watershed, which is within the Addicks Reservoir Watershed.

Table B2.7
Langham Creek - Observed Rainfall-Runoff

Storm Event	Duration (hours)	Total Rainfall (inches)	Total Runoff (inches)	Difference (%)	Antecedent Condition	Urbanization	Recurrence
10/28/2002	12	3.53	2.84	80.2	High	Medium	2 Yr
11/3/2002	48	5.96	4.80	80.6	High	Medium	2-5 Yr
11/17/2003	48	4.71	1.92	40.9	Low	Medium	2 Yr
7/24/2006	48	4.44	3.71	83.6	Medium	Medium	2 Yr
9/12/2008	48	6.87	5.21	75.8	Low	Medium	5-10 Yr
7/11/2012	96	10.42	6.11	58.6	Low	Medium	10 Yr

The average runoff percentage is 70%. There is a correlation between antecedent condition and runoff percentage.

Table B2.8 presents the results of the evaluation of the Bear Creek sub-watershed, which is within the Addicks Reservoir Watershed.

Table B2.8
Bear Creek - Observed Rainfall-Runoff

Storm Event	Duration (hours)	Total Rainfall (inches)	Total Runoff (inches)	Difference (%)	Antecedent Condition	Urbanization	Recurrence
11/22/2004	96	7.74	7.03	90.8	High	Medium	5 Yr
7/24/2006	48	4.59	3.59	78.2	Low	Medium	2 Yr
4/24/2007	12	1.52	0.95	62.3	Low	Medium	< 2 Yr
9/12/2008	48	4.62	3.46	74.9	Low	Medium	2 Yr
7/11/2012	48	9.14	4.21	46.0	Low	Medium	10 Yr

The average runoff percentage is also 70%, and there is also correlation between antecedent condition and runoff percentage. For the one high antecedent moisture condition, the rate is about 91%.

Table B2.9 presents the results of the evaluation of the Upper Cypress Creek watershed at Katy-Hockley Road.

Table B2.9
Upper Cypress Creek - Observed Rainfall-Runoff

Storm Event	Duration (hours)	Total Rainfall (inches)	Total Runoff (inches)	Difference (%)	Antecedent Condition	Urbanization	Recurrence
10/18/1998	48	9.34	3.69	39.5	Low	Low	10-20 Yr
11/4/2002	48	7.25	3.61	49.8	High	Low	5-10 Yr
11/24/2004	96	10.26	3.60	35.1	High	Low	10-20 Yr
4/29/2009	48	4.61	2.78	60.3	Low	Low	2 Yr
7/12/2012	96	15.57	3.43	22.0	Low	Low	100-250 Yr

The average runoff percentage is much lower, at 41%, and varies between 22% and 60%. The 60% event occurs with a low antecedent moisture condition and a relatively smaller rainfall, which is counter-intuitive. The analysis of gage data at Cypress Creek and Katy-Hockley Road is complicated by the presence of the overflow. If runoff escapes the watershed upstream of the gage, then it is not possible to measure the rainfall-runoff relationship upstream. It is not known which of the above events produced an overflow to Addicks Reservoir. The rainfall data suggests that the 2012 would produce an overflow, however, the corresponding rainfall-runoff data in Bear Creek does not. It is believed that overflow may occur at the watershed divide, and then get captured in the large land areas between the watershed divide and drainage collection systems. Based on this, it is difficult to ascertain a rainfall-runoff percentage in Upper Cypress, but this data lends credence to the notion that there are greater losses in Upper Cypress watershed when compared to the Addicks watershed (or just about any other watershed in Harris County).

Exhibit B2.4 presents a summary of the rainfall-runoff relationships throughout Harris County. Overall, the average rate was 70%, but it was much lower in Cypress Creek.

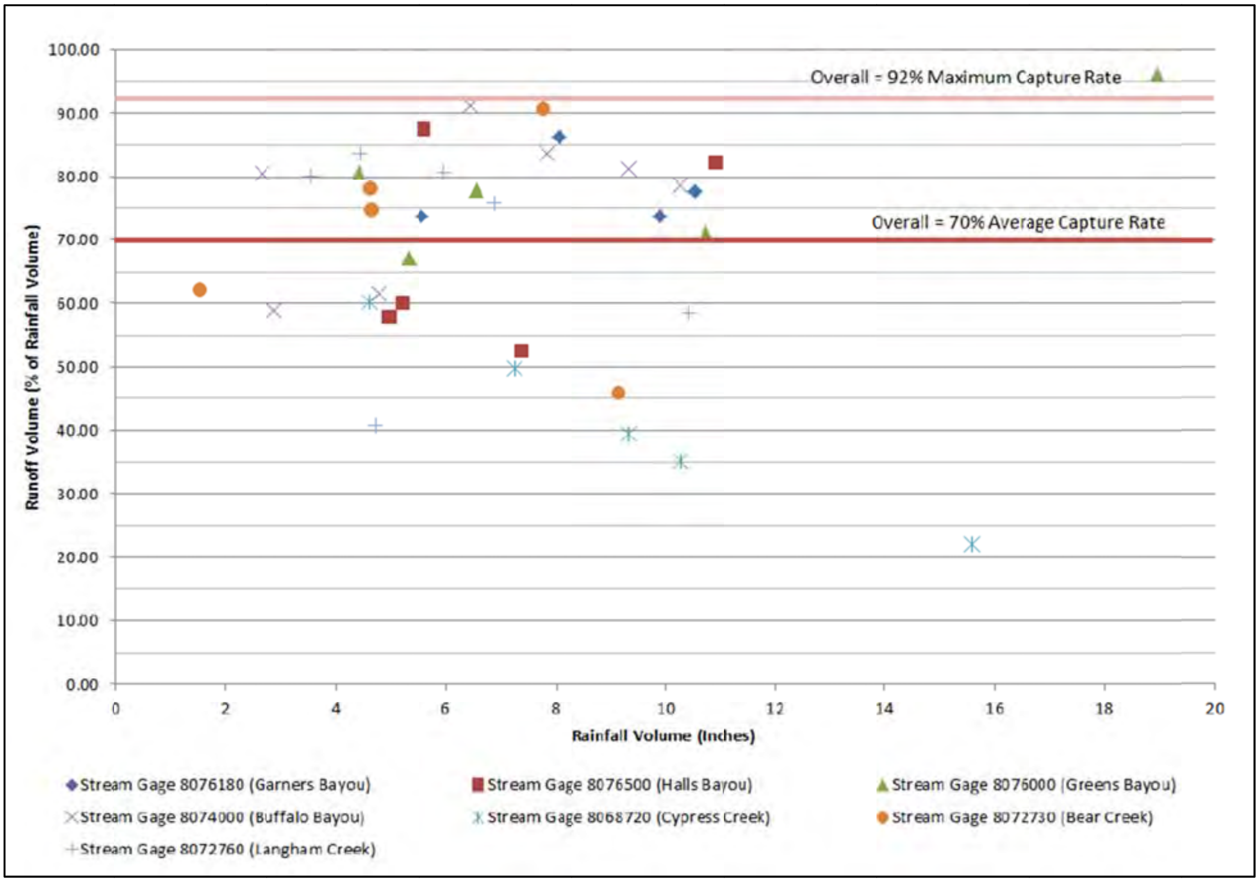


Exhibit B2.4
Observed Rainfall-Runoff in Harris County

The data from the RG Miller study does not lend itself to making specific conclusions regarding the rainfall-runoff relationship. This was not an intended outcome of the investigation. It does, however, provide additional insight to the general relationship. The overall average rainfall-runoff rate of 70% is consistent with computed values. The study does support the notion that there may be a lower runoff rate associated with the Upper Cypress Watershed.

3.0 Evaluation of Observed Events

As noted in the previous section, the potential impact of land development activity on pool elevations in Addicks Reservoir is not well quantified. While previous studies have adequately determined a stage-frequency relationship for the reservoirs, previous studies of development impacts have not resulted in usable conclusions.

Since the mid-1980's, the HCFCD has operated a number of rainfall and flood gages throughout Harris County. The utilization of data from these gages, along with data provided by the USACE, can be utilized to evaluate specific events by comparing rainfall, reservoirs stages, and releases. The evaluation of these events supports the determination of rainfall-runoff relationships in the watershed, as well as the simulation of potential behavior during those particular events in the event the rainfall-runoff relationship is altered by land development activity.

Two events of are particular interest – the event from the Winter of 1992 and the event from Spring of 2009. Both events established record pool elevations in the Addicks and Barker Reservoirs, however the events are very different. The 1992 event occurred after about three months of rainfall. While over 20 inches of rainfall fell between late December, 1991 and March, 1992, there was never a "massive" single event in the watershed that would typically be expected when record pool elevations are established. Instead, there were many days of smaller rainfall, and an almost constant threat of rain – inhibiting the ability of the USACE to release volume from the reservoir. Over this period, the reservoir's stage elevation "ratcheted" up, and hence this phenomena is often referred to as the "ratcheting" effect. The 2009 event was the result of about 14 days of rainfall in late April and early May, and was more representative of a single event rainfall. While there was some rainfall in the early part of the period, the reservoir mostly recovered, and the record pool elevations were mainly result of large rainfalls on two days in late April.

3.1 Simulation of March, 1992 Event

On March 10, 1992, Addicks Reservoir crested at a pool elevation 100.6 feet, which is equivalent to a storage volume of 57,900 acre-feet. At that time, this is the highest elevation observed in Addicks Reservoir since its construction in the 1940's, resulting in the closure of a county roads and facilities in Bear Creek Park, as well as the temporary closing of State Highway 6.

This section describes the simulation of the rainfall and reservoir elevations observed between December, 1991 and March, 1992 that resulted in record pool elevations in Addicks Reservoir. The approach described and applied involves using a mass balance using rainfall observed at gages in the watershed, recorded daily pool elevations, and release data obtained from the USACE.

3.1.1 Rainfall Data – December, 1991 to March, 1992

HCFCD monitors and records rainfall at four gages in or near the Addicks Reservoir watershed. The location of these rain gages is shown in Exhibit B3.1. On December 8, 1991, Addicks Reservoir was empty. Table B3.1 summarizes the rainfall recorded at each of these four gages in the 90-day period under consideration. As the table indicates, the four gages averaged just over 25 inches of rainfall over the 90 day period. Table B3.2 presents the daily rainfall at each of these gages between December 8, 1991 and March 5, 1992. The maximum single day rainfall of 4.02 inches was recorded on December 22, 1991 at the gage along Cypress Creek at Katy-Hockley Road.

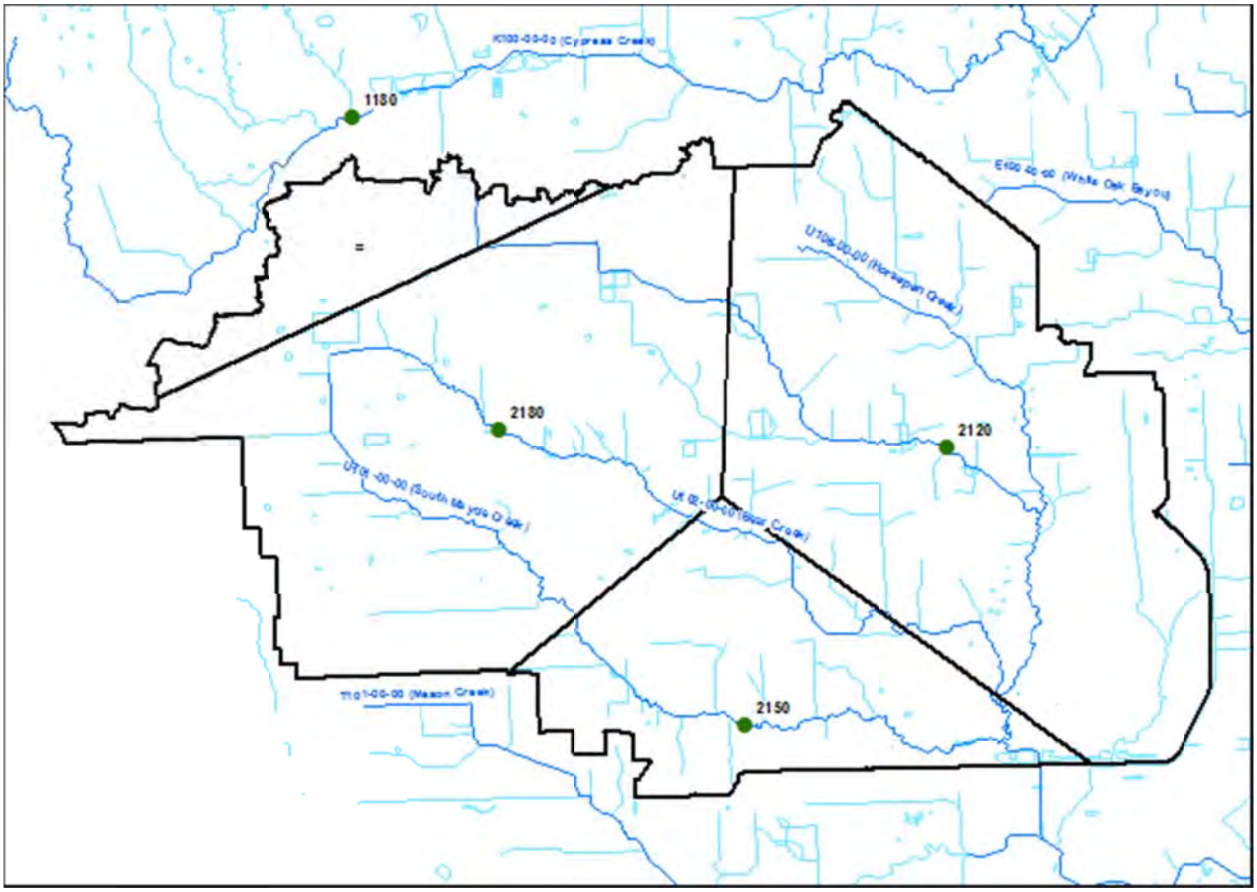


Exhibit B3.1
Location of Rainfall Gages

Table B3.1
Summary of Observed Rainfall – 1991-92 Event

Gage No	Location	Peak Total Rainfall (in)				
		7-day	14-day	30-day	60-day	90-day
2180	Bear Creek at 529	5.8	7.2	10.1	18.3	23.9
2150	S Mayde Crk at Greenhouse	4.9	7.1	9.6	16.0	24.6
2120	Langham at W Little York	5.7	8.4	11.0	20.2	28.5
1180	Cypress at Katy-Hockley	6.2	7.4	10.2	17.4	23.6
	Average	**5.6**	**7.5**	**10.2**	**18.0**	**25.2**

Table B3.2
Observed Daily Rainfall (inches) – 1991-92 Event

Date	2180 Bear Creek @ FM 529	2150 S Mayde Crk @ Greenhouse	2120 Langham Crk @ W Little York	1180 Cypress Crk @ Katy-Hockley
12/8/1991	0.24	0.04	0.04	0.04
12/9/1991	2.09	2.60	2.91	1.61
12/10/1991	0.00	0.00	0.00	0.00
12/11/1991	0.04	0.20	0.16	0.08
12/12/1991	0.00	0.00	0.00	0.00
12/13/1991	0.04	0.16	0.16	0.00
12/14/1991	0.00	0.00	0.00	0.00
12/15/1991	0.00	0.00	0.00	0.00
12/16/1991	0.00	0.00	0.00	0.00
12/17/1991	0.04	0.04	0.12	0.08
12/18/1991	0.83	0.63	0.91	0.98
12/19/1991	0.08	0.12	0.12	0.16
12/20/1991	0.00	0.00	0.00	0.00
12/21/1991	3.43	2.99	3.54	4.02
12/22/1991	0.67	0.35	0.47	0.43
12/23/1991	0.08	0.04	0.00	0.00
12/24/1991	0.00	0.00	0.00	0.00
12/25/1991	0.00	0.00	0.00	0.00
12/26/1991	1.61	1.34	1.54	1.61
12/27/1991	0.00	0.16	0.20	0.12
12/28/1991	0.00	0.00	0.00	0.00
12/29/1991	0.04	0.00	0.00	0.00
12/30/1991	0.00	0.08	0.00	0.00
12/31/1991	0.00	0.00	0.04	0.08
1/1/1992	0.00	0.00	0.00	0.00
1/2/1992	0.12	0.04	0.04	0.04
1/3/1992	0.00	0.00	0.04	0.00
1/4/1992	0.16	0.20	0.12	0.20
1/5/1992	0.43	0.55	0.59	0.51
1/6/1992	0.04	0.00	0.00	0.00
1/7/1992	0.00	0.12	0.08	0.00
1/8/1992	0.47	0.47	0.87	0.08
1/9/1992	0.00	0.00	0.00	0.00
1/10/1992	0.00	0.00	0.00	0.00
1/11/1992	0.39	0.16	0.16	0.43
1/12/1992	0.63	0.43	0.63	0.47
1/13/1992	0.08	0.00	0.00	0.04
1/14/1992	0.00	0.00	0.00	0.00
1/15/1992	0.00	0.00	0.00	0.00
1/16/1992	0.00	0.00	0.00	0.00
1/17/1992	1.02	0.24	1.14	1.22
1/18/1992	0.91	0.00	1.26	0.87
1/19/1992	0.00	1.26	0.04	0.08
1/20/1992	0.00	0.00	0.00	0.00
1/21/1992	0.43	0.00	0.39	0.51
1/22/1992	0.08	0.47	0.12	0.16
1/23/1992	0.00	0.00	0.00	0.00

Date	2180 Bear Creek @ FM 529	2150 S Mayde Crk @ Greenhouse	2120 Langham Crk @ W Little York	1180 Cypress Crk @ Katy-Hockley
1/24/1992	0.00	0.00	0.00	0.00
1/25/1992	0.00	0.00	0.00	0.00
1/26/1992	0.31	0.20	0.39	0.20
1/27/1992	0.63	0.51	0.75	0.67
1/28/1992	0.00	0.00	0.04	0.00
1/29/1992	0.16	0.04	0.00	0.00
1/30/1992	0.00	0.00	0.00	0.00
1/31/1992	0.00	0.00	0.00	0.00
2/1/1992	0.00	0.00	0.00	0.00
2/2/1992	0.00	0.00	0.00	0.00
2/3/1992	2.48	1.77	2.28	1.85
2/4/1992	0.75	0.67	0.91	0.83
2/5/1992	0.04	0.16	0.12	0.00
2/6/1992	0.00	0.00	0.00	0.00
2/7/1992	0.00	0.00	0.00	0.00
2/8/1992	0.00	0.00	0.00	0.00
2/9/1992	0.00	0.00	0.00	0.00
2/10/1992	0.00	0.00	0.00	0.00
2/11/1992	1.06	1.34	1.42	0.94
2/12/1992	0.31	0.35	0.12	0.12
2/13/1992	0.00	0.00	0.00	0.00
2/14/1992	0.00	0.00	0.00	0.04
2/15/1992	0.00	0.00	0.00	0.04
2/16/1992	0.08	0.12	0.12	0.04
2/17/1992	0.00	0.00	0.00	0.00
2/18/1992	0.00	0.00	0.00	0.00
2/19/1992	0.00	0.00	0.00	0.00
2/20/1992	0.00	0.00	0.00	0.00
2/21/1992	0.00	0.00	0.00	0.00
2/22/1992	0.94	1.18	1.42	1.69
2/23/1992	0.00	0.12	0.00	0.00
2/24/1992	1.42	1.30	1.38	1.34
2/25/1992	0.00	0.00	0.00	0.00
2/26/1992	0.00	0.04	0.00	0.00
2/27/1992	0.00	0.00	0.00	0.00
2/28/1992	0.00	0.00	0.00	0.00
2/29/1992	0.00	0.00	0.00	0.00
3/1/1992	0.00	0.00	0.00	0.00
3/2/1992	0.00	0.00	0.00	0.00
3/3/1992	0.00	0.00	0.00	0.00
3/4/1992	1.46	3.74	3.43	2.01
3/5/1992	0.35	0.24	0.04	0.00
3/6/1992	0.00	0.16	0.47	0.00
3/7/1992	0.00	0.00	0.00	0.00
3/8/1992	0.00	0.00	0.00	0.00
3/9/1992	0.00	0.00	0.04	0.00
3/10/1992	0.00	0.00	0.00	0.00

The return interval of rainfall is described in terms of intensity – or the amount of rainfall over a time period. HCFCD uses a 24-hour rainfall in the consideration of hypothetical events, as this is an appropriate rainfall to consider given the size of most of the watersheds in Harris County. The National Weather Service (NWS) has published charts that depict the recurrence interval (which can be converted to annual probability) for various duration rainfall events give a particular location. NWS Technical Paper No. 40 (TP-40) provides rainfall intensities between the 1-year and 100-year recurrence interval for rainfall durations between 30-minutes and 24-hours. NWS Technical Paper No 49 (TP-49) provides rainfall intensities between the 2-day and 10-day recurrence interval.

Even though the rainfall over the 90-day period occurred from different meteorological events, the measured rainfall over the time period can be related to a return interval and annual probability for a 90-day period. Rainfall values were taken from different durations for particular return intervals and plotted for each return period. Trend line equations for each return period were developed using the power equation as illustrated in Exhibit B3.2.

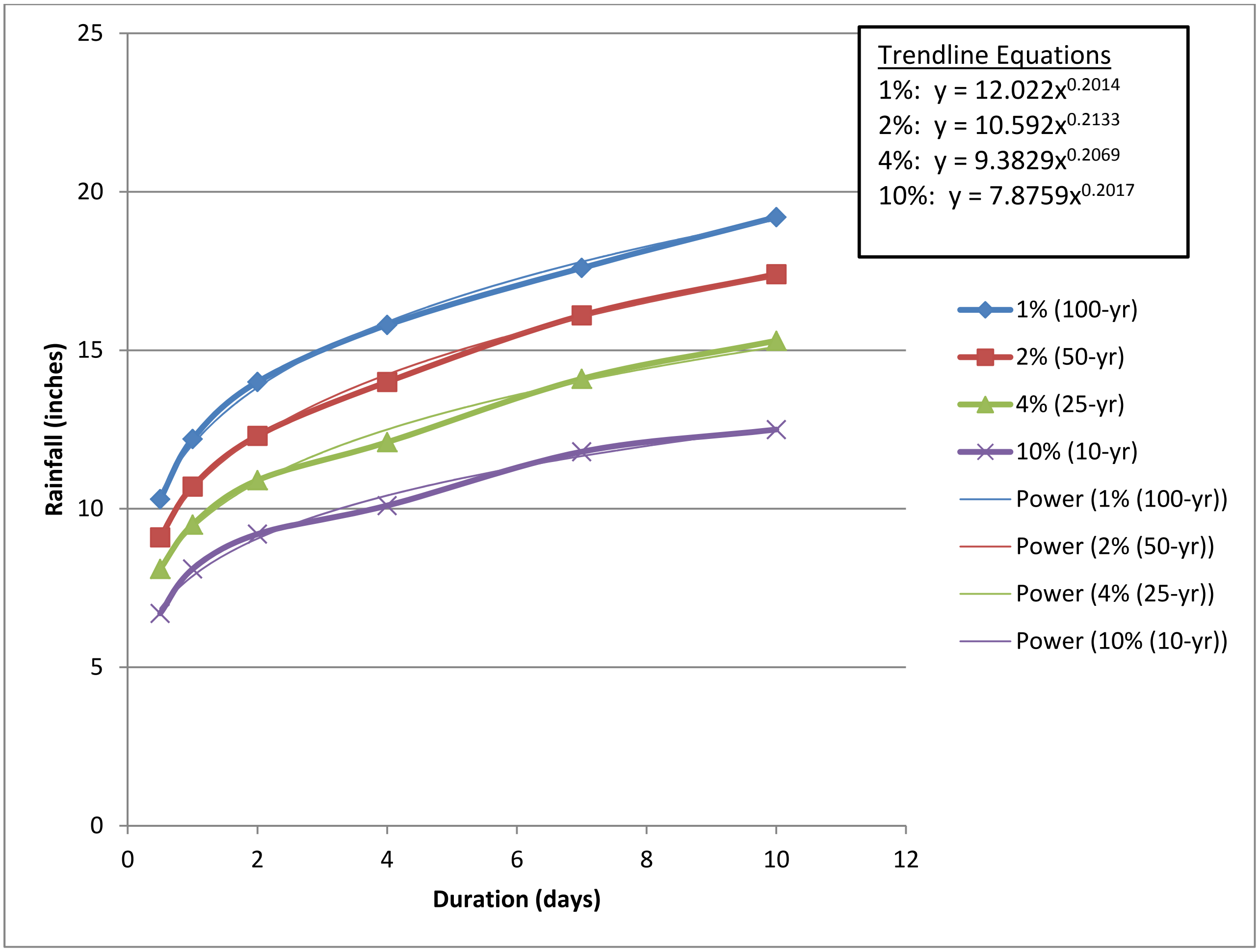


Exhibit B3.2
Determination of Rainfall Depth for Long Duration Events

The resultant trend line equations were used to extrapolate the data to provide return intervals for 90-day durations, which then facilitated the determination of a return interval to the observed rainfall events over the 90-day period at each of the four gages along with a watershed wide estimation that considers the weighted average of the four gages. This is summarized in Table B3.3. As the table indicates, the return intervals for the observed rainfall over the 90-day period ranges between a 24-year event (Cypress Creek at Katy-Hockley Road) and a 70-year event (Langham Creek at West Little York Road). Considering the weighted average of the four gages, the rainfall associated with the March, 1992 event on Addicks Reservoir approximated a 38-year event.

Table B3.3
Annual Probability and Return Interval for Observed Rainfall – 1991-1992 Event

Gage No	Location	Rainfall (inches)	Weight (%)	Annual Probability (%)	Return Interval (yr)
	10% (10-yr) 90-day Rainfall	19.5		10%	10-yr
	4% (25-yr) 90-day Rainfall	23.8		2%	25-yr
	2% (50-yr) 90-day Rainfall	27.7		4%	50-yr
	1% (100-yr) 90-day Rainfall	29.7		1%	100-yr
2180	Bear Creek at 529	23.9	37%	4%	25-yr
2150	S Mayde Crk at Greenhouse	24.6	17%	3%	29-yr
2120	Langham at W Little Yk	28.6	39%	1%	70-yr
1180	Cypress at Katy-Hockley	23.6	7%	4%	24-yr
	Weighted Average	25.8		3%	38-yr

3.1.2 Reservoir Releases – December, 1991 to March, 1992

The combined release from Addicks and Barker Reservoir is limited to a peak rate of 2,000 cfs. The release is further restricted such that the reservoir releases cannot contribute to a flow in excess of 2,000 cfs along Buffalo Bayou at Piney Point Drive as measured by a USGS gaging station at that location. Therefore, if there are additional flows contributing to Buffalo Bayou, whether from rainfall, irrigation, or wastewater discharges, the releases must be further restricted to ensure that the 2,000 cfs threshold is not exceeded.

The USGS gage along Buffalo Bayou at Piney Point is located approximately nine miles downstream of the Addicks Reservoir outlet, so there is a considerable travel time between the reservoir and the gage. This requires that gate operations consider future conditions when making operational decisions. For example, if rainfall is anticipated within the next ten hours, discharges will be further restricted or closed completely in order to ensure the threshold at the Piney Point gage is not exceeded. Often times, outflows are restricted even when a potential rainfall does not occur. Because of this, simulation of gate operations based upon historical data is particularly challenging. Actual release data was obtained from the USACE, and therefore simulation of gage operating decisions was not necessary.

Table B3.4
Addicks Reservoir Daily Release and Pool Storage – 1991-1992 Event

Date	Average Release Rate (cfs)	Pool Storage Volume (ac-ft)
12/8/1991	49	0
12/9/1991	322	2,739
12/10/1991	548	5,215
12/11/1991	607	5,380
12/12/1991	356	5,215
12/13/1991	202	5,334
12/14/1991	303	5,127
12/15/1991	400	4,551
12/16/1991	555	3,705
12/17/1991	438	2,846
12/18/1991	213	2,819
12/19/1991	36	3,661
12/20/1991	0	4,311
12/21/1991	0	10,117
12/22/1991	0	20,078
12/23/1991	170	24,384
12/24/1991	233	26,365
12/25/1991	99	27,418
12/26/1991	0	30,715
12/27/1991	380	34,285
12/28/1991	721	34,730
12/29/1991	721	35,050
12/30/1991	627	35,757
12/31/1991	246	36,017
1/1/1992	0	35,822
1/2/1992	462	36,082
1/3/1992	933	35,178
1/4/1992	610	34,349
1/5/1992	409	34,285
1/6/1992	706	33,781
1/7/1992	185	33,280
1/8/1992	0	34,730
1/9/1992	310	35,435
1/10/1992	433	35,370
1/11/1992	80	34,985
1/12/1992	0	36,669
1/13/1992	579	33,718
1/14/1992	717	32,845
1/15/1992	715	31,740
1/16/1992	618	30,595
1/17/1992	134	31,074
1/18/1992	0	36,082
1/19/1992	326	38,192
1/20/1992	349	38,528
1/21/1992	101	39,068
1/22/1992	583	39,475
1/23/1992	730	38,865
1/24/1992	919	37,659
1/25/1992	483	36,342
1/26/1992	264	36,212
1/27/1992	146	27,992
1/28/1992	435	38,327
1/29/1992	662	37,992
1/30/1992	1,06	36,604
1/31/1992	1,20	34,730
2/1/1992	734	33,342
2/2/1992	276	32,783
2/3/1992	95	35,370
2/4/1992	0	40,643
2/5/1992	649	44,111
2/6/1992	893	44,546
2/7/1992	972	43,966
2/8/1992	984	42,961
2/9/1992	981	41,828
2/10/1992	978	40,574
2/11/1992	224	42,748
2/12/1992	285	44,764
2/13/1992	700	44,764
2/14/1992	432	44,255
2/15/1992	821	43,606
2/16/1992	602	42,677
2/17/1992	863	41,618
2/18/1992	977	40,023
2/19/1992	972	38,461
2/20/1992	968	36,866
2/21/1992	578	35,564
2/22/1992	0	38,797
2/23/1992	285	40,505
2/24/1992	53	42,748
2/25/1992	526	46,014
2/26/1992	744	46,385
2/27/1992	743	45,718
2/28/1992	965	44,401
2/29/1992	984	42,819
3/1/1992	980	41,129
3/2/1992	625	39,749
3/3/1992	244	39,339
3/4/1992	17	50,808
3/5/1992	0	55,291
3/6/1992	101	57,534
3/7/1992	254	57,787
3/8/1992	103	57,787
3/9/1992	386	57,619
3/10/1992	761	56,199

For the analysis of the rainfall that preceded the March, 1992 event on Addicks Reservoir the USACE provided daily average discharge data. This data, as well as the daily pool elevation (taken at midnight) is provided on Table B3.4.

Over the duration of the period, a total of 85,571 acre-feet was released from Addicks Reservoir. The pool elevation at the end of the period, on March 10, 1992, was 56,199 acre-feet.

3.1.3 Rainfall/Runoff Relationship - December, 1991 to March, 1992

Based upon the total Addicks Reservoir storage volume of 59,166 acre-feet on March 10, 1992, and the cumulative release of 85,571 acre-feet since December 8, 1991 (the last prior date that the reservoir was empty), it can be derived that 144,777 acre-feet of runoff contributed to Addicks Reservoir between December 8, 1991 and March 10, 1992.

During dry times, the watershed flowrate averages about 40 cfs. The source of this flow is primarily effluent from treatment plants and excess runoff from irrigation. Over the course of the event it is estimated that about 7,458 acre-feet of runoff volume were provided by non-rainfall sources.

Based upon this, that leaves a total of about 134,228 acre-feet of inflow volume from the rainfall that was recorded between December 8, 1991 and March 10, 1992. As noted previously, the weighted average of the rainfall from the four gages in or near the watershed is 25.84 inches. If 100% of the rainfall were to runoff to Addicks Reservoir, this volume would be 187,410 acre-feet. By comparing the estimated inflow with the computed rainfall volume, it can be deduced that 74.6% of the rainfall that fell in the Addicks Reservoir watershed during this period eventually found its way into Addicks Reservoir.

This runoff rate is consistent with the previous studies, and is consistent with the existing understanding of the rainfall-runoff relationship in Harris County. This relationship is more complex than applying a simple rainfall-runoff conversion factor. Tracking the individual rainfall events during the period of concern does not show a consistent factor. As expected, the early rainfalls produce runoff at a lower rate reflective of the drier antecedent moisture condition. As the time passes, rainfall is converted to runoff at a higher rate because the soils have become saturated. However, the direct approach of using a consistent factor is expeditious and reasonable, especially considering the uncertainties associated with daily simulations – and is an effective way to consider the behavior of rainfall and runoff as long as these limitations are understood.

3.1.4 Effects of Urbanization – December, 1991 to March, 1992

The daily simulation was utilized to consider the impacts of urbanization on pool elevations in the reservoir. The inflows were adjusted to consider three scenarios – 80% runoff, 90% runoff, and 100% runoff. These consider the change in expected pool elevation considering a future development scenario in the watershed. Table B3.5 summarizes the results of these simulations.

Table B3.5
Sensitivity to Rainfall/Runoff – 1991-92 Event

Rainfall	Runoff	Stage (feet) (1973 adj)	Storage (ac-ft)
March 1992 Event	74.6% runoff (1991 Development)	100.6	58,153
March 1992 Event	80% runoff	102.2	73,758
March 1992 Event	90% runoff	104.1	92,407
March 1992 Event	100% runoff	105.7	111,055
100-year (USACE)		104.1	92,602
Government Land		106.1	116,300

As Table B3.5 indicates, increasing the rainfall-to-runoff conversion factor from 74.6% to 90% would have resulted in an increase in pool elevation from 100.6 feet to 104.1 feet, and the reservoir storage volume would increase by almost 60%. Furthermore, pool elevations would reach the 1% (100-year) threshold, even though the rainfall event is closer to a 40-year event. A rainfall-runoff conversion factor of 90% is a realistic depiction of a fully developed watershed. A 100% runoff factor is presented to show an upper bound, but that is not considered a reasonable full development condition.

3.1.5 Effects of Urbanization – March, 1992 adjusted to 1%

The weighted rainfall for the watershed during the December, 1991 to March, 1992 event yielded 25.84 inches of rainfall. The extrapolation exercise presented earlier predicted a 1% (100-year) 90-day rainfall to be 29.70 inches. In order to consider a 1% (100-year) rainfall that duplicated the patterns of the 1992 event, each rainfall ordinate was increased by about 13% in order to increase the rainfall to a 1% (100-year) equivalent. The results of this simulation are presented in Table B3.6.

Table B3.6
Adjustment of 1991-92 Event to a 1% (100-year) Event

Rainfall	Runoff	Stage (feet) (1973 adj)	Storage (ac-ft)
March 1992 Event adj to 1%	74.6% runoff (1991 Development)	103.3	84,339
March 1992 Event adj to 1%	80% runoff	104.4	96,044
March 1992 Event adj to 1%	90% runoff	106.2	117,478
March 1992 Event adj to 1%	100% runoff	107.8	138,912
100-year (USACE)		104.1	92,602
Government Land		106.1	116,300

During the adjusted March 1992 event, the predicted peak pool elevation was 103.3 feet. This is lower than the USACE computed 100-year elevation of 104.1 feet, but is similar considering the divergence of methods. Furthermore, the USACE simulation considers occasional overflows from Cypress Creek that would tend to influence the computed storage volumes.

Using a rainfall-runoff factor of 90%, the stage elevations increase to 106.2 feet, just higher than the limit of government land. In such an event, reservoir pool elevations would encroach upon private property on the fringes of the reservoir.

3.2 Simulation of April, 2009 Event

On April 30, 2009, Addicks Reservoir crested at an estimated pool elevation of 100.0 feet. (This elevation is based on a conversion of 3.1 feet between the NGVD 1927, 1973 adjustment, used in this analysis; and the NAVD 1988, 2001 adjustment pool elevation reported by the USACE This elevation was estimated by using the USGS published daily pool storage volume of 59,300 acre-feet in conjunction with the stage-storage relationship for Addicks Reservoir. This pool elevation is the second highest in recorded history, after the 1992 event. Unlike the 1992 event, which resulted from rainfall over a 90-day period, the rainfall that led to the record pool in 2009 occurred over a much shorter duration.

This section describes the simulation of the rainfall and reservoir elevations observed in late April 2009. This approach uses a mass balance from rainfall observed at gages in the watershed and recorded daily pool elevations. However, this required the use of assumed releases.

3.2.1 Rainfall Data – April, 2009

As with the analysis of the March, 1992 event, rainfall was taken from four gages in and near the Addicks watershed. However, two of the four gages predicted unreasonably low rainfalls. The gage at Langham Creek and West Little York Road, for instance, only recorded 0.08 inches during this period, while many adjacent gages recorded in excess of ten inches. Nearby gages were used as surrogates for the questionable gages. The gage at Mason Creek and Prince Creek Drive was used in place of the South Mayde Creek gage at Greenhouse Road; and a gage along White Oak Bayou at Lakeview as used in lieu of the gage along Langham Creek. These gages returned reasonable data when comparing surrounding areas. The weightings for each gage were the same as those utilized in the 1992 analysis.

Table B3.7 summarizes the rainfall recorded at each of the four gages in the 14-day period under consideration. As the table indicates, the four gages averaged 13.5 inches over the period. Comparing with the return period frequency for a 14-day rainfall event, this event approximates a 10-year event. Table B3.8 depicts the daily rainfall at each of these gages between April 16, 2009 and May 5, 2009. The maximum single day rainfall of 6.32 inches was recorded at the gage along Bear Creek at FM 529 on April 29. This gage actually recorded 11.88 inches over the two-day period of April 28 and April 29.

3.2.2 Reservoir Releases – April, 2009

Daily release data for the 2009 event were obtained from the USACE Over the course of the event, 7,991 acre-feet were released from Addicks Reservoir.

Table B3.7
Annual Probability and Return Interval for Observed Rainfall – 2009 Event

Gage No	Location	Rainfall (inches)	Weight (%)	Annual Probability (%)	Return Interval (yr)
	10% (10-yr) 14-day Rainfall	13.4		10%	10-yr
	4% (25-yr) 14-day Rainfall	16.2		2%	25-yr
	2% (50-yr) 14-day Rainfall	18.6		4%	50-yr
	1% (100-yr) 14-day Rainfall	20.4		1%	100-yr
2180	Bear Creek at 529	15.9	37%	4%	23-yr
2020	Mason Creek at Prince Creek Dr	15.3	17%	5%	18-yr
550	White Oak Bayou at Lakeview	10.8	39%	23%	4-yr
1180	Cypress at Katy-Hockley	11.5	7%	18%	5-yr
	Weighted Average	13.5		10%	10-yr

Table B3.8
Observed Daily Rainfall (inches) – 2009 Event

Date	2180 Bear Creek @ FM 529	2020 Mason Crk @ Prince Crk Dr	550 White Oak Bayou @ Lakeview	1180 Cypress Crk @ Katy-Hockley
4/16/2009	0.00	0.00	0.00	0.00
4/17/2009	0.00	0.56	0.00	0.00
4/18/2009	1.68	3.04	1.68	2.36
4/19/2009	2.16	0.00	2.52	1.32
4/20/2009	0.00	0.00	0.00	0.00
4/21/2009	0.00	0.00	0.00	0.00
4/22/2009	0.00	0.00	0.00	0.00
4/23/2009	0.00	0.00	0.00	0.00
4/24/2009	0.00	0.48	0.00	0.00
4/25/2009	0.08	0.08	0.36	0.00

Date	2180 Bear Creek @ FM 529	2020 Mason Crk @ Prince Crk Dr	550 White Oak Bayou @ Lakeview	1180 Cypress Crk @ Katy-Hockley
4/26/2009	0.08	0.00	0.43	0.28
4/27/2009	0.04	2.24	0.00	0.00
4/28/2009	5.40	5.44	2.00	2.68
4/29/2009	6.48	0.00	3.76	4.88
4/30/2009	0.00	0.00	0.00	0.04
5/1/2009	0.00	3.44	0.04	0.00
5/2/2009	0.00	0.00	0.00	0.00
5/3/2009	0.00	0.00	0.00	0.00
5/4/2009	0.00	0.00	0.00	0.00
5/5/2009	0.00	0.00	0.00	0.00

There are a number of factors that may contribute to releases. During the 1992 event, as the reservoir stages "ratcheted" up, it is conceivable that the USACE was very aggressive in its releases. However, the 90-day period was a very "wet" period that would have inhibited the ability to release. Since the 2009 event is of much shorter duration, the simulation is less sensitive to the release assumption. However, it is an important consideration, and the lack of real release data compromises the assessment.

The USGS publishes daily reservoir pool storage volumes. These volumes were utilized in the analysis, and are presented in Table B3.9.

Table B3.9
Addicks Reservoir Daily Release (Estimated) and Pool Storage (Observed) – 2009 Event

Date	Average Release Rate (cfs)	Pool Storage Volume (ac-ft)
4/16/2009	458	-
4/17/2009	458	64
4/18/2009	458	1,480
4/19/2009	458	12,300
4/20/2009	458	14,400
4/21/2009	458	13,200
4/22/2009	458	11,100
4/23/2009	458	8,700
4/24/2009	458	6,200
4/25/2009	458	5,570

Date	Average Release Rate (cfs)	Pool Storage Volume (ac-ft)
4/26/2009	458	6,100
4/27/2009	458	5,880
4/28/2009	458	35,300
4/29/2009	458	55,800
4/30/2009	458	59,800
5/1/2009	458	59,800
5/2/2009	458	58,600
5/3/2009	458	57,500
5/4/2009	458	56,000
5/5/2009	458	54,100

Based upon the assumed releases, a total of 18,158 acre-feet was released from Addicks Reservoir. The pool elevation at the end of the period, on March 10, 1992, was 54,100 acre-feet.

3.2.3 Rainfall and Runoff Relationship - April, 2009

Based upon the total Addicks Reservoir storage volume of 54,100 acre-feet on May 5, 2009 and the estimated cumulative release of 18,158 acre-feet since April 16, 2009 (the last prior date that the reservoir was empty), it can be estimated that 72,258 acre-feet of runoff contributed to Addicks Reservoir between April 16, 2009 and May 5, 2009.

During dry times, the watershed flowrate averages about 40 cfs. The source of this flow is primarily effluent from treatment plants and excess runoff from irrigation. Over the course of the event it is estimated that about 1,587 acre-feet of runoff volume were provided by non-rainfall sources.

Based upon this, that leaves a total of about 70,671 acre-feet of inflow volume from the rainfall that was recorded between April 16, 2009 and May 5, 2009. As noted previously, the weighted average of the rainfall from the four gages in or near the watershed is 13.51 inches. If 100% of the rainfall were to runoff to Addicks Reservoir, this volume would be 98,051 acre-feet. By comparing the estimated inflow with the computed rainfall volume, it can be estimated that 72.0% of the rainfall that fell in the Addicks Reservoir watershed during this period eventually found its way into Addicks Reservoir. A daily simulation was conducted, and adjusting this rainfall-runoff factor such that the resultant simulated pool elevation matches the observed elevation resulted in a rainfall-runoff factor of 74.5%. This difference can be attributed to assumptions regarding the arrival time in the reservoir from the rainfall. The simulation assumed that all rainfall arrives in the reservoir on the day it was measured. In reality, rainfall arrives in the reservoir over several days.

This runoff rate is consistent with the previous studies, and is consistent with the existing understanding of the rainfall-runoff relationship in Harris County. Furthermore, it is consistent with the rate computed in the analysis of the March, 1992 event. Because of the assumptions required for the missing rainfall and the releases, this simulation cannot be utilized to generate conclusions. However it can be used in concert with the March, 1992 simulation as a check for reasonableness, and the results suggest that the assumption of about 75% for the existing rainfall –runoff relationship is likely reasonable and valid.

3.2.4 Effects of Urbanization – April, 2009

The daily simulation was utilized to consider the impacts of urbanization on pool elevations in the reservoir. The inflows were adjusted to consider three scenarios – 80% runoff, 90% runoff, and 100% runoff. These consider the change in expected pool elevation taking into account a future development scenario in the watershed. Table B3.10 summarizes the results of these simulations.

Table B3.10
Sensitivity to Rainfall/Runoff – 2009 Event

Rainfall	Runoff	Stage (feet) (1973 adj)	Storage (ac-ft)
April 2009 Event	74.5% runoff (2009 Development)	101.1	63,902
April 2009 Event	80% runoff	101.6	68,011
April 2009 Event	90% runoff	102.6	77,362
April 2009 Event	100% runoff	103.6	86,720
100-year (USACE)		104.1	92,602
Boundary of Reservoir Right-of-Way		106.1	116,300

As Table B3.10 indicates, increasing the rainfall-to-runoff conversion factor from 74.6% to 90% would have resulted in an increase in pool elevation from 101.1 feet to 102.6 feet, and the reservoir storage volume would increase by about 21%. Furthermore, pool elevations would set a new record, even though the rainfall event is closer to a 10-year event. As noted previously, a rainfall-runoff conversion factor of 90% is a realistic depiction of a fully developed watershed. A 100% runoff factor is presented to show an upper bound, but that is not considered a reasonable full development condition.

3.2.5 Effects of Urbanization – April, 2009 adjusted to 1%

The weighted rainfall for the watershed during the April, 2009 event yielded 13.51 inches of rainfall. The extrapolation exercise presented earlier predicted a 1% (100-year) 14-day rainfall to be 20.4 inches. In order to consider a 1% (100-year) rainfall that duplicated the patterns of the 2009 event, each rainfall ordinate was increased by about 51% in order to increase the rainfall to a 1% (100-year) equivalent. The results of this simulation are presented in Table B3.11. It should be noted that this exercise did not consider the impact of an overflow event – it only considers the impact of local runoff within the Addicks Reservoir watershed.

During the adjusted April, 2009 event, the predicted peak pool elevation was 102.2 feet. This is notably lower than the USACE computed event (104.1 feet).

Using a rainfall-runoff factor of 90%, the stage elevations increase to 106.5 feet, just higher than the limit of government land. In such an event, reservoir pool elevations would encroach upon private property on the fringes of the reservoir.

Table B3.11
Adjustment of 2009 Event to a 1% (100-year) Event

Rainfall	Runoff	Stage (feet) (1973 adj)	Storage (ac-ft)
April 2009 Event adj to 1%	74.5% runoff (2009 Development)	104.6	98,232
April 2009 Event adj to 1%	80% runoff	105.3	106,225
April 2009 Event adj to 1%	90% runoff	106.4	120,360
April 2009 Event adj to 1%	100% runoff	107.5	134,496
100-year (USACE)		104.1	92,602
Government Land		106.1	116,300

4.0 Summary

This appendix presents a summary overview of Addicks Reservoir, and considers the behavior of the reservoir during two observed events. Furthermore it attempts to predict the behavior of the reservoir should these events have occurred during a future developed condition.

The following summary and conclusions have been identified as a result of this review and analysis:

- Addicks Reservoir is subject to operational constraints which prohibit it from performing in the manner that was originally planned. The reservoir maintains sufficient capacity to manage the expected runoff volume from typical design events in Harris County, including the 24-hour 100-year event. In such an event, pool elevations will be maintained within the boundaries of government owned land.
- The Addicks Reservoir pool has the capacity to impound significant volumes of water before pool elevations rise to the level of the spillways. Eventually, pool elevations would exceed reservoir lands and inundate private property at the reservoir fringes. At current development levels, it would take an extraordinary rainfall to achieve these pool elevations.
- Current development policy requires detention basins to ensure that downstream peak discharges are not increased as a result of development. However, detention basins only address the peak flowrate and do not provide mitigation for the increase in volume. While this may not be a concern in free-flowing watersheds, the impact of increased volumes should be considered when long term storage features are downstream.
- Simulations of the two largest recorded events on Addicks Reservoir suggest that the increase in the rainfall-runoff relationship associated with new development will, if not mitigated, significantly increase pool elevations in Addicks Reservoir.
- Simulations of these events suggest that that during larger events about 75% of rainfall is converted to runoff that makes its way into Addicks Reservoir. Furthermore, past studies suggest that developed watersheds convert about 90% of rainfall to runoff. This 15% increase is equivalent to two-inches when considering a 1% (100-year) 24-hour rainfall amount of 13.5 inches.
- Land development activity in Upper Cypress Creek, with current detention policy, will result in a longer duration of flood flows. This will result in a higher volume of overflow

into the Addicks watershed, and eventually will increase the expected pool elevation in Addicks Reservoir.

- This analysis did not consider Barker Reservoir. However, Barker Reservoir is subject to the same operational constraints as Addicks Reservoir, and the two reservoirs work as a single system. All conclusions regarding Addicks Reservoir could be applied to Barker Reservoir, with the exception of those regarding the overflow from Cypress Creek.

Appendix C

Formulation of Management Strategies

August 18, 2015

Table of Contents

Table of Contents

Table of Contents

Table of Contents

1.0 Introduction

This appendix describes and documents the process used to formulate and evaluate the alternative strategies in support of the Cypress Creek Overflow Management Plan study. Specifically, the appendix describes the work in support of the Texas Water Development Board (TWDB) scope item *Task 2: Identifying Mitigation Strategies*.

According to the scope description for this task, two combinations are to be identified for further investigation. These two combination strategies are (1) Combination Plan 3 – Mound Creek Reservoir with Conveyance "D" and (2) Combination Plan 5 – Katy Hockley North Reservoir. These titles identify the prominent feature of each plan. There are additional features included in both of these plans, including the construction of an enlarged overflow conveyance channel along Bear Creek, detention in John Paul's Landing, temporary implementation features, land development policy, and other features described in this appendix.

There are two additional strategies that are possible outcomes – both variants of a minimal or do-nothing approach. A pure do-nothing approach requires no action by the Harris County Flood Control District (HCFCD). Development activity would continue under policy and criteria described in the *HCFCD Policy, Criteria, & Procedure Manual*, *Harris County Flood Plain Regulations, Regulations of Harris County, Texas for the Approval and Acceptance of Infrastructure and* other pertinent regulations. A variant on the pure do-nothing approach is similar, but with the adoption of additional development guidelines and criteria for the Upper Cypress Creek, Addicks Reservoir, and Barker Reservoir watersheds developed in recognition of the unique hydrology and phenomena related to the overflow and the Addicks and Barker reservoir system.

This appendix provides a detailed description of the development of these two strategies.

1.1 Study Area

The general study area for the Cypress Creek Overflow Planning Study is the Upper Cypress Creek watershed and the Addicks Reservoir watershed, as depicted Exhibit C1.1. The Upper Cypress Creek is defined as the watershed that contributes to flows in Cypress Creek upstream of US 290. The total study covers 277 square miles, with the Addicks Reservoir watershed contributing 136 square miles, and the Upper Cypress Creek watershed contributing 141 square miles. Approximately 63 square miles of the study area is in Waller County, all of which is in the Upper Cypress Creek watershed.

1.1.1 Historic Land Characterization

The study area lies within an area known as the Katy Prairie, an area that covers over one-thousand square miles. The Katy Prairie is part of the Western Gulf coastal grasslands, and is bound by the Brazos River on the southwest, pine-hardwood forest to the north, and the City of Houston to the east. The natural setting is characterized by tall-grass prairie with pothole wetlands and riparian corridors along waterways. Occasional fires were common, which hindered growth of trees and maintained the grasslands.

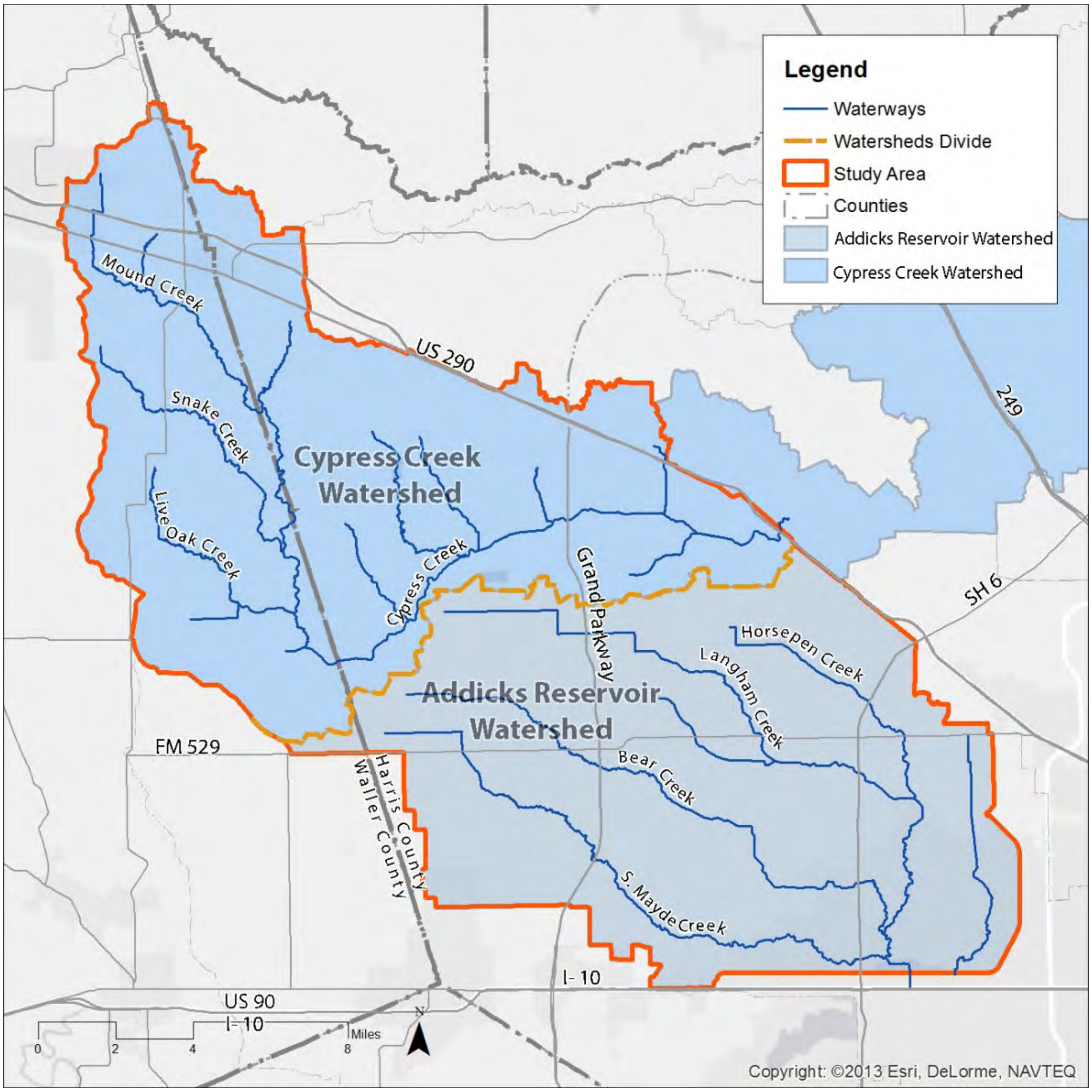


Exhibit C1.1
Cypress Creek Overflow Management Plan – Study Area

In the past one hundred years, changes in land use have threatened the natural prairie. Much of the area has been converted to agricultural use. Measures were put in place to prevent and extinguish fires. Additionally, the encroachment of land development continues to threaten the native prairie. Exhibit C1.2 shows areas of remaining remnant prairie compiled by the HCFCD. Based upon this compilation, there are only about 2,000 acres of remaining remnant prairie in the study area.

In 1992, the Katy Prairie Conservancy (KPC) was established to conserve and sustain what is left of the Katy Prairie. The KPC pursues its mission by protecting prairie land and agricultural land by acquisition, conservation easements, and management easements. The KPC has a goal of protecting about 50,000 acres.

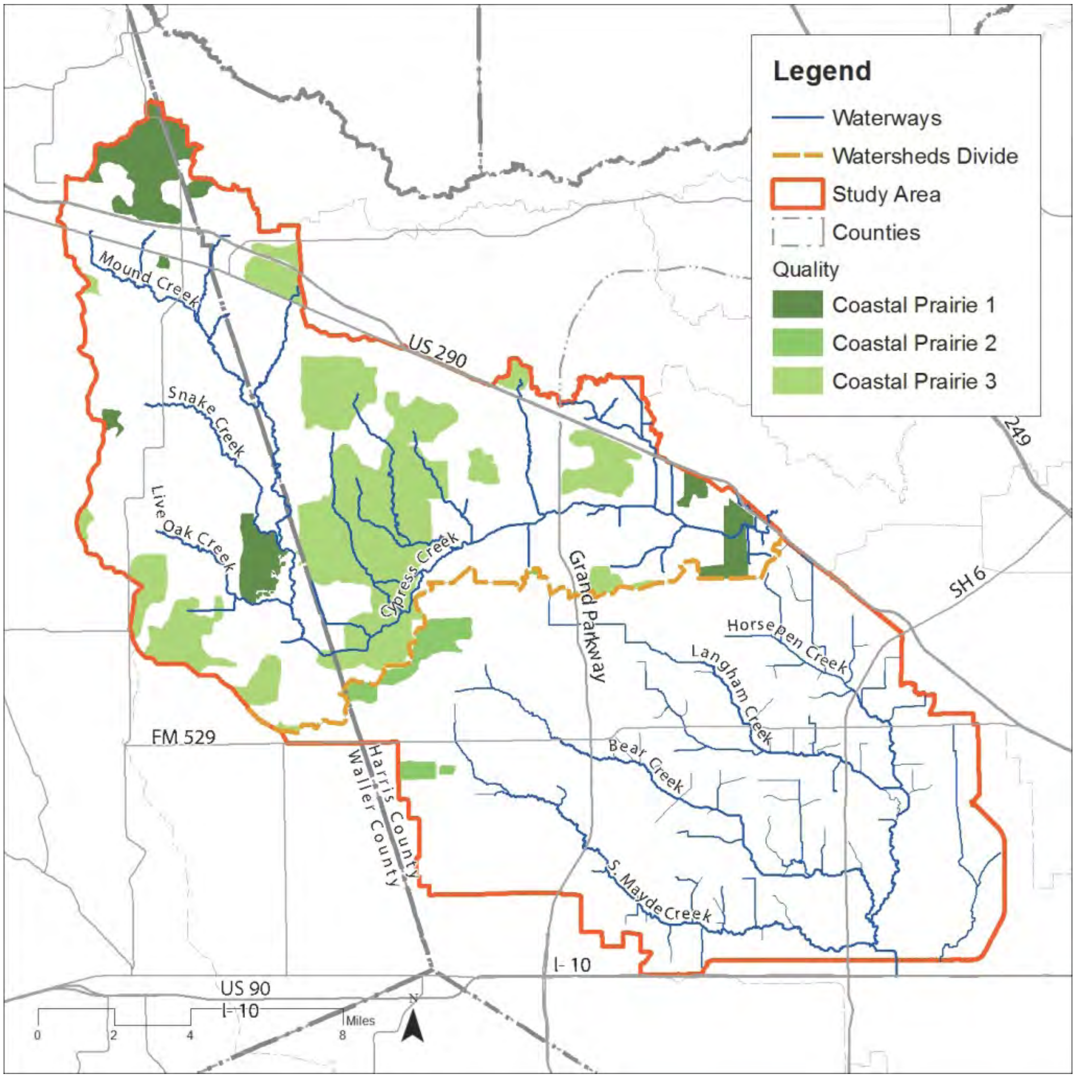


Exhibit C1.2
Remnant Prairie in the Study Area

1.1.2 Wildlife and Habitat

The Katy Prairie has a large population of wildlife, and is particularly known for diverse population of birds. Currently the Katy Prairie supports beaver, alligator, deer, coyote, bobcat, and squirrels. In addition, 196 different bird species were recorded during bird counts between 1977 and 1994. As rice farming became more prominent in the 1950's, vast amounts of snow geese began to migrate to the prairie during winter months.

As noted above, it is estimated that only about 2,000 acres of remnant prairie remains within the study area. Most of the prairie has been lost to the encroachment of development, implementation of agricultural, or to invasive species. There still remain strands of Texas Prairie Dawn (Hymenoxys Texana), a small plant that has been on the U.S. Endangered Species list since 1985.

1.1.3 Topography

The natural topography is very flat, and generally drains from the northwest to the southeast. Exhibit C1.3 depicts the topography, with elevations as high as 300 feet above mean sea level in the upper part of the Cypress Creek watershed in Waller County, and as low as 80 feet in Addicks Reservoir. As the exhibit indicates, there is a relatively more fall in the upper Cypress Creek watershed, with natural land slopes of about 10-20 feet per mile, as compared to the Addicks Reservoir watershed where land slopes are about 4-6 feet per mile.

There are a number of agricultural berms in the watershed. Furthermore, many of the existing roadways are elevated slightly above natural grade and effectively serve as berms. Exhibit C1.4 shows the location of roadways and other berms in the study area.

1.1.4 Streams and Flood Plains

A large portion of the Upper Cypress Creek watershed drains to Mound Creek, which forms the headwaters of Cypress Creek. Mound Creek drains south, originating upstream of US-290 near the City of Waller, and then draining south for a distance of about ten miles to its confluence with Snake Creek. The confluence of Mound Creek and Snake Creek forms the headwater of Cypress Creek, which continues to drain southward for about three miles until it makes an abrupt turn to the northeast. As Cypress Creek travels to the northeast and then gradually toward the east, it receives flow from the north via a number of tributaries, including HCFCD Unit No. K172-00-00, K160-00-00 (Rock Hollow Branch), K157-00-00, and K155-00-00. After making the turn to the northeast, Cypress Creek flows for about 14 miles until it crosses US 290, and extends another 33 miles downstream to its confluence with Spring Creek.

The Addicks Reservoir was constructed by building a dam across two channels – Langham Creek and Turkey Creek. Langham Creek includes four major tributaries: South Mayde Creek, Bear Creek, Horsepen Creek, and Dinner Creek.

The location of the main channels in the study area, along with Addicks Reservoir, is shown on Exhibit C1.5. Most of the streams in the Cypress Creek watershed are natural, although the main channel of Cypress Creek was channelized in the 1950's. Since that time, it has become incised and unstable, has re-vegetated, and appears natural.

Most of the channels in the Addicks watershed, particularly those in the developed portion of the watershed, have been deepened and straightened. A bypass was constructed along Bear Creek to divert flow around a large meander and increase capacity in as it flows into Addicks Reservoir. Within Addicks Reservoir, the channels remain natural.

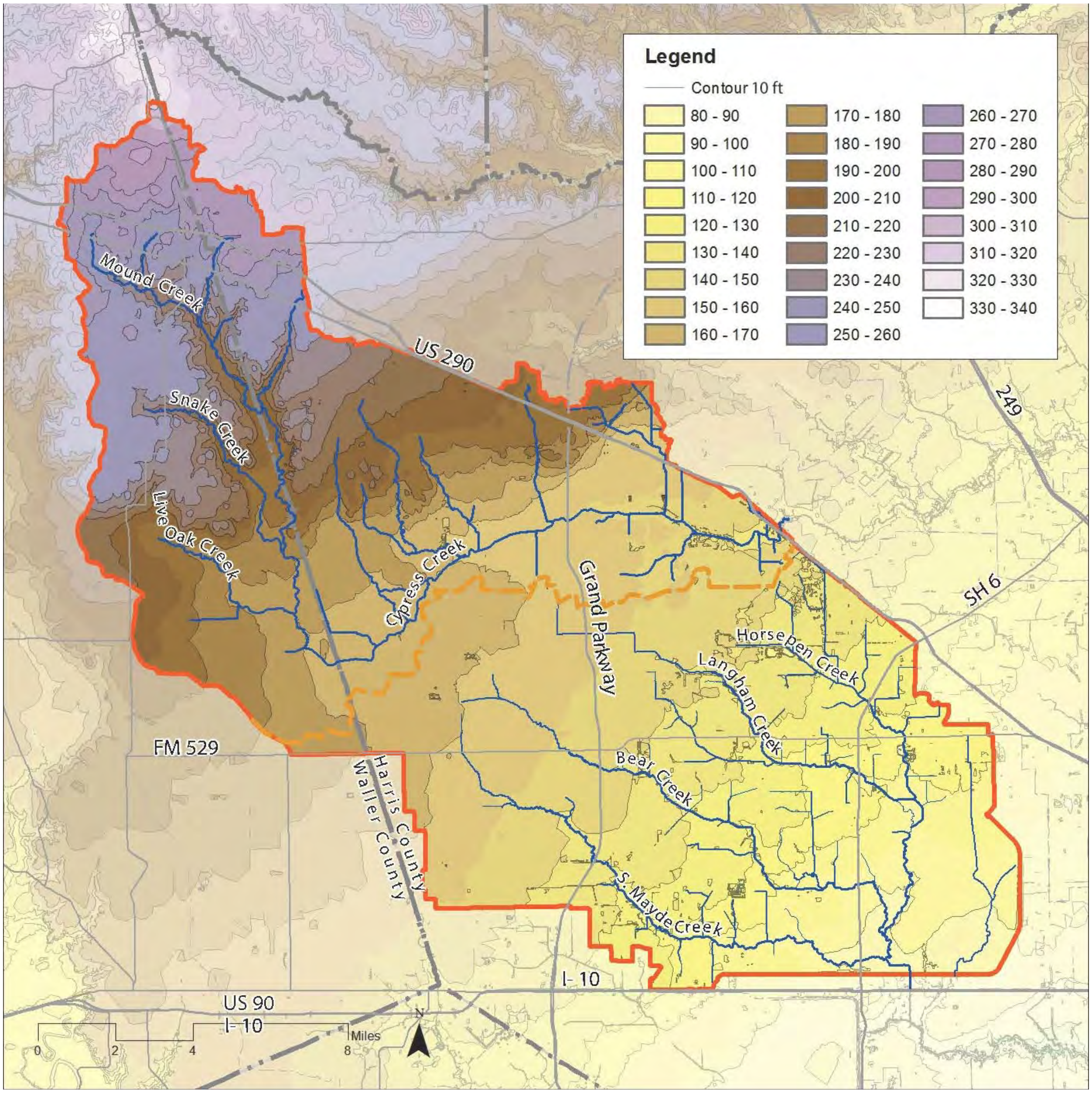


Exhibit C1.3
Topography

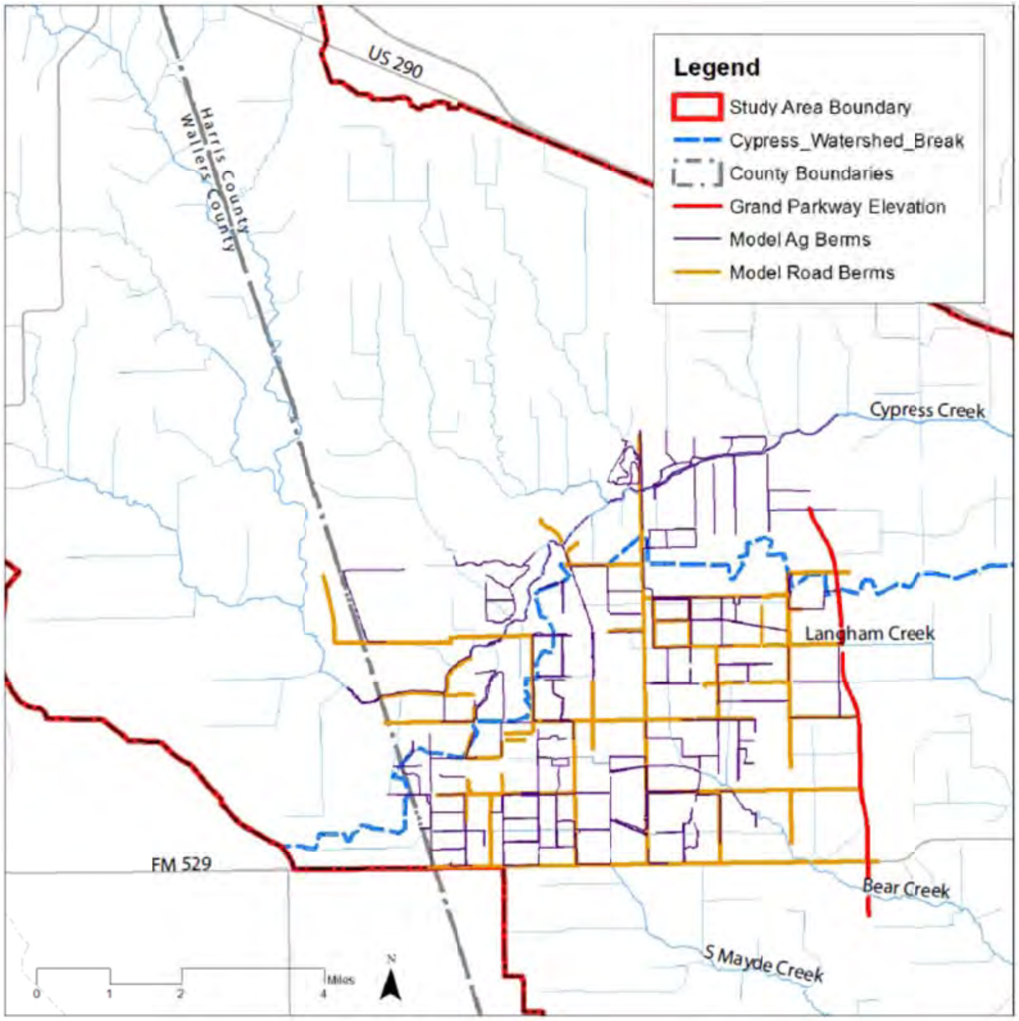


Exhibit C1.4
Roadways and Berms

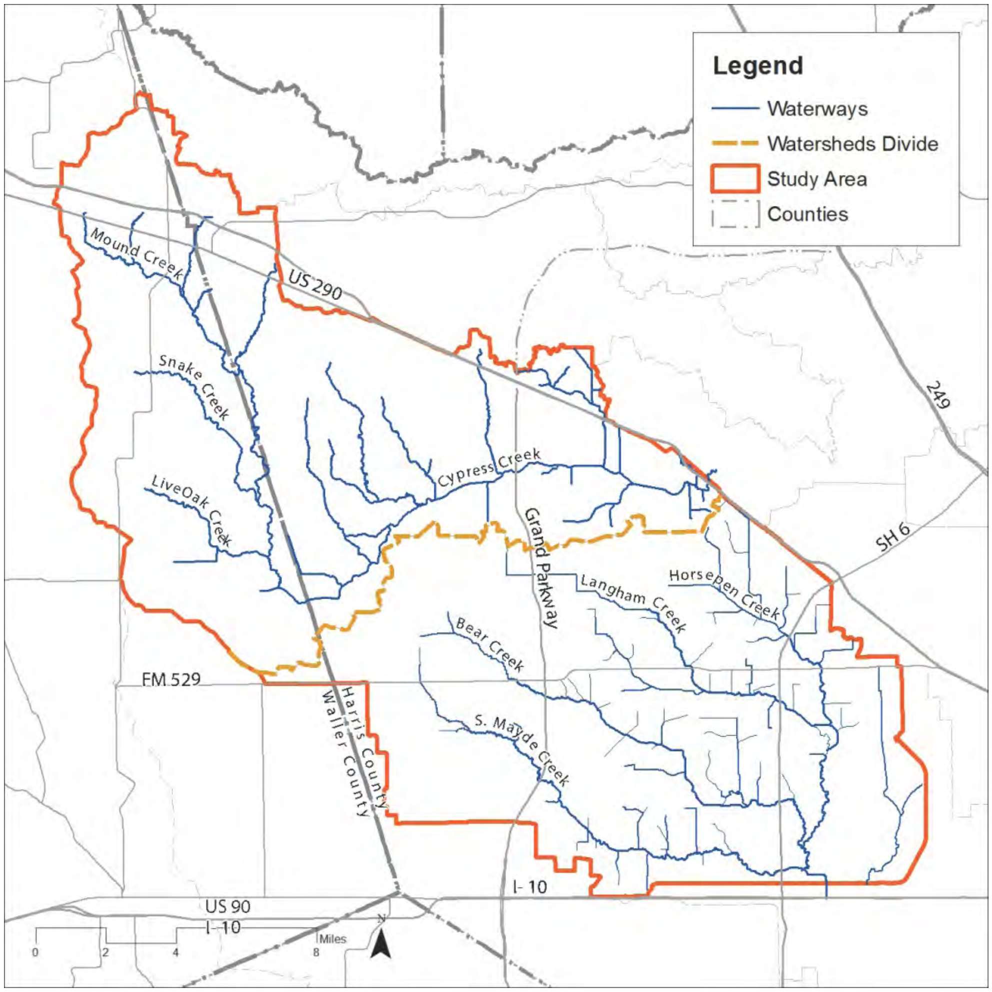


Exhibit C1.5
Channels in the Study area

Exhibit C1.6 shows the 100-year floodplains in the study area as depicted on the effective Flood Insurance Rate Maps (FIRMs). There are large natural floodplains in the Cypress Creek watershed, and smaller out of bank floodplain in the Addicks Reservoir watershed, primarily to the modifications of the channels. There has been historic flooding in the developments along South Mayde Creek, Bear Creek, and Horsepen Creek. The floodplain maps for these channels depict some out of bank flood risk during 1% event, particularly along South Mayde Creek. There is also a large overflow floodplain associated with the overflows from the Cypress Creek watershed to the Addicks Reservoir watershed.

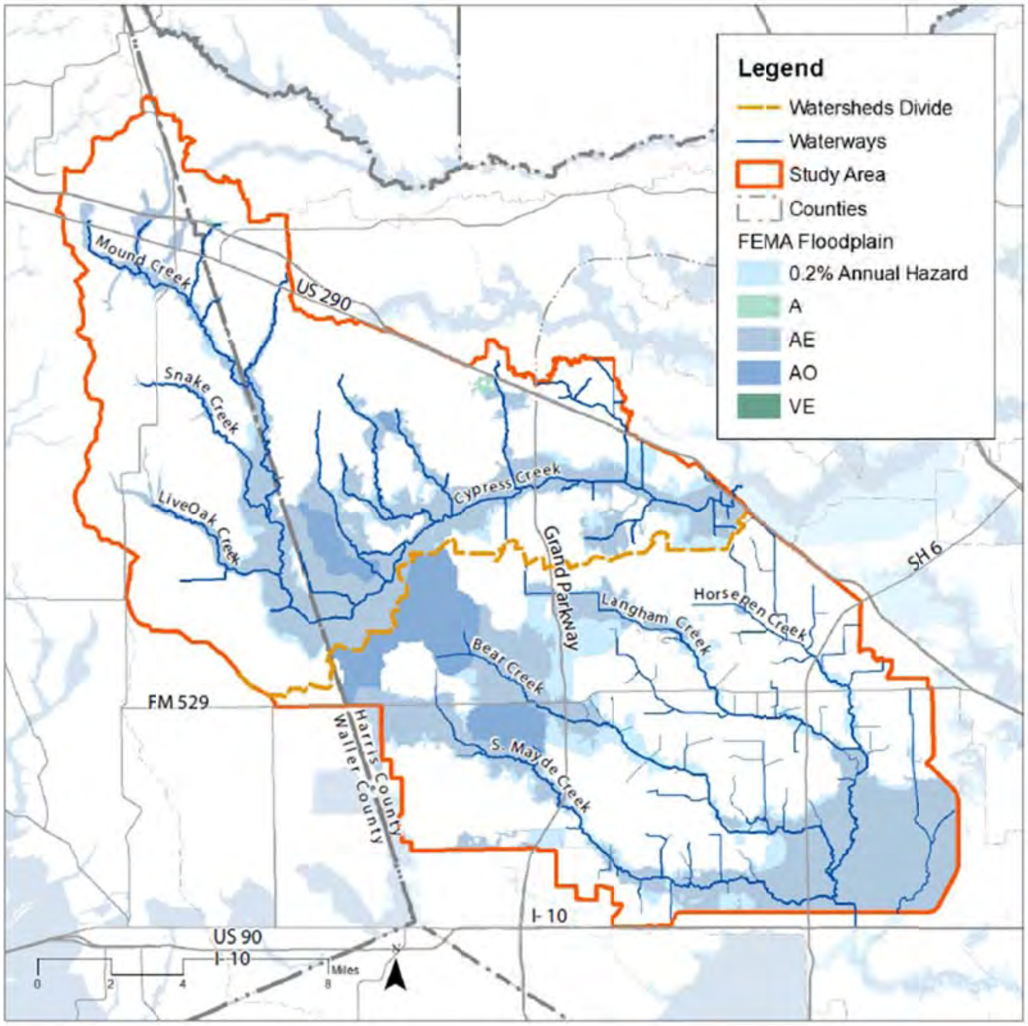


Exhibit C1.6
Effective Special Flood Hazard Areas (from FIRM Panels)

1.1.5 Wetlands

The study area consists of natural wetlands associated with the coastal prairie. Many of these are known as “prairie potholes”, which are natural depressions common in the coastal prairie. Other wetlands have been created by agricultural uses such as rice farming. Exhibit C1.7 shows the wetlands depicted in the U.S. Fish and Wildlife’s National Wetland Inventory (NWI). As the exhibit indicates, there are many small scale wetlands dispersed throughout the study area.

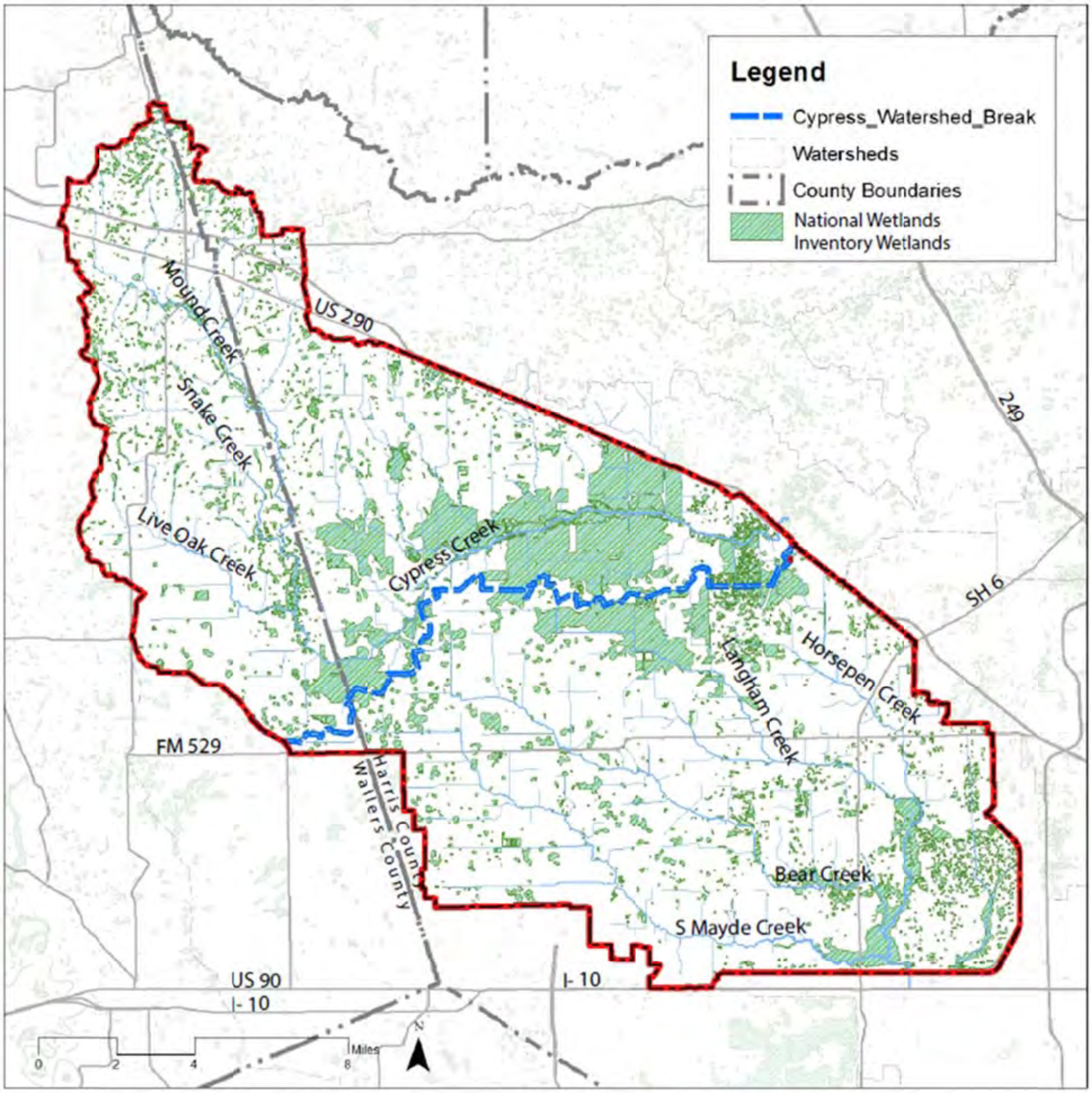


Exhibit C1.7
Wetlands in the Study Area (Source: U.S. Fish and Wildlife NWI)

1.1.6 Land Use

Exhibit C1.8 depicts the land use as of 2013 in the study area. The majority of the study area is undeveloped, although about 55 square miles are developed. Most developed land is concentrated in the eastern and southern portion of the study area, in areas closer to the urbanized portion of the Houston metropolitan area. Most development is single family residential, with commercial and retail along the primary corridors.

The undeveloped land is primarily agricultural, with a combination of ranch land and row crops. Historically, much of the area was used for rice farming, however much of this agricultural use has converted to corn in the past twenty years. Rice farming required the construction of agricultural berms to facilitate flooding of the rice fields. As these farms have converted away from rice, some of the berms have been removed, or at least the berms have been "broken" in places.

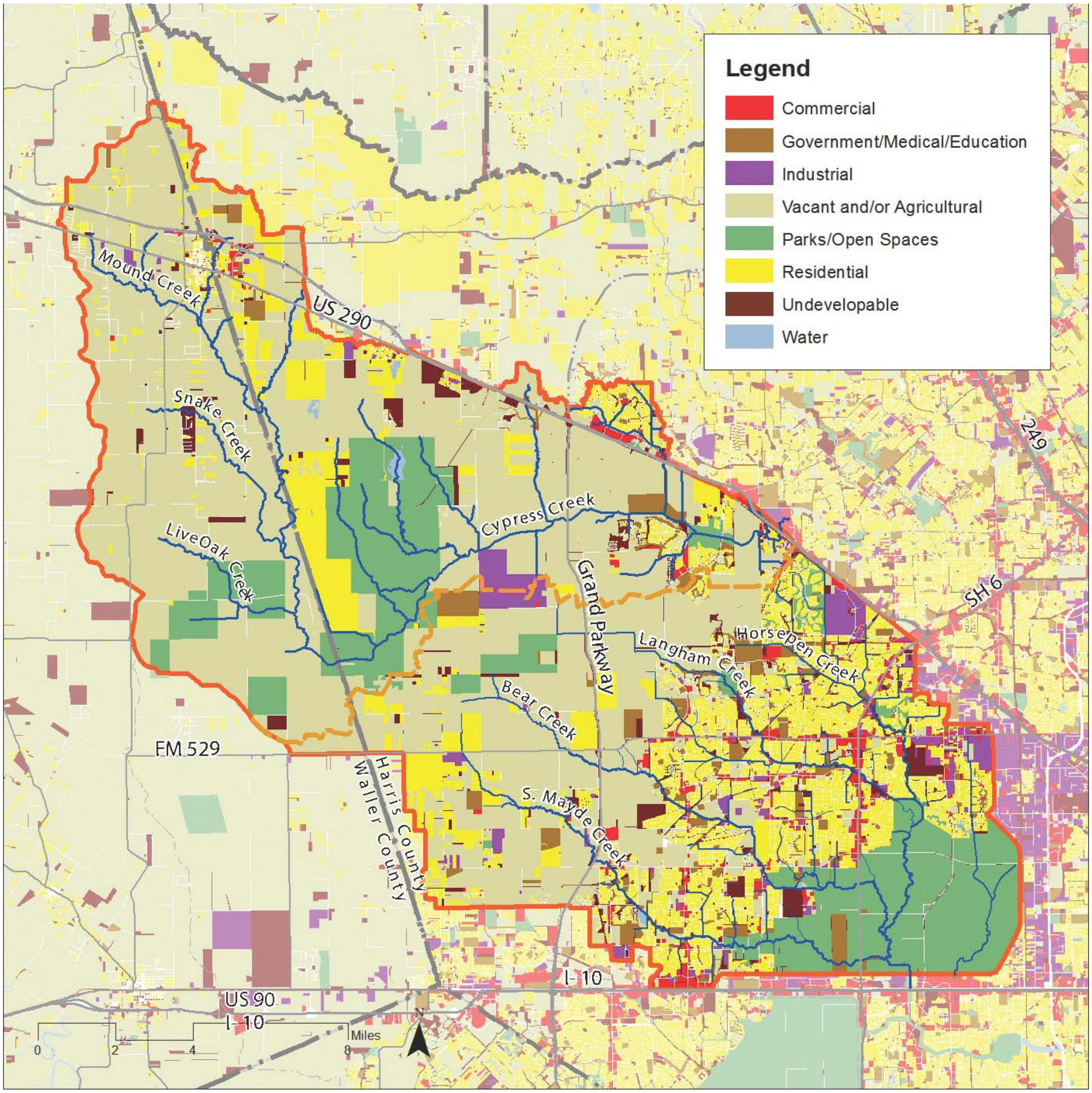


Exhibit C1.8
Land Use in the Study Area (Source: Houston-Galveston Area Council)

1.1.7 Hydrology

The study area is known as an area of poor natural drainage due to the flat topography, numerous wetlands, agricultural berms, rice farming, and native prairie. When the Harris County Flood Control District Clark Unit Hydrograph Methodology was developed in the 1980's, engineers found it necessary to include a ponding component into many of the subareas within the study area in order to accurately reflect the drainage characteristics. The natural and agricultural features, while inhibiting drainage, provide a natural attenuation and relief to downstream flow rates – providing a flood control benefit to the downstream watershed. Native prairie grasses are known to develop deep and robust root systems that open up the notoriously poorly draining clay soil characteristic to the Texas coastal plain, and substantially increase the ability of the soil to absorb runoff. This is presented in greater detail in Appendix D.

1.1.8 Transportation

The location of highways and major roadways is shown on Exhibit C1.9. There are three existing major grade separated highways in the study area. US 290 runs from the southeast to the northwest, and mostly defines the northern and eastern boundary of the study area (Mound Creek drains a small area north of US 290 to the south). Interstate 10 runs east-west, and is generally located along the southern boundary of the study area. Segment E of the Grand Parkway was constructed in 2012 and 2013, and opened in 2014. Segment E runs north-south through the study area, and connects Interstate 10 and US 290.

Arterial roads are generally planned on a one-mile grid. Major east west roadways are Little York, Clay Road, FM 529, Longenbaugh Road, and West Road. Major north-south roadways are FM 362, State Highway 6, Katy-Hockley Road, and Fry Road. Much of the road grid in the undeveloped areas has not been constructed. Exhibit C1.10 shows the layout from the Houston-Galveston Area Council's (H-GAC) Major Thoroughfare Plan (MTP). This plan, which has been adopted by cities and counties in the region, forms the basis for roadway planning activity.

There are a number of small commuter airports. The most prominent airport is West Houston airport, located along Bear Creek just west of SH 6 and Addicks Reservoir. There is an abandoned railroad trestle east of and parallel to Katy-Hockley Road. There are no active railroads in the study area.

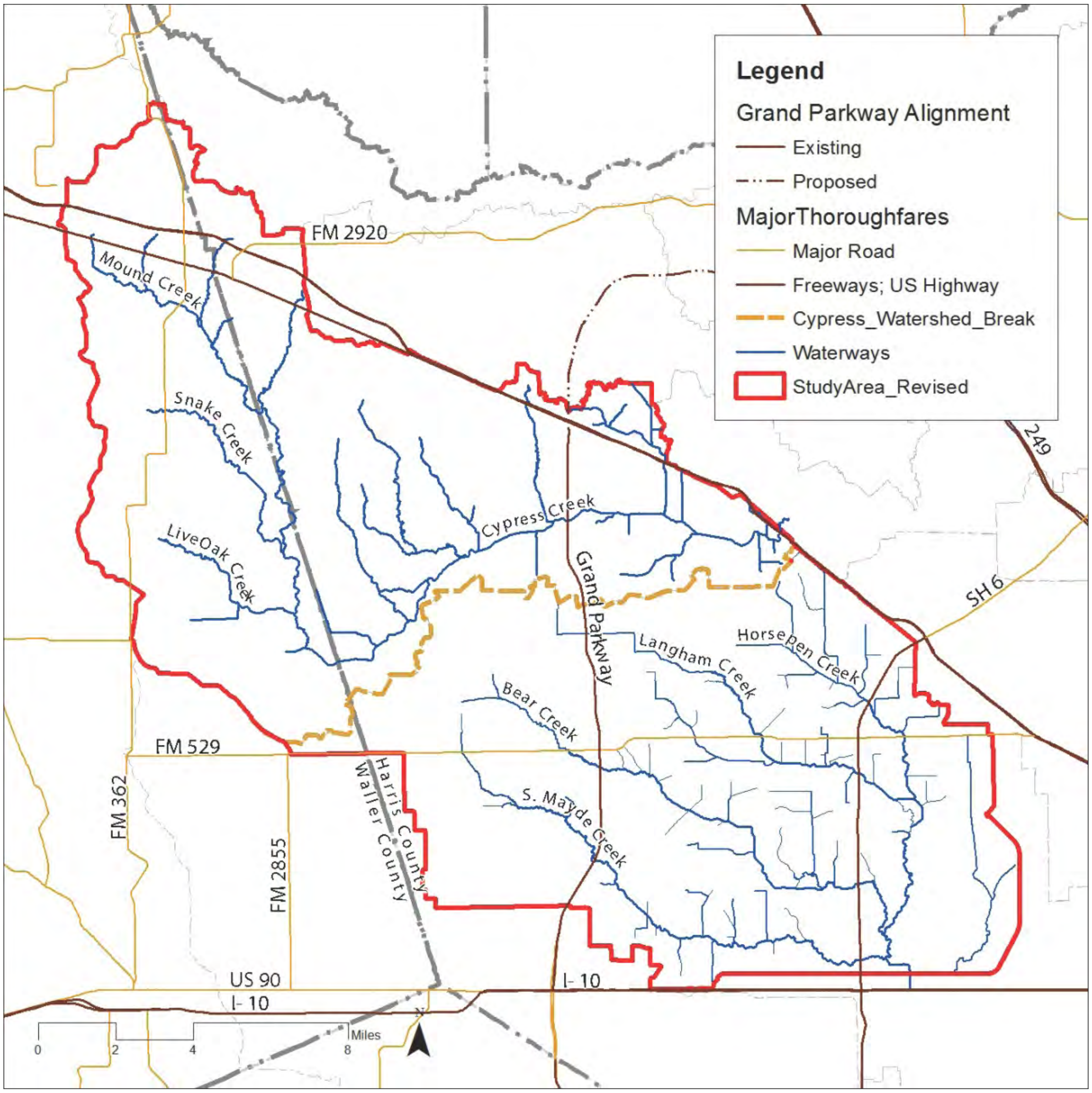


Exhibit C1.9
Major Roadways in the Study Area

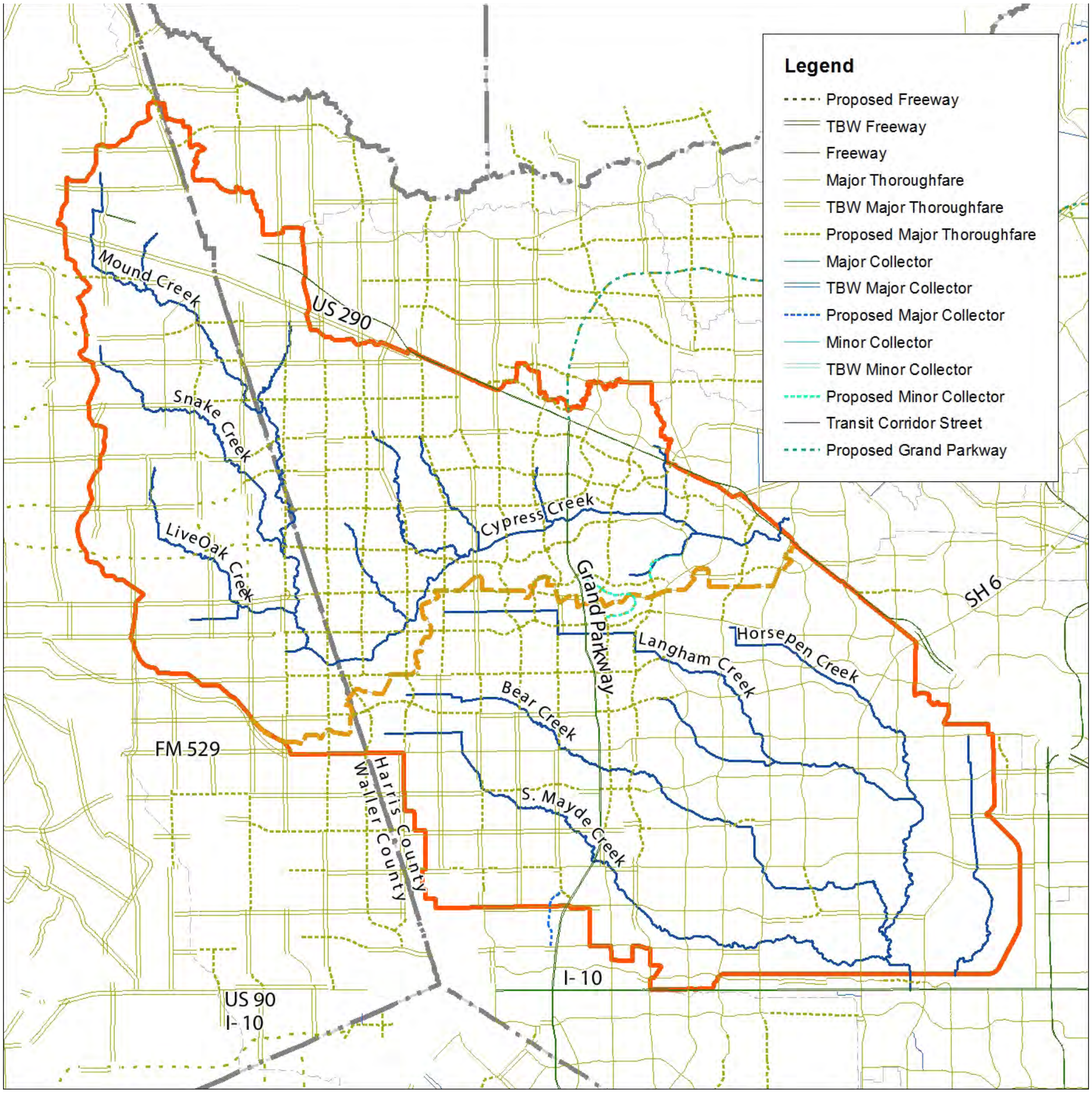


Exhibit C1.10
2011 Major Thoroughfare Plan

1.1.9 Addicks and Barker Reservoirs

Addicks and Barker Reservoirs were constructed by the U.S. Army Corps of Engineers (USACE) in the 1940's as a major component of the Buffalo Bayou and Tributaries flood control plan as authorized by the River and Harbor Act of 1938, and modified by the Flood Control Acts of 1939 and 1954. The reservoirs are part of a larger scheme to reduce flood risk in downtown Houston and the Houston Ship Channel, as both experience devastating floods in 1929 and 1935.

The original plan included a third reservoir, White Oak Reservoir, along with canals to the north and south of Houston, and to prevent flood flows from Cypress Creek from leaving the Cypress

Creek watershed. Flow from the reservoirs was un-gated, but the outflow structure limited the combined flow from the two reservoirs to 15,700 cfs. This original plan is depicted in Exhibit C1.11.

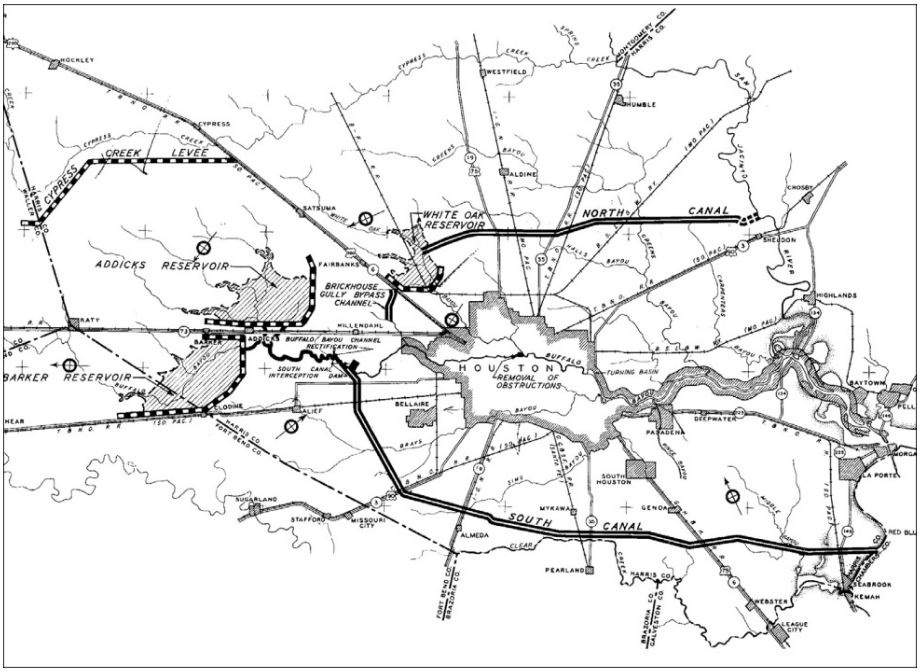


Exhibit C1.11
Buffalo Bayou Flood Control Plan (1940)

National priorities during and after World War II changed, resulting in modifications to the plan. The north and south canals were eliminated, and were replaced by channel enlargements along Buffalo Bayou. The levee along the Cypress Creek watershed divide was eliminated, as it was determined that it would be more economical to acquire additional land for Addicks Reservoir (land equivalent to three vertical feet was acquired, as it was determined that flow from the Cypress Creek watershed would increase the reservoir inundation by one-third).

Gates were placed upon both reservoirs to limit flows. In 1968, the USACE was directed to abandon the plan to modify Buffalo Bayou. As a result, they modified operations of the gates to limit the combined flow from both reservoirs to 2,000 cfs as measured at a gauge along Buffalo Bayou downstream of the reservoir, at Piney Point Drive. During rainfall events (or anticipated events), the gates are closed to allow Buffalo Bayou to receive and convey local flows. When gates are open, flows are restricted to 2,000 cfs. Exhibit C1.12 shows the location of Addicks and Barker Reservoirs.

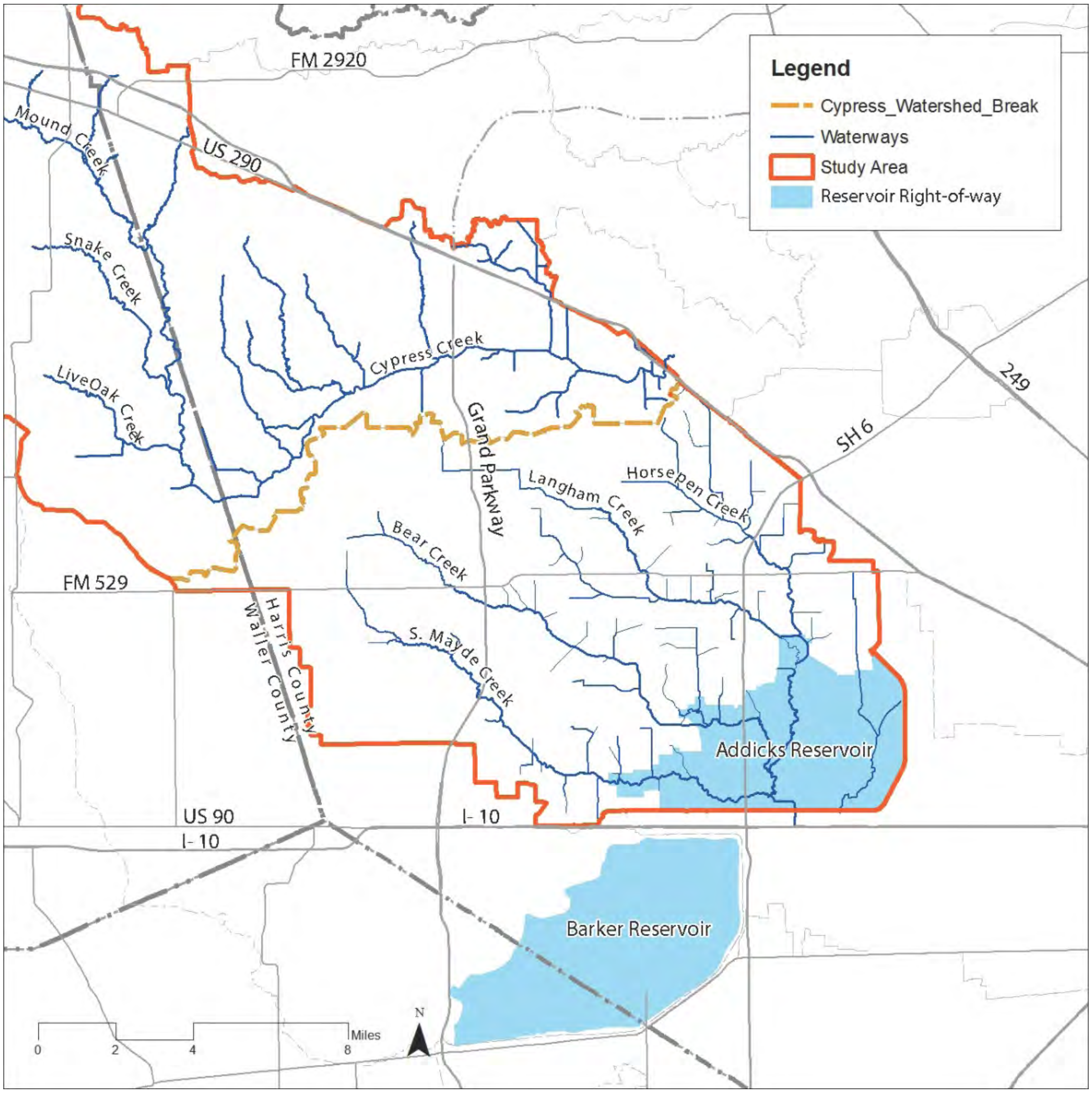


Exhibit C1.12
Addicks and Barker Reservoirs

This restricted operations results in much higher expected pool elevations than originally planned by the USACE. In addition, there has been considerable development in areas outside of the land acquired for the reservoirs but that is well below the height of the dams. For Barker Reservoir, the reservoir 1% (100-year) pool elevation exceeds government owned land. For Addicks Reservoir, the 1% (100-year) pool elevation is contained within government owned land. However, a larger event could inundate property outside the reservoir boundary that is below the elevation of the reservoir spillways. Exhibit C1.13 depicts the relevant water surface elevations for Addicks Reservoir.

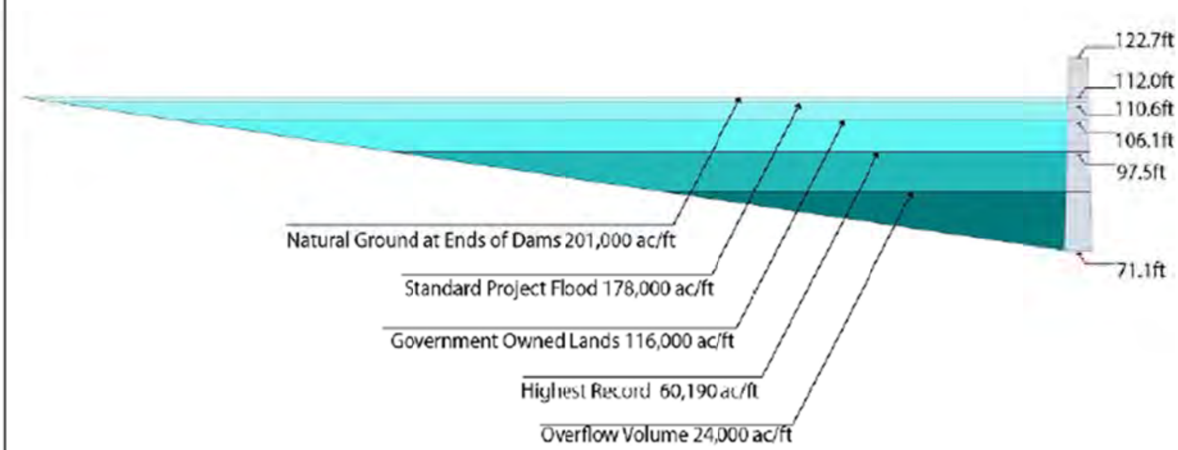


Exhibit C1.13
Addicks Reservoir Levels

Current land development restrictions aim to restrict the increase in peak discharges in channels and into Addicks and Barker Reservoir as land development activities occur. This is generally accomplished via the construction of detention basins, which temporarily hold runoff and meter it out at pre-development flow rates. However, the installation of impervious surfaces associated with land development increase runoff volume. Detention basins only address the rate of runoff and do not address the quantity of runoff. As development occurs, it is expected that additional volume will drain into the reservoir, increasing the projected pool elevation in both reservoirs.

Addicks and Barker Reservoir are addressed in greater detail in Appendix B. Increases in runoff volume due to land development activities are discussed in Appendix B and Appendix D.

1.1.10 Parks

There are a number of parks within the study area. In particular, there are three major parks operated by Harris County Precinct 3.

Bear Creek Pioneers Park is located within Addicks Reservoir. The park occupies over 2,000 acres, and includes ball fields, a picnic area, golf courses, a wildlife habitat, trails, and other features. The park is influenced by elevations in Addicks Reservoir. During large storage events, park facilities and roadways are inundated, and it is necessary to relocate wildlife to higher ground.

Paul Rushing Park is located on 232 acres along Katy Hockley Road in the Addicks Reservoir watershed. The park facilities include ball fields, a dog park, a chain-of-lakes, wildlife viewing area, a playground, and other features. The park is within the area subject to flooding from the Cypress Creek overflow.

John Paul's Landing (JPL) is a future Precinct 3 park located near the intersection of Katy-Hockley Road and Sharp Road. It occupies over 800 acres, and will consist of large lakes that will provide a recreational amenity while also serving to store stormwater. A portion of John Paul's Landing is within the area that may be inundated from the Cypress Creek overflow.

1.1.11 Population and Growth

As part of its Region H water supply planning, the Texas Water Development Board (TWDB) developed population growth projections throughout the Region. Based upon the data from these projections, the 2010 population within the study area is about 101,000 people. The concentration of this population is in the eastern portion of the Addicks watershed, along the Interstate 10 corridor, and to a lesser extent along the US 290 corridor.

Outward development and growth from the Houston metropolitan area is encroaching upon the study area, and there is a current and future demand for new housing. The opening of the Grand Parkway will provide transportation access to many undeveloped acres, and will allow the undeveloped land in the study area to better meet the growth demand. The TWDB projections through 2040 are presented in Table C1.1. They show that the population in the study area is projected to increase: to about 459,000 in 2020 (an increase of 146,000 from 2010); to 505,000 in 2040 (an increase of 192,000 from present); and, to 535,000 in 2060 (an increase of 222,000 from present). Based upon these projections, the population in the study area is anticipated to increase by almost 250%. The majority of this growth is expected to be concentrated in the next ten years.

Table C1.1
Study Area Population Projections

Year	Population
2010	313,000
2020	459,000
2030	482,000
2040	505,000
2050	522,000
2060	535,000

Source: TWDB Region H Projections

Table C1.2 converts the population growth to land growth. This conversion assumes 2.4 persons per unit, and 2 units per acre. Based upon this, approximately 40,000 acres will be developed within the study area by 2040. Furthermore, much of this development will occur in the near-term, with an expected development of over 30,000 acres by 2020.

Table C1.2
Study Area Growth Projection

Year	Population	Units	Acres	Acreage Increase
2010	313,000	130,417	65,208	-
2020	459,000	191,250	95,625	30,417
2030	482,000	200,833	100,417	35,208
2040	505,000	210,417	105,208	40,000
2050	522,000	217,500	108,750	43,542
2060	535,000	222,917	111,458	46,250

Future growth is anticipated to progress along the major transportation corridors such as the Grand Parkway and US 290, as the natural progression of growth is outward from the center of the metropolitan area. Typical growth patterns begin with single family developments, mostly driven by large master planned communities. Where population grows, schools, multi-family, retail, and commercial development follow. Based upon this, much of the near-term growth will occur in areas subject to the Cypress Creek overflow.

1.1 Problem Description

Much of the study area is subject to inundation from occasional flooding. As growth occurs land development activity will attempt to recover land from the flood plain in a manner consistent with growth patterns throughout the Houston area. While development criteria of the Harris County Flood Control District (HCFCD) and Harris County has been developed in a manner to ensure that this development does not aggravate or increase flood risk, much of the study area is influenced by a large, shallow overflow floodplain when flood flows along Upper Cypress Creek exceed the watershed divide and overflow toward Addicks Reservoir. This situation is unique, and current development criteria have not been developed with consideration of this phenomenon. Given the nature of the overflow, including the large volume of flow associated with it, ad hoc solutions at an individual development level may be difficult to plan, analyze, and monitor. The end result may not be sustainable.

Overall, the problem is multi-faceted, and can be summarized as follows:

- Significant land development activity is projected over the next 10 years in the study area, portions of which are subject to frequent inundation from the Upper Cypress Creek watershed overflows to the Addicks Reservoir watershed (see Appendix A). Current land development criteria are not tailored to this phenomenon, and mitigation requirements are unclear.

- Portions of the study area, many of those in the epicenter of immediate development pressure, are subject to frequent inundation from overflows from the Cypress Creek watershed to the Addicks Reservoir watershed. Ad-hoc solutions to the overflow, at an individual development level, may not provide a sustainable or economical solution to the overflow flooding.
- The Katy Prairie is an endangered environmental resource that includes natural features that provide a measure of flood relief downstream. There are active interests, including the Katy Prairie Conservancy, that are trying to protect and preserve portions of the Katy Prairie. These efforts are aligned with the goal to reduce flood risk (See Appendix D).
- The Addicks and Barker reservoirs have limited capacity, their outflows are restricted, and they do not have capacity to receive additional runoff volume. Current criteria are geared at maintaining peak flow rates into the reservoirs, but development activity under existing criteria will increase the volume of runoff and the expected pool elevations associated with flood events (see Appendix B).
- The Cypress Creek watershed, including areas downstream of the study area, has a history of flooding. Cypress Creek is unable to accept additional flows, including any additional flows that would result from accepting flow that currently goes to the Addicks Reservoir watershed.

1.2 Previous Studies

There have been many studies that relate to and consider the current flood risk in the study area. These are presented in this section, with a brief summary.

1.3.1 Buffalo Bayou Project Plan (1940)

The U.S. Army Corps of Engineers developed the Buffalo Bayou Project Plan as part of the original Buffalo Bayou and Tributaries project pursuant to the Flood Control Act of 1936 and in response to flood events in 1929 and 1935. This plan called for a number of measures to reduce flooding in downtown Houston, including three reservoirs (Addicks, Barker, and White Oak), channelization of Buffalo Bayou from the reservoirs to the ship channel, a North Canal to the San Jacinto River, a South Canal to Galveston Bay, and a levee along the Addicks/Cypress watershed divide to prevent the Cypress Creek overflow from contributing to flow in Buffalo Bayou. The plan called for Addicks and Barker Reservoirs to release a combined 15,700 cfs to Buffalo Bayou via ungagged outlets.

Addicks and Barker were subsequently constructed in the early 1940's. In addition, about six miles of Buffalo Bayou downstream of the reservoirs was widened and straightened. During pre-construction planning for Addicks Reservoir, it was determined that it would be more economical to increase the capacity of Addicks Reservoir to accommodate the Cypress Creek overflow and delete the levee at the watershed divide. Additional land was acquired to accommodate three additional feet in pool depth, increasing the volume by as the overflow volume is about one-third of the reservoir design event volume.

1.3.2 Buffalo Bayou and Tributaries – Revision (1952)

The original project plan was reviewed by the USACE in 1952. They concluded that rising land cost and rapid development made the construction of the White Oak Bayou reservoir and the North and South Canals impractical. The review recommended rectification of While Oak Bayou and Brays Bayou instead, along with the already planned rectification of Buffalo Bayou. Because a measure of flood control was already being afforded to Buffalo Bayou by Addicks and Barker Reservoirs, priority was placed on the rectification of White Oak Bayou and Buffalo Bayou, and these channel projects were subsequently completed in the 1960's.

1.3.3 Addicks and Barker Reservoir Regulation Manual, 1962

The planned rectification of Buffalo Bayou was met with opposition, and in the 1960's the USACE prepared a feasibility report to consider gating the remaining conduits at Addicks and Barker Reservoirs. At that time, the non-damaging capacity of Buffalo Bayou was estimated to be 3,000 cfs, and Addicks and Barker were gated and operated to ensure that the combined discharge from the reservoirs, less tributary inflows below the dams, remained less than 3,000 cfs. The maximum impoundment in Addicks Reservoir occurred shortly thereafter, in 1968, from a storm with about nine inches of rainfall over a 72-hour period.

Subsequent to that, the non-damaging discharges estimation was reduced to 2,000 cfs and reservoir operations were revised to reflect this. That is the reservoir policy that is in place to date.

1.3.4 Flood Hazard Study (1984)

As part of an effort to perform detailed studies in support of FEMA's development of FIRMs for Harris County, HCFCD completed the Flood Hazard Study. This study included the development of a hydrologic methodology to determine peak flow rates along the streams and channels in Harris County which led to the hydrologic and hydraulic modeling used to establish Base Flood Elevations and the delineations of Special Flood Hazard Areas. The Flood Hazard Study utilized a distributed 24-hour rainfall in Harris County, exponential loss rates, and the Clark Unit Hydrograph methodology to compute hydrographs for subwatersheds. Equations for the Clark Unit Hydrograph parameters TC (time of concentration) and R (storage) were developed from an empirical analysis of recorded rainfall and stream flow in Harris County. In addition, certain areas were determined to have additional influence from agricultural activities that pond water. For these areas, which are prominent in the Upper Cypress Creek watershed, a methodology was developed to address the Clark Unit Hydrograph R parameter based upon the amount of ponding in the subwatershed. The Flood Hazard Study estimate that the peak rate of overflow from the Cypress Creek watershed to the Addicks Reservoir watershed was 8,200 cfs during a 1% (100-year) event.

1.3.5 Cypress Creek Master Plan (1986)

On behalf of HCFCD, Turner Collie & Braden prepared a master plan for the Cypress Creek watershed that considered the entire network of existing and future channels and future development. Among the stated objectives of the plan was the elimination of overflow into the Addicks Reservoir. Among the many recommendations of the resultant plan is a regional detention basin (Basin 4) located along Cypress Creek where it makes the sharp turn to the northeast (near Sharp Road). Basin 4 would be created by berms, and would inundate 4,920 acres of land during the 1% (100-year) event and provide 20,070 acre-feet of storage. This basin would eliminate the overflow from the Cypress Creek watershed to the Addicks Watershed.

The plan also recommends a regional basin (Basin 5) located on Mound Creek on the Harris-Waller county line. During a 1% (100-year) event, this basin would occupy 883 acres and store 6,785 acre-feet.

This master plan was used to establish a watershed impact fee, provide direction in coordinating land development activity, and to support the implementation of various projects. The detention features identified in the previous paragraph have not been constructed.

1.3.6 Regional Detention Project for Cypress Creek (1989)

On behalf of HCFD, Van Sickle, Mickelson, & Klein was engaged to develop a plan to refine and implement features of the master plan, including Basin 4 and 5, as described in the previous paragraph. Alternative configurations of the master plan concepts were presented. The Basin 4 configuration included a dam immediately upstream and parallel to Katy-Hockley Road, with the resultant reservoir occupying 7,743 acres. However, the features described in this plan were never constructed.

1.3.7 Addicks Watershed Master Plan (2001)

On behalf of HCFCD, Bernard Johnson, Inc. (BJI) and Lockwood Andrews & Newnam, Inc. (LAN) completed a watershed master plan for the Addicks Reservoir watershed. This plan was delivered over three phases between 1991 and 2001, and considered existing and future channels in the watershed, future development, and Addicks Reservoir itself. The studies include extensive simulation of Addicks Reservoir using HEC-5. However, difficulty in obtaining reliable operations data and limitations of the software compromised the ability to derive conclusions from the analysis.

The master plan identified a future network of channels and regional detention basins to serve future development in the area. The plan did not consider the overflow from the Cypress Creek watershed.

1.3.8 Katy Corridor Study (2000)

On behalf of HCFCD, Costello, Inc. completed a study of the potential to utilize the Interstate 10 corridor as a conduit to drain Addicks and Barker Reservoirs. This study was initiated by the Texas Department of Transportation’s (TxDOT) planning study of the Katy Freeway Corridor that ultimately led to the widening of the freeway. There were suggestions at public meetings that a drainage corridor could be installed during construction that would provide outfall for the reservoirs, as well as drainage for the Katy Freeway and areas along the Katy Freeway that have drainage issues. The conduit would extend all the way to Buffalo Bayou near Downtown.

The analysis concluded the plan was not feasible due to the cost. However, the feasibility study did result in the analysis of Addicks and Barker Reservoirs by Dr. Wurbs, as well as other studies of the reservoirs. Dr. Wurbs study, which is discussed in more detail in Appendix B, included a HEC-WMS simulation of Addicks and Barker Reservoirs, and considered future development and reservoir operations.

1.3.9 U.S. Army Corps of Engineers - Section 216 Study

After the record pool elevations in 1991, HCFCD asked the USACE to consider measures to address the flood risk associated with Addicks and Barker Reservoir. The USACE performed a Section 216 Reconnaissance Study, which is an expedited study using available data to determine the likelihood of a federal interest in a project. The study utilized updated hydrology developed by the USACE in 1977, and confirmed a risk of flood damages from flood events. However, the expected annual damages was substantially less than the cost of the various mitigation alternatives, and the study concluded there was no federal interest in a project to address flood risk upstream of Addicks and Barker Reservoirs.

1.3.10 Tropical Storm Allison Recovery Project (2007)

After flooding in 2001 associated with Tropical Storm Allison, HCFCD and FEMA partnered on a countywide study to update flood management tools, including topography, benchmarks, models, and floodplain maps. The emphasis of this project was to modernize the flood risk management tools, and the project resulted in new models and maps in Harris County, including the portion of the study area in Harris County.

The study, known as the Tropical Storm Allison Recovery Project (TSARP), resulted in a refined understanding of the flooding in the study area. In addition, additional adjustments to the models as part of a post-TSARP Physical Map Revision predicted higher flood elevations along Upper Cypress Creek and higher overflow discharges and volumes.

1.3.11 Waller County Master Drainage Plan

On behalf of Waller County and the TWDB, Halff & Associates developed a master drainage plan for Waller County. This plan considers a number of elements, including updates to floodplain mapping and development criteria. The master drainage plan also identified and quantified drainage concerns, and considered a number of structural and non-structural solutions. A number of potential regional detention sites were identified, including several along Cypress Creek tributary channels just north of US 290, as well as along Mound Creek and Mound Creek tributaries south of US 290.

1.3.12 Upper Langham Creek Master Drainage Plan

On behalf of HCFCD, Brown & Gay developed a master plan for Upper Langham Creek. This master plan proposes a wide “frontier” channel with online detention within the corridors. An impact fee program has been developed but has not been adopted. Development guidelines in support of the plan have also been developed.

2.0 Planning Framework

The formulation of mitigation strategies is a deliberate process designed to arrive at an optimum set of mitigation strategies the appropriately consider the spectrum of problems and opportunities. The development of a planning framework helps to clarify and organize complex problems to assist in the development, evaluation, and adoption of strategies. The planning framework for the Cypress Creek overflow study includes an acknowledgement of the planning setting, the establishment of planning objectives and constraints, and the identification of opportunities afforded by the project.

2.1 Planning Setting

The planning setting refers to all factors inclusive and contributing to the planning activity, including location, time, and people.

2.1.1 Geographical Focus

Section 1.1 presents a detailed description of the study area associated with this planning study. Within this study area, there is a geographical focus on (1) the area associated with the overflow from Upper Cypress Creek to Addicks Reservoir, (2) Preservation lands and future preservation lands, (3) Addicks Reservoir, and (4) areas utilized for various mitigation measures.

The Cypress Creek overflow inundates approximately 20,800 acres of land. During a 1% (100-year) event, it conveys approximately 23,355 acre-feet of runoff at a peak flow rate of 12,678 cfs. Exhibit C2.1 depicts the area subject inundation from the overflow during a 1% (100-year event).

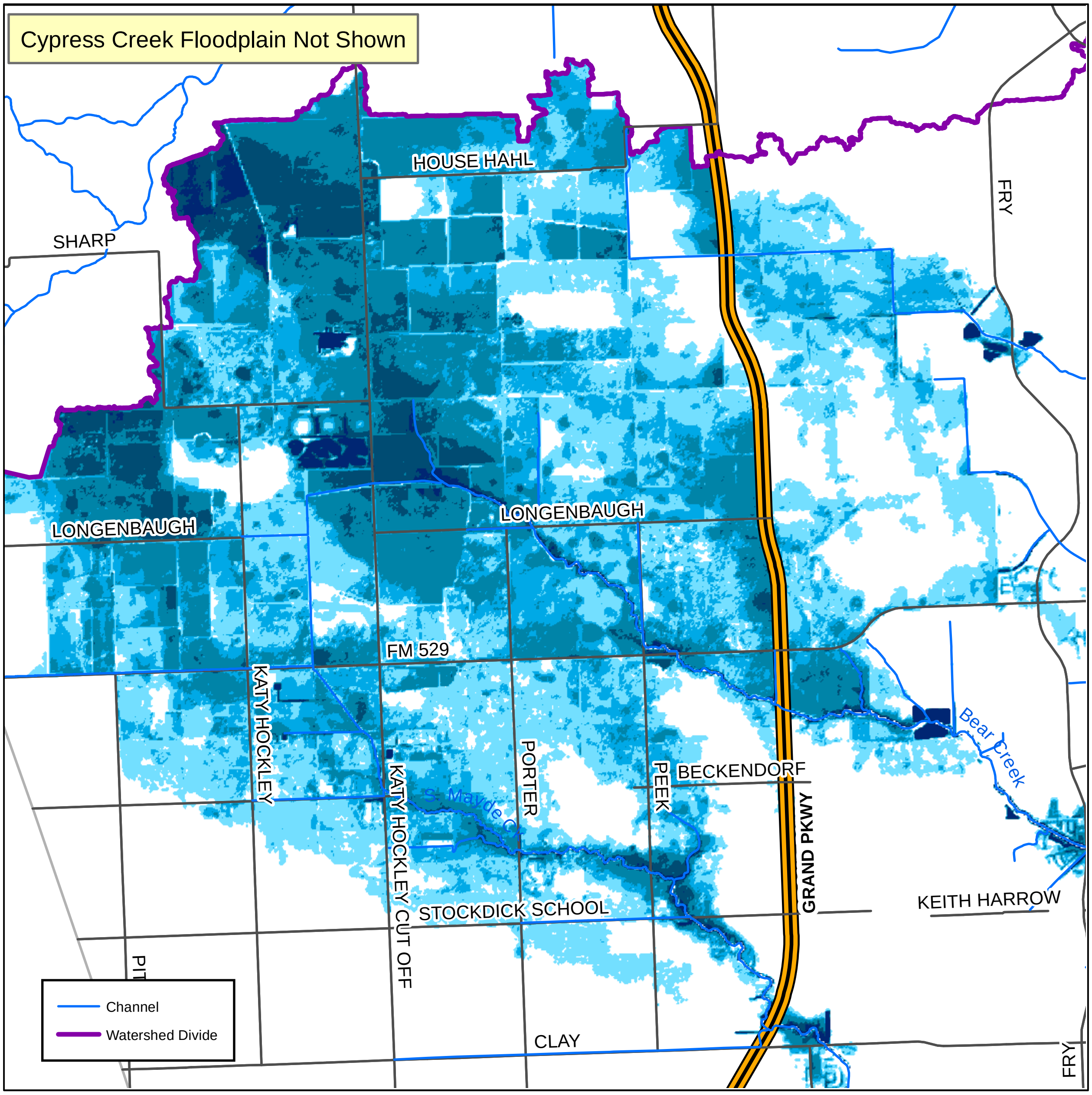


Exhibit C2.1
Cypress Creek Overflow – Area Subject to Inundation from a 1% (100-yr) Event

2.1.2 Analysis Period

Based upon the population and growth projections presented earlier, the study area is expected to see a substantial growth over the next twenty years. During this time period, the vast majority of the area impacted by the overflow will be subject to land development pressure and will likely build out. A reasonable analysis period for a study of this nature is 50 years, and since it is likely that the area of concern will fully develop in this period, the "future" condition in study area assumes full development.

2.1.3 Project Sponsor

This study is being conducted by the HCFCD with a planning grant from the TWDB. The determination of the role of the HCFCD, if any, could be an output of this study or be determined at a later date. The overarching goal is to identify if a regional solution is desirable, and if so, to identify the regional solution(s) and then identify the roles and responsibilities of the various parties.

2.1.4 Cypress Creek Overflow Project Steering Committee

The HCFCD invited a number of parties to participate in the Cypress Creek Overflow Steering Committee (Steering Committee) to oversee and direct the planning study. A specific criterion was utilized to determine eligibility for membership. A member:

- Has made, or had the capability to make, a major investment in property in the study area
- Has the ability to regulate or prepare policies to regulate the use of land within the study area
- Has already developed a master plan for a major portion of the study area
- Has the ability to construct major public infrastructure projects in the study area
- Is willing to work in a collaborative environment with other steering committee members to reach a consensus master plan for drainage and flood control
- Can dedicate the time to complete the study on schedule

The Steering Committee met biweekly starting in June, 2011. The critical framework items were developed by the project team in close coordination with the Steering Committee, and the Steering Committee was instrumental is supporting planning activities discussed throughout this appendix. The Steering Committee, including its constituent membership, is discussed in more detail in Appendix H. Organizations represented included TWDB, HCFCD, Harris County Public Infrastructure Department, Harris County Precinct 3, Harris County Precinct 4, the City of Houston, USACE, Waller County, the West Houston Association, the Katy Prairie Conservancy, and the Bayou Preservation Association.

2.1.5 Stakeholders

Stakeholders are those who are strongly influence by a project, or those who may strongly influence the project. Many of the largest stakeholders are represented on the Steering Committee. However, a more comprehensive Stakeholder Committee was developed for the purpose of providing occasional briefing throughout the project. Membership of this committee included neighborhood groups, advocacy groups, environmental interest, and other interested parties.

A more detailed discussion of the Stakeholder Committee is presented in Appendix H.

2.1.6 General Public

Public communication was provided via the HCFCD website, which provided occasional updates and summaries of public meetings and by public meetings held to provide an overview of the study, answer questions, and receive comments. The TWDB grant required three public meetings be held. These meetings are summarized in Appendix H.

2.2 Planning Objectives

Planning objectives are specific objectives used to formulate and evaluate alternative strategies. These are different that overall study goals and objectives, which provide a more comprehensive overview regarding the general purpose of the study activity. In contrast, planning objectives are specifically directed at management strategies, and management strategies are evaluated based upon how well they address the planning objectives without violating planning constraints.

The primary motive of the planning objectives is to address the flood control benefit of the resultant strategy. However, motives of other stakeholders are relevant as well, as meeting multiple needs will encourage funding participation by others.

The planning objectives utilized in this study are as follows:

2.2.1 Objective 1 – Overflow Management

Identify and implement a management plan consisting of structural and/or nonstructural measures that allows for a predictable, fair, and sustainable approach for a regional management plan

The development of the overflow area is a near certainty. Current land development policy and flood plain criteria are tailored to riverine flooding. However, the unique phenomena of the large overflow area requires specific development policy and guidelines. To maintain orderly development of the area, and to avoid future drainage problems caused by a lack of overall planning, a comprehensive understanding of the challenges in implementing a public policy drainage plan is necessary. This planning effort must balance the competing interests of land use: preservation; business interests; and, environmental mitigation needs.

The Management Overflow objective strives to: (1) identify development policies that recognize the unique nature of the overflow; and, (2) identify a regional structural solution that is more economical and favorable to land utilization and development practices than individual ad-hoc solutions, assuming such ad-hoc solutions exist.

This objective, the management of the overflow, drives the planning effort. While the remaining objectives are vital to the study, this one objective underscores the overall purpose and need of the planning study.

2.2.2 Objective 2 – No Adverse Flood Risk to the Existing Communities Upstream and Downstream of the Addicks Reservoir

Estimate the impacts of future runoff on Addicks Reservoir and determine if additional development guidelines should be adopted to protect the existing communities adjacent to the reservoir.

Addicks Reservoir, as well as Barker Reservoir, does not have available capacity to accept additional runoff volume. Most of the study area drains to Addicks Reservoir, however a small portion of the Cypress Creek makes its way to Barker Reservoir via Cane Island Branch. Anticipated land development activity in the Addicks Reservoir watershed will increase the total volume of runoff into Addicks Reservoir. In addition, increased runoff volume in the upper Cypress Creek watershed will lead to a longer duration of flow that produce overflows into the Addicks Reservoir watershed, and consequently, a larger volume of overflow that will drain to Addicks and Barker Reservoirs.

The Cypress Creek Overflow Planning Study provides an opportunity to identify measures, structural and/or non-structural, to offset this anticipated increase, and even to provide for a net decrease in volume into the reservoirs.

2.2.3 Objective 3 – Conservation

Preserve contiguous green space in the study area, including the preservation and re-establishment of native prairie grasslands.

The Katy Prairie includes remnant prairie vegetation, wetlands, and agricultural practices that provide a measure of flood control to areas downstream, including Cypress Creek, the tributary channels to Addicks Reservoir, and Addicks Reservoir itself. These systems also make a positive contribution to water quality and natural habitat. There is a flood control interest in the preservation of this land. Given the countywide challenges related to flooding, HCFCD does not have the reasonable financial resources to secure vast amounts of land in the Katy Prairie nor does it have the authority to prohibit development activity that is accomplished in conformance with appropriate criteria. However, the Katy Prairie Conservancy has a stated goal to secure 50,000 acres of contiguous land within the Katy Prairie, and there is a flood control interest in supporting this goal.

2.2.4 Objective 4 – Flood Damage Reduction

Reduce existing riverine and overflow flood risk to existing structures in the study area.

The study area includes structures subject to flooding. There are riverine floodplains, and a history of flood damages, along South Mayde Creek, Bear Creek, and Horsepen Creek. There are also rural home sites in the overflow area that are subject to flooding. This objective considers the potential reduction in flood risk in the study area.

2.2.5 Objective 5 – Facilitate Projects by Other Public Entities

Implement strategies that assist others, including Waller County, Harris County Precincts 3 and 4, and Harris County PID, in the implementation of their respective plans and programs.

There are many public entities with master plans and programs that overlay the study area. Where possible, it is desirable to identify common elements between those plans and programs and mitigation strategies that support the Cypress Creek Overflow Planning Study. This will provide a greater efficiency in the delivery of public infrastructure, and will encourage a greater amount of cost sharing.

2.3 Planning Constraints

Planning constraints are outcomes to be avoided or minimized. Some constraints are absolute, and cannot be violated, while others are not absolute and mitigation strategies are evaluated on their success in minimizing violation of the constraint. The planning constraints utilized in the study area as follows:

2.3.1 Constraint 1 – Avoid Increase in Flood Risk

Avoid any action or measure that will increase the risk of flooding within, and downstream of, the study area.

This is an absolute constraint that is common to HCFCD planning studies. No measure will be considered that increases water surface elevations associated with the 1% (100-year) event unless proper provisions are included in the plan (such as property acquisition or drainage easements) that contain the 1% (100-yr) flood. The consideration of potential impacts should include simulations of the overflow independent of local flows from rainfall in the Addicks Reservoir watershed.

This constraint also recognizes that no measure or strategy will be considered that reduces flood risk associated with pool elevations in Addicks Reservoir.

2.3.2 Constraint 2 – Value

Strategies should be economically viable, with net benefits in excess of costs.

An economic analysis will be conducted for any recommended strategy to ensure that it returns benefits from its investment. A wide range of economic benefits may be considered, including flood damage reduction, intensification of land use, environmental benefits, and other tangible and intangible benefits.

Constraint 3 – Implementable

Strategies should be implementable, with a reasonable phase-in plan that recognizes cost and cash flow, funding partnerships, phasing, and near-term delivery. Implementation may not delay ongoing land development activity.

There must be a reasonable means to implement the recommended strategies. The market demand for new housing is current, and land development activity is certain in the near-term. Strategies may not delay current activity, and implementation plans must recognize this. Implementation of strategies must identify a funding source, and the plans must be implementable in a manner that recognizes the cash flows from various funding sources.

2.3.3 Constraint 4 – Compatible with Plans and Programs of Other Public Entities

Strategies must be compatible with features, plans, and program of other public entities in the study area, including Waller County, Harris County Precincts 3 and 4, and Harris County PID.

While Objective 5 strives to identify synergy between other entities and strategic measures, this constraint requires that infrastructure owned and maintained by others is not compromised as a result of any recommended strategies. If they are, the plan must include provisions to offset this, including coordination with the particular entity.

Furthermore, strategies should be in alignment with plans and programs by others and, if not, the affected entity should be engaged to determine if an acceptable refinement or revision to the plan and program can be identified.

3.0 "Do-Nothing" Strategy

This section describes the current and future condition should a "do-nothing", "structural", or "non-structural" option be taken. As such, this "do-nothing" strategy is a viable strategy, and all other management strategies will be compared to the "do-nothing" strategy, as it serves as a baseline for plan comparison and evaluation.

The "do-nothing", or "without project", scenario is discussed in greater detail in Appendix E: Cost Estimates and Benefit/Cost Determination.

3.1 Description of Cypress Creek Overflow

Flows within the upper portion of Cypress Creek, upstream of Katy-Hockley Road, begin to exceed channel banks and occupy the floodplain during events slightly smaller than the 50% (2-year) annual probability event. During slightly larger events, approximately equivalent to the 20% (5-year) annual probability event, flood flows exceed the watershed boundary between the Cypress Creek and Addicks Reservoir watersheds. As a result, some flood flows escape the Cypress Creek watershed, and sheet flows overland to the tributary channels that feed Addicks Reservoir, including Langham Creek, Bear Creek, and South Mayde Creek. In addition, a small amount of overflow is known to reach a tributary of Barker Reservoir known as Cane Island Branch. The overflow is described in more detail in Appendix A.

Overflows from Cypress Creek to Addicks Reservoir begin to occur in the vicinity of Sharp Road. This is where Cypress Creek makes the huge turn to the northwest, bucking natural grade while the natural topography continues from northwest to southeast (see Exhibit C1.3). During "smaller" overflow events, which include those up to about the 10% (10-year) annual probability event, observed water surface elevations at Sharp Road support the hydraulic model predictions of an overflow event. However, observations of water surface elevations at gauges along Bear Creek and Addicks Reservoir do not indicate that an overflow event occurred. During these events, it is likely that the overflow is dissipated in the undeveloped areas between the watershed divide and the tributary channels, and a significant volume of the overflow does not make its way to the tributary channels or the reservoir.

Exhibit C2.1 depicts the overflow inundation during a 24-hour, 1% (100-year) annual probability event. Table C3.1 tabulates key hydrologic and hydraulic parameters associated with the overflow for both the 1% (100-year) event and the 10% (10-year) event.

Table C3.1: Hydrologic Characteristics of the Cypress Creek Overflow

Parameter	10% (10-year)	1% (100-year)
Peak Flow, Cypress Creek at Sharp Rd (upstream of overflow)	7,424 cfs	18,419 cfs
Peak Flow, Cypress Creek at Grand Parkway (downstream of overflow)	1,675 cfs	5,138 cfs
Peak Flow, Overflow to Addicks watershed	3,278 cfs	12,678 cfs
Total Flow Volume, Cypress at Katy-Hockley Road	11,464 ac-ft	28,021 ac-ft
Total Overflow Volume, Overflow to Addicks Watershed	6,439 ac-ft	23,355 ac-ft
Overflow Inundation, Addicks Reservoir Watershed	8,606 ac	20,838 ac

As the table indicates, the overflow inundates almost 21,000 acres of land during the 1% (100-year) event. Table C3.2 summarizes overflow areas subject to various inundation depths.

Table C3.2: Total Area (Acres) of Overflow, by Depth

Overflow Depth (feet)	10% (10-year)	1% (100-year)
0.0 – 0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	8,606	20,838

It should be noted that this inundation also includes land areas that are also inundated by natural riverine floodplains associated with Langham Creek, Bear Creek, and South Mayde Creek. These particular areas are subject to inundation by either event. The traditional method of recovering this land for development will likely be less effective given the large volume of the overflow.

Table C3.3 depicts the total peak discharge and volume contributing to flow in each tributary, and also depicts the peak discharge from the local (non-overflow) event as it discharges into Addicks Reservoir for the 1% (100-year) event. During such an event, a total of 23,355 acre-feet overflows into Addicks Reservoir, with the majority of this volume in Bear Creek. During a local 24-hour 1% (100-year) rainfall event over the Addicks Reservoir Watershed, approximately 67,000 acre-feet is expected to drain into Addicks Reservoir. A similar event over the Upper Cypress Creek watershed will result in an overflow of approximately 23,350 ac-ft into Addicks Reservoir. Therefore, during a combined event, almost 100,000 acre-feet will be drain to Addicks Reservoir, with almost 25% coming from the Upper Cypress Creek watershed.

Table C3.3: Peak 1% Flow Rates and Flow Volumes Along Addicks Tributaries

Parameter	Addicks Watershed Rainfall (Local)		Upper Cypress Watershed Rainfall (Overflow)	
	Peak Flow (cfs)	Volume (ac-ft)	Peak Flow (cfs)	Volume (ac-ft)
Langham Creek				
At Fry Rd	1,980	3,143	394	1,580
Entering Addicks Reservoir	8,701	13,568	394	1,580
Bear Creek				
At Fry Rd	6,031	8,514	2,593	15,836
Entering Addicks Reservoir	7,959	11,899	2,593	15,836
South Mayde Creek				
At The Grand Parkway	4,473	6,627	1,918	5,939
Entering Addicks Reservoir	11,508	17,123	1,918	5,939
Addicks Reservoir				
Total Addicks Reservoir	42,731	67,005	4,905	23,355

3.2 Land Development in the Overflow Area

As noted in Section 1.1.10, the eventual and imminent development of undeveloped land in the study area is a certainty. Within the 277 square mile study area, approximately 210 square miles are undeveloped. Accounting for conservation land, the Addicks Reservoir, parkland, and other public land, 165 square miles have future development potential. Of this, about 32.5 square miles (almost 21,000 acres) are subject to inundation from the Cypress Creek overflow. Land development activity is expected in the eastern and southern portions of the study area, with most of it located in the overflow area. Exhibit C3.1 shows an aerial photograph of the study area along with the overflow, and illustrates the amount of land subject to future land development.

The inundation associated with the overflow from Cypress Creek to the Addicks Reservoir watershed presents challenges to land development activity in the areas subject to inundation. These challenges are different and more complex than those associated with traditional riverine flooding. The delineation of this area was accomplished by using an approximation method since a precise determination method is not available. Engineers will be required to demonstrate that land development projects result in no net loss of conveyance and no net increase in conveyance. This will typically require the development of a pre-project condition and post-project condition calculation.

The availability of two-dimensional models, such as the one utilized for this overflow study, are well suited for the simulation of the overflow. As such, two-dimensional models may be used to evaluate the impact of land development projects as it pertains to the overflow.

3.2.1 Development Yield

Land development activity will likely have to reserve land for the accommodation of the overflow. Furthermore, additional land and facilities will likely be required to store the overflow in order to avoid increasing the rate of conveyance of the overflows through a typical development site.

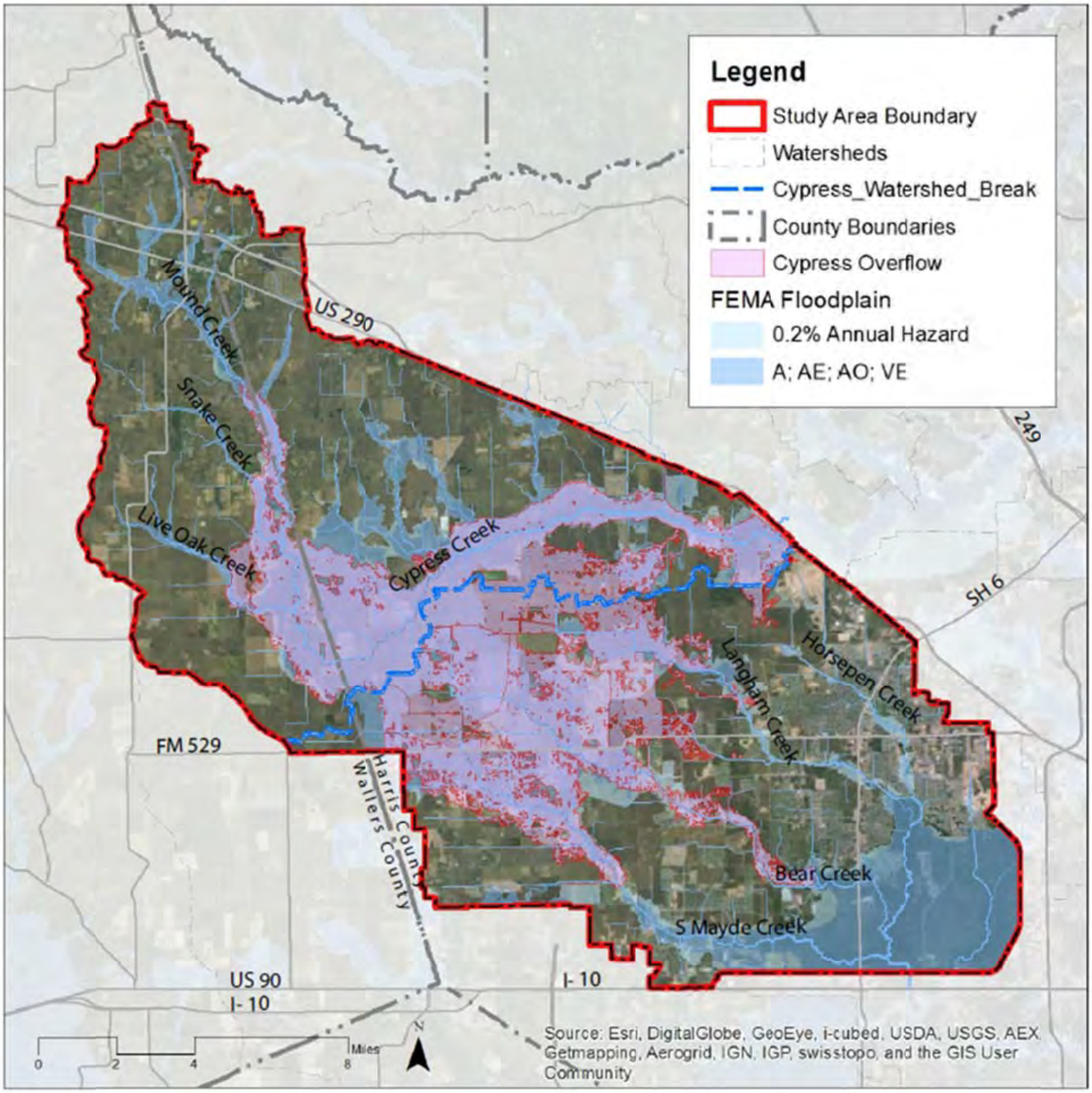


Exhibit C3.1
Aerial Photograph with Overflow Floodplain

Larger developments take advantage of an economy-of-scales, and may be able to manage the overflow in a manner that minimizes the loss of effective yield. Medium sized developments, such as smaller single family subdivisions, may apply the same approach. However, it is likely they will incur a larger reduction in effective yield. Smaller developments, such as single lot commercial developments and multi-residential developments, will also see a reduction in effective yield. This reduction could be substantial, and alter the development attractiveness for smaller sites.

In areas not impacted by the overflow, a typical development will reserve about 10% of its acreage for stormwater detention to ensure no adverse downstream impact as a result of increasing runoff volume and efficiency. This is in addition to land lost to other non-income producing purposes, such as streets, water and wastewater facilities, pipelines, and common areas. The percentage of land available for income generating development, such as single-family residential, multi-family residential, commercial retail, etc. is known as the *development yield.* Typically, the development of land results in a development yield of between 50-65%, depending on the character and nature of development. Over a large area, the development yield averages about 58%.

The dedication of land to manage the overflow will further reduce the effective yield of the development. As noted, additional land will likely be reserved to manage the overflow through the site in a manner that maintains conveyance and does not adversely impact downstream. The amount of land required to manage the overflow varies. Generally, smaller developments and developments deeper in the overflow will require proportionally more land to manage the overflow.

Table C3.4 presents three development scenarios. The first is a traditional land development in an area that is not affected by the overflow. The second is a development that requires 15% of its acreage to manage the overflow, and the third is a development that requires 30% of its land to manage the overflow. Land use categories and percentages are assigned based upon traditional development patterns. For the overflow conditions, the percentage of land for streets and common areas is reduced to reflect the reduced development footprint. The final category presents the development yield. As the table indicates, a typical development without an overflow will have a yield of 58%. A development that must dedicate 15% of its land to the overflow will have its yield reduced to 49%; and a development that must dedicate 30% of its land to the overflow will have its yield reduced to 41%.

Table A3.4: Typical Land Use Breakdown

Land Use	**Traditional**	**With Overflow (15% for Conveyance)**	**With Overflow (30% for Conveyance)**
Overflow Conveyance	0%	15%	25%
Roads and Easements	25%	21%	18%
Common Areas	7%	6%	5%
Detention	10%	9%	7%
Yield = Income Development (single family, multi-family, commercial)	58%	49%	41%

The uplift in land value from land development is the basis for land development activity, which is vested in the income derived from the yield. Considering the yields presented in Table A3.4: if the total uplift is reduced by about 15%, then 15% of the land must be reserved to manage the overflow; and, if the total uplift in land value is reduced by 30%, then 30% of the land must be reserved to manage the overflow. This results in a simple relationship, that for every percentage of land reserved for the overflow, the same percentage of value uplift is lost. Since there are fixed costs associated with development, such as professional and financing costs, the reduction in uplift will reduce profit margins, and at some point development will not be profitable. Areas deeper in the overflow, as well as smaller properties that are not part of a larger development plan, will likely remain undeveloped due to the lack of profitability.

3.2.2 Adverse Impact from Land Development

Development activities will be required to demonstrate no adverse impact in accordance with HCFCD and Harris County criteria. While these criteria have been developed to ensure no increase in flood risk, there was no consideration of the overflow phenomena in the development of the criteria. Some unintended impacts may be possible due to the lack of such consideration.

One potential risk is the loss of dissipation of overflows provided by the natural undeveloped and agricultural land. As mentioned earlier, smaller overflow events have been observed near the watershed divide that are not later observed in Addicks Reservoir. This has been attributed to the dissipation and attenuation provided by the undeveloped land. If this land is developed, the overflow will be conveyed and stored, but it is unlikely that the dissipation provided by the undeveloped areas will be duplicated.

As land development in the area progresses, there will be pressure on the undeveloped tracts to develop. Potential income will rise, increasing development margins and allowing for the development of tracts with a lower yield. In such cases, areas deeper in the overflow will develop. While developments must demonstrate no downstream or upstream impact, land development activity in areas of higher and deeper flood risk have a much smaller margin for error. There is potential that impacts may be incurred that are not captured in impact studies, and those impacts may not be properly mitigated.

Land development activity in the Upper Cypress Creek watershed (upstream of the overflow) and the Addicks Reservoir watershed will also contribute additional runoff volume to Addicks Reservoir. With the current operating policies, there is no availability for additional runoff volume in the reservoir. This is discussed in Section 3.4.

3.3 Structural Flood Damage

Most flood risk to existing structures in the study area lies within the Addicks Watershed, where the riverine floodplain of the Addicks Reservoir floodplain has the potential to inundate homes. There has been a history of house flooding along South Mayde Creek, Bear Creek, and Horsepen Creek. In addition, there are structures subject to flooding in the overflow and along upper Cypress Creek and Mound Creek, although these areas are mostly undeveloped.

The HCFCD has developed a structure database of homes subject to flood risk. This database estimates the first floor elevation for each structure. This estimation is typically an adjustment to the LiDAR data to reflect the elevation of the structure above grade. In some instances, the structure database has replaced this estimated elevation with a field survey elevation. This database was utilized, along with computed flood elevations, to assess the structural risk associated with major flooding sources in the study area. This is discussed in greater detail in Appendix E.

Without a regional plan, development criteria strives to ensure that new development does not increase existing flood risk. Therefore, it is assumed that in the "without project" condition, the risk of flooding for these structures will remain unchanged. It is also assumed that new land development will occur in recognition of the existing flood risk, and therefore new structures will be constructed at an elevation 1.5 feet above the base flood (1%, or 100-year), in accordance with Harris County Flood Plain policy.

3.3.1 Cypress Creek Overflow

The area subject to the overflow is rural in nature. There are a few homes and structures subject to flooding, but the overflow area is not densely developed.

3.3.2 Langham Creek (U100-00-00)

Langham Creek has been enlarged and improved as part of a master plan developed in the 1980's. The floodplain is generally contained within its banks in the developed areas. There is an Upper Langham Creek Master Drainage Plan to assist in new land development activity as that area continues to expand.

3.3.3 South Mayde Creek (U101-00-00)

South Mayde Creek has an extensive out of bank floodplain in the developed neighborhoods upstream of Addicks Reservoir. The channel has a low level of service rating, and has a history of exceeding its channel banks and flooding homes.

3.3.4 Bear Creek (U102-00-00)

Bear Creek has been improved to accommodate development activity based upon a master plan that was developed in the 1980's. This plan includes a bypass channel that increases the capacity of the system to convey flows. There is an out of bank floodplain in the vicinity of Fry Road, and this area experienced flooding within the past five years.

3.3.5 Mound Creek (K166-00-00)

There is large and wide floodplain along Mound Creek, and flood flows regularly exceed the channel banks and occupy the floodplain. Mound Creek has the lowest possible level of service ranking. However, there is minimal development along Mound Creek, and flooding of homes is not a known concern along Mound Creek.

3.3.6 Upper Cypress Creek (K100-00-00)

Upper Cypress Creek has a large floodplain that is frequently inundated. Upstream of Katy-Hockley Road, there are no known structures in the floodplain. There is land development activity downstream of Katy-Hockley Road, and these developments are avoiding the creek altogether. There are known structural flooding concerns in the vicinity of US 290 and downstream of US 290.

3.4 Addicks Reservoir

The unique hydrology for Addicks Reservoir is discussed in Appendix B: Investigation of Addicks Reservoir Flood Risk. In summary, Addicks and Barker Reservoir were initially designed under a different operating concept than is currently implemented. The original concept called for un-gated conduits with a combined peak discharge of 15,700 cfs. Today, the reservoirs are gated, with a maximum combined release of 2,000 cfs when the gates are open (the gates are closed when there is existing rainfall or the threat of rainfall).

The Federal Government acquired land upstream of the reservoirs based upon the original operating plan. The plan also originally called for a levee along the Cypress Creek and Addicks Reservoir watershed divide to prevent the overflow from entering the Addicks watershed. It later purchased additional land upstream of the Addicks Dam when it was determined that this would be more cost effective than constructing the levee.

Table C3.5 depicts key data associated with both Addicks and Barker Reservoirs.

Table C3.5: Addicks and Barker Reservoir Data

	Addicks Reservoir	**Barker Reservoir**
Watershed area (square miles)	136	130
Elevation (1973 adj. of 1929 datum)		
Top of dam	122.7 (121.6)	114.7 (112.5)
Maximum design water surface	112.7	105.0 (105.4)
Standard project flood	110.6 (102.9)	100.4 (96.7)
Natural ground at ends of dam	112.0	106.0
0.5% (200-Year)	105.7	99.1
Government owned land	106.1	97.3
1% (100-Year)	104.1	97.0
March 1992 flood (Barker flood of record)	100.6	95.9
April 2008 flood (Addicks flood of record)	100.7	
Conduit invert	71.1	73.2
Storage Capacity (acre-feet)		
Maximum design water surface	212,500	192,500 (199,000)
Standard project flood	178,600 (79,600)	123,700 (76,300)
Natural ground at ends of dam	200,800	209,000
Government owned land	116,300	83,400
March 1992 flood of record	57,900	66,910
Conduit invert	0	0
Surface area (acres)		
Natural ground at ends of dam	16,420	16,740
Government owned land	12,460	12,060

Current development policy aims to prevent the increase in peak discharge from development activity, as peak discharges define flood risk along downstream channels. However, the flood risk within Addicks and Barker Reservoirs, with their restricted release policy, is driven by inflow volume. Detention associated with land development in the Addicks watershed will offset peak discharges, and will delay the time it takes for runoff to reach the watershed. However, it will not mitigate the increase in volume associated with land development. The change in volume associated with land development in the Addicks watershed is illustrated in

Figure C3.1, which depicts runoff hydrographs associated with the existing condition and traditional land development (with detention) condition.

Development in the Cypress Creek watershed will result in a similar increase in runoff volume. Although the peak discharge associated with the overflow will not increase, flood flows along Cypress Creek will rise for a longer duration as the watershed develops, resulting in an increased overflow volume. Figure C3.2 illustrates this, and shows the overflow hydrograph associated with the existing condition and a traditional development (with detention) condition. A large portion of the upper Cypress Creek watershed lies within Waller County, and is outside the jurisdiction of the HCFCD and Harris County. However, Waller County has adopted similar criteria as Harris County, and it is anticipated that its policy will continue to mirror Harris County's policy.

Appendix D: Land Use and Runoff considers the impact of land development on runoff volume. It was determined that, for a single 24-hour 1% (100-year) rainfall event, a typical land development will increase the volume of runoff by the volume equivalent to two inches over the development. Appendix B considered the cumulative risk to Addicks Reservoir based upon long term simulations. The analyses determined that the future development of the Addicks Reservoir watershed and Upper Cypress Creek watershed will increase the total pool volume and elevations in Addicks Reservoir.

3.5 Conservation Land

Approximately 15,400 acres of land is currently held in conservation. Existing covenants and easements ensure the preservation of this land, and there is no risk of future development of this property. In addition, the HCFCD holds 440 acres of land for conservation interest. There are a number of potential uses for the conservation lands. In some instances, conservation goals are to maintain current agricultural practices. In other areas, the goal is preservation of existing remnant prairies and wetlands, while in others there are initiative to restore prairie, wetlands, and natural streams. Some of these are in the form of mitigation banks, where credits are sold to offset impacts elsewhere.

Substantial ecological value is obtained from contiguous green space when compared to non-contiguous green space of the same area. It is anticipated that conservation interests will continue to progress towards securing more land. However, land development pressure in the study area will impact land prices and affect landowner motivations, which could hinder conservation interests.

Without a regional plan, land development interests will be required to dedicate substantial land to conveying the overflow. This will result in green space preservation associated with land development, however this land will be altered and excavated to convey and store the overflow. Economics may dictate that certain smaller tracts, and tracts subject to deeper overflows, may not develop, leaving some intermittent vacant tracts in the overflow area. The cumulative impact of land development will result in some undeveloped areas and other green areas, but these areas may not be contiguous and as such would have minimal ecological value.

3.6 Summary

The "Do-Nothing" or "without project" alternative is presented in Table C3.7. As summarized in this section, land development activity will continue without a regional plan. However, the development yield on the property will be incrementally reduced because of the need to convey the overflow. Over the entire overflow area, this reduction is estimated to average about 30%, reducing the average development yield from 58% to 41%. The impact on yield will vary by development activity. Larger impacts would occur on smaller developments and those in areas with higher flood depths, and smaller impacts on large master planned developments and those developments with smaller flood depths.

Over the full overflow area, the reduction in income from land development associated with the smaller yield is estimated to be about $150 million. This is based upon the income generation of $40,000 per acre of land prior to applying the development yield. The decrease in yield and income will impact the nature and character of resultant development. With smaller yields, land developers will recover losses by reducing amenities and potentially decreasing unit sizes. This may result in a lower quality development product throughout the region.

Regional solutions also present an opportunity to increase the conservation footprint. Without such solutions, conservation activity may be constrained as conservation competes with anticipated land development interests.

Table C3.7
Bookend Concept – Do Nothing

Description	• When flood flows in Cypress Creek reach a certain threshold (10% annual chance, or 10-year event), flood flows break over the south watershed divide and flow overland to tributaries of Addicks Reservoir (Bear Creek and South Mayde Creek) • This approach describes the status-quo and the impacts of taking no deliberate actions, structural or non-structural, to address the overflow area • Future development activity within the overflow area and tributary watersheds will be in conformance with Harris County Flood Control District criteria and other relevant criteria • See attached schematic layout
Category	"E" – Do Nothing
Key Dimensions	During a one day 1% annual chance event (or 100-year), and based upon current models: • Almost 21,000 acres are inundated by the overflow, of which about 19,500 acres are developable (and the remaining 1,500 acres are already in conservation or public) • This overflow results in widened floodplains in receiving channels • Existing Conditions: Volume of overflow = 23,355 ac-ft (100-yr) • Full Development of Upper Cypress watershed, volume (with detention) = 26,400 ac-ft
Flood Risk Reduction	None
Open Space Preservation and Recreation	• No open space preservation and recreation initiatives are part of plan • Indirect green space preservation should properties not identify alternative development methods and land remains in agricultural or other non-development uses
Addicks Reservoir	• No benefits to Addicks Reservoir • Additional development in Addicks watershed will add volume, as will additional volume from development of Cypress Creek watershed
Cypress Creek	• No impact to Cypress Creek watershed
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth – to be provided by current development procedures • Current development/detention policy
Cost Estimates	• No capital costs incurred • Additional costs incurred for land development activity due to: -Uncertainty due to mitigation requirements -Substantial delays in development of overflow -Potential adverse impacts from unpredictable development activity will have economic consequences, such as reduced ad-valorum value for local tax base
Risks and Uncertainties	• Uncertain development risk and process • Potential for less desirable infrastructure • Potential for impacts to downstream properties due to potential ad-hoc, property by property development solutions

4.0 Bookend Strategies

The initial planning iteration involved the identification of single strategic measures to address the overflow. These strategies strived to be complete strategies that fully managed the overflow (Planning Objective 1). Other planning objectives and constraints were considered, and impacts to them were identified, however the "bookend" management strategy targeted the management of the overflow.

The bookend strategies include both structural and non-structural measures. During the course of the planning study, they were presented to the Steering Committee, and an alternatives workshop was held with the Steering Committee. Each is described below. A summary table for each was prepared during the study, and these are presented as Tables C4.1-C4.10.

Bookend measures fall under a number of categories, each of which have been assigned a lettered category: nonstructural (category "A"), mitigation measures (category "B"), storage (category "C"), and conveyance (category "D"). In addition, the do-nothing alternative described in Section 3.0 was assigned category "E".

4.1 Nonstructural Measures ("A")

Nonstructural measures are those that reduce flood damage and risk in the overflow without physically altering the drainage system or overflow. Four specific nonstructural measures were considered: Acquisition (measure "A1"), Development Criteria (measure "A2"), an Overflow Protection Zone (measure "A3"), and Prairie Restoration (measure "A4"). Two of these – Development Criteria and Prairie Restoration - fall short of the "bookend" concept because they do not provide a full solution, as a full solution is not viable. However, they are still presented in this solution set because they may potentially contribute to a larger combined solution.

4.1.1 Acquisition of Overflow ("A1")

The goal of this measure is to preserve the existing overflow by prohibiting future land development in the area inundated by the overflow. Given the lack of land use authority, this would require the establishment of conservation easements, public drainage easements, or fee ownership of the subject properties.

This bookend concept is summarized in Table C4.1. Approximately 19,500 acres would be secured, with an estimated cost of $500 million. A source of funding would have to be identified. Funding could be partially obtained through grants, but the vast majority of funding would require public investment. There are instances of public support - via election, approving additional fees and/or taxes for conservation – although the ultimate outcome of such an initiative is uncertain.

There are a number of advantages to this concept. First, it fully addresses potential flood risk, as there is minimal concern regarding inundation of undeveloped land. Second, it contributes to the preservation of the prairie and existing agricultural land uses. While it does not directly contribute to the reduction of volume to Addicks Reservoir, the lack of land development for the preserved land will ensure that it does not contribute to additional volume.

Disadvantages include the challenges and uncertainty regarding funding. Furthermore, this plan does not address future housing demand, and would ultimately eliminate tax revenue from the affected land.

Table C4.1
Bookend Concept – Acquisition of Overflow

Description	• Prohibit development of areas in current overflow area • Establish conservation easements or fee ownership of overflow lands
Category/Concept	"A" – Non-structural/A1
Land Acquisition	• Approximately 19,500 acres of land will have to be secured through conservation easements or fee • Lands subject to conservation easement may still be used for agriculture production, recreation or conservation
Implementation Considerations	• A financing mechanism would be necessary to raise funds necessary for securing land • Some public and private grants may be able to assist, at low levels • A third party could implement the plan and act as agent in securing land
Flood Risk Reduction	• If land acquired in fee, existing structures in overflow area will be removed • If land secured by conservation easement, existing structures will remain if owner desires • No land would be recovered for new development
Open Space Preservation and Recreation	• Abundant opportunities from securing the overflow area, including: -Passive and active recreation -Connectivity between Cypress Creek, Conservation land, Harris County Parks, and Addicks Reservoir -Prairie restoration -Eco-Tourism
Implementation Time	• Environmental Clearance: n/a • Policy establishment and financing framework: 2 years • Land/Easement acquisition: 10 years
Addicks Reservoir	• Elimination of additional volume from the potential development of 19,500 acres
Cypress Creek	• No change, other than additional flows from development in the Cypress Creek watershed
Roadways and MTP	• No direct impact to MTP • Future thoroughfare designs should consider overflow
Cost Estimates	• Estimated cost = $500 million (land acquisition/easements, at an average of $25,000/acre
Development Policy	• n/a
Alternative Versions	• This concept may be pursued as a smaller scale • There are multiple implementation scenarios
Risks and Uncertainties	• The identification of a funding source will likely require public/voter approval • Land owners could potentially oppose land use restrictions • Tax authorities could be concerned about loss of potential ad-valorum value of 9,500 acres • Land or easement pricing could climb significantly over acquisition period

4.1.2 Overflow Development Criteria ("A2")

The goal of this measure is to implement development policy specifically tailored for areas in the overflow. Existing development policy related to land development in the floodplain was developed in consideration for development in areas subject to a riverine floodplain, typically with Base Flood Elevations (or FEMA Special Flood Hazard Area Zone AE). In such areas, the relevant conveyance computations are performed using the HEC-RAS computer model

The overflow area is shallow and does not currently have Base Flood Elevations. A hydraulic model was used to determine the areas subject to inundation, but there is no model that provides computed water surface elevations in the overflow.

Table C.4.2 describes this measure. A two-dimensional computer model would be developed to represent the overflow, and this model (or similar) would be used by land development interests in the evaluation of land development projects on the overflow. HCFCD would develop additional criteria and policy for the development overflow lands, and this policy would fully recognize the unique character of the overflow. The policy would be developed in order to ensure that, as land development occurs, development activities would not increase flood risk upstream and downstream – including areas subject to inundation from the overflow.

Table C4.2
Bookend Concept – Overflow Development Criteria

Description	• Develop and adopt policy to guide land development activity in the overflow • Establish a master two-dimensional hydraulic model to be utilized by developers in the analysis of proposed
Category/Concept	"A" – Non-structural/A2
Land Acquisition	• n/a
Flood Risk Reduction	• None, except reduction of risk of impacts due to ad-hoc solutions done if there is no overall plan
Open Space Preservation and Recreation	• No direct benefit • Indirect benefit - residual conveyance areas, as it will be difficult to demonstrate no adverse impact to flood risk without substantial preservation of land for conveyance
Implementation Time	• Development and adoption policy and hydraulic model: 1 year
Addicks Reservoir	• Protected from potential increase in volume resulting from development of 9,500 acres • No change in flood risk from Cypress Creek overflow (same conveyance and volume as today)
Cypress Creek	• No change, other than additional flows from development in the Cypress Creek watershed
Roadways and MTP	• No direct impact to MTP, however planners may consider revision to reflect large undeveloped areas • Future thoroughfare designs should consider overflow
Implementation Strategies	• Establish clear high-level performance standards for the use of the hydraulic model and outcomes in the watershed • Establish a conservation district (or similar) to oversee land acquisition, provide care of properties, and implement secondary uses • Funding source of conservation district must be established • Utilize a third-party to act as land agent to acquire conservation easements • Must include an educational component
Cost Estimates	• No capital costs incurred
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth • On-site detention at a rate of 0.55 ac-ft/ac OR regional volume in enlarged "frontier" channels (to be refined in final plan configuration) • Volume mitigation may be necessary in Addicks watershed (to be refined in final plan configuration)
Alternative Versions	• Adopt policy but require development interests to provide the hydraulic model and analysis
Risks and Uncertainties	• The acceptance of policy by the development community is uncertain and could hinder adoption • Uncertainty regarding ability of policy to protect against undesirable development plans

Advantages to this concept are the inclusion of specific policy related development in the overflow. In addition, there is no capital cost associated with this strategy.

As a stand-alone “bookend” strategy, there are a number of disadvantages. The measure does not fully address the overflow, or flood risk from the overflow. It only provides criteria such that future land developments are protected from flood risk and do not adversely impact other developments. The measure makes no provision for the reduction of flow volume into Addicks Reservoir, or for the conservation of green space. While this concept will likely result in land being preserved for conveyance of overflow, this land will likely be graded and will not provide contiguous areas of green space.

4.1.3 Overflow Conveyance Zone (“A3”)

The goal of this measure is identify and secure a corridor, known as the Overflow Protection Zone, dedicated to overflow conveyance. This land would be acquired in easement or fee, and land developers would be permitted to fill (or levee) areas in the adjacent overflow.

Table C4.3 describes this measure. The Overflow Protection Zone would be computed using two-dimensional models in a manner similar to a FEMA floodway. The model would be encroached along one or more primary overflow paths, with a pre-defined allowable rise in water surface used to determine the width. Once established, the Overflow Protection Area would be acquired in easement or fee in order to prevent its development. Once scenario would be for land developers to donate this land in order to have the right to fill or levee adjacent areas.

A collection area would be required to intercept and train the overflow into the corridor. This may be done as an initial activity by the project sponsor, or it could be allowed to occur naturally as land development occurs. In order to ensure that there is no effect on the rate or volume of overflow from Cypress Creek, the collection area must be moved to the south of the watershed divide, as a berm near the divide would affect water surface elevations in the overflow.

Advantages to this measure are the relative passive role that public entities would play in the implementation, and particularly the lack of necessary capital investment. There would be a need to construct a transition into Bear Creek, and the public may have a role in acquiring the rights to the Overflow Protection Zone. Another advantage is the protection of the corridor, providing a large contiguous green space, and connectivity between downstream features in Addicks Reservoir and upstream features such as parks and lands held for conservation purposes.

Disadvantages include the cost associated with securing the Overflow Protection Zone. Also, as land development occurs on a site by site basis, overflow flooding will remain prominent. The overflow will not be contained in the corridor until the vast majority of the overflow area develops. The measure does not reduce the volume of flow into Addicks Reservoir. There is concern that concentrating the overflow into one or two corridors may provide for a more efficient conveyance, potentially increasing flow in downstream channels. If so, measures would have to be employed to offset this result.

Table C4.3
Bookend Concept: Overflow Protection Zone

Description	• Acquire land (conservation easements or fee) in the primary conveyance area, which is the deepest portion of the overflow – area to be known as the "Overflow Protection Zone" • Define Overflow Protection Zone with two-dimensional model, using encroachments and maximum allowable rise in overflow flood elevation • Allow development in "Overflow Fringe" (the unprotected overflow), but require it to be at elevations above the allowable rise in the Overflow Protection Zone • Acquire land for "training" of overflow
Category/Concept	"A" – Nonstructural/A3
Land Acquisition	• For this summary, assume that it the same dimensions as Structural Alt B1.3 (Floodway) • Approximately 5,500 acres of land will be acquired
Implementation Considerations	• Financing and managing entity must be identified/established • Development activity may not construct levees • Ultimate Bear Creek will be constructed by others in current alignment of channel • No hydraulic modeling of overflow will be required of development interest • Managing entity will construct transition to Bear Creek
Flood Risk Reduction	• Once fully developed, the residual Overflow Protection Zone will convey 100% of the overflow • Approximately 6,700 acres of developable overflow area will be recovered • No change in flood risk to existing Bear Creek
Open Space Preservation and Recreation	• The Overflow Protection Zone provides a meaningful corridor that can be utilized for passive and active recreation • Connectivity will be provide between Addicks Reservoir and Cypress Creek • The collection area provides opportunities for preservation and wetland mitigation • Approximately 1,600 acres will be preserved as linear green space • Approximately 2,840 acres will be preserved in collection area, in addition to existing conservation land
Estimated Implementation Time	• Environmental Clearance: 2 years (for Bear Creek channel transition)(upstream and downstream channel work by others will need environmental clearance) • Policy establishment and financing framework: 2 years • Land/Easement acquisition: 5 years • Training berm construction will be by developers, under guidance from plan
Addicks Reservoir	• No increase in volume of runoff or in flood risk in Addicks Reservoir • Slight increase in runoff volume from development in Addicks Watershed and Upper Cypress Watershed (via overflow) – not affected by detention policy
Cypress Creek	• No change in flow rates or flow volume in Cypress Creek
Roadways and MTP	• As roads are constructed/reconstructed they should recognize future fill requirements and regulatory elevations in the Overflow Protection Zone • MTP may be altered to minimize diagonal crossings of Overflow Protection Zone • Roadway designs will consider long term overflow
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth • On-site detention at a rate of 0.55 ac-ft/ac OR regional volume in enlarged "frontier" channels (to be refined in final plan configuration); Opportunity for regional detention within conveyance zone • Volume mitigation may be necessary in Addicks watershed (to be refined in final plan configuration)
Cost Estimates	• $174,000,000 (land $165,000,000)
Alternative Versions	• Alternative versions involve variations on width of Overflow Protection Zone • Larger Overflow Protection Zone results in smaller surcharge, lower fill requirement, higher land acquisition cost, smaller collection area, and less land recovered for development • Criteria can require developers to reconstruct/construct MTP roadways at higher elevations
Risks and Uncertainties	• As incremental implementation occurs, a rise in surcharge elevations will extend the effective Overflow Fringe area outside of current overflow area • General acceptance of the development community

4.1.4 Prairie Restoration ("A4")

As summarized in Appendix D, research indicates that native prairie grasses significantly increase the infiltration ability of soil, and particularly poorly draining soils such as those found in the study area. The goal of this measure is to decrease the net volume of runoff by restoring areas to their native prairie condition.

This bookend concept is summarized in Table C4.4. The solution, as presented, assumes that 2,000 acres of the study area are restored to native prairie, including 1,000 acres in the Upper Cypress Creek watershed and 1,000 acres in the Addicks Reservoir watershed. The primary advantage of this measure is the reduction in volume to Addicks Reservoir, along with a slight reduction in flow and overflow during large rainfall events.

The total cost of this measure, as described, is estimated to be about $34,000,000. The source of funding is unknown, although there may be opportunities to tie prairie restoration efforts to development requirements, where land developers purchase credits in prairie restoration banks. A third party would be identified to oversee and manage the restoration efforts.

Advantages to this measure are the volume reduction in overflow, which will help offset impacts in the volume of runoff from new land development. In addition, flow rates in the Addicks and Cypress systems will be marginally lower. In addition, the restoration of prairie would have substantial ecological benefits to the prairie.

Disadvantages are that this measure is not a stand-alone bookend, and only marginally contributes to the project objectives. In addition, restoration activity is challenging and many prairie restoration efforts have not been successful. While the restoration of prairie would reduce volume, the restoration of only 2,000 acres would only have marginal impacts to Addicks Reservoir.

4.2 Mitigation Measures ("B")

Mitigation measures are those measures that strive to offset the potential adverse impacts created by land development. For example, current policy requires development to install stormwater detention, and this is an example of a mitigation measure commonly employed. However, as noted earlier, traditional mitigation measures do not address the unique phenomena associated with the Cypress Creek overflow and Addicks Reservoir. For purposes of this report, mitigation measures refers to those specific measures.

Mitigation measures are generally considered non-structural measures, but for purposes of this presentation they are categorized separately. Three specific mitigation measures are considered– Upper Cypress Creek Extended Detention (B1), Addicks Reservoir High-Flow Retention (B2), and Development Incentives (D3). All of these fall short of the "bookend" concept because they do not provide a full solution, as a full solution is not viable. However, they are still presented in this solution set because they may potentially contribute to a larger combined solution.

Table C4.4
Bookend Concept – Prairie Restoration

Description	• Undertake prairie restoration initiatives to decrease runoff from green space • Research suggests that native prairie vegetation increases the infiltration capacity of soil, including clay soils • This summary sheet assumes 1,000 acres of prairie restoration in the Upper Cypress watershed and 1,000 acres of prairie restoration in the Addicks watershed. This is not a complete solution, and will not eliminate overflow
Category/Concept	"A" – Nonstructural/A4
Land Acquisition	• 2,000 acres of land will be secured through conservation easements or fee • Lands subject to conservation easement may not be used for agriculture production
Implementation Considerations	• A third party will be identified to lead and maintain restoration efforts • Policy could be used to require developers to contribute to prairie restoration through a prairie mitigation bank
Flood Risk Reduction	• Review of literature suggests that restored prairie will absorb substantial runoff -100% for 1-year event -50% for 100-year event • This only includes rainfall on prairie lands • Experiments are being performed to determine behavior
Open Space Preservation and Recreation	• The restoration of prairie provides open space
Estimated Implementation Time	• Environmental Clearance: n/a • Land/Easement acquisition: 2 years • Mature prairie restoration: 10+ years
Addicks Reservoir	• Reduction in runoff volume from restored prairie • Reduction in volume due to less volume during overflow events • Volume reduction is marginal
Cypress Creek	• Reduction in volume and peak flow from restored prairie
Roadways and MTP	• No direct impact to MTP
Development Policy	• To be determined in final configuration, as this is not a complete solution • Estimate 1 ac of prairie restoration will offset volume increase from 1 ac of development
Cost Estimates	• Estimated cost = $65,000,000 ($45,000,000 land acquisition/easements)
Alternative Versions	• This concept may be pursued as a different scale • Land costs can be reduced by using conservation lands • Prairie restoration might include construction and restoration of 2'-3' berms to further the storage capacity
Risks and Uncertainties	• There is limited science regarding the benefits of restored prairie to infiltration • Uncertainty regarding the ability to successfully restore prairie to the extent required

4.2.1 Upper Cypress Creek Extended Detention ("B1")

The goal of this measure is to ensure that development in the Upper Cypress Watershed does not contribute additional volume to the overflow, and ultimately to Addicks Reservoir. Current development policy strives to prevent the increase in peak discharges downstream, however it does not attempt to address the increase in runoff volume due to the addition of impervious cover and the removal of natural depression storage. The effect of land development with current detention policy is that the peak discharge is maintained, however the floodwaters will rise for a longer duration, thus allowing for an increase in overflow volume.

This bookend concept is described in Table C4.5. The policy requires land development to temporarily store the entire 100-year rainfall. Outfall rates will be substantially throttled down when compared to existing runoff rates. This will prevent land development from having a significant contribution to the overflow, as the overflow will fall and rise prior to the majority of flow draining from the basin.

The advantage to this concept is that it is a relatively simple means to prevent land development from increasing overflow volume, and it does not require the retention of flow. Furthermore, it may actually serve to reduce peak discharges downstream, including areas downstream of the study area.

Table C4.5
Bookend Concept – Upper Cypress Creek Extended Detention

Description	• Develop and adopt policy requiring land development to detain a higher volume of runoff generally equivalent to full retention of 1% event) • Runoff will be drained at a much lower rate than pre-project
Category/Concept	"B" – Mitigation Measures/B1
Key Dimensions	• Required volume control increased from 0.55 ac-ft/ac to 1.00 ac-ft/ac • Allowable outflow rate from development is 0.15 cfs/acre
Flood Risk Reduction	• As Upper Cypress watershed develops: -peak discharge in Upper Cypress reduced -overflow frequency, flow rate, and volume reduced • Full development of Upper Cypress Creek watershed eliminates overflow for 24-hour event
Open Space Preservation and Recreation	• Additional multi-use and open space amenities in developments
Estimated Implementation Time	• Implementation occurs with development • Benefits accrue during implementation window
Addicks Reservoir	• Reduced overflows as watershed develops • Overflows ultimately eliminated
Cypress Creek	• Peak flows reduced in Upper Cypress • Volume of flow in Cypress Creek increases with development and reduction/elimination of overflow
Roadways and MTP	• No direct impact to MTP
Implementation Strategies	• Provide incentives for developers to utilize LID techniques to reduce detention volume requirement (Concept BB4)
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth • Does not address Addicks watershed detention policy
Cost Estimates	• No capital costs incurred • Additional costs incurred for land development activity due to additional detention requirement
Alternative Versions	• Detention volume can be reduced with implementation of other measures
Risks and Uncertainties	• Timing of events could result in substantial rainfall falling on a "wet" system • Requires adoption of detention policy for watershed in both Harris County and Waller County • Depends upon development activity to gain solution

A disadvantage is that it requires substantially more storage volume (almost twice as much) as current policy. In addition, if the large rainfall event is preceded by a smaller event, the basins may still have stored volume, decreasing their availability for the subsequent event. In addition, much of the affected area is in Waller County, and will require Waller County to adopt a similar policy in the study area.

4.2.2 Addicks Watershed High Flow Detention ("B2")

The goal of this measure is to offset runoff volume increases into Addicks Reservoir as a result of land development in the study area. The concept is to adopt a specific watershed policy that requires land developments to detain runoff from larger events. This volume would be held until it evaporated or was re-used, such as for irrigation.

This bookend concept is described in Table C4.6. Land development would require an additional basin that provides long term retention. The development would be configured such that only large rainfall events would contribute runoff to this basin. This is necessary because the normal rate of runoff would overwhelm the basin because of limitations on evaporation or secondary use. This analysis considers that events larger than the 1% event would overflow into the retention basin. It is estimated that the volume required for detention/retention would increase from about 0.55 acre-feet per acre to approximately 0.80 acre-feet per acre.

The advantage of this concept is that is prevents land development from increasing volume to Addicks Reservoir during larger events. In addition, it provides a source of irrigation or secondary water use.

The disadvantage is that it only provides volume protection for large events. It has been demonstrated that repeated smaller events can impact the reservoir, and this policy would result in no mitigation for numerous smaller events. Another disadvantage is the use of long term retention that relies upon evaporation. Evaporation is limited in winter months. During wet periods, when the concerns regarding reservoir volume are the greatest, the need for irrigation is minimal. Another disadvantage is the additional volume required for land development activity.

4.2.3 Development Incentives ("B3")

The goal of this measure is to offset runoff volume increases into Addicks Reservoir as a result of land development in the study area. The concept is to provide incentives to encourage land developers to implement measures that address the peak volume of runoff. This objective is similar to the objective for concepts B2 (Section 4.1.4) and B3 (Section 4.1.5), however it does not explicitly require a specific action or mitigation. In contrast, it is incentive based and is outcome based, and does not specify specific methods for volume management.

This bookend concept is described in Table C4.7. There are a number of methods land developers may employ to address volume. These include: retention based measures; water re-use; low impact development (LID) measures such as cisterns, bio-swales, and pervious pavements; on-site or off-site prairie restoration; and, managed, extended detention (via pumps or valves). Incentives may take the form of relief from other land development requirements in the overflow, or some other means that have yet to be identified.

Table C4.6
Bookend Concept – Addicks Watershed High-Flow Retention

Description	• Develop and adopt policy requiring land development to retain runoff without outfall • Infiltration and Evaporation will be utilized to "drain" basins • Because of prolonged drain time, basins will be designed to only accept high flows
Category/Concept	"B" – Mitigation Measures/B2
Key Dimensions	• Required volume control increased from 0.55 ac-ft/ac to 0.80 ac-ft/ac • Drainage will designed so that 1-year event drains directly to outfall without detention • Flows in excess of 1-year event will be directed to retention • No outfall permitted from retention basins
Flood Risk Reduction	• As Addicks watershed develops: -peak discharge in Addicks tributaries decreases for larger events -volume of flow into Addicks Reservoir from larger events decreases
Open Space Preservation	• Additional multi-use and open space amenities in developments • Additional multi-use and open space amenities in developments
Estimated Implementation Time	• Implementation occurs with development • Benefits accrue during implementation window
Addicks Reservoir	• Reduced overflows as watershed develops • Overflows ultimately eliminated
Cypress Creek	• Peak flows reduced in Upper Cypress • Volume of flow in Cypress Creek increases with development and reduction/elimination of overflow
Roadways/MTP	• No direct impact to MTP
Implementation Strategies	• Provide incentives for developers to utilize LID techniques to reduce detention volume requirement (Concept BB4)
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth • Does not address Cypress watershed detention policy
Cost Estimates	• No capital costs incurred • Additional costs incurred for land development activity due to additional retention requirement
Alternative Versions	• Retention volume can be reduced with implementation of other measures
Risks and Uncertainties	• Timing of events could result in substantial rainfall falling on a "wet" system • Depends upon development activity to gain solution

The advantage of this concept is that is helps offset the increase in volume into Addicks Reservoir. The use of LID techniques could encourage a greater application of these technologies throughout the region. In addition, LID techniques will result in increased water quality. Overall, the fact that this concept is outcome based relies upon the land developer to demonstrate a method that meets the goals, and avoids a direct regulatory requirement.

Disadvantages of this concept include the relative difficulty of addressing volume control with the poorly draining soils in the study area. In this region, past application of LID techniques has been used to slow runoff in a manner that differs from traditional detention, however it has not been used to successfully reduce runoff volume. Furthermore, the availability of incentives for land development may be very limited. This technique may be more suited for smaller developments than for larger subdivision developments.

Table C4.7
Bookend Concept – Development Incentives

Description	• Develop incentives to encourage development to implement measures to reduce runoff volume • Incentives may include reduction in detention requirement • May be used to facilitate small site commercial development • Measures may include Low Impact Development features such as rain gardens, bioswales, rainwater harvesting, and permeable pavement
Category/Concept	"B" – Mitigation Measures/B3
Flood Risk Reduction	• Combined with other measures, LID will assist in reducing volume of runoff in Cypress Creek, the overflow, and Addicks reservoir • Depending on application, LID measures can provide the equivalent of about 0.2 acre-feet of detention • LID measures will partially offset increases in runoff volume to Addicks Reservoir associated with new development
Open Space Preservation and Recreation	• None
Estimated Implementation Time	• Implementation occurs with development • Benefits accrue during implementation window
Addicks Reservoir	• Reduced volume in Addicks Reservoir compared to full developed condition
Cypress Creek	• Reduced volume in Cypress Creek compared to full developed condition
Roadways and MTP	• No direct impact to MTP
Implementation Strategies	• Develop incentives to encourage use • Increase understanding of potential applications in areas with poorly draining soil
Cost Estimates	• No capital costs incurred • Additional costs incurred for land development activity due to additional retention requirement
Risks/Uncertainties	• Acceptance of concept by development community

4.3 Reservoir Storage Measures ("C")

Reservoir storage measures are those that manage the overflow by storing large volumes of runoff is designated reservoir areas. The reservoir would slowly release runoff in a manner that does not result in an overflow. Two primary bookend reservoirs were considered – a reservoir in the Addicks and Cypress Watershed that collects overflow waters, known as the Katy-Hockley Reservoir (C1); and a reservoir along Mound Creek (C2), upstream of the overflow that strives to reduce flows and eliminate the overflow. A number of permutations of both of these were considered, however one specific concept for each was developed as a bookend solution.

4.3.1 Katy Hockley N - Cypress Reservoir ("C1")

The goal of the Katy Hockley N - Cypress Reservoir bookend concept is to fully capture and temporarily store the overflow and flows along Cypress Creek. The reservoir would have un-gated outlets into Bear Creek, South Mayde Creek, and Langham Creek that release flow at a rate that can be accommodated by each channel. In addition, there would be an outlet to Cypress Creek that would be designed to duplicate pre-project runoff conditions. It would likely be necessary to operate gates on the Cypress Creek outlet in order to duplicate pre-project conditions. Conveyance improvements would be required along Bear Creek between the reservoir outlet and the enlarged channel adjacent to existing development.

Table C4.8 describes the bookend measure in more detail. An earthen dam would be constructed to impound water overflows. During the 1% (100-year) event, 7,600 acres of land would be inundated, providing 26,300 acre-feet of storage volume at a water surface elevation of 167 feet. During that event, maximum depths in the reservoir would be about 6 feet. Drain time in the reservoir would be about four to five days.

The configuration presented in this measure would cost about $350 million. Of this, $200 million is land acquisition. Cost estimates may vary significantly with land prices.

Advantages to this measure are that it fully addresses the overflow, and areas downstream would develop in a manner similar to other watersheds. It would provide a large green space, and could contribute to the conservation footprint. The vast majority of the reservoir area would be inundated very infrequently, and this inundation would be shallow in depth and short in duration. In total, 17,000 acres would be recovered for land development. Addicks Reservoir would benefit by protecting the acreage behind the dam from future land development.

Disadvantages to this measure are the overall cost and implementation time. Environmental permitting could be time-consuming, and it would probably require conformance with the National Environmental Policy Act (NEPA). In addition, the dam would be classified as high hazard, and would require permitting from the Texas Commission on Environmental Quality (TCEQ). There is large land acquisition component, and there is possibility that covenants assigned to existing conservation lands could prevent those lands from being used for occasional inundation. It would be difficult, if not impossible, to phase the reservoir, and benefits would not be realized until full implementation of the plan. It could also be difficult to design structures to prevent diversion of additional volume from the Cypress Creek watershed to Addicks Reservoir watershed, and to duplicate existing flow behavior into Cypress Creek. Consequently, it could become necessary to manage these with gates at one or more of the outlets.

Table C4.8
Bookend Concept – Katy Hockley N - Cypress Reservoir

Description	• A reservoir with an earth dam along Longenbaugh Rd and Katy-Hockley Road • Un-gated outlets to Bear Creek, S. Mayde Creek, and Langham Creek • Gated outlet to Cypress Creek – operated to duplicate pre-project flow conditions • See attached Schematic Layout
Category	"C" – Reservoir/C1
Key Dimension	• 26,300 ac-ft of storage (100-Yr) • 7,605 surface acres • 100-Yr Water Surface Elevation = 167.0 feet • Drain time: 4-5 days (proposed 3,000 cfs outfall); 12-13 days (existing 1,000 cfs outfall) • Overflow spillway to pass larger events
Lands Impacted	• Undeveloped land: 3,844 ac • Conservation land: 2,046 ac • Conservation land: 216 ac • Harris County land: 672 ac
Primary Outfall (Gates and Conduits)	• Gated outfall to Cypress to duplicate "without reservoir" condition – but additional flows may be directed down Cypress if (1) there is capacity, and (2) there are volume concerns in Addicks Reservoir (this would be extremely rare) • Outfall discharge rate to: • -Addicks Tributaries = 3,000 cfs: -S. Mayde Creek = 680 cfs (existing capacity) -Langham Creek = 200 cfs (existing capacity) -Bear Creek = 2,120 cfs (existing capacity = 150 cfs, improvements required)
Secondary Outfall (Spillway)	• TCEQ Dam Class: High Hazard • Must safely pass Probably Maximum Precipitation (Overflow from 44.8" rainfall in 24 hours) • Spillway cress at 100-year reservoir stage will pass extreme flows • Top of dam elevation accounts for extreme event plus wave height and runup
Channel Mod	• Bear Creek will be enlarged to provide 100-year conveyance of the reservoir outflow of 2,120 cfs
Flood Risk Reduction	• The overflow will be completely managed by the reservoir, and will be operated to prevent induced flood risk downstream in Cypress Creek • During non-overflow events, the reservoir will provide attenuation to protect areas downstream (this is an unintended benefit) • A net of about 17,000 acres of overflow area will be recovered
Preservation and Recreation	• The reservoir area will provide secured green space and opportunities for additional preservation • The reservoir will provide opportunities for passive recreation • 4,010 acres will be preserved, in addition to the 2,260 acres of land within the reservoir area that are already protected • Stream mitigation banks and wetland banks could be installed within the reservoir area
Permitting and Environmental Clearance	• The project will most likely require an Environmental Impact Statement in conformance with NEPA • Bear Creek modifications will require stream mitigation(this could be provided by features within the reservoir)
Cost Estimate	• $350 million (Land: $200 million)
Estimated Implementation Time	• Environmental Clearance – 7-12 years • Land acquisition and relocations – 3-5 years • Construction – 2-3 years

Table C4.8 (Continued)
Bookend Concept – Katy Hockley N - Cypress Reservoir

Addicks Reservoir	• No increase in volume of runoff or in flood risk in Addicks Reservoir from channel • Slight increase in runoff volume from development in Addicks watershed unrelated to this concept • Reservoir will slightly delay runoff and provide some attenuation during non-overflow events
Cypress Creek	• No change in flow rates or flow volume in Cypress Creek • Channel stability measures would be necessary downstream of gated outfall

4.3.2 Mound Creek Reservoir ("C2")

The goal of the Mound Creek Reservoir bookend concept is to reduce flows along Cypress Creek upstream of the overflow in order to eliminate the overflow. The reservoir would involve a dam downstream of the confluence of Mound Creek and Live Oak Creek. The dam would include a gated outlet conduit to Mound Creek as well as an overflow spillway. The gates would be operated in a manner to ensure that the reservoir releases do not contribute to downstream flooding along Cypress Creek. Even with the reservoir in place, local inflows downstream of the reservoir would result in 100-year water surface elevations along Upper Cypress Creek which would result in a very small overflow. In order to prevent this, this bookend measure would include a small berm along the Cypress Creek/Addicks Reservoir watershed divide.

Table C4.9 describes the bookend measure in more detail. Approximately 36 square miles of drainage area contribute to the reservoir. During a 1% (100-year) event, 4,600 acres of land would be inundated, providing 48,600 acre-feet of storage volume at a water surface elevation of 205. Maximum depths in the reservoir would be about 20 feet. When open, the gated outlet would discharge flows from the reservoir at a maximum rate of 2,000 cfs. Drain time during a 1% (100-year) annual probability event would be dependent upon the percentage of time the gates are open. If the gates are open 50% of the time, drain time would be 24 days. Approximately 18,000 acres would be recovered from the overflow.

The height of the dam would be about eight feet above the 1% (100-year) elevation in order to account for the probable maximum precipitation and wave height and runup. The height of the dam would vary, with a maximum height of about 28 feet. The berm at the watershed divide would extend for a length of 14,500 feet, and would have a maximum height of five feet.

This measure would cost approximately $330 million. This includes $130 million for land acquisition.

Advantages of this measure would be that the topography upstream of the dam provides for more efficient storage, as runoff can be stored at a greater depth. It would also allow for the use of conservation land for storage. This measure is also compatible with the Waller County Master Drainage Plan, which calls for a regional detention basin in the same vicinity. Addicks Reservoir would benefit by removing the potential for an overflow event into the Addicks Reservoir watershed.

Disadvantages of this measure would be the overall cost and implementation time. Environmental permitting could be time-consuming, and it would probably require conformance with the National Environmental Policy Act (NEPA). In addition, the dam would be classified as high hazard, and would require permitting from the Texas Commission on Environmental Quality (TCEQ). There is large land acquisition component, and there is a possibility that covenants assigned to existing conservation lands would prevent those lands from being used for occasional inundation. It would be difficult, if not impossible, to phase the reservoir, and benefits would not be realized until full implementation of the plan. Another significant disadvantage would be the need to gate the reservoir, with operations that limit releases during potential rainfall events. This could result in a long drain times, and the potential for a "ratchet effect" in the reservoirs similar to Addicks and Barker Reservoirs. While this measure eliminates the overflow, there would be net increase in volume in Cypress Creek during events where the overflow is eliminated (computed flood elevations would not change). As noted, a berm along the watershed divide would be necessary to prevent overflows, even during smaller events.

Table C4.9
Bookend Concept – Mound Creek Reservoir

Description	• A reservoir with an earth dam downstream of confluence of Mound Creek and Live Oak Creek • Gated outlet to Cypress Creek- operated to prevent discharge that contributes to overflow and to prevent inducing additional flood risk downstream • See attached Schematic Layout
Category/Concept	"C" – Reservoir/C2
Key Dimension	• 48,600 ac-ft of storage (100-Yr) • 4,600 surface acres • 100-Yr water surface elevation = 205 feet • Top of dam elevation = 213 feet • Upstream contributing drainage area = 57 square miles • Upstream peak 100-year discharge = 14,000 cfs
Land Acquisition	• Undeveloped land: 4,900 ac • Conservation land: 775 ac • Conservation land: 660 ac
Primary Outfall (Gates)	• Controlled discharge rate (for draining) = 2,000 cfs – gates closed with rain threat • Drain time depends on frequency of open gates (HEC-ResSim model necessary to fully evaluate): -Open 100% of time = 12 days; 50% of time = 24 days; 25% of time = 48 days -HEC-ResSim model necessary to determine risk-based expected drain time
Secondary Outfall (Spillway)	• TCEQ Dam Class: High Hazard • Must safely pass Probably Maximum Precipitation (44.8" rainfall in 24 hours) • Spillway cress at 100-year reservoir stage will pass extreme flows • Top of dam elevation accounts for extreme event plus wave height and runup
Downstream Berm at Watershed Divide	• Watershed downstream of reservoir contributing to overflow = 36 square miles • Residual overflow potential exists with Mound Creek Reservoir • 100-year residual overflow volume = 2,000 ac-ft (compared to 23,500 ac-ft without reservoir) • Berm along watershed divide proposed to prevent overflows • Potential induced flood risk offset by flood protection provided by reservoir • Berm dimensions: Length = 25,000 feet; max height = 5'
Flood Risk Reduction	• The overflow will be completely managed by the reservoir, and will be operated to prevent induced flood risk downstream in Cypress Creek • All potential overflow to Addicks Reservoir will be maintained in the Cypress Creek watershed • During non-overflow events, the reservoir will provide storage, reducing flood risk in Cypress Creek • Approximately 18,000 acres of developable overflow area will be recovered
Preservation and Recreation	• The reservoir area will provide secured green-space and opportunities for additional preservation • The reservoir will provide opportunities for passive recreation • 4,600 acres will be preserved in the reservoir area • Stream mitigation banks and wetland banks could be installed within the reservoir area
Permitting and Environmental Clearance	• The project will most likely require an Environmental Impact Statement in conformance with NEPA • The outlet area and downstream channel protection will require stream mitigation (this could be provided by features within the reservoir) • Estimated time for environmental clearance: 7-12 years

Table C4.9 (Continued)
Bookend Concept – Mound Creek Reservoir

Implementation Time	• Environmental Clearance – 7-12 years • Land acquisition and relocations – 3-5 years • Construction – 2-3 years
Addicks Reservoir	• Current overflows will be redirected to Cypress Creek, substantially relieving Addicks Reservoir • Slight increase in runoff volume from development in Addicks watershed (this increase is the same regardless of detention policy)
Cypress Creek	• Overflow will be redirected to Cypress Creek, increasing volume of flow in Cypress Creek • Reservoir will only release when there is downstream capacity, providing flood risk reduction to Cypress Creek • Channel stabilization measures will be incorporated downstream of reservoir
Roadways and MTP	• Reservoir impacts the following alignments: -East-West: Cypress-North Houston, Jack, Smalley, Mound -North-South: Mathis, Penick • Alignments may remain, but will not serve development within reservoir • Proposed roadways must cross embankment • Proposed roadways must be elevated within reservoir or be subject to periodic but infrequent inundations
Pipelines	• No adjustments required in reservoir
Scalability	• Reservoir must be constructed in one piece. • The watershed divide berm may be constructed as a later phase, but full recovery of overflow area requires the construction of the berm
Development Policy	• Additional “collector” channel network improvements required to provide outfall depth • On-site detention at a rate of 0.55 ac-ft/ac OR regional volume in enlarged “frontier” channels (to be refined in final plan configuration) • Mound Reservoir may be used as a regional basin for upstream development if sufficient drainage infrastructure is installed • Volume mitigation may be necessary in Addicks watershed (to be refined in final plan configuration)
Cost Estimates	• $330,000,000 (Land: $140,000,000)
Alternative Versions	• Location of the embankment and reservoir can be adjusted slightly • Reservoir size can be modified to incorporate elements of Waller County Drainage Plan Gated outflow can be modified to increase flow and increase drain time, but that would require downstream flood easements and a higher berm at watershed divide
Risks and Uncertainties	• The timeline for environmental clearance is uncertain, and could be indefinite • The variability of real estate costs could substantially impact overall cost estimate • Public concerns regarding overflows being held and kept in Cypress Creek watershed • Hydrologic concerns regarding limited discharge capacity, operations, and potential “ratcheting” effect similar to Addicks and Barker Reservoir • Potential impacts to stream stability along Cypress Creek

4.4 Overflow Conveyance Measures ("D")

Conveyance measures are those that manage the overflow by concentrating it into reserved or defined corridors that convey it to Addicks Reservoir. Two bookend conveyance measures were considered, the conveyance of the overflow via an enlarged Bear Creek, and the conveyance of the overflow via a bermed floodway (floodway is defined as "an area designated for high conveyance of floodwaters", and not to be confused with FEMA's very specific definition of a regulatory floodway).

4.4.1 Overflow Conveyance Channel ("B1")

The goal of the overflow conveyance channel would be to capture the overflow after it crosses the watershed divide into the Addicks Watershed, and convey to Addicks Reservoir in an enlarged Bear Creek channel. This conveyance system would eliminate the existing inundation from the overflow during events up to and including the 1% (100-yr) event.

Table C4.10 describes the bookend measure in more detail. Collection channel/berms would be constructed on the south side of the watershed divide, and would function to collect the overflow and convey it to the Bear Creek channel. These would be sized in a manner that maintains the current water surface elevations in Cypress Creek as well as the current overflow rates and volumes. The lower upper reach of Bear Creek, upstream of the existing development, would be substantially deepened and widened, and the stream would be extended upstream to the collection channel/berms. This system would deliver substantially higher flow rates to the lower reach of Bear Creek, and therefore the lower reach would be widened to accompany the additional flows. The enlargement of Bear Creek would require the reconstruction of numerous roadway and pipeline crossings, as well as the acquisition of approximately 50 homes, 2 wastewater treatment plants, and nine holes of a 27-hole golf course. The 1% (100-yr) peak discharge into Addicks Reservoir from Bear Creek would increase from 7,950 cfs to 12,000 cfs. A small residual overflow would remain east of Katy-Hockley Road. This small overflow would be managed by local measures related to land development.

This measure would cost approximately $185 million. This includes $35 million for land acquisition.

Advantages to this measure would be that it fully addresses the overflow, and areas currently subject to the overflow would develop in a manner similar to other watersheds. It would recover a large amount of land for development, and also eliminate the riverine floodplain along Bear Creek. This measure would provide relief to existing flood risk along Bear Creek from local events. It would also eliminate the current overflow that enters South Mayde Creek, which is a heavily strained channel. This measure could be phased from downstream to upstream, although phasing would require interim provisions for collecting the overflow. The large channel corridor provides a means of connectivity from Bear Creek Park in Addicks Reservoir to John Paul's Landing, Paul Rushing Park, and Cypress Creek.

Disadvantages to this measure would be the high cost and interruptions associated with real estate acquisitions, relocations, and reconstruction of infrastructure. The measure would likely require conformance with NEPA, and the deepening of Bear Creek would require Section 404 permits from the USACE. The measure would bring considerably higher flow rates into Addicks Reservoir, although existing flow volume would not be increased. This measure would not preserve green space. The large potential development footprint would result in more runoff volume into Addicks Reservoir as the watershed develops.

Table C4.10
Bookend Concept – Overflow Conveyance Channel

Description	• Frontier type channel extension of Bear Creek to convey overflow to Addicks Watershed • Frontier channel extends from Cypress Creek watershed divide to West Little York • Conventional channel enlargement and deepening from West Little York into Addicks Reservoir • Attenuation area at collection channels to slightly reduce overflow rate • See attached Schematic Layout
Category/Concept	"D" – Conveyance/B1
Key Dimension	• Extents: -Bear Creek extended 8,300 feet upstream to Addicks/Cypress watershed divide -Bear Creek modified and enlarged from Addicks Reservoir to watershed divide • Frontier channel section (typical): -Low flow – Bottom-width = 20', side-slopes = 3:1, depth = 6' -High flow – Bottom width = 175', side-slopes = 4:1, depth = 14' -Channel depth = 20', Bench width (total, both sides) = 120', Right-of-way = 450 feet • Trapezoid channel section (where land is constrained): -Bottom-width = 150', side-slopes = 4:1, depth = 20' -Right-of-way = 360 feet
Land Acquisition	• Undeveloped land: 567 ac • Developed land: 89 ac (includes undeveloped land in "developed" area downstream of Fry Rd.) • Approximately 50 existing single family houses would be acquired • Two wastewater treatment plants would be relocated • Nine holes of an existing 27-hole golf facility would be acquired
Flow Capacity	• Peak 100-year overflow from Cypress Creek = 14,000 cfs • Detention policy for local Bear Creek watershed development: -"Delayed" runoff from detention results in coincidental timing with overflow -Recommend elimination of detention requirement in watershed -Channel necessary for overflow exceeds size of channel required for future development • Downstream flow constraints: -Channel enlargements required through developed areas downstream of West Little York -This will require some acquisitions of existing infrastructure, business, and homes -Flow capacity capped at ultimate 100-year runoff of Bear Creek watershed = 14,000 cfs -Additional channel capacity reserved for local runoff during coincidental events – see below
Collection of Overflow	• Collection channels will be constructed parallel, and south of, the overflow boundary • Collector channel complex will provide about 460 acre-feet of storage during 100-year event • A small berm will be constructed alongside the south bank of the collectors to ensure capture and to provide storage • 31,000 linear feet of collection channels will be constructed
Coincidental Events	• During the time that overflows are conveyed, additional channel capacity will be reserved for local events • For Bear Creek watershed, 2-yr ultimate flow rate = 4,000 cfs • Design channel includes this capacity in excess of design flow rate • Requires storage in collection area to reduce overflow rate by 4,000 cfs (100-yr event)
Flood Risk Reduction	• The conveyance channel will accommodate 100% of the overflow • Approximately 17,000 acres of developable overflow area will be recovered • The conveyance channel will be designed such that it either (1) does not increase flood risk along Bear Creek, or (2) reduces flood risk along Bear Creek • Bear Creek flood risk will be substantially reduced for local (non-overflow) events
Preservation and Recreation	• The conveyance channel provides a corridor that can be utilized for recreation • Connectivity will be provided between Addicks Reservoir and Cypress Creek • Aesthetic enhancements may be included • Approximately 337 acres will be preserved as linear green space • Approximately 230 acres will be preserved in collection area

Table C4.10 (Continued)
Bookend Concept – Overflow Conveyance Channel

Permitting and Environmental Clearance	• The project will most likely require an Environmental Impact Statement in conformance with NEPA. • Bear Creek modifications will require stream mitigation • The corridor channel may allow for mitigation in place
Implementation Time	• Environmental Clearance – 3-6 years • Land acquisition and relocations – 3-5 years • Construction – 3-4 years
Addicks Reservoir	• No increase in volume of runoff or in flood risk in Addicks Reservoir from channel • Slight increase in runoff volume from development in Addicks watershed (this increase is the same regardless of detention policy) • Inflows to Addicks Reservoir would be expedited
Roadways and MTP	• Crossings for 13 roadways would be modified to cross the enlarged channel • No impact to Master Thoroughfare Plan
Pipelines	• The enlarged channel crosses 15 known pipelines that would require adjustments
Scalability	• The channel would be constructed in phases, from downstream to upstream • Land recovery benefits are not accrued until channel extends into undeveloped areas • An interim benefit may be realized with a partial extension into undeveloped areas, but temporary flow collection channels or berms would have to be installed
Development Policy	• Additional "collector" channel network improvements required to provide outfall depth for parcels that do not have access to the conveyance channel • Conventional detention may not be necessary for development in Addicks watershed; however, volume mitigation will likely be necessary to offset impacts to Addicks Reservoir (to be refined)
Cost Estimates	• Total Concept: $185,000,000 (Land: $35,000,000)
Alternative Versions	• Variety of channel configurations may be utilized, Size presented appears to be optimal • Detention policy in Bear Creek could be maintained, but this does not reduce size requirements of ultimate Bear Creek • Cost savings may be realized by identifying agreeable arrangement with Pine Forest Country Club that involves reconfiguration of a few golf holes to preserve 27-hole facility
Risks and Uncertainties	• The timeline for environmental clearance is uncertain, and could be indefinite • Public rejection of large conveyance channel • Required acquisition of homes, businesses, and infrastructure • Approval by Corps of Engineers (channel modifications extend into Addicks Reservoir)

4.4.2 Overflow Bermed Floodway ("D2")

The goal of the bermed floodway is to funnel the overflow into a designated area via a series of berms. The berms would intercept the overflow and train it into the floodway, and the floodway itself would be defined by berms. This system would eliminate the existing inundation from the overflow during events up to and including the 1% (100-yr) event.

Table C4.11 describes the bookend measure in more detail. Training berms would intercept the overflow and funnel it to the designated floodway. Since the berms would cause a slight rise in water surface elevation, it would be necessary for them to be offset away from the watershed divide in order to prevent them from influencing water surface elevations along Cypress Creek. As a result, a 1,800-acre "collection area" would be created that would remain undeveloped and would serve to attenuate flow prior to it entering the floodway. This conveyance area would be acquired as part of the measure. The floodway itself would be centered on the existing Bear Creek corridor, would be about 2,000 feet wide, and would be defined by berms approximately six feet high. The berms would have a wide top width to allow for vegetation. Perimeter channels would be constructed on the outside of the berms to provide for lateral drainage, as access to Bear Creek would be interrupted by the berms. A transition structure would be constructed to facilitate the connection between the floodway and the enlarged Bear Creek channel as it enters the developed reach. Some channel enlargements would be required in the lower portion of Bear Creek. This would require some land acquisition.

This measure would cost approximately $200 million. This includes $150 million for land acquisition. The cost estimate is very sensitive to land costs.

There are a number of advantages to this measure. It avoids the need for a larger capital project as compared to the other structural solutions. It also avoids the need for Section 404 permitting along Bear Creek, although a permit may be required for the transition structure. It is less likely than other large structural measures to require NEPA conformance, however this is uncertain. The measure preserves a wide corridor that could be utilized for secondary and passive uses, such as recreation. The conveyance corridor also protects the deepest overflow area from future development. The collection area provides a large conservation and preservation area, and also provides some attenuation of flow. This measure could be phased, although provisions must be made for interim interception and training of overflows.

Disadvantages include the amount of land acquisition in the prime development area. In addition, there would some expediting of flow into Addicks Reservoir. Channel work will be required in the lower reaches of Bear Creek. Roadway crossings would have to be adjusted to cross the berms. The berms would likely be treated as levees by FEMA, and would have to meet their criteria for levee height and maintenance. No benefits would be provided to Addicks Reservoir.

Table C4.11
Bookend Concept – Overflow Bermed Floodway

Description	• Establishment of a "floodway" contained by berms that define overland flow path along existing Bear Creek channel and extended to collection area • Floodway will transition into existing Bear Creek channel upstream of West Little York • No modification to Bear Creek downstream of West Little York • Training berms will collect overflow south of watershed divide and funnel flow into floodway • Perimeter channels will be constructed on exterior of each berm to collect and convey local runoff • See attached Schematic Layout
Category/Concept	"D" – Conveyance/D2
Key Dimensions	• Overflow floodway has a right-of-way width of 2,500 feet -1,980 feet for floodway -100 feet for each berm/levee – (200' total) -160 feet for each perimeter channel (320' total) • Floodway extends about 29,000 feet, from transition to Bear Creek near West Little York upstream to collection area near Katy-Hockley Road • Berm height < 6' – berms will be sufficiently wide to allow for vegetation
Land Acquisition	• Undeveloped land: 4,505 ac • Conservation Land (Training Area): 1,099 ac
Flow Capacity	• Peak 100-year overflow from Cypress Creek = 14,000 cfs • Detention policy for local Bear Creek watershed development: -"Delayed" runoff from detention results in coincidental timing with overflow -Recommend elimination of detention requirement in watershed -Channel necessary for overflow exceeds size of channel required for future development • Downstream flow constraints: -Channel enlargements required through developed areas downstream of West Little York -This will require some acquisitions of existing infrastructure, business, and homes -Flow capacity capped at ultimate 100-year runoff of Bear Creek watershed = 14,000 cfs -Additional channel capacity reserved for local runoff during coincidental events – see below
Collection of Overflow	• Training berms will be constructed south of watershed divide to funnel overflow toward floodway • The berms will be located a sufficient distance away from watershed divide to prevent impact to Cypress Creek • Resultant berm/training complex requires 3,940 acres of land, and provides substantial storage – reducing peak 100-year overflow rate from 14,000 cfs to about 6,000 cfs • Approximately 38,000 linear feet of training berms required • Collection area could include Paul Rushing Park and John Paul Landing – depends upon Precinct 3 preference
Flow Capacity	• Peak 100-year overflow from Cypress Creek = 14,000 cfs • Peak 100-year flow in floodway, after storage in "training" area = 6,000 cfs • Concept assumes current detention policy in Bear Creek watershed
Perimeter Channels	• Right-of-way of 160 feet will be reserved for future drainage needs tied to development activity • Ultimate channels may be constructed in order to provide source of material for berms: -Cost estimates assume a 14-foot deep channel with 30-foot bottom width -If material is not needed, right-of-way will be reserved for future channel -Interim channel will then be constructed to provide drainage

Table C4.11 (continued)
Bookend Concept – Overflow Bermed Floodway

Downstream Bear Creek	• Bear Creek downstream of West Little York has adequate capacity to convey overflows from the floodway without modification • A structure will be designed and constructed to transition flow from the floodway and the perimeter channels into Bear Creek
Flood Risk Reduction	• The floodway and collection area accommodate 100% of the overflow • Approximately 6,700 acres of developable overflow area will be recovered
Preservation and Recreation	• The floodway provide a meaningful corridor that can be utilized for passive and active recreation • Connectivity will be provided between Addicks Reservoir and Cypress Creek • The collection area provides opportunities for preservation and wetland mitigation • Approximately 1,660 acres will be preserved as linear green space. • Approximately 2,840 acres will be preserved in collection area, in addition to existing Conservation land
Permitting and Environmental Clearance	• The project may require an Environmental Impact Statement in conformance with NEPA, but this is uncertain
Implementation Time	• Environmental Clearance – 2-3 years • Land acquisition and relocations – 2-3 years • Construction – 1-2 years
Addicks Reservoir	• No increase in volume of runoff or in flood risk in Addicks Reservoir from channel • Slight increase in runoff volume from development in Addicks watershed (this increase is the same regardless of detention policy) • Inflows to Addicks Reservoir would be mildly expedited
Cypress Creek	• No change in flow rates or flow volume in Cypress Creek
Roadways and MTP	• Crossings for five crossing would be modified to cross the floodway and the perimeter channels • Crossing over floodway would involve wide numerous culverts with embankment – with total culvert flow area of 1200 square feet • Six roads must be raised to cross berms (in two places each for five roads) • No impact to Master Thoroughfare Plan
Pipelines	• The floodway crosses 8 known pipelines • The floodway will not require pipeline adjustments • The perimeter channels will require separate pipeline adjustments (2 for each crossing)
Scalability	• The floodway could be constructed in phases, from downstream to upstream • An interim benefit may be realized with a partial extension into undeveloped areas, but temporary collection berms would need to installed
Development Policy	• Additional “collector” channel network improvements required to provide outfall depth for parcels that do not have access to the perimeter channels • On-site detention at a rate of 0.55 ac-ft/ac OR regional volume in enlarged “frontier” channels (to be refined in final plan configuration) in either collector channels or perimeter channels • Volume mitigation may be necessary in Addicks watershed (to be refined in final plan configuration)
Cost Estimates	• Total Concept: $200,000,000 (Land: $150,000,000)
Alternative Versions	• Variety of floodway widths and collection configurations possible • Size presented appears to be optimal
Risks and Uncertainties	• Challenges related to transition structure into Bear Creek • From a regulatory standpoint, collection area might be treated as a reservoir • FEMA will require that berms be certified as levees • The timeline for environmental clearance is uncertain, and could be indefinite • Required modifications to roadway crossings • The variability of real estate costs could substantially impact overall cost estimate

5.0 Formulation of Management Strategies

The "bookend" concepts described in the preceding section were utilized as a basis for the development of the management strategies. Management strategies are defined as a *combination of one or more measures, structural or nonstructural, and of a scale and orientation that maximizes the planning objectives and avoids the constraints.* A deliberate process was utilized to arrive at management measures. This process is as follows:

Step 1 – Screen "bookend" concepts
Step 2 – Identify primary measures that target the primary objective
Step 3 – Supplement primary measures based upon full array of objectives and constraints
Step 4 – Refine scale and orientation to optimize performance

Each of the steps in the formulation of the management strategies involved close consultation with the steering committee. Step 1 of this plan formulation process is described in Section 5.1. The subsequent steps are presented in the description of the formulation of the six management strategies identified in this study, in Section 5.2.

The TWDB grant requires the identification of two management strategies. Section 5.3 describes the process of selecting these two strategies, and presents these two strategies in greater detail.

5.1 Screening of "Bookend" Concepts

The bookend concepts were presented in detail in Section 4.0, and are listed in Table C5.1. This table lists each strategy, its respective concept number and category, and notes whether or not it completely or partially addresses the primary objective.

The bookend concepts were the subject of a workshop with steering committee members. The purpose of the workshop was to gain feedback regarding these concepts, determine if they should be considered in future plans, identify additional permutations or orientations of these concepts, and identify additional concepts for inclusion. For purposes of this study, all of these activities are considered as "screening" of the bookend concepts, and the results of this are presented in this section.

Table C5.1
Bookend Concepts

Concept Number	Bookend Concept	Category	Primary Objective *Complete/Partial/None*
C1	Katy-Hockley North/Cypress Reservoir	Storage	Complete
C2	Mound Creek Reservoir	Storage	Complete
D1	Conveyance Channel	Conveyance	Complete
D2	Bermed Floodway	Conveyance	Complete
A1	Acquisition	Non-Structural	Complete
A2	Development Criteria	Non-Structural	Partial
A3	Conveyance Zone	Non-Structural	Complete
A4	Prairie Restoration	Non-Structural	None
B1	Upper Cypress Extended Detention	Mitigation	None
B2	Addicks High Flow Retention	Mitigation	None
B3	Development Incentives	Mitigation	None
E1	Do-Nothing	Do-Nothing	None

5.1.1 Storage Category ("C")

In the screening activity, both reservoir concepts were considered viable and worthy of future consideration. However, the size and magnitude of each reservoir was of concern, and it was recommended that, if possible, reservoir concepts be combined with other concepts in order to reduce their general footprint.

The Katy Hockley N - Cypress Reservoir (C1) was determined to be effective and economic. Concerns were raised regarding the challenges with operating a gate on Cypress Creek and avoiding impacts to Cypress Creek and/or changing the character of the overflow. A revised Katy-Hockley Reservoir layout was developed that did not encroach on the watershed divide. In order to prevent impacts to Cypress Creek while maximizing storage potential, the reservoir was revised to have two separate cells, with a berm separating the two. This allows for a "stepped" pool elevation within the reservoir. This third reservoir concept was given the notation C3, and called the Katy-Hockley Reservoir.

It was determined that the Katy-Hockley North/Cypress Reservoir (C1) would result in higher water surface elevations along the watershed divide as a result of a control structure and dam along Cypress Creek, and that this would result in an increase in volume of overflow into the Addicks watershed. In order to prevent an increase in volume to Addicks Reservoir, an equalization structure was included into the concept. This structure would be simply a channel within the reservoir that allows for flow from the Addicks watershed portion of the reservoir back into the Cypress watershed portion of the reservoir. A backflow prevention device would be installed to prevent this channel from contributing additional volume from Cypress to Addicks.

In evaluating the Mound Creek Reservoir (C2), concerns were raised regarding the operations of the gated outlet, and it was noted that an uncertain condition could arise similar to that in Addicks and Barker Reservoir. Overall, however, the notion of a reservoir on Mound Creek was well received. The initial location was moved slightly northward to avoid high value prairie land that would be located in the lowest part of the original reservoir layout. Concerns were also raised regarding existing conservation easements within the reservoir footprint, as it might be difficult or impossible to use these lands for occasional inundation.

For all the large reservoir concepts, concerns were raised regarding the time that would be required to plan, permit, and construct the projects. Land development pressure is immediate, and both reservoirs could take between 5 and 10 years to construct, if not longer.

An additional storage measure was identified that takes advantage of capacity within the proposed lakes at John Paul's Landing (JPL). JPL is a Harris County Precinct 3 Park, and the Precinct intends to construct lakes over 400 acres of the site. The lakes will have eight feet of freeboard between adjacent ground and the permanent water surface, resulting in the potential for 3,200 acre-feet of detention storage. The Upper Langham Creek Master Drainage Plan has claimed most of this capacity, but it is anticipated that about 500 acre-feet are available for the Cypress Creek Overflow Management Plan. The additional storage measure, known as JPL Detention and denoted as A4, proposes to use the remaining 500 acre-feet of detention. The measure targets the overflow east of Katy-Hockley Road, and requires a small channel to capture and convey overflow to the storage area. This overflow occupies substantially less than 500 acre-feet, so the remainder of the storage will be provided by siphoning flow out of Bear Creek. This plan is estimated to cost $328,000,000.

5.1.2 Conveyance Category ("D")

The Conveyance Channel (D1) was recognized for its ability to contain the overflow and recover land. However, concerns were raised about the need for significant enlargements in the lower reaches of Bear Creek. The large number of acquisitions, including homes and a golf course, were not considered reasonable and likely would not be accepted by the community. A smaller conveyance channel was suggested.

The Overflow Conveyance Zone (D2) concept was not well received by the steering committee. Concerns were voiced regarding the width of the corridor, the need for downstream channel enlargements, and the need to modify all roadway crossings. This concept was eliminated from further consideration.

A variation of the Conveyance Channel (D1) was developed that attempted to avoid the need for channel enlargements in the lower reach of Bear Creek. This concept is known as the Frontier Channel Conveyance/Storage, and was given the notation D3. It calls for the construction of a frontier channel along Bear Creek in the areas currently subject to the overflow. The frontier channel would be sufficiently deep and wide to provide the storage necessary to reduce peak flow rates in the overflow so that they would not exceed the capacity of the lower reach of Bear Creek. Channel crossings and other encroachments would be used to control water surface elevations in the overflow and to ensure the required storage volume. Collection channels would collect overflow and deliver it to the frontier channel.

5.1.3 Nonstructural Category (“A”)

Four non-structural concepts were introduced. Two of these, Acquisition (A1) and the Conveyance Zone (A3), fully address the primary objective. The other two, Development Criteria (A2) and Prairie Restoration (A4), do not. However, they do address secondary objectives and could be part of a larger comprehensive strategy.

Acquisition (A1) was considered to be an unreasonable solution, at least as a core measure. While it would fully meet conservation objectives, the cost would be extremely high. While it was noted that voter’s might approve dedicated funds for a conservation and recreation purpose, this outcome would be uncertain. A scaled down version of this measure could be included as part of a larger strategy.

The adoption of a Conveyance Zone (A3) raised concerns regarding the property within the zone. Policy would allow for the increase in water surface elevations in the conveyance zone, and therefore it would be necessary to acquire the land within the zone by fee or easement. Because of this, the size of the zone, and the need for a collection system, this measure was rejected and eliminated from further consideration.

Development Criteria (A2) and Prairie Restoration (A4) were recognized as potential contributors to a larger strategy. It is widely recognized that unique development criteria is necessary for the portions of the study area that are impacted by the overflow. There was some general hesitancy regarding requirements for prairie restoration, as there are unknowns regarding cost and responsibility, and it may be best as an optional measure.

5.1.4 Mitigation Category (“B”)

None of the mitigation measures provide a full solution, and in fact they do not address the overflow itself. Upper Cypress Extended Detention (B1) and Addicks High Flow Retention (B2) address volume into Addicks Reservoir. The goal of these measures would be to ensure that volume into Addicks Reservoir does not increase as land development occurs in the study area. The steering committee supported the notion of protecting Addicks Reservoir from volume increases as development occurs, but both of these measures were overly complex and considered difficult to implement. A simplified approach was identified that called for retention of the equivalent of two inches of runoff for development in the Addicks Watershed and the Upper Cypress Watershed upstream of the overflow. Consequently, these two measures were eliminated, and the revised approach is included in the Development Criteria (A2).

Development Incentives (B3) were determined to be too vague. An alternative approach, that may achieve the same result, is to evaluate proposed land developments based upon their outcome, and leave the means to achieve the outcome to the individual land developers. As such, the adoption of Development Criteria (B3) would facilitate the use of low impact development measures and any other measures necessary to achieve the necessary outcome.

5.1.5 Do-Nothing Category (“E”)

While a do-thing approach is always a viable alternative to any planning activity, it is widely agreed that, at minimum, specific development criteria is needed in the overflow. In discussions with the steering committee, there was sentiment that the land development community is better positioned to provide the overflow solution. As such, the development criteria could include requirements for development as well as provisions for reserving a corridor. The purpose of the corridor would be to ensure that future solutions are not precluded by land development activity.

5.1.6 Summary of Screening

Table C.5.2 summarizes the results of the screening activity. It lists the original bookend measures as well as the additional measures developed during screening, and details the outcome for each measure.

Table C5.2
Summary of Bookend Concept Screening

Concept Number	Bookend Concept	Carry Forward?	Comment
C1	Katy-Hockley North/Cypress Reservoir	Yes	Reduce size, must ensure no change in overflow volume
C2	Mound Creek Reservoir	Yes	Reduce size, remove gate requirement
C3	Katy-Hockley Reservoir (New)	Yes	
D1	Conveyance Channel	Yes	Reduce size, avoid downstream channel modifications
D2	Bermed Floodway	No	
D3	Frontier Channel Conveyance/Storage (New)	Yes	
A1	Acquisition	Yes	Reduce in size
A2	Development Criteria	Yes	Outcome based, include retention of 2" of runoff, reserve corridor
A3	Conveyance Zone	No	
A4	Prairie Restoration	Yes	Use as an option for volume control in A2
B1	Upper Cypress Extended Detention	No	Simplified version in A2
B2	Addicks High Flow Retention	No	Simplified version in A2
B3	Development Incentives	No	Use as option for volume control in A2
E1	Do-Nothing	No	Replaced by A2 as a stand-alone

5.2 Management Plan 1 – Katy-Hockley Reservoir

This strategy is based upon the Katy-Hockley Reservoir (C3) located entirely in the Addicks Watershed. The reservoir would capture overflow after it crosses the watershed divide. This measure would be supplemented by John Paul's Landing (JPL) storage (C4) and Development Criteria (A2). The reservoir would outfall into Bear Creek, which would be enlarged between the reservoir and the downstream development (where the existing channel is larger).

5.2.1 Configuration

Management Strategy 1 – Katy Hockley Storage is depicted in Exhibit C5.1. There would be two cells within the reservoir, referred to as the lower cell and the upper cell. The lower cell would be located along Katy-Hockley Road, and the upper cell would be located immediately to the west of and adjacent to the lower cell. The purpose of the two cells would be to maximize the use of available volume within the reservoir footprint without exceeding the natural ground elevation at the watershed divide, as this would be necessary to prevent an influence on the volume of overflow.

The berms would vary in height, with a maximum height of eleven feet. They would be constructed using excavated material from within the reservoir. This would be the only excavation within the reservoir.

Bear Creek would be enlarged for a distance of about 22,000 feet, from the outlet of the lower pool near the intersection of Longenbaugh Road and Porter Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel would utilize natural channel design principles within a 500-foot corridor. The channel would be sufficiently deep to accept drainage from lateral channels. In addition, an outlet channel would be located along the perimeter of the dam to provide drainage access for the upper pool. The two pools would have a combined maximum 1% (100-year) release of 4,500 cfs, which is the maximum capacity of the lower reach of Bear Creek.

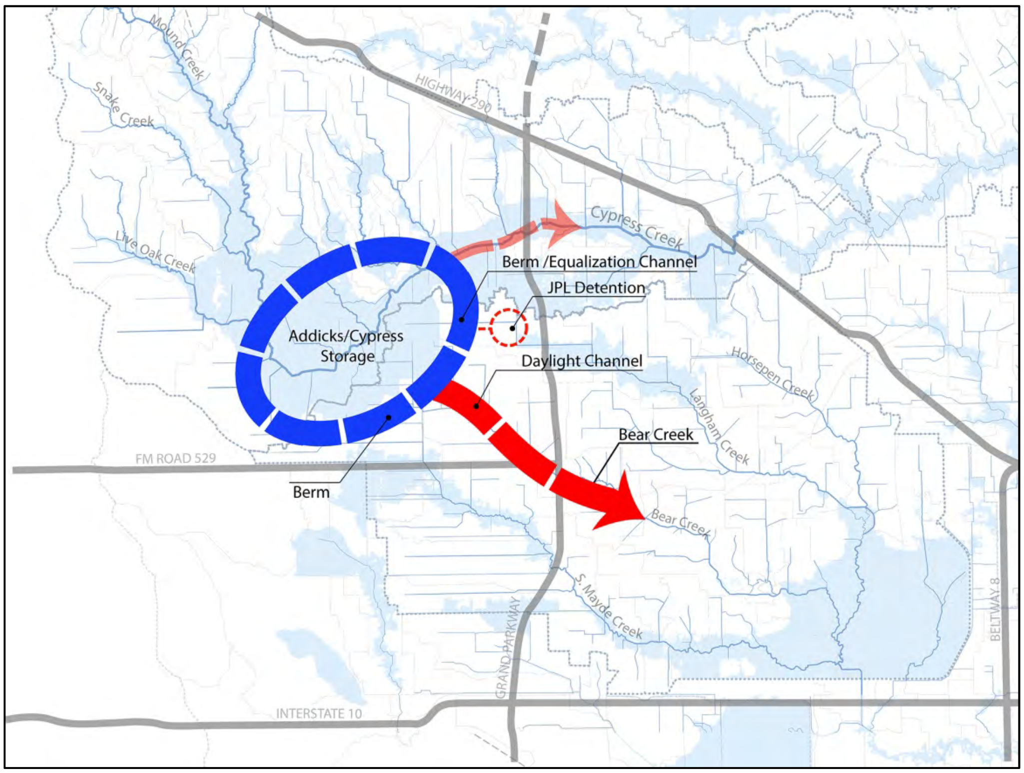


Exhibit C5.1
Management Plan 1 – Katy-Hockley Storage

The lower pool would inundate 3,300 acres at a 1% (100-yr) pool elevation of 161.9, providing 6,600 acre-feet of storage. It would outfall at a peak rate of 3,000 cfs via a constrained channel section. Not including current channel areas, the average depth would be about two feet, and the maximum depth is about five feet. This cell would drain in about two days.

The upper pool would inundate 2,600 acres at a 1% (100-year) water surface elevation of 165.4, providing 4,200 acre-feet of storage. It would outfall at a peak rate of 1,500 cfs via a box culvert conduit into an outlet channel that runs along the perimeter of the dam and ultimately into Bear Creek near the lower pool outlet. The average depth would be about two feet, with a maximum depth of eight feet. This cell would drain in about five days.

In both pools, the dam would include a wide spillway that protects the structure from larger events. During extreme events (those larger than 1% (100-year), flows could exceed downstream capacity – however, the net impact of the extreme event flow would be less than the existing condition.

In total, approximately 5,900 acres of land would be inundated during the 1% (100-yr) event. This includes 5,425 acres of private land, 245 acres of conservation land, and 230 acres of public land. The current footprint would include Paul Rushing Park, however this footprint could be revised to avoid the park. This would result in a decrease in storage volume.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that would prevent the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria would require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome based, and developers will determine the approach to manage this runoff.

5.2.2 Implementation Considerations

This strategy would require a dam safety permit from the TCEQ. A Section 404 permit would be required for the enlargement of Bear Creek, however the utilization of natural channel design principles would facilitate mitigation-in-place. With a project of this magnitude, there is the potential for NEPA conformance, which could take 3-5 years.

Construction of the reservoir would require the acquisition of significant land areas. This would be time consuming and may take several years. In addition, construction of the project would take 3-4 years.

There is not a clear means to phase in the project, however the use of two reservoir pools allows for the phasing of the reservoir itself.

Overflow spillways would be constructed to manage events larger than the 1% (100-year) event. This would be sized and configured to maintain the existing water surface elevations along Cypress Creek, and would result in unmanaged flows downstream of the storage cells. However, these flows will not exceed current flow rates should such an event occur. No additional land would be required to accommodate events larger than the 1% (100-yr) event.

5.2.3 Benefits

This strategy manages the entire overflow, and removes it from all areas outside the footprint of the project. Approximately 15,000 acres of the overflow area is recovered for land development. In addition, the reservoir provides some relief to flood flows in the Bear Creek and South Mayde Creek watersheds, as it occupies portions of the contributing drainage area to those streams. The strategy protects an additional 5,425 acres of land from development, increasing the conservation footprint in the study area, and ensures that this area does not contribute additional volume to Addicks Reservoir via development.

5.2.4 Costs

This strategy has an estimated cost of $328,000,000. This includes $176,000,000 for land and $125,000,000 for construction. A high level cost estimate is presented in Table C5.3.

Table C5.3
Management Plan 1, Katy-Hockley Reservoir
Cost Estimate

Reservoir		
Land	$ 166,000,000	
Earthwork	$ 13,100,000	
Outlet Works	$ 8,750,000	
Site Prep and SWPPP	$ 5,230,000	
Other	$ 1,250,000	
Outfall Channel		
Land	$ 10,100,000	
Earthwork	$ 22,200,000	
JPL Detention Excavation	$ 26,100,000	
Adjustments	$ 12,500,000	
Site Prep and SWPPP	$ 3,960,000	
Other	$ 6,000,000	
Summary		
TOTAL LAND		$ 176,000,000
Construction	$ 99,900,000	
Construction Contingency (25%)	$ 25,000,000	
TOTAL CONSTRUCTION		$ 125,000,000
Engineering/Design (8%)	$ 9,990,000	
Environmental/Permitting/ROW (4%)	$ 4,990,000	
Construction Management (10%)	$ 12,500,000	
TOTAL PROFESSSIONAL		$ 27,500,000
GRAND TOTAL		**$ 328,000,000**

5.2.5 Objectives

Table C5.4 summarizes the planning objectives in consideration of Management Plan 1. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures will prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul’s Landing (JPL).

Table C5.4
Management Plan 1 – Katy-Hockley Reservoir
Review of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Overflow is fully managed
2	Relief to Addicks Reservoir	No reduction in volume to Addicks, however increases from development are mitigated
3	Conservation	Over 5,400 acres added to conservation footprint
4	Flood Damage Reduction	Minor reduction in flow along Bear Creek and South Mayde Creek
5	Facilitate Projects by Other Entities	Does not interface with Waller County Master Drainage Plan. Assists in the implementation of lakes in JPL

5.2.6 Constraints

Table C5.5 summarizes the planning constraints in consideration of Management Plan 1.

Table C5.5
Management Plan 1 – Katy-Hockley Reservoir
Review of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk No change in overflow volume or rate
2	Value	Project is relatively expensive
3	Implementable	It would take a long time to construct
4	Compatible with Plans and Programs of Others	Minor inundations of Paul Rushing Park

5.2.7 Potential Variations

Additional flow capacity for outfall is available in Langham Creek and South Mayde Creek. The capacity of South Mayde Creek is relatively low, at 800 cfs, however outfall up to this amount could be directed into South Mayde Creek if necessary or desired. In addition, Langham Creek can convey approximately 2,200 cfs, and the presence of JPL detention facilitates release into Langham Creek.

The current footprint inundates Paul Rushing Park. While these inundations would be infrequent (approximately once every 10 years), short in duration (less than one day), and shallow (mostly less than two feet), the project could be aligned to avoid the park completely. This would result in a slightly longer berm and a slightly reduced storage capacity for the lower pool.

5.3 Management Plan 2 – Mound Creek Reservoir plus Overflow Conveyance "C"

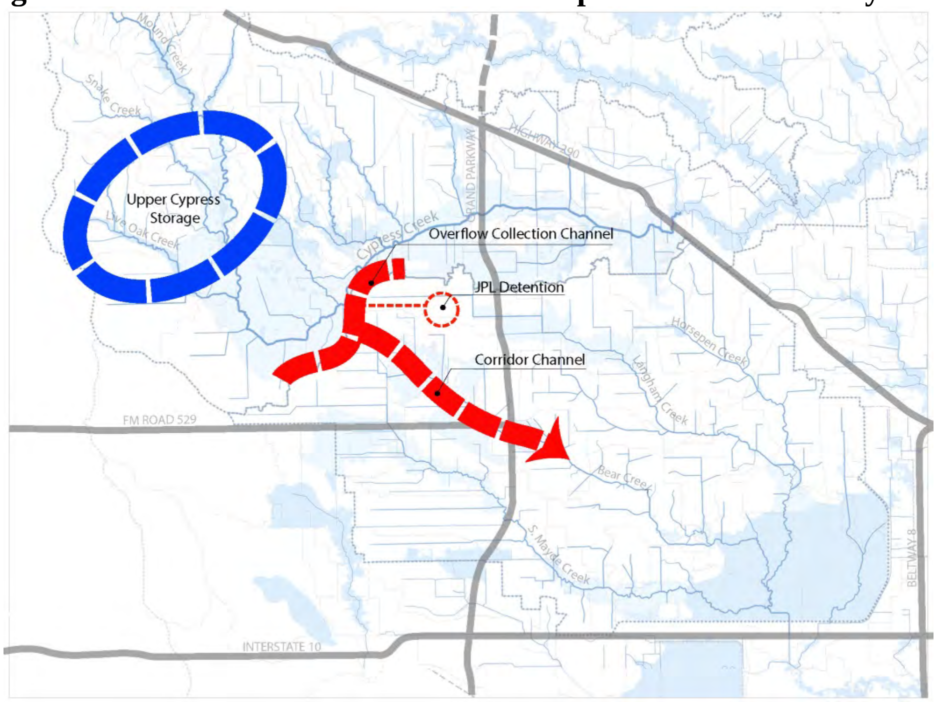
This strategy is based upon a scaled down version of both the Mound Creek Reservoir (A2) and the Overflow Conveyance Channel (B1). The conveyance channel would be reduced in size and capacity to recognize the constraints in flow rate in the lower reach of Bear Creek, and to therefore avoid the need for this channel modification in the developed portion of lower Bear

Creek. This measure would be supplemented by JPL storage (C4) and Development Criteria (A2). The conveyance channel would include collection channels along the watershed divide (this "collection" configuration is known as Conveyance "C"). Bear Creek would be constructed using natural channel design techniques within a 500-foot corridor.

5.3.1 Configuration

Management Plan 2 – Mound Creek Reservoir plus Overflow Conveyance "C" is depicted in Exhibit C5.2. The channel would be expanded to convey 4,500 cfs of discharge into the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The channel would utilize natural channel design techniques, and would be sufficiently deep to accept drainage from lateral systems. The overflow would be intercepted by collection channels adjacent to, and south of, the watershed divide that convey flow to the conveyance channel (Conveyance "C").

Exhibit C5.2
Management Plan 2 – Mound Creek Reservoir plus Overflow Conveyance "C"



The existing peak 1% (100-year) overflow of 12,678 cfs would be reduced by the construction of the Mound Creek Reservoir. However, since the reservoir would still allow for a considerable overflow, the required storage volume would be substantially smaller. The reservoir flood to a 1% (100-year) pool elevation of 188 feet would inundate 3,765 acres of land during the 1% (100-year) event, storing 15,730 acre-feet. The maximum storage depth would be 13 feet, with an average depth of seven feet. The vast majority of the reservoir would drain in three days, although the lowest areas near the outlet could drain over a week. With the reservoir in place, the peak overflow would be reduced to 5,500 cfs. The peak overflow volume would be reduced from 23,355 acre-feet to approximately 17,000 acre-feet.

There reservoir would be controlled by an earthen dam with a maximum height of 22 feet. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur. The embankment would include a stabilized emergency spillway that would pass events in excess of the 1% (100-year) event. Such flows could exceed the design capacity of existing infrastructure, but would not exceed current flow rates for a similar event.

There would be a primary outlet structure to Mound Creek, and a secondary outlet structure to Live Oak Creek. The Mound Creek outlet would be in the form of an armored open channel, while the Live Oak Creek outfall would be via a boxed structure.

The reservoir footprint influences 3,765 acres of land. This includes 1,520 acres of private land and 2,245 acres of conservation land.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria requires developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome based, and developers will determine the approach to manage this runoff.

5.3.2 Implementation Considerations

This strategy would require a dam safety permit from the TCEQ. A Section 404 permit would be required for the enlargement of Bear Creek and the construction of the dam on Mound Creek and Live Oak Creek. The utilization of natural channel design principles would facilitate mitigation-in-place of stream impacts. With a project of this magnitude, there is the potential for NEPA conformance, which could take 3-5 years, or longer.

Construction of the reservoir would require the acquisition of significant land areas. This would be time consuming and may take several years. In addition, there are concerns that covenants associated with conservation easements could prohibit the use of conservation land for detention, and there are also concerns that inundation would compromise the conservation function of the land. However, the inundation is very infrequent, shallow, and of short duration, and would not expected to adversely impact its function. Construction of the project would take 3-5 years, or longer.

5.3.3 Benefits

This strategy manages the entire overflow, and removes it from all areas outside the footprint of the project. Approximately 19,000 acres of the overflow area is recovered for land development. The reservoir reduces peak flow rates in the upstream portions of Cypress Creek, and reduces overflow volume to Addicks Reservoir. The strategy protects an additional 1,520 acres of land from development, increases the conservation footprint in the study area, and ensures that this area does not contribute additional volume to Addicks Reservoir via development. This land is of high ecological quality and is located in the Upper Cypress Creek watershed adjacent to existing preservation land.

5.3.4 Costs

This strategy has an estimated cost of $247,000,000. This includes $78,600,000 for land and $138,000,000 for construction. A high level cost estimate is presented in Table C5.6.

Table C5.6
Management Plan 2 - Mound Creek Reservoir plus Overflow Conveyance "C"

Reservoir		
Land	$ 62,300,000	
Earthwork	$ 19,400,000	
Outlet Works	$ 15,200,000	
Site Prep and SWMMM	$ 2,070,000	
Other	$ 250,000	
Overflow Collection		
Land	$ 3,750,000	
Earthwork	$ 2,640,000	
Site Prep and SWMMM	$ 1,980,000	
Outfall Channel		
Land	$ 12,600,000	
Earthwork	$ 21,000,000	
JPL Detention	$ 23,900,000	
Adjustments	$ 12,500,000	
Structures	$ 750,000	
Site Prep and SWMMM	$ 4,330,000	
Other	$ 6,630,000	
Summary		
TOTAL LAND		$ 78,600,000
Construction	$ 111,000,000	
Construction Contingency (25%)	$ 27,700,000	
TOTAL CONSTRUCTION		$ 138,000,000
Engineering/Design (8%)	$ 11,100,000	
Environmental/Permitting/ROW (4%)	$ 5,530,000	
Construction Management (10%)	$ 13,800,000	
TOTAL PROFESSSIONAL		$ 30,400,000
GRAND TOTAL		**$ 247,000,000**

5.3.5 Objectives

Table C5.7 summarizes the planning objectives in consideration of Management Plan 2. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures would prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul's Landing (JPL).

5.3.6 Constraints

Table C5.8 summarizes the planning constraints in consideration of Management Plan 2. The major concerns are the cost and implementation time.

Table C5.7
Management Plan 2 - Mound Creek Reservoir plus Overflow Conveyance "C"
Summary of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Overflow is fully managed
2	Relief to Addicks Reservoir	Reduction in overflow volume to Addicks Reservoir, increases from development are mitigated
3	Conservation	Over 1,500 acres added to conservation footprint
4	Flood Damage Reduction	Reduction in peak flow rates along Upper Cypress Creek
5	Facilitate Projects by Other Entities	Mound Creek could be expanded to accommodate Waller County Master Drainage Plan, Assists in the implementation of lakes in JPL

Table C5.8
Management Plan 2 – Mound Creek Reservoir plus Overflow Conveyance "C"
Summary of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk, does increase volume in Cypress Creek by reduction of overflow volume
2	Value	Project is relatively expensive
3	Implementable	It would take a long time to construct
4	Compatible with Plans and Programs of Others	Compatible

5.3.7 Potential Variations

The Waller County Master Drainage Plan calls for excavated detention in a location similar to the proposed location of the Mound Creek Reservoir. The reservoir could be slightly enlarged to accommodate this plan. There are potential variations on the size of the overflow corridor.

There are also variations in the configuration of the collection area, as noted in Section 5.4.

5.4 Management Plan 3 – Mound Creek Storage plus Overflow Conveyance "D"

This strategy is based upon a scaled down version of both the Mound Creek Reservoir (A2) and the Overflow Conveyance Channel (B1). The conveyance channel would be reduced in size and capacity to recognize the constraints in flow rate in the lower reach of Bear Creek, and to therefore avoid the need for this channel modification in the developed portion of lower Bear Creek. This measure would be supplemented by JPL storage (C4) and Development Criteria (A2). The conveyance channel would include a collection and conservation area downstream of the watershed divide, and the overflow would be collected in channels that are supplemented by small berms on the side opposite of the overflow (this "collection" configuration is known as

Conveyance "D"). Bear Creek would be constructed using natural channel design techniques within a 500-foot corridor.

This strategy is similar to that presented in Section 5.3, with one large difference being the means of collecting the overflow and conveying into the channel.

5.4.1 Configuration

Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "D" is depicted in Exhibit C5.3. The channel would be expanded to convey 4,500 cfs of discharge into the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The channel would utilize natural channel design techniques, and would be sufficiently deep to accept drainage from lateral systems. The overflow would continue to inundate about 2,200 acres, 1,580 acres of which is privately held land with the remainder currently being held as conservation. The 1,580 acres would be preserved as a conservation area, and the collection channels would be located on the south and east perimeter of this conservation area. The conservation area helps assure that the collection would not influence overflow rates and volume, and also provides for additional conservation area. In addition, it would provide some additional attenuation of overflow.

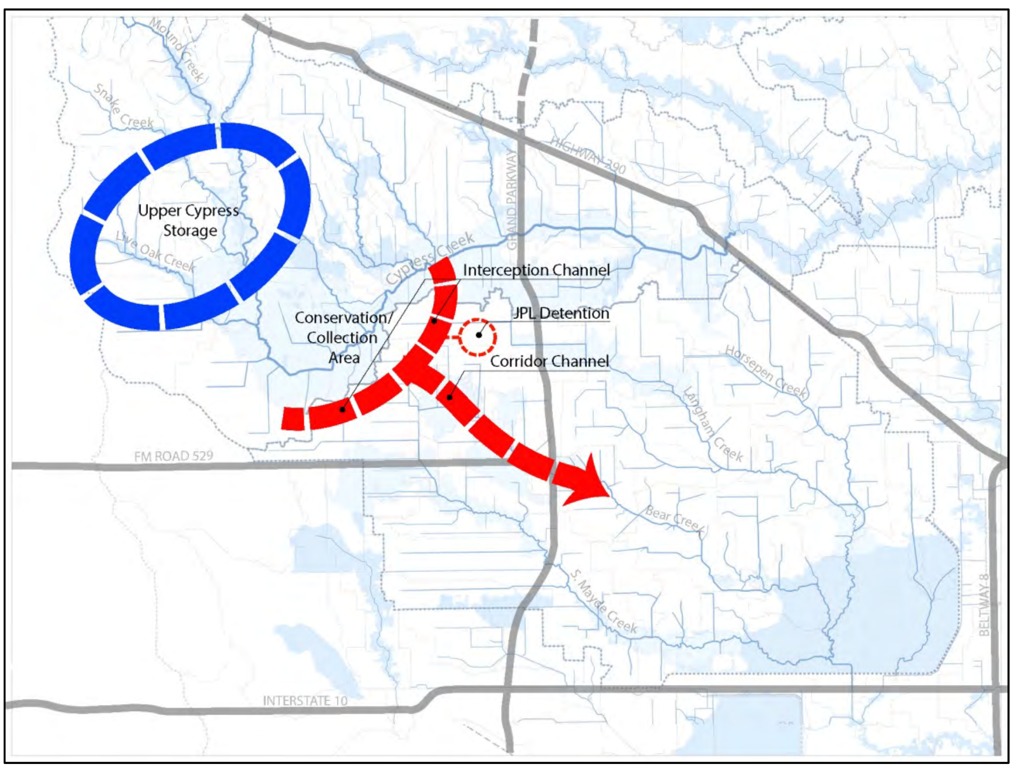


Exhibit C5.3
Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "D"

The existing peak 1% (100-year) overflow of 12,678 cfs would be reduced by the construction of the Mound Creek Reservoir. However, since the reservoir would still allow for a considerable overflow, the required storage volume is substantially smaller. The reservoir flood to a 1% (100-year) pool elevation of 188.0 would inundate 3,765 acres of land during the 1% (100-year) event, storing 15,730 acre-feet. The maximum storage depth would be 13 feet, with an average depth of seven feet. The reservoir would drain in three days. With the reservoir in place, the peak overflow would be reduced to 5,500 cfs. The peak overflow volume would be reduced from 23,355 acre-feet to approximately 17,000 acre-feet.

There reservoir would be controlled by an earthen dam with a maximum height of 22 feet. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur. The embankment would include a stabilized emergency spillway that would pass events in excess of the 1% (100-year) event. Such flows could exceed the design capacity of existing infrastructure, but would not exceed current flow rates for a similar event.

There would be a primary outlet structure to Mound Creek, and a secondary outlet structure to Live Oak Creek. The Mound Creek outlet would be in the form of an armored open channel, while the Live Oak Creek outfall would be via a boxed structure.

The reservoir footprint influences 3,765 acres of land. This includes 1,520 acres of private land and 2,245 acres of conservation land. In addition, the conservation area influences 2,200 acres, including 400 acres of public land (the HCFCD's Hornberger Tract) that is being held in conservation.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into John Paul's Landing (JPL). In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria would require developers to manage the volume equivalent of two inches of runoff. The criteria would be outcome based, and developers will determine the approach to manage this runoff.

5.4.2 Implementation Considerations

This strategy would require a dam safety permit from the TCEQ. A Section 404 permit would be required for the enlargement of Bear Creek and the construction of the dam on Mound Creek and Live Oak Creek. The utilization of natural channel design principles would facilitate mitigation-in-place of stream impacts. With a project of this magnitude, there is the potential for NEPA conformance, which could take 3-5 years, or longer.

Construction of the reservoir requires the acquisition of significant land areas. This would be time consuming and may take several years. In addition, there are concerns that covenants associated with conservation easements may prohibit the use of conservation land for detention, and there are also concerns that inundation would compromise the conservation function of the land. However, the inundation is very infrequent, shallow, and of short duration, and is not expected to adversely impact its function. Construction of the project would take 3-5 years, or longer.

5.4.3 Benefits

This strategy manages the entire overflow, and removes it from all areas outside the footprint of the project. Approximately 18,500 acres of the overflow area is recovered for land development. The reservoir will reduce peak flow rates in the upstream portions of Cypress Creek, and will reduce overflow volume to Addicks Reservoir. The strategy protects an additional 3,100 acres of land from development, increasing the conservation footprint in the study area, and ensuring that this area does not contribute additional volume to Addicks Reservoir via development. This land is of high ecological quality and is located in the Upper Cypress Creek watershed adjacent to existing preservation land.

5.4.4 Costs

This strategy has an estimated cost of $290,000,000. This includes $116,000,000 for land and $143,000,000 for construction. A high level cost estimate is presented in Table C5.9.

Table C5.9
Management Plan 3 - Mound Creek Reservoir plus Overflow Conveyance "D"
Cost Estimate

Reservoir		
Land	$ 62,300,000	
Earthwork	$ 19,400,000	
Outlet Works	$ 15,200,000	
Site Prep and SWPPP	$ 2,070,000	
Other	$ 250,000	
Overflow Collection		
Land	$ 40,700,000	
Earthwork	$ 5,550,000	
Site Prep and SWPPP	$ 2,480,000	
Outfall Channel		
Land	$ 12,600,000	
Earthwork	$ 21,000,000	
JPL Detention	$ 23,900,000	
Adjustments	$ 12,500,000	
Structures	$ 750,000	
Site Prep and SWPPP	$ 4,330,000	
Other	$ 6,630,000	
Summary		
TOTAL LAND		$ 116,000,000
Construction	$ 114,000,000	
Construction Contingency (25%)	$ 28,500,000	
TOTAL CONSTRUCTION		$ 143,000,000
Engineering/Design (8%)	$ 11,400,000	
Environmental/Permitting/ROW (4%)	$ 5,700,000	
Construction Management (10%)	$ 14,300,000	
TOTAL PROFESSSIONAL		$ 31,400,000
GRAND TOTAL		**$ 290,000,000**

5.4.5 Objectives

Table C5.10 summarizes the planning objectives in consideration of Management Plan 3. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures will prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul's Landing (JPL).

Table C5.10
Management Plan 3 - Mound Creek Reservoir plus Overflow Conveyance "D"
Summary of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Overflow is fully managed
2	Relief to Addicks Reservoir	Reduction in overflow volume to Addicks Reservoir, increases from development are mitigated
3	Conservation	Over 3,000 acres added to conservation footprint
4	Flood Damage Reduction	Reduction in peak flow rates along Upper Cypress Creek
5	Facilitate Projects by Other Entities	Mound Creek could be expanded to accommodate Waller County Master Drainage Plan, Assists in the implementation of lakes in JPL

5.4.6 Constraints

Table C5.11 summarizes the planning constraints in consideration of Management Plan 3. The major concerns are the cost and the implementation time.

Table C5.11
Management Plan 3 - Mound Creek Reservoir plus Overflow Conveyance "D"
Summary of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk, does increase volume in Cypress Creek by reduction of overflow volume
2	Value	Project is relatively expensive
3	Implementable	It would take a long time to construct
4	Compatible with Plans and Programs of Others	Compatible

5.4.7 Potential Variations

The Waller County Master Drainage Plan calls for excavated detention in a location similar to the proposed location of the Mound Creek Reservoir. The reservoir could be slightly enlarged to accommodate this plan. There are potential variations on the size of the overflow corridor.

5.5 Management Plan 4 – Private Sector Strategy w/ Channel Reserve

This strategy is fully based upon the No-Action Measure (F), but includes the adoption of Development Criteria (A2). In discussions with the Steering Committee, it was widely agreed that some development criteria would be necessary to recognize the unique nature of the overflow area as well as Addicks and Barker watersheds, and the development and adoption of such criteria would occur even without a project. As such, this management strategy adequately serves as a surrogate for the "do-nothing" alternative. The development criteria would require the reservation of a corridor along Bear Creek to maintain the existing overflow and to allow for any future measures or solutions, should they be desired.

5.5.1 Configuration

Management Plan 4 – Private Sector Strategy w/ Channel Reserve is depicted on Exhibit C5.4. A 1,000 foot corridor would be defined along Bear Creek between the watershed divide and the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. As development occurs, the project would acquire the land within the corridor.

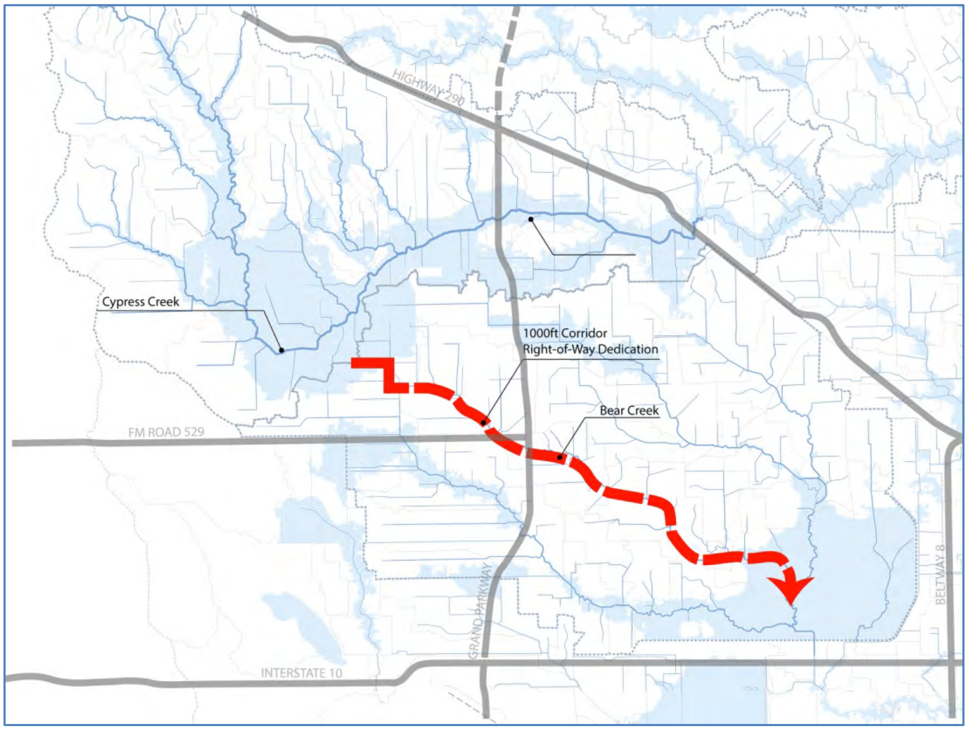


Exhibit C5.4
Management Plan 4 – Private Sector Strategy w/ Channel Reserve

Development criteria would be developed and adopted, and guidelines prepared, that establish requirements and methods for evaluating potential impacts to the overflow. These criteria would require the use of a two-dimensional flow model similar to the one used to delineate and quantify the overflow. The criteria would also require provisions to manage runoff volume, and will require the management of the equivalent of two-inches of runoff volume.

Land developers could utilize the reserved corridor for their stormwater detention if they can demonstrate that there would be no adverse impact to the system. However, they would be required to dedicate this land to the public in lieu of compensation.

5.5.2 Implementation Considerations

This strategy relies upon the private sector to identify and solve issues related to the overflow. The only implementation issues are the adoption of criteria and the reservation of land as development occurs.

There may be challenges in the development of certain properties in the overflow. This strategy does not attempt to address those challenges.

5.5.3 Benefits

This strategy provides a 1,000 foot corridor through the area which may provide connectivity opportunities between Bear Creek Park, Paul Rushing Park, John Paul's Landing (JPL), and on into the Upper Cypress watershed. The corridor may provide other conservation and recreation opportunities as well. It total, over 600 acres is reserved. The development criteria ensures that new land development does not increase runoff volume into Addicks Reservoir.

5.5.4 Costs

This strategy relies upon the private sector for implementation, and therefore has no cost public cost associated with it.

5.5.5 Objectives

Table C5.12 summarizes the planning objectives in consideration of Management Strategy 4. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures will prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul's Landing (JPL).

Table C5.12
Management Plan 4 – Private Sector Strategy with Channel Reserve
Summary of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Not managed by project
2	Relief to Addicks Reservoir	Increases from development are mitigated
3	Conservation	Over 600 acres in corridor
4	Flood Damage Reduction	
5	Facilitate Projects by Other Entities	

5.5.6 Constraints

Table C5.13 summarizes the planning constraints in consideration of Management Strategy 4. The major concerns are the cost and the implementation time.

Table C5.13
Management Plan 4 – Private Sector Strategy with Channel Reserve
Summary of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk
2	Value	Minimal cost
3	Implementable	No public implementation, some properties may have trouble developing
4	Compatible with Plans and Programs of Others	Compatible

5.5.7 Potential Variations

Potential variations in this strategy include the size and orientation of the corridor, and specific nuances of the Development Criteria.

5.6 Management Plan 5 – Katy Hockley N - Cypress Reservoir

This strategy is based upon the Katy Hockley N - Cypress Reservoir (C1) located in both the Upper Cypress and Addicks watersheds. The reservoir would capture flow along Cypress Creek and the overflow area in one contiguous pool, and includes outlets to Cypress Creek and Bear Creek. Bear Creek would be enlarged between the reservoir and the downstream development (where the existing channel is larger). An internal Reservoir Balance channel and structure would be constructed to prevent the increase in volume to either Addicks Reservoir or Cypress Creek. This measure would be supplemented by JPL storage (C4) and Development Criteria (A2).

5.6.1 Configuration

Management Plan 5 – Katy Hockley N - Cypress Reservoir is depicted in Exhibit C5.5. The reservoir would be formed by an earthen berm or dam that extends along Longenbaugh Road, around and outside of Paul Rushing Park, and northward along Katy-Hockley Road across Cypress Creek. The berms would vary in height, with a maximum height of eight feet. They would be constructed using excavated material from within the reservoir. This is the only excavation within the reservoir.

Bear Creek would be enlarged for a distance of about 24,000 feet, from the outlet of the lower pool near the intersection of Longenbaugh Road and West Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel would utilize natural channel design principles within a 500-foot corridor. The channel would be sufficiently deep to accept drainage from lateral channels. The outlet to Bear Creek would be restricted to 2,000 cfs via a boxed conduit. This restriction is necessary to prevent the diversion of additional flow volume from Cypress Creek to Addicks Reservoir during events smaller than the 1% (100-year) event. The outlet to Cypress Creek would be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year), the release to Cypress Creek would be restricted to 5,300 cfs. This results in a combined maximum release of 7,300 cfs.

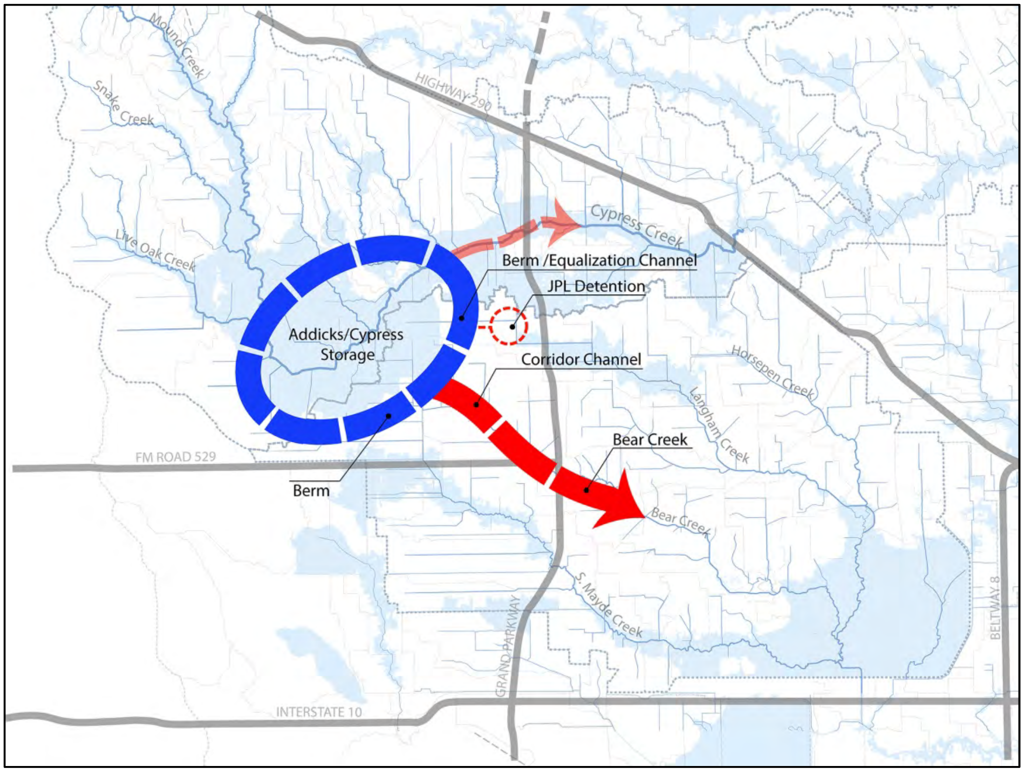


Exhibit C5.5
Management Plan 5 – Katy Hockley N – Cypress Reservoir

The 1% (100-year) reservoir pool elevation would be 168.0, inundating 7,400 acres and providing 26,500 acre-feet of storage. The maximum depth in the basin, excluding existing channels, would be eight foot, with an average depth of four feet. The reservoir would drain in three days.

The dam would include wide spillways that protect the structure from larger events. During extreme events (those larger than 100-year event), flows could exceed downstream capacity – however, the net impact of the extreme event flow would be less than the existing condition. There would be spillways that allow extreme event flows to discharge into both watersheds.

There would be a small channel inside the reservoir along the south dam that direct low flows to the outlet to Bear Creek. In addition, there would be a channel inside the east dam that allows flows to drain back to the Cypress Creek watershed from the Addicks watershed. This is necessary because the higher elevations along Cypress Creek created by the dam would result in the diversion of additional volume across the watershed, and this channel would be necessary to return volume to Cypress Creek. A backflow prevention structure would be constructed near the watershed divide to ensure the channel does not allow for flow from the Cypress Creek watershed to the Addicks Reservoir watershed.

In total, approximately 7,400 acres of land would be inundated during the 1% (100-year) event. This includes 3,540 acres of private land, 3,401 acres of conservation land, and 459 acres of public land (held for conservation).

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria would require developers to manage the volume equivalent of two inches of runoff. The criteria would be outcome based, and developers will determine the approach to manage this runoff.

5.6.2 Implementation Considerations

This strategy would require a dam safety permit from the TCEQ. A Section 404 permit would be required for the enlargement of Bear Creek and for the structure along Cypress Creek. However the utilization of natural channel design principles would facilitate mitigation-in-place. With a project of this magnitude, there is the potential for NEPA conformance, which could take 3-5 years.

Construction of the reservoir requires the acquisition of significant land areas. This would be time consuming and may take several years. In addition, construction of the project would take 3-4 years.

There is not a clear means to phase in the project.

5.6.3 Benefits

This strategy manages the entire overflow, and removes it from all areas outside the footprint of the project. Approximately 17,000 acres of the overflow area is recovered for land development. In addition, the reservoir provides some relief to flood flows in the Bear Creek and South Mayde Creek watersheds, as it occupies portions of the contributing drainage area to those streams. The strategy protects an additional 5,120 acres of land from development, increasing the conservation footprint in the study area, and ensures that this area does not contribute additional volume to Addicks Reservoir via development.

5.6.4 Costs

This strategy has an estimated cost of $358,000,000. This includes $199,000,000 for land and $130,000,000 for construction. A high level cost estimate is presented in Table C5.14.

Table C5.14
Management Plan 5 – Katy Hockley N – Cypress Reservoir
Cost Estimate

Reservoir		
Land	$ 187,000,000	
Earthwork	$ 13,100,000	
Outlet Works	$ 14,700,000	
Site Prep and SWPPP	$ 4,220,000	
Other	$ 750,000	
Outfall Channel		
Land	$ 12,600,000	
Earthwork	$ 23,200,000	
JPL Detention	$ 23,900,000	
Adjustments	$ 12,500,000	
Structures	$ 750,000	
Site Prep and SWPPP	$ 4,330,000	
Other	$ 6,630,000	
Summary		
TOTAL LAND		$ 199,000,000
Construction	$ 104,000,000	
Construction Contingency (25%)	$ 26,000,000	
TOTAL CONSTRUCTION		$ 130,000,000
Engineering/Design (8%)	$ 10,400,000	
Environmental/Permitting/ROW (4%)	$ 5,200,000	
Construction Management (10%)	$ 13,000,000	
TOTAL PROFESSSIONAL		$ 28,600,000
GRAND TOTAL		**$ 358,000,000**

5.6.5 Objectives

Table C5.15 summarizes the planning objectives in consideration of Management Plan 5. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures will prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul's Landing (JPL).

Table C5.15
Management Plan 5 – Katy Hockley N - Cypress Reservoir
Summary of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Overflow is fully managed
2	Relief to Addicks Reservoir	No reduction in volume to Addicks, however increases from development are mitigated
3	Conservation	Over 5,000 acres added to conservation footprint
4	Flood Damage Reduction	Minor reduction in flow along Bear Creek and South Mayde Creek
5	Facilitate Projects by Other Entities	Does not interface with Waller County Master Drainage Plan. Assists in the implementation of lakes in JPL

5.6.6 Constraints

Table C5.16 summarizes the planning constraints in consideration of Management Plan 5.

Table C5.16
Management Plan 5 – Katy Hockley N - Cypress Reservoir
Summary of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk No change in overflow volume or rate
2	Value	Project is relatively expensive
3	Implementable	It would take a long time to construct
4	Compatible with Plans and Programs of Others	

5.6.7 Potential Variations

Additional flow capacity for outfall is available in Langham Creek and South Mayde Creek. The capacity of South Mayde Creek is relatively low, at 800 cfs. However, outfall up to this amount could be directed into South Mayde Creek, if necessary or desired. In addition, Langham Creek can convey approximately 2,200 cfs, and the presence of John Paul's Landing detention facilitates release into Langham Creek.

The original plan does not propose gated outlets, although the configuration could be revised to include gates. This would allow operations to optimize outfall to Cypress Creek and Bear Creek depending on the conditions of the two – and would allow Addicks Reservoir to receive additional volume when it has the capacity or, conversely, allow Cypress Creek to receive additional volume when Addicks Reservoir is stressed. In either situation, criteria should ensure a constant open release of at least 2,000 cfs.

5.7 Management Plan 6 – Frontier Channel / Storage/Conveyance "D"/Storage

This strategy is based upon the Frontier Channel w/ Storage/ Conveyance "D" (D3) measure. A wide "frontier" channel would be constructed along Bear Creek downstream to the enlarged Bear Creek channel, approximately 7,500 feet upstream of Fry Road. The plan would include a conservation area and collection system similar to Conveyance "D" described in Section 5.4. This measure would be supplemented by JPL storage (C4) and Development Criteria (A2).

5.7.1 Configuration

Management Plan 6 – Frontier Channel w/ Storage/Conveyance "D" is depicted in Exhibit C5.6. A 2,200 acre conservation area would be established immediately downstream of the overflow. This area would preserve about 1,580 acres of currently private land, and would facilitate the attenuation of flow and interception of runoff into collection channels south and east of the conservation area. The collection channels would vary in width from 300 feet and 1,000 feet, and would provide attenuation of the overflow while conveying it to the "frontier" channel along Bear Creek.

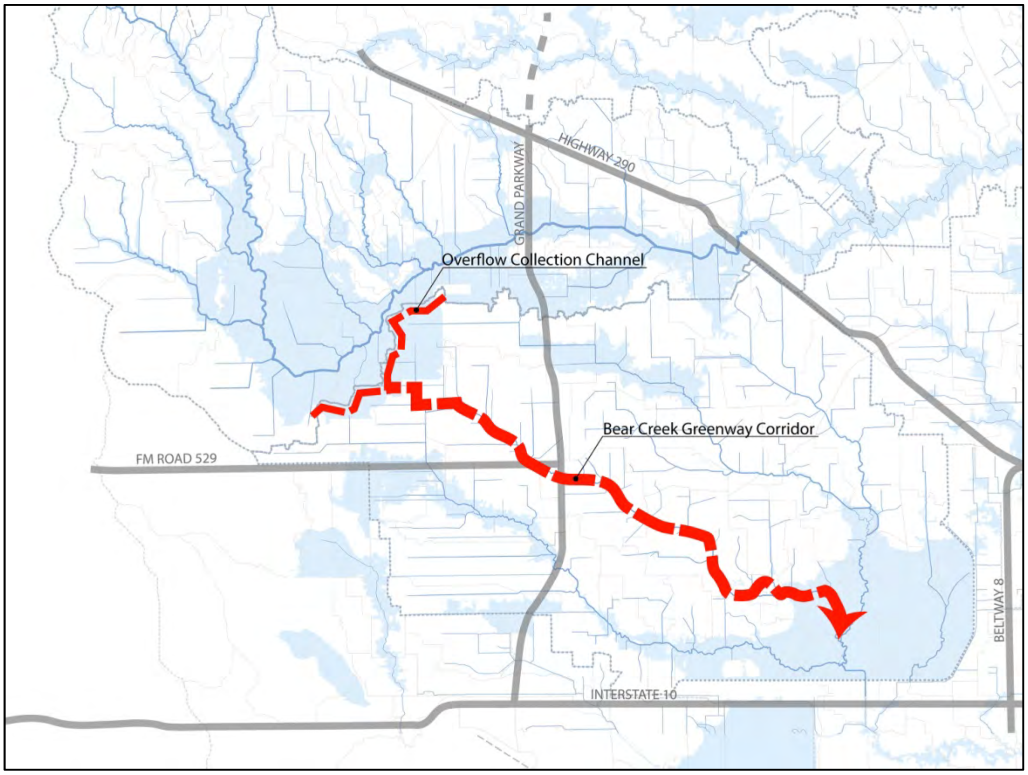


Exhibit C5.6
Management Plan 6 – Frontier Channel w/ Storage/Conveyance "D"

Bear Creek would be widened and deepened as a "frontier" section, using natural channel design techniques and including intermittent structures to maximize storage and assist in the attenuation and reduction of flows. The frontier channel would be located in a 1,000 foot wide corridor, and would extend for a length of about 24,000 feet. It would originate near the intersection of Katy-Hockley Road and West Road. In total, approximately 2,900 acres of land would be reserved for the project.

Approximately 500 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area's lands develop. The criteria would require land developers to manage the volume equivalent of two inches of runoff. The criteria would be outcome based, and land developers will determine the approach to manage this runoff.

5.7.2 Implementation Considerations

This strategy would require extensive excavation, and the identification of a means to spoil the material. However, implementation may be partnered with ongoing development activity, and construction could occur in conjunction with development. In addition, this measure could be phased from upstream to downstream, as long as provisions are made to funnel the overflow into the collection area.

A Section 404 permit would be required for the enlargement of Bear Creek and for the structure along Cypress Creek. However the utilization of natural channel design principles would facilitate mitigation-in-place. With a project of this magnitude, there is the potential for NEPA conformance, although this is considered unlikely for this plan.

Construction of the plan would take a long time due to the land acquisition and the large amount of excavation. Construction may take 5-7 years or longer.

5.7.3 Benefits

This strategy manages the entire overflow, and removes it from all areas outside the footprint of the project. Approximately 18,000 acres of the overflow area is recovered for land development. The strategy protects an additional 2,900 acres of land from land development, increasing the conservation footprint in the study area, and ensuring that this area does not contribute additional volume to Addicks Reservoir via land development. The attenuation in the corridor provides a slight decrease in local runoff to Bear Creek, and the corridor will also slightly reduce local flows in South Mayde Creek.

5.7.4 Costs

This strategy has an estimated cost of $337,000,000. This includes $77,800,000 for land and $213,000,000 for construction. A high level cost estimate is presented in Table C5.17.

5.7.5 Objectives

Table C5.18 summarizes the planning objectives in consideration of Management Plan 6. As the table indicates, the primary objective is fully addressed. In addition, the conservation footprint is increased, and measures will prevent expected increases to runoff volume to Addicks Reservoir as development occurs. The strategy assists in the construction of lakes in John Paul’s Landing.

5.7.6 Constraints

Table C5.19 summarizes the planning constraints in consideration of Management Plan 6.

Table C5.17
Management Plan 6 – Frontier Channel w/ Storage/Conveyance "D"
Cost Estimate

Overflow Collection		
Land	$ 40,700,000	
Earthwork	$ 5,550,000	
Site Work and SWPPP	$ 2,480,000	
Conveyance/Storage Corridor		
Land	$ 35,400,000	
Earthwork	$ 114,000,000	
Land	$ 1,650,000	
JPL Detention	$ 23,900,000	
Adjustments	$ 12,500,000	
Structures	$ 1,500,000	
Site Work and SWPPP	$ 3,880,000	
Other	$ 6,000,000	
Summary		
TOTAL LAND		$ 77,800,000
Construction	$ 170,000,000	
Construction Contingency (25%)	$ 42,500,000	
TOTAL CONSTRUCTION		$ 213,000,000
Engineering/Design (8%)	$ 17,000,000	
Environmental/Permitting/ROW (4%)	$ 8,500,000	
Construction Management (10%)	$ 21,300,000	
TOTAL PROFESSSIONAL		$ 46,800,000
GRAND TOTAL		**$ 337,000,000**

Table C5.18
Management Plan 6 – Frontier Channel w/ Storage/Conveyance "D"
Summary of Planning Objectives

No	Objective	Summary
1	Overflow Management (Primary)	Overflow is fully managed
2	Relief to Addicks Reservoir	No reduction in volume to Addicks, however increases from development are mitigated
3	Conservation	About 2,900 acres added to conservation footprint
4	Flood Damage Reduction	Minor reduction in flow along Bear Creek and South Mayde Creek
5	Facilitate Projects by Other Entities	Does not interface with Waller County Master Drainage Plan. Assists in the implementation of lakes in JPL

Table C5.19
Management Plan 6 – Frontier Channel w/ Storage/Conveyance "D"
Summary of Planning Constraints

No	Constraint	Summary
1	Avoid Increase in Flood Risk	No increase in flood risk No change in overflow volume or rate
2	Value	Project is relatively expensive
3	Implementable	It would take a long time to construct
4	Compatible with Plans and Programs of Others	

5.7.7 Potential Variations

Additional flow capacity for outfall is available in Langham Creek and South Mayde Creek. The capacity of South Mayde Creek is relatively low, at 800 cfs. However, outfall up to this amount could be directed into South Mayde Creek if necessary or desired. In addition, Langham Creek can convey approximately 2,200 cfs, and the presence of JPL detention facilitates release into Langham Creek.

5.8 Evaluation of Management Strategies

The management strategies were presented and discussed with the Steering Committee over the course of several meetings. In the course of the meetings refinements were made to the strategies, and additional strategies were added. The six strategies presented in this section include these refinements.

5.8.1 Evaluation Process and Considerations

The six management strategies are summarized in Table C5.20. This table includes relative comparisons of various attributes of the strategies. In addition, the evaluation included a complete consideration of the full set of planning objectives and constraints. The goal of the evaluation was to gain feedback from the Steering Committee in the evaluation of the objectives and constraints, to identify management strategies that the Steering Committee could accept and endorse, and ultimately to identify two strategies to carry forward for additional evaluation.

The following bullet points summarize considerations and conclusions of the Steering Committee and the planning team:

- The high cost and the implementation time associated with the structural solutions is of large concern to the land development interests
- In order to utilize conservation land as part of the solution, the project must return increase the net value of conservation in the study area
- Development criteria must be adopted for both Harris County and Waller County, and it may be necessary to return in-kind value back to Waller County in recognition of it adopting policy that addresses a problem in Harris County
- Development criteria is necessary, however outcome-based criteria is preferred over prescriptive criteria
- A private sector solution should always be considered a viable option

There was general consensus among the steering committee regarding these considerations and conclusions, and they framed the further evaluation and identification of preferred strategies.

Table C5.20
Comparison of Management Plans

Plans 1-3

Parameter	Plan 1	Plan 2	Plan 3
	Katy-Hockley Reservoir	**Mound Crk Reservoir w Overflow Conveyance "C"**	**Mound Crk Reservoir w Overflow Conveyance "D"**
Managed Storage			
100yr Pool Elev	161.9 (upper pool)/ 165.4 (lower pool)	188.0	188.0
PMP Pool Elev	n/a	191.7	191.7
PMP+Freeboard (4.5')	n/a	196.5	196.5
100yr Storage (ac-ft)	10,800(6,600+4,200)	15,730	15,730
PMP Storage (ac-ft)	n/a	27,500	27,500
PMP Spillway Length (ft)	4,000	6,000	6,000
Storage/Conservation Land			
Private (ac)	5,424	1,520	3,100
Conservation (ac)	245	2,245	2,245
Public (ac)	230	0	400
Total (ac)	5,899	3,765	5,745
Collection/Channel Land			
Private (ac)	325	570	650
Conservation (ac)	0	30	0
Public (ac)	0	0	0
Total (ac)	325	600	650
Excavation/Earthwork			
Volume (cy)	4,600,000	8,200,000	8,900,000
Attributes			
Unit Land Value	Highest	Low	Low/Moderate
Change in Overflow Volume	None	Decrease	Decrease
Permits	Moderate	Most Difficult	Most Difficult
Criteria Change	Yes	Yes	Yes
Storage Area - Inundation Depth	8 ft max, 2 ft avg (upper cell) 5 ft max, 2 feet avg (lower cell)	13 ft max, 7 ft avg	13 ft max, 7 ft avg
Storage Area Drain Time	5 days (upper cell) 2 days (lower cell)	3 days (most)	3 days (most)
Land Removed from Overflow	15,000 ac	19,000	18,500
Cost			
Land	$176,000,000	$78,600,000	$117,000,000
Construction	$125,000,000	$138,000,000	$126,000,000
Professional	$27,500,000	$30,400,000	$28,000,000
Total	$328,000,000	$247,000,000	$271,000,000

Table C5.20 (Continued)
Comparison of Management Plans

Plans 4-6

Parameter	Plan 4	Plan 5	Plan 6
	Private Sector with Channel Reserve	**Katy Hockley N - Cypress Reservoir**	**Frontier Channel w Storage/Conveyance "D"**
Managed Storage			
100yr Pool Elev		168.0	
PMP Pool Elev		170.7	
PMP+Freeboard (4.5')		175.2	
100yr Storage (ac-ft)		26,500	
PMP Storage (ac-ft)		56,636	
PMP Spillway Length (ft)		8,000 (4,000+4,000)	
Storage/Conservation Land			
Private (ac)	0	5,120	1,180
Conservation (ac)	0	5,725	0
Public (ac)	0	415	400
Total (ac)	0	11,260	1,580
Collection/Channel Land			
Private (ac)	0	420	1,180
Conservation (ac)	0	0	0
Public (ac)	0	0	0
Total (ac)	0	420	1,180
Excavation/Earthwork			
Volume (cy)	TBD	7,100,000	20,000,000
Attributes			
Unit Land Value	Moderate	Moderate/High	Moderate
Change in Overflow Volume	None	None	None
Permits	Easiest	Difficult	Easy/Moderate
Criteria Change	Yes	Yes	Yes
Storage Area - Inundation Depth	n/a	8 ft max, 4 ft avg	n/a
Storage Area Drain Time	n/a	4-6 days	n/a
Land Removed from Overflow	19,000 (by others)	18,000 ac	18,000 ac
Cost			
Land		$206,000,000	$77,800,000
Construction		$134,000,000	$213,000,000
Professional		$29,000,000	$46,800,000
Total	n/a	$369,000,000	$337,000,000

5.8.2 Identification of Preferred Management Plans

According to the TWDB Grant, two management plans are to be identified and studied in greater detail. It was determined that the two preferred strategies are Management Plan 3 – Mound Creek Reservoir Plus Overflow Conveyance "D" and Management Plan 5 – Katy Hockley N - Cypress Reservoir. In addition, as a surrogate for the no-action, the Management Plan 4 – Private Sector Strategy with Channel Reserve remains a viable alternative. Due to its passive nature, it does not warrant further analysis and refinement beyond the identification and adoption of Development Guidelines.

In the review and discussion of the management strategies, the concept of the Mound Creek Reservoir was well received by the steering committee. The reservoir is located furthest away from areas of land development pressure, and therefore the land may be less expensive. In addition, the topography of the area results in more efficient storage. The reservoir could also be refined to include provisions for the Waller County Master Drainage Plan, and may afford additional recreation and park opportunities for Waller County. When compared with other structural alternatives, it is the least expensive.

Management Plans 2 and 3 both consider the Mound Creek Reservoir, with the only difference being the means to intercept and collect the overflow. While Management Plan 2 is less expensive, it does not contribute very much to conservation interests. The location of the reservoir requires the use of conservation land, and additional conservation measures are necessary to ensure that the project contributes to the net conservation value in the study area. That is the primary basis of the selection of Management Plan 3 over Management Plan 2. It was further determined that these two strategies were too identical to warrant the selection of both of them, so Management Plan 2 was omitted from further consideration.

It was determined that Management Plan 5 – Katy Hockley N - Cypress Reservoir was preferable to Management Plan 1 –Katy-Hockley Reservoir and to Management Plan 6 – Frontier Channel Conveyance "D" /Storage. This was mostly by a process of elimination. The goal of Management Plan 1 was to maintain the storage within the Addicks Reservoir. This concept was originally developed for a reservoir situated further to the south and to the east, however known land development activity resulted in its alignment nearer to the watershed divide. This caused challenges with the allowable pool, eventually resulting in the two reservoir pools. Holding the pool elevation to natural ground elevation at the watershed divide ultimately compromised the effectiveness of the reservoir, and the alignment for Management Strategy 5 was determined to be more effective and superior.

Management Plan 6 relies upon excavation to provide the necessary storage. The project will require a substantial amount of storage volume to prevent increasing the flood risk in downstream channels. The most effective and economical means to obtain large volume of storage is by using the natural topography of land and dams along waterways, as excavation proves to be too costly and difficult to implement. Cost estimates in support of the evaluation confirmed this, resulting in the elimination of Management Plan 6.

Management Plan 5 is also costly, but it does provide a very large conservation footprint, and avoids the prime development activity to the south and east.

6.0 Preferred Management Plans

The two preferred management strategies, Management Plan 3 – Mound Creek Reservoir with Conveyance "D" and Management Plan 5 – Katy Hockley N - Cypress Reservoir were considered in greater detail. In doing so, refinements were made to their configuration, and cost estimates were developed in greater detail. In addition, considerations were made to their potential implementation. This section describes these two strategies in greater detail, including their refinements. Appendix F describes implementation in greater detail, and Appendix E described the cost estimates in greater detail.

6.1 Management Plan 3 – Mound Creek Reservoir Plus Overflow Conveyance "D"

Management Plan 3 – Mound Creek Reservoir with Overflow Conveyance "D" was introduced in Section 5.4 of this document. This section provides more detail of this management plan.

6.2.1 Description of Features

The Mound Creek Reservoir with Overflow Conveyance "D" (Management Plan 3) is depicted in Exhibit C5.5. A reservoir would be formed by an earthen dam that extends across Mound Creek just upstream of the confluence with Live Oak Creek. West of Mound Creek, the dam would extend for about 14,000 feet to the west; while east of Mound Creek the dam would turn toward the north extending for a distance of about 11,000 feet. The dam would vary in height, with a maximum height of 22 feet and an average height of about 18 feet. The dam would be constructed using excavated material from within the reservoir. This is the only excavation within the reservoir.

The primary outfall from the Mound Creek Reservoir would be via Mound Creek, which would remain open through the channel section. The dam would extend near to the edge of the channel banks. During normal flow, Mound Creek would flow as it does today. However, when larger rainfalls result in flows exceeding the banks and occupying the floodplain, the dam would impede this overbank flow and result in the inundation and subsequent attenuation within the reservoir. The Mound Creek channel would be stabilized with rip-rap and slope paving, as necessary, through the dam opening to prevent erosion and degradation of the channel. The outlet to Cypress Creek would be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year), the release to Cypress Creek would be restricted to 7,500 cfs. A secondary outfall at Live Oak Creek would be constructed to ensure that flow is maintained along Live Oak Creek. This outfall would be single 6' x 6' concrete box structure.

Within the Addicks Watershed, there would be collection channels along Katy-Hockley Road and Longenbaugh Road that intercept the residual overflow. These channels would vary in width. Along Longenbaugh, the channel would be about 100 feet wide, and along Katy Hockley Road, the channel would vary between 150 feet and 300 feet wide. The area between these interception channels and Cypress Creek is currently conservation land or is privately owned. This management plan calls for the acquisition of the private land (either in fee or via flooding and/or conservation easements) in order increase the overall conservation footprint. During the construction of these channels, a berm would be constructed along the interception channel on the opposite bank of the overflow (south of the Longenbaugh interception channel, and east of the Katy-Hockley Longenbaugh channel. These berms would be 3-5 feet high, and would ensure that the overflow does not extend past the interception channels should they become full. During larger events, such as the 1% (100-year) event, the inundation channels would become full and the berms will cause a slight rise in the water surface elevation in portions of the overflow. Therefore the conservation area acquired for the property would also provide attenuation of the overflow. Existing conservation land would not be affected by this rise in water surface elevation. In total, the conservation/collection area would occupy 2,200 acres – 1,580 acres of private land, 440 acres of public land, and 180 acres of existing conservation land.

Bear Creek would be enlarged for a distance of about 24,000 feet, from where the interception/collection channels join Bear Creek downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel would utilize natural channel design principles within a 500-foot corridor. The channel would be sufficiently deep to accept drainage from lateral channels.

The 1% (100-year) reservoir pool elevation would be 188.0 feet, inundating 2,980 acres during this event. This would result in a maximum flood depth of about 14 feet, excluding existing channels. The reservoir would be sized to recognize the probably maximum precipitation (PMP), which is the largest conceivable meteorological event. The land acquisition, dam construction, and overflow spillway would be designed in consideration of that event. The dam would include wide spillways that protect the structure from larger events. During extreme events (those larger than 1%, or 100-year, flows could exceed downstream capacity – however, the net impact of the extreme event flow would be less than the existing condition.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

The plan also includes the adoption of development criteria in the study area to ensure that future land development activity does not increase flood risk associated with Addicks Reservoir. Mitigation of potential increases in runoff volume may be in the form of extended detention, retention, low impact development, prairie restoration, or other measures. It is recommended that land developers be given the opportunity to present a method for the consideration of the Flood Control District.

6.2.2 Updated Cost Estimate

The Mound Creek Reservoir with Overflow Conveyance "D" is estimated to cost about $177 million. This differs from previous estimates in the report in that it includes additional features for phased implementation as well as in-kind contributions. The in-kind contributions would be from conservation interests in return for providing additional conservation land, and land development interests which would donate a portion of the outfall channel right-of-way and construct much of the outfall channel. It should be noted that the estimated cost is very sensitive to land cost. Table C6.1 presents a cost summary.

Table C6.1
Plan 3 Cost Estimate – with In-Kind Contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	215	ac	$22,500	$4,837,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total – Land					*$15,825,000*
E2	Collection Channel Excavation	785,000	cy	$8	$5,887,500	
E2	Daylight/Bear Crk Channel Excavation	739,400	cy	$8	$5,545,500	
D5	Backslope Drains	20,000	lf	$25	$500,000	
R3	Katy-Hockley Road	1	ea	$1,500,000	$1,500,000	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$14,183,000*	
	25% Contingency			25%	$3,545,750	
	Total – Construction					*$17,728,750*
	Engineering/Design			8%	$1,418,300	
	Environmental/Permitting/ROW			4%	$709,150	
	Construction Management			10%	$1,772,875	
	Total – Professional					*$3,900,325*
ELEMENT 1 – TOTAL						**$37,454,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land Dedicated by Dev	295	ac	$0	$0	
	Total – Land					*$0*
A1	Channel Excavation	2,059,800	0	$0.0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
	Subtotal - Construction				*$6,263,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$626,300	
	Environmental/Permitting/ROW			4%	$313,150	
	Construction Management			10%	$782,875	
	Total – Professional					*$1,722,325*
ELEMENT 2 TOTAL						**$9,551,075**

Table C6.1 (Continued)
Plan 3 Cost Estimate – with In-Kind Contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total – Land					*$0*
D6	JPL Control Structure	1	ea	$250,000	$250,000	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,750*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Conservation/Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Collection Channels	90	ac	$22,500	$2,025,000	
L9	Convert Temp Esmt to Permanent	1,580	ac	$16,875	$26,662,500	
L6	County Land	440	ac	$0	$0	
	Total – Land					*$28,687,500*
E1	Excavation	1,573,800	cy	$3	$4,721,400	
D5	Back Slope Drains	13,000	lf	$25	$325,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	230	ac	$7,000	$1,610,000	
S3	Silt Fence	33,000	lf	$2	$66,000	
S5	Hydromulch	230	ac	$3,000	$690,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
	Subtotal - Construction				*$7,527,400*	
	25% Contingency			25%	$1,881,850	
	Total - Construction					*$9,409,250*
	Engineering/Design			8%	$752,740	
	Environmental/Permitting/ROW			4%	$376,370	
	Construction Management			10%	$940,925	
	Total - Professional					*$2,070,035*
ELEMENT 4 TOTAL						**$40,166,785**

Table C6.1 (Continued)
Plan 3 Cost Estimate – with In-Kind Contributions

Element 5 - Mound Creek Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	1,520	ac	$22,500	$34,200,000	
L7	Conservation land	665	ac	$0	$0	
L7	Conservation land	1,580	ac	$0	$0	
	Total - Land					*$34,200,000*
E6	Key Trench Excavation	106,950	cy	$7.5	$802,125	
E5	Embankment	1,236,950	cy	$15	$18,554,250	
D2	Mound Ck Outfall Rip-Rap/Slope Paving	15,000	sy	$125	$1,875,000	
D3	Spillway	52,000	lf	$250	$13,000,000	
	Live Oak 200 lf 1-6'x6' box	7,200	sf-lf	$15	$108,000	
E2	Live Oak Excavation	267	cy	$7.5	$2,000	
D2	Live Oak Rip-Rap/Slope Paving	1,733	sy	$125	$216,666	
S1	Mobilization	1	ea	$100,00 0.0	$100,000	
S2	Clear and Grub	190	ac	$7,000	$1,330,000	
S3	Silt Fence	27,500	lf	$2	$55,000	
S5	Hydromulch	190	ac	$3,000	$570,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	1,000	lf	$250	$250,000	
	Subtotal - Construction				$36,878,041	
	25% Contingency			25%	$9,219,510	
	Total - Construction					*$46,097,552*
	Engineering/Design			8%	$3,687,804	
	Environmental/Permitting/ROW			4%	$1,843,902	
	Construction Management			10%	$4,609,755	
	Total - Professional					*$10,141,461*
ELEMENT 5 TOTAL						**$90,439,013**

Plan Totals	
Land	$78,712,500
Construction	$79,467,552
Professional	$19,552,896
TOTAL PLAN COST	**$177,732,948**

6.2.3 Benefits

The completed plan manages the entire overflow without the inundation of private land (excluding the conservation land identified as part of the plan). This removes the floodplain associated with the overflow from over 18,500 acres of developable land. In addition, the flood risk from the overflow is mitigated from existing structures and infrastructure, including roads and parks. The collection/conservation area also provides a measure of flood relief to downstream riverine systems, including Cypress Creek, Bear Creek, and (to a lesser extent) South Mayde Creek.

In addition to flood relief, the plan increases the conservation footprint in the study area by about 3,100 acres. Furthermore, this conservation land is contiguous to existing conservation land, assisting in the long-term establishment of a large contiguous conservation area. The plan also provides a 500-foot green space corridor between the proposed reservoir and the existing Bear Creek channel, affording the opportunity for recreational connectivity between facilities in Addicks Reservoir and Paul Rushing Park, John Paul’s Landing, and any future features associated with the proposed reservoir.

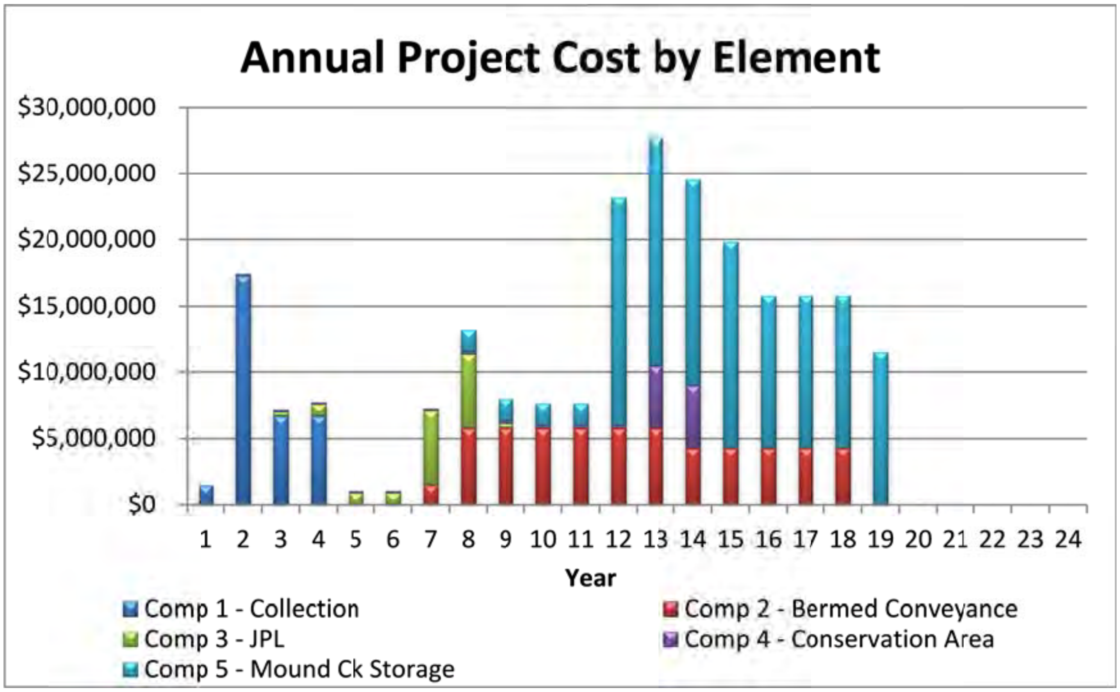
The plan does not reduce flood risk in the upstream fringes of Addicks Reservoir. However, the policy associated with the plan offsets the expected increase in runoff due to land development activity. Furthermore, development policy also results in decreased runoff from sites, providing a small amount of relief to the downstream systems. In addition, by increasing the permanent undeveloped footprint in the watershed, there is an assurance that this area will not increase the volume into Addicks Reservoir.

6.2.4 Implementation

The features described in this management plan would take many years to implement. There is a long lead time associated with funding, land acquisition, permitting, and construction. However, development pressure is imminent, and to be viable a phased implementation must be available. An implementation strategy has been developed that allows for the incremental recovery of developable land in a manner that attempts to recognize these realities. Five "components" are presented. They are similar to phases, however they do not necessarily have to progress in order from 1 to 5.

1. As an interim measure, protect a portion of the overflow by building the interception collection channel near Katy-Hockley Road. This will result in an inundated collection area, and will require some excavation in the location of the future outfall channel to daylight these collection channels. Temporary flooding easements, permanent easements, or fee ownership of the collection area will be acquired. Minor channel modifications will be made to Bear Creek in the vicinity of Fry Road to increase its carrying capacity.
2. As development occurs, the 500' wide corridor along Bear Creek will be dedicated and the reservoir outlet channel will be constructed by land developers. These first two measures will remove the overflow from 5,500 acres.
3. Excavate detention within basins in John Paul's Landing (JPL), and construct diversion from Bear Creek and outfall structure. Land developers will construct diversion channel to JPL. This will remove the overflow from 3,500 acres for development.
4. Acquire the land for the conservation/collection area.
5. Acquire the land for the Mound Creek Reservoir, construct the dam and associated reservoir structure, and construct the interception/collection channel along Longenbaugh Road. This will remove the overflow from 9,500 acres.

A cost and cash-flow model was developed to assist in evaluation of implementation and funding strategies. This tool would be used in the management of the implementation, but in the meantime a hypothetical project implementation schedule has been developed that tries to match funding and revenue stream with projected development demand. Exhibit C6.1 presents two outputs from that model, which assumes full implementation over 18 years.



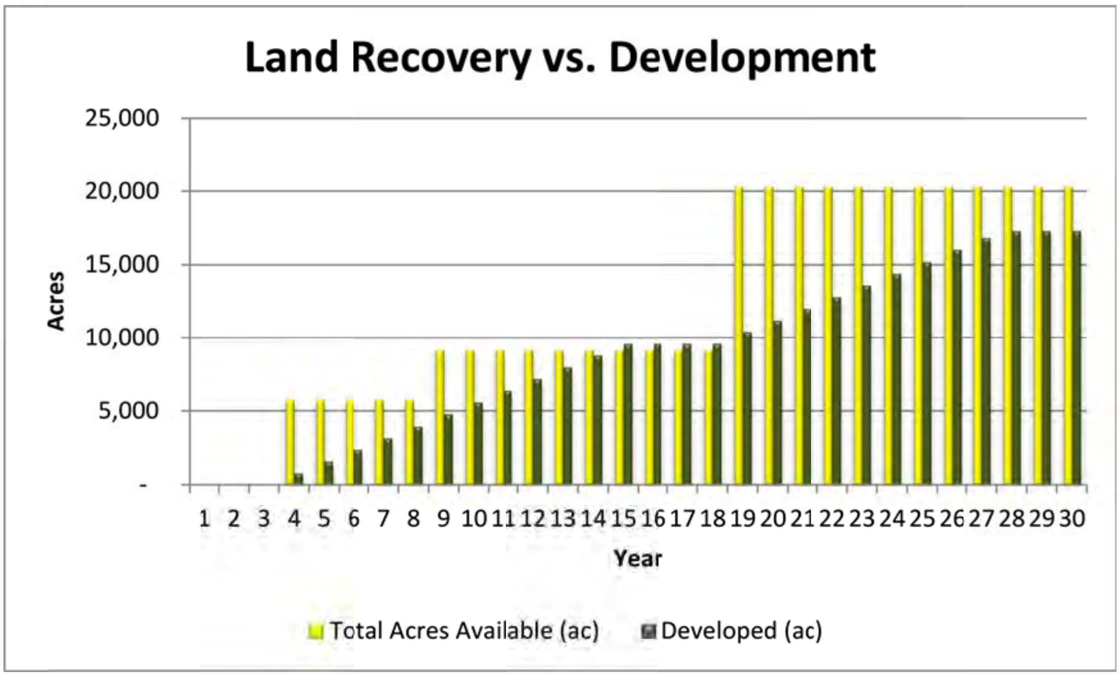


Exhibit C6.1
Implementation of Management Strategy 3

6.2 Management Strategy 5 – Katy Hockley N - Cypress Reservoir

Management Strategy 5 – Katy Hockley N - Cypress Reservoir was introduced in Section 5.6 of this document. This section provides more detail of this management plan.

6.2.1 Description of Features

Katy Hockley N – Cypress Management Plan (Management Plan 5) is depicted in Exhibit C5.7. A reservoir would be formed by an earthen berm or dam that extends along Longenbaugh Road, around and outside of Paul Rushing Park, and northward along Katy-Hockley Road across Cypress Creek. The berms would vary in height, with a maximum height of 12 feet. They would be constructed using excavated material from within the reservoir. This is the only excavation within the reservoir.

Bear Creek would be enlarged for a distance of about 24,000 feet, from the outlet of the reservoir near the intersection of Longenbaugh Road and West Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel would utilize natural channel design principles within a 500-foot corridor. The channel would be sufficiently deep to accept drainage from lateral channels. The outlet to Bear Creek would be restricted to 2,000 cfs via a boxed conduit. This restriction would be necessary to prevent the diversion of additional flow volume from Cypress Creek to Addicks Reservoir during events smaller than the 1% (100-year) event. The outlet to Cypress Creek would be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year), the release to Cypress Creek would be restricted to 5,300 cfs. This results in a combined maximum release of 7,300 cfs.

A 9,000 linear foot reach of Bear Creek would be modified to increase its capacity from an existing drop structure just downstream of Fry Road to areas upstream of existing development. The enlarged channel would have a 30-foot bottom width and side-slopes of about 3:1 (h:v) that mimic existing side-slopes. The modifications would generally occur within existing right-of-way and will not require any structural acquisitions. The improvements would extend under the Fry Road and West Little York crossings – this would require minor modification of the structures to accommodate the deepened channel. These modifications would only be necessary for the phasing, as described in Section 6.2.4, and would not necessary be for the final configuration.

The 1% (100-year) reservoir pool elevation would be 168.0, inundating 7,400 acres and providing 26,500 acre-feet of storage. The maximum depth in the basin, excluding existing channels, would be eight feet, with an average depth of four feet. The reservoir would drain in three days. The dam would include wide spillways that protect the structure from larger events. During extreme events (those larger than 1%, or 100-year, flows could exceed downstream capacity. However, the net impact of the extreme event flow would be less than the existing condition. There would be spillways that allow extreme event flows to discharge into both watersheds. There would be a small channel inside the reservoir along the south dam that directs low flows to the outlet to Bear Creek. In addition, there would be a channel inside the east dam that allows flows to drain back to the Cypress Creek watershed from the Addicks watershed. This would be necessary because the higher elevations along Cypress Creek created by the dam would result in the diversion of additional volume across the watershed, and this channel would be necessary to return volume to Cypress Creek. A backflow prevention structure would be constructed near the watershed divide to ensure the channel does not allow for flow from the Cypress Creek watershed to the Addicks Reservoir watershed.

In total, approximately 7,400 acres of land would be inundated during the 1% (100-year) event. This includes 3,540 acres of private land, 3,401 acres of conservation land, and 459 acres of public land (held for conservation).

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

The plan also includes the adoption of development criteria in the study area to ensure that future land development activity would not increase flood risk associated with Addicks Reservoir. Mitigation of potential increases in runoff volume could be in the form of extended detention, retention, low impact development, prairie restoration, or other measures. It is recommended that land developers be given the opportunity to present a method for the consideration of the Flood Control District.

6.2.2 Updated Cost Estimate

The Katy-Hockley North Management conservation interests, in return for providing additional conservation land, would obtain a portion of the outfall channel right-of-way from land developers. Construction of the outfall channel would be by land developers. It should be noted that the estimate is very sensitive to land cost.

Table C6.2
Plan 5 Cost Estimate – with In-Kind Contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	285	ac	$22,500	$6,412,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$17,400,000*
E2	Collection Channel Excavation	785,000	cy	$7.5	$5,887,500	
E2	Daylight/Bear Ck Channel Excavation	739,400	cy	$7.5	$5,545,500	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$12,183,000*	
	25% Contingency			25%	$3,045,750	
	Total - Construction					*$15,228,750*
	Engineering/Design			8%	$1,218,300	
	Environmental/Permitting/ROW			4%	$609,150	
	Construction Management			10%	$1,522,875	
	Total - Professional					*$3,350,325*
ELEMENT 1 - TOTAL						**$35,979,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land	295	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	2,059,800	0	$0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
S1	Mobilization	1	ea	$100,000	$100,000	
E2	Channel Excavation	80,000	cy	$8	$600,000	
D5	Backslope Drains	10000	lf	$25	$250,000	
S3	Silt Fence	20,000	lf	$2	$40,000	
S5	Hydromulch	28	ac	$3,000	$84,000	
D12	Remove Ex Structure	1	ea	$50,000	$50,000	
R7	Adjust Bridges at Fry and W Little Yk	2	ea	$250,000	$500,000	
	Subtotal - Construction				*$7,887,000*	
	25% Contingency			25%	$1,971,750	
	Total - Construction					*$9,858,750*
	Engineering/Design			8%	$788,700	
	Environmental/Permitting/ROW			4%	$394,350	
	Construction Management			10%	$985,875	
	Total - Professional					*$2,168,925*
ELEMENT 2 TOTAL						**$12,027,675**

Table C6.2 (Continued)
Plan 5 Cost Estimate – with In-Kind Contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	289,900	0	$0.0	$0	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,562,500	
	Total - Construction					*$7,812,500*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,7500*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Acquire Land for KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	3536	ac	$22,500	$79,560,000	
L3	Land value C	0	ac	$30,000	$0	
L7	Conservation land	4610	ac	$0	$0	
L7	Conservation land	1,115	ac	$0	$0	
L6	County Land	415	ac	$0	$0	
L9	Land Value B Convert Temp Esmt to Perm	1,584	ac	$16,875	$26,730,000	
	Total - Land					*$106,290,000*
	Total - Construction					*$0*
	Engineering/Design			8%	$0	
	Environmental/Permitting/ROW			4%	$0	
	Construction Management			10%	$0	
	Total - Professional					*$0*
ELEMENT 4 TOTAL						**$106,290,000**

Table C6.2 (Continued)
Plan 5 Cost Estimate – with In-Kind Contributions

Element 5 - Construct KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
	Total - Land					*$0*
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
E6	Key Trench Excavation	89,800	cy	$7.5	$673,500	
E5	Embankment	788,200	cy	$15	$11,823,000	
D2	Cypress Outlet - riprap/slope paving	13,300	sy	$125	$1,662,500	
D3	Cypress Spillway	18,667	lf	$250	$4,666,750	
D3	Bear Ck Spillway	18,667	lf	$250	$4,666,750	
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
D3	Spillway	18,667	lf	$250	$4,666,667	
D1	S Mayde Ck - 200 lf 1-6'x8' box	9,600	sf-lf	$15	$144,000	
E2	S Mayde Excavation	356	cy	$8	$2,667	
D2	S Mayde Rip-Rap/Slope Paving	1,733	sy	$125	$216,667	
D1	Balance Structure 50 lf 9-6'x6' box	16,200	sf-lf	$15	$243,000	
D11	Balance Structure Backflow Prevention	6	ea	300,000	$1,800,000	
E5	Road Emb - Warren Rnch, Hebert	380,000	cy	$15	$5,700,000	
D1	Road Culvert - Warren Rnch, Hebert	180,000	sf-lf	$15	$2,700,000	
L2	Add ROW - Warren Rnch, Hebert	41	ac	$22,500	$922,500	
	Add Pvmt - Warren Rnch, Hebert	120,000	sy	$50	$6,000,000	
S1	Mobilization	1	ea	100,000	$100,000	
S2	Clear and Grub	400	ac	$7,000	$2,800,000	
S3	Silt Fence	53,900	lf	$2	$107,800	
S5	Hydromulch	400	ac	$3,000	$1,200,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	3,000	lf	$250	$750,000	
	Subtotal - Construction				$52,047,600	
	25% Contingency			25%	$13,011,900	
	Total - Construction					*$69,059,500*
	Engineering/Design			8%	$5,204,760	
	Environmental/Permitting/ROW			4%	$2,602,380	
	Construction Management			10%	$6,505,950	
	Total - Professional					*$143,313,090*
ELEMENT 5 TOTAL						**$79,372,590**

Plan Totals	
Land	$123,690,000
Construction	$97,959,500
Professional	$21,551,090
TOTAL PLAN COST	**$243,200,590**

6.2.3 Benefits

The completed plan manages the entire overflow without the inundation of private land (excluding the conservation land identified as part of the plan). This removes the floodplain associated with the overflow from over 18,000 acres of developable land. In addition, the flood risk from the overflow is mitigated from existing structures and infrastructure, including roads and parks. The larger reservoir also provides a measure of flood relief to downstream riverine systems, including Cypress Creek, Bear Creek, and (to a lesser extent) South Mayde Creek.

The channel modifications to increase the capacity of Bear Creek in the vicinity of Fry Road reduces flood risk in the vicinity from local rainfall events. This area is subject to flooding from events in excess of the 10% (10-year), and neighborhoods adjacent to Bear Creek experienced flooding in 2012.

In addition to flood relief, the plan increases the conservation footprint in the study area by about 5,000 acres. Furthermore, this conservation land is contiguous to existing conservation land, assisting in the long-term establishment of a large contiguous conservation area. The plan also provides a 500-foot green space corridor between the proposed reservoir and the existing Bear Creek channel, affording the opportunity for recreational connectivity between facilities in Addicks Reservoir and Paul Rushing Park, John Paul's Landing, and any future features associated with the proposed reservoir.

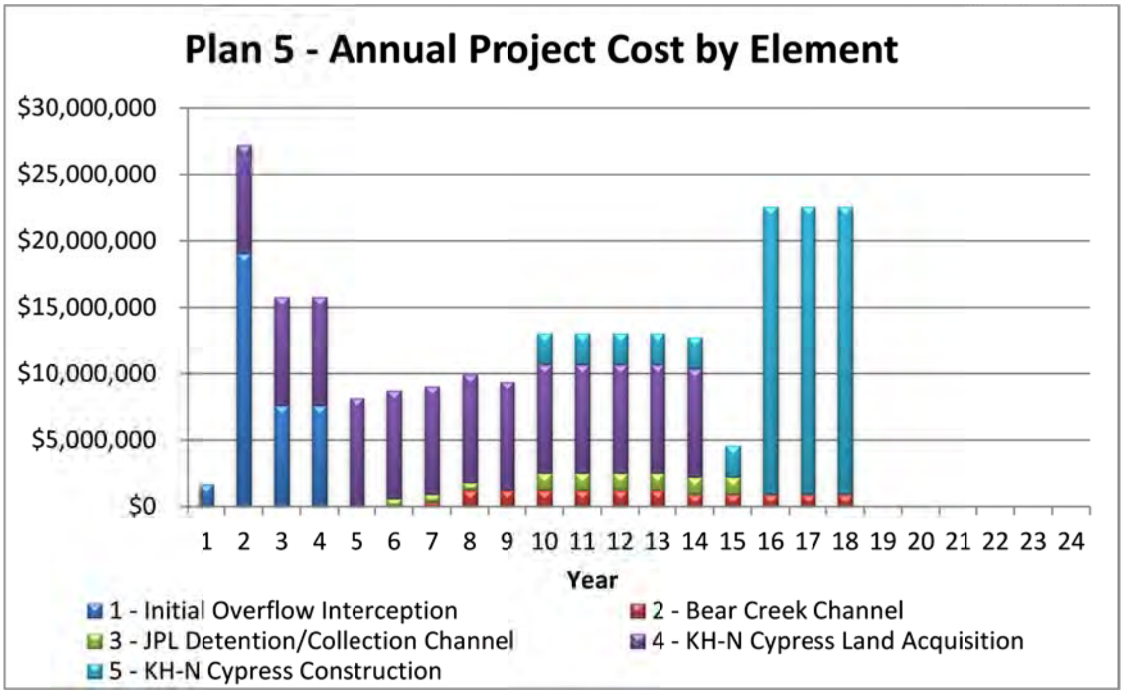
The plan does not reduce flood risk in the upstream fringes of Addicks Reservoir. However, the policy associated with the plan offsets the expected increase in runoff due to land development activity. Furthermore, development policy also results in decreased runoff from sites, providing a small amount of relief to the downstream systems. In addition, by increasing the permanent undeveloped footprint in the watershed, there is an assurance that this area does not increase in volume into Addicks Reservoir.

6.2.4 Implementation

The features described in this management plan would take many years to implement. There would be a long lead time associated with funding, land acquisition, permitting, and construction. However, development pressure is imminent, and to be viable a phased implementation must be available. An implementation strategy has been developed that allows for the incremental recovery of developable land in a manner that attempts to recognize these realities. Five "components" are presented. They are similar to phases, however they do not necessarily have to progress in order from 1 to 5.

1. As an interim measure, protect a portion of the overflow by building temporary collection channels and berms on the south side of the future channel. This will result in an inundated collection area, and will require some excavation in the location of the future outfall channel to daylight these collection channels. Temporary flooding easements, permanent easements, or fee ownership of the collection area will be acquired. Minor channel modifications will be made to Bear Creek in the vicinity of Fry Road to increase its carrying capacity.
2. As development occurs, the 500' wide corridor along Bear Creek will be dedicated and the reservoir outlet channel will be constructed by developers. These initial measures will remove the overflow from 9,000 acres.
3. Excavate detention within basins in John Paul's Landing (JPL), and construct diversion from Bear Creek and outfall structure. Developers will construct diversion channel to JPL. This will remove the overflow from 3,500 acres.
4. Acquire land for the reservoir.
5. Construct the dam and associated reservoir structure. This will remove the overflow from 5,500 acres.

A cost and cash-flow model was developed to assist in evaluation of implementation and funding strategies. This tool would be used in the management of the implementation, but in the meantime a hypothetical project implementation schedule has been developed that tries to match funding and revenue stream with projected development demand. Exhibit C6.2 presents two outputs from that model, which assumes full implementation over 18 years.



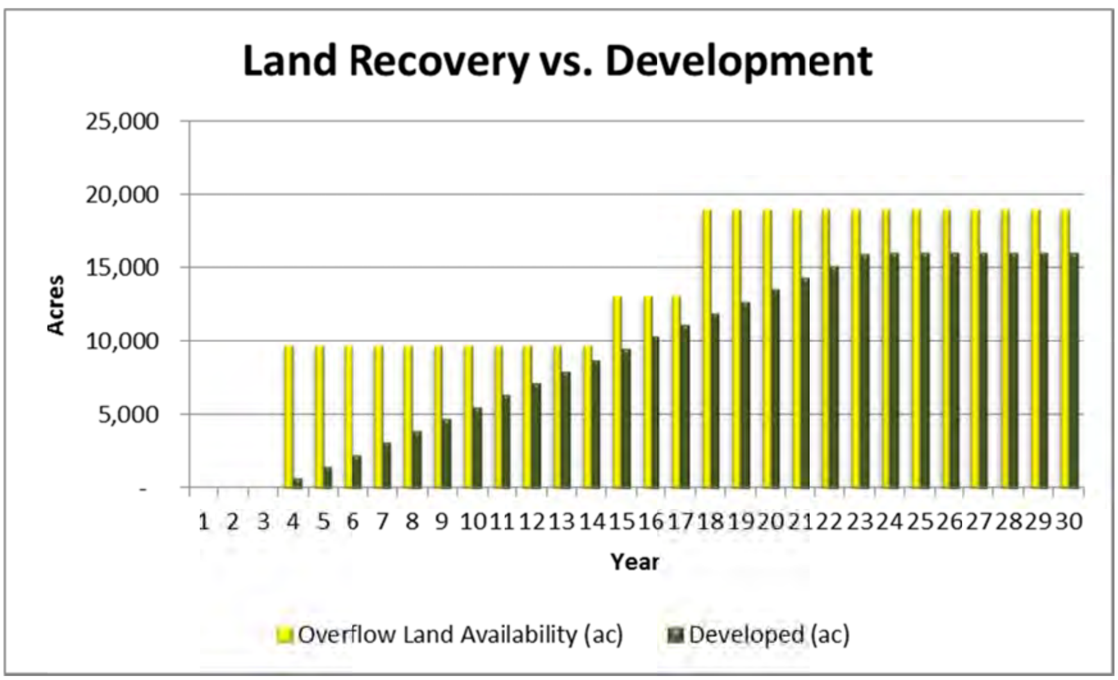


Exhibit C6.2
Implementation of Management Strategy 5

Appendix D

Land Use and Stormwater Runoff Rates Investigation

August 18, 2015

Table of Contents

1.0 Introduction

This appendix describes and summarizes an analysis of the relationship between rainfall and runoff in the defined Cypress Creek Overflow Management Plan study area. Specifically, the appendix describes research and analysis in support of the Texas Water Development Board (TWDB) scope item *Task 3: Benefits of Prairie Restoration for Flood Control*. Additional studies pursuant to this task are being conducted on behalf of the study. However, this initial review developed data to be applied and utilized in the study, including scope item *Task 2: Identifying Mitigation Strategies.*

1.1 Background

The Study Area for the Cypress Creek Overflow Management Plan is defined as the Upper Cypress Creek watershed, which is the portion contributing to drainage along Cypress Creek at US 290, along with the Addicks Reservoir watershed. This study area, which is illustrated on Exhibit D1.1, encompasses 277 square miles. The study area lies within an area known as the Katy Prairie, an area that covers over one-thousand square miles (Reference 1). The Katy Prairie is part of the Western Gulf coastal grasslands, and is bound by the Brazos River on the southwest, pine-hardwood forest to the north, and the City of Houston to the east. The natural setting is characterized by tall-grass prairie with pothole wetlands and riparian corridors along waterways.

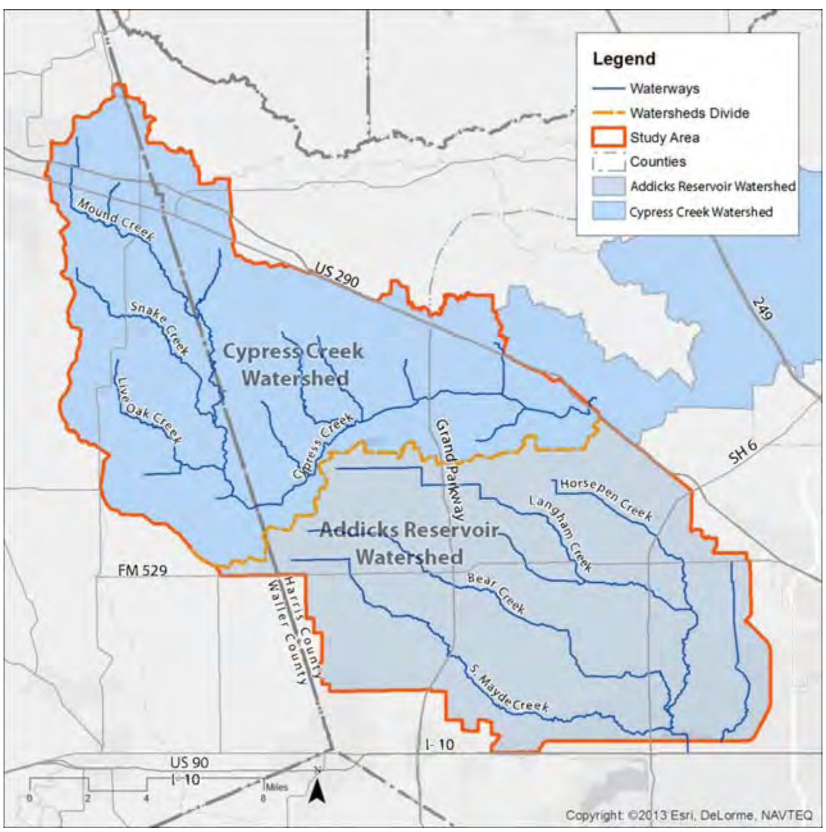


Exhibit D1.1
Cypress Creek Overflow Management Plan – Study Area

The land use within the study area has evolved and changed over time. Exhibit D1.2 depicts current land use in the study area. Areas to the east and south, and along the US 290 corridor, have been transformed into single-family subdivisions along with their supporting commercial centers and schools. The vast open area has been transformed into agricultural land – historically rice farming and ranching. However, many of the rice farms have been converted to row crops due to the rising cost of water. There are still remnants of the native prairie, particularly in areas near Cypress Creek.

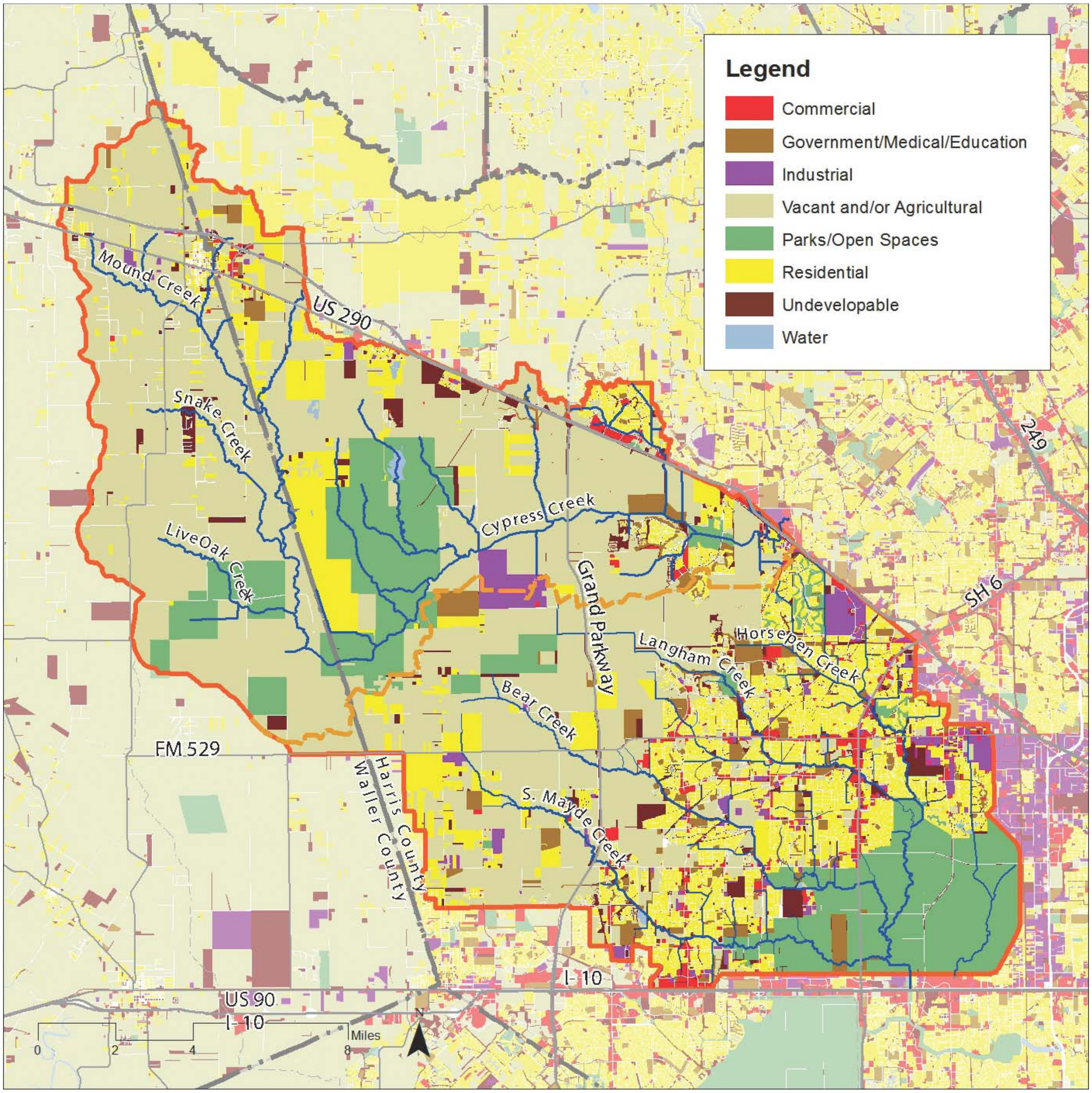


Exhibit D1.2
Land Use in the Study Area (Source: Houston-Galveston Area Council)

1.2 Rainfall and Runoff

The relationship between rainfall and runoff is generally understood, and can be quantified through a number of methodologies and numerical models. Rainfall data and gauge data are utilized to evaluate these methods. The U.S. Geologic Survey and the Harris County Flood Control District (HCFCD) operate a robust network of rainfall and streamflow gauges that allow for the continued evaluation of the rainfall and runoff relationship. HCFCD, in their *HCFCD Hydrology and Hydraulics Manual*, specifies parameters for runoff using the Green and Ampt Method. These parameters are based upon calibration of hydrologic models, and are prescribed on a watershed-by-watershed basis as presented in the effective hydrologic models for each watershed.

The determination of the parameters treats all land as either impervious or pervious. Furthermore, the parameters are applied to all impervious land without recognition of the land use. In other words, lawns, pastures, and crops are all treated similarly. While this is generally adequate for determining peak flowrates to support hydraulic models, it does not facilitate a deeper understanding of the relationship between rainfall volume and runoff volume. The type of vegetation is generally believed to have an impact on the rainfall-runoff relationship. In particular, native prairie plants are known to develop deep robust root systems, which open up the soil for additional infiltration (see Exhibit D1.3). The impact of these root systems is even more prominent in areas of poorly draining soils, such as in Harris County.

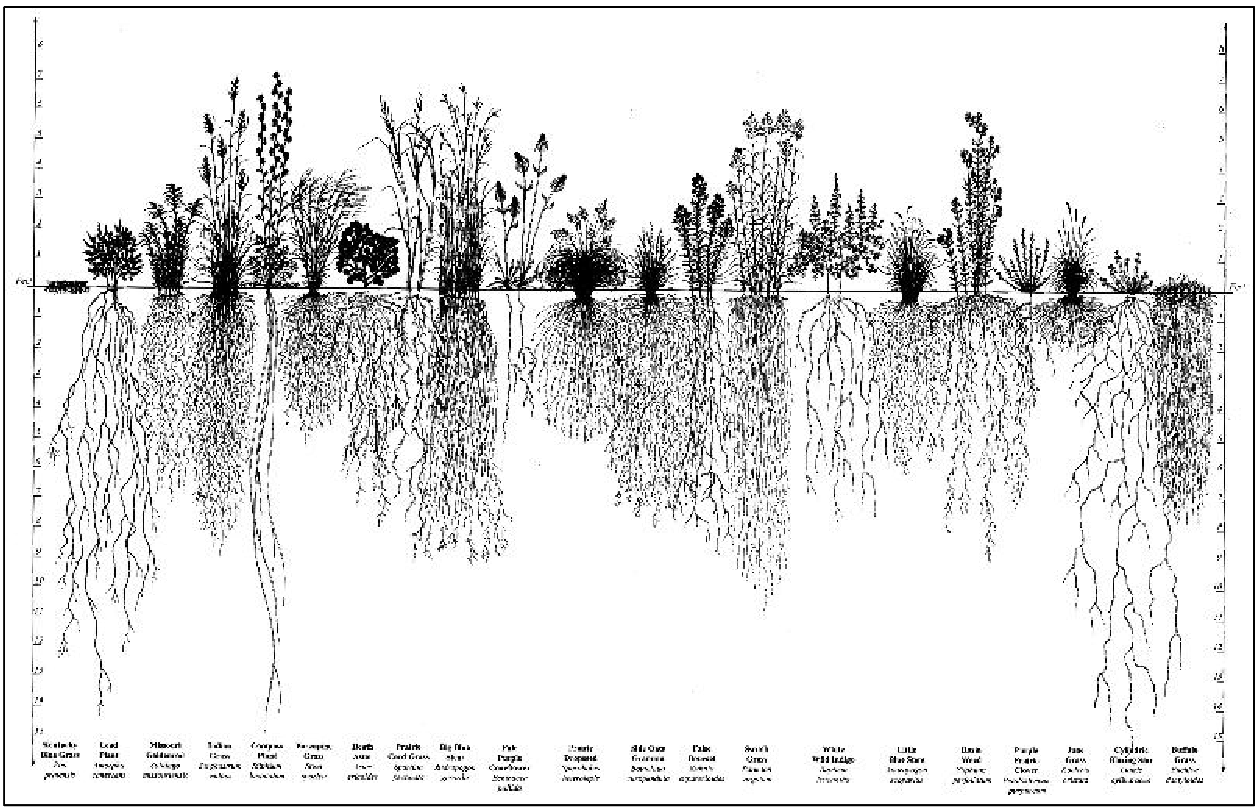


Exhibit D1.3
Prairie Vegetation – Root Structure (*Reference 3***)**

1.3 Purpose of Review

The purpose of this review is to better understand the relationship between rainfall and runoff volume. Beyond this, the focus of the review is the impact of land use and vegetation type on the rainfall-runoff relationship, with a particular focus native prairie, agricultural land, and single-family subdivisions.

This review considers common methodologies, research efforts by others, data collected by HCFCD as part of Task 3, and the evaluation of current hydrology models. This evaluation is not a scientific review and does not make specific conclusions. However, insights and understanding to be applied at a planning level are derived from this effort. Further study efforts by HCFCD, as described in Appendix I, will be monitored into the future and my ultimately confirm or supersede the results described in this appendix

2.0 Research Efforts

This section describes research efforts related to the rainfall-runoff relationship. Section 2.1 describes research in the 1930's by the U.S. Department of Agriculture's Soil Conservation Service, which is now known as the Natural Resources Conservation Services (NRCS). Section 2.2 describes two academic studies that developed relationships related to various vegetation types, including native prairie.

2.1 NRCS Research

The NRCS Curve Number (CN) method is a widely applied approach for predicting the runoff volume to result from a specific precipitation volume. The defining characteristic of this method is the notion of a runoff curve number which helps describe the amount of precipitation (P), in inches, that is converted into direct runoff (Q), in inches. The relationship between P and Q is a function of the potential maximum retention (S), in inches. The CN establishes the value of S via the following relationship:

$$S = 1000/CN - 10$$

Therefore, a high value for CN results in a lower value for S, and therefore a smaller maximum retention. This results in a larger volume of P being converted to Q. Alternatively, a low CN results in a higher value for S, and therefore a larger maximum retention. This results in a smaller volume of P being converted to Q.

The value for CN may vary between 30 and 100. It is determined from tables corresponding to various types of land uses. Furthermore, values are provided for four general soil types: A, B, C, and D. These generalized soil types represent the soil's ability to infiltrate and absorb water. At one end of the spectrum, "A" soils represent well-draining soils with high permeability, such as sandy soils. At the other end, "D" soils represent poorly draining soils with low permeability, such as clay soils.

While the CN runoff equation is not an infiltration equation, it is used as a surrogate. The methodology is widely criticized for its simplicity and lack of theory, however it is widely utilized due to its ease of application. In attempting to determine the infiltration behavior of natural prairie, there is a thought that the data obtained in the development of the NRCS CN methodology may provide some insight into the infiltrating capacity of native prairie vegetation. Consequently, review regarding the development of the methodology was pursued.

2.1.1 Research Background

The Flood Control Act of 1936 authorized the Department of Agriculture's Soil Conservation Service (SCS)(which become the Natural Resources Conservation Service in 1994) to carry out surveys and investigations of watersheds and to install measures for retarding runoff and water flow and preventing soil erosion. The first effort was to obtain infiltration rates at many locations, and the SCS made thousands of infiltrometer runs during the 1930's and 1940's. Table D2.1 lists the locations used in the research. The original data and plots from the watersheds listed in Table D2.1 have been lost over time (Reference 2). Only some of these sites were utilized in the development of the runoff curve number, and these are noted in the table.

G.W. Musgrave described a classification of soils depending on their infiltration rate. It grouped all soils into four basic groups depending on the minimum infiltration capacity, laboratory tests, and soil texture. As noted earlier, the four groups were A, B, C, and D, with sands in group A and clays in group D.

Table D2.1
Data Stations for SCS Research

Town	State	Stations/ Watersheds	Land Use	Used for CN?
Amot Forest	New York	2	Idle, wooded	
College Park	Maryland	4	Pasture, Wooded	
Watkinsville	Georgia	1	Pasture	
Statesville	North Carolina	1	Wooded	
Edwardsville	Illinois	1	Pasture	Yes
Elmwood	Illinois	6	Pasture	
Lafayette	Indiana	6	Pasture, Wooded	
East Lansing	Michigan	1	Wooded	
Bethany	Missouri	3	Pasture	
Coshocton	Ohio	8	Pasture, Wooded, Meadow	Yes
Hamilton	Ohio	1	Pasture	Yes
Zanesville	Ohio	2	Pasture, Wooded	
LaCrosse	Wisconsin	2	Pasture	
Bentonville	Arkansas	3	Pasture, Wooded	Yes
Guthrie	Oklahoma	4	Wooded, Idle, Pasture	
Muskogee	Oklahoma	1	Pasture	Yes
Stillwater	Oklahoma	1	Rangeland	
Garland	Texas	1	Meadow	Yes
Tyler	Texas	2	Pasture, Wooded	
Vega	Texas	2	Pasture	Yes
Hays	Kansas	1	Pasture	
Hastings	Nebraska	3	Pasture, Meadow	Yes

Source: Fennessey, Miller, and Hamlett(Reference 4)

It was not until the mid-1950's that Congress, with the passage of the Small Watershed Act, directed the Soil Conservation Service (SCS) to develop a rainfall-runoff relationship. The SCS developed the relationship from groundwork provided in the 1930's and 1940's, including from the sites listed in Table 1 and the soil classifications. The development of the rainfall-runoff relationship led to the development of the curve number, as well as the runoff equations now described in NEH-4, TR-20, and TR-55.

2.1.2 Native Prairie

Without the underlying experimental data from these, we cannot make any direct conclusions regarding the behavior of native prairie as it relates to runoff volume and infiltration. A review of the sites where data was acquired indicates they were primarily pasture and wooded, with some idle site, meadow, and one rangeland. The rangeland land use is an appropriate description of native prairie, and it is likely that data acquired from the Stillwater site is from prairie vegetation.

Chapter 9 of the NRCS National Engineering Handbook (NEH) provides guidance for assigning CN for various land cover. Of interest is recommended CN values for "Sage-grass – sage with an understory of grass," as sagebrush is a common native prairie plant. Of all the land covers and uses described in NEH, this item best represents "native prairie". How well it represents the various cross sections of potential prairie is unknown.

Table D2.2 shows recommended CN values for some relevant land uses for the four soil classifications. It is interesting to note that the CN for sage-grass is substantially lower than the other cover types in this table (the cover types were selected because they are consistent with the study area in question). For example, the CN for sage-grass, with a "good" hydrologic condition and soil type "D" is 55. This is an extremely low number for a "D" soil, and is the same as "B" soils for woods. There are contributing factors to the CN besides the infiltration, however there would most likely be more interception in wooded areas, suggesting the difference is mostly in the soils (and perhaps in depression storage that may be more common in some prairie areas). Overall, this seems to support the notion that native prairie substantially reduces infiltration capability.

2.2 Academic Research

As noted earlier, there is a common belief that prairie grass can substantially increase the drainage characteristics of soils, including otherwise poorly drainage soils. There is significant discussion of native prairie plant materials in literature associated with rain gardens and other water quality materials. It has been stated that established native prairie will increase the infiltration rates by a factor of ten, even with clay soils. The theory is that the deep root systems change the soil medium by adding carbon and decreasing bulk density. The roots themselves open up voids in the soil, and leave drainage openings especially as they decompose. They also encourage the presence of earthworms who work to open up the soil.

Table D2.2
Recommended Runoff Curve Numbers

Cover Description		**Hydrologic Soil Group**			
Cover Type	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Pasture, grassland, or range-continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow-continuous grass protected from grazing and generally mowed for hay	Good	30	58	71	78
Brush-brush-forbs-grass mixture with brush the major element	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods-grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Herbaceous-mixture of grass, weeds and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Sage-grass-sage with an understory of grass	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55

Source: NEH, Chapter 9 (Reference 5)

However, actual research supporting this belief is limited. While there are many statements of the benefits, virtually all of them point back to two research efforts – one by Iowa State University and another by Washington State University. These are discussed below, along with a mention of additional study efforts.

2.2.1 Iowa State Study

An experiment was conducted by Iowa State (Bharati, et. al., 2002, Reference 6) as an agricultural study, as they were interested the infiltration rate of crops as compared to other land uses. They established numerous test plots adjacent to the crops, and made infiltration measurements. They found that the crops had substantially lower infiltration rates than the test plots, and that the test plots with restored native prairie had substantially higher infiltration rates. Furthermore, a study of the soils found greater amounts of clay (which have very fine particles resulting in low infiltration) in the prairie soil as compared to the crops, but the prairie still had substantially higher infiltration. Table D2.3 summarizes the experiment.

Table D2.3
Average Hourly Infiltration Rates From a Multispecies Buffer

Treatment	Average Hourly Infiltration Rate (cm/hr)
Silver Maple	38
Grass Filter (Prairie)	25
Switchgrass (Prairie)	19
Bean	10
Corn	4
Pasture	3

Source: Bharati, et. al., 2002

2.2.2 Washington State Study

The objective of the Washington State Study (Fuentes, et. al, 2004, Reference 7) study was to compare the temporal patterns of hydraulic properties under natural prairie, conventional till, and no-till farm fields in the Palouse region of eastern Washington. The natural prairie had never been disturbed, and was considered some of the best examples of natural soil and vegetation in the region. The natural prairie was adjacent to the conventional till fill, while the no-till field was located 30 miles to the north. The soils are silt dominated and consist of about 13% clay by weight. The soils in the areas are generally well draining, and are be classified as Group A or B using the NRCS classification.

Their research found that the hydraulic conductivity is substantially higher for the native prairie. They describe the difference as "an order of magnitude".

2.2.3 Additional Studies

More recently, a study was published by Philip Gerla, who is a professor the University of North Dakota and is also the prairie hydrologist for the Nature Conservancy. This study was not reviewed, although in an interview Dr. Gerla made statements consistent with the general consensus of the Iowa State study and Washington State study.

There have been other experiments tied to the use of rain gardens. In Wisconsin, the USGS performed a study of drainage behavior in rain gardens, and found rain gardens' clay soils behaved as if they had sandy soil when native prairie vegetation is installed.

2.2.4 Summary

There have not been a large number of research efforts to investigate the impact on native prairie vegetation on soil infiltration. The Iowa State and Washington State studies described above were actually seeking to determine the impact of agriculture activity, and the impact of prairie vegetation was analyzed primarily to provide a comparison. However both studies, and subsequent studies by others, support the concept that native prairie vegetation contributes to the infiltrative capacity of the soil. Furthermore, this contribution is most significant for poorly draining soils. The Iowa State study found the infiltration rate was increased by a factor between five and ten, while the Washington State study concluded the impact was on "order of magnitude."

3.0 Computation of Native Prairie Impacts on Runoff Volume

In light of the conclusions above, computations were performed to attempt to quantify the impact of native prairie vegetation on the rainfall-runoff relationship, specifically as it pertains to runoff volumes. Initial data collected and analyzed as part of the Cypress Creek Overflow Management Study was utilized and compared to the NRCS methods described in Section 2.1.

3.1 HCFCD Data Collection

As part of the Cypress Creek Overflow Management Planning Study, HCFCD installed rainfall and flow measuring gauges at select locations in order to measure the rainfall-runoff relationship. The locations were identified to capture various land uses in the study area. This activity is described in Appendix I.

In order to make proper scientific conclusions regarding these sites, data from a sufficient number of events must be captured, and there was not sufficient data collected in the one year period to make scientific conclusions. However, the initial data collection is adequate to make initial analyses, and to compare the results of these analyses to the research and studies presented in this Appendix.

One aspect of the data collection and analysis is to compute a NRCS Runoff Curve Number (CN) for each site based upon guidance provided by the NRCS, which is referred to as the TR-55 Manual Technique. In addition, a CN was computed based upon the observed data. As noted previously, additional data is required to increase the confidence of the CN computation, however preliminary values are presented in Table D3.1. There were concerns with the data collected at the Manor Tract and the Upper Tucker Tract, so those field data computations are not shown.

Table D3.1
Runoff Curve Number Analysis

Station Designation	Land Use	CN - TR-55 Manual Technique	CN - Field Data Computation
Bing Tract	Cattle Grazing (previously rice farming)	88	73
Manor Tract	Cattle Grazing (previously rice farming)	88	N/A
Upper Tucker Tract	Native Prairie	75	N/A
Lower Tucker Tract	Native Prairie	65	53
Kroger Tract	Commercial Development	95	97
Westgate Tract	Single Family Development	87	87

The computed CN, based upon the observed data, are generally consistent with the CNs computed based upon the land use. The Bing Tract does compute a substantially lower CN, and this may be due to the fact that the change in land use (from rice farming to cattle grazing) is recent. There is a very close correlation for the two development tracts.

The Lower Tucker Tract also has a lower observed CN when compared to the computed CN. This may be due to the land use selected in the determination of the CN. The value used in the TR-55 calculation is based upon the general land cover. As noted in Section 2.1, the NRCS does not provide a specific value for prairie, but that "sage-grass - sage with an understory of grass" is a type of prairie vegetation. For "D" soils and good hydrologic conditions, the NRCS recommends a CN of 55, which correlates to the observed value of 53. This is just one plausible explanation for this difference. Appendix I explores the analysis is greater detail. However, the observed data does support the notion that native prairie vegetation substantially increases the infiltrative capacity of the soil. A CN of 53 is extremely low considering the soil types in the study area.

3.2 Impact of Prairie Restoration

The existing HEC-HMS subarea models and a sensitivity analysis of NRCS CNs (by HCFCD) were used to determine potential benefits from prairie restoration. A spreadsheet was developed to compute potential volume decreases provided by restoration of native prairie based on the change in the Runoff Curve Number (CN). This analysis assumes an existing CN of 85 for areas to be restored to native prairie. According to NEH, the appropriate CN for D soils for sage-grass is 55. To be conservative, a reduction to 60 is assumed. Table D3.2 summarizes the results. The analysis was conducted for a 50% (2-year) 24-hour rainfall, and for a 1% (100-year) 24-hour rainfall.

Table D3.2
NRCS Curve Number Reduction in Volume

Event	50% (2-yr)	1% (100-yr)
Existing CN	85	85
Existing Precipitation (In)	2.0 in	12.0 in
Existing Runoff (In)	0.80 in	10.08 in
Existing Runoff (% Precip)	40%	84%
Proposed CN	60	60
Proposed Precipitation (In)	2.0 in	12.0 in
Proposed Runoff (In)	0.06 in	6.56 in
Proposed Runoff (% Precip)	3%	55%
Additional Losses (in)	0.74 in	3.52 in
Additional Losses (ac-ft/ac)	.06 ac-ft/ac	0.29 ac-ft/ac
Additional Losses (ac-ft/1000 ac)	62 ac-ft	293 ac-ft

Presuming that native prairie would be capable of lowering the CN from 85 to 60, these calculations suggest that substantial benefit would be gained from the establishment of native prairie. For events up to the 2-year event, the prairie would capture almost 100% of the runoff, and for large events, the establishment of prairie would be equivalent to 0.29 acre-feet per acre of detention, reducing runoff by 55%.

4.0 Rainfall-Runoff Relationship

In light of the conclusions above, computations were performed to attempt to quantify the impact of various land types on the rainfall-runoff relationship, specifically as it pertains to runoff volumes. Calculations were performed using the HCFCD HEC-HMS watershed models. In addition, a 2012 study prepared by R.G. Miller on behalf of the HCFCD entitled *Rainfall Volume vs. Runoff Volume Evaluation Study* was reviewed, as was the inflow data into Addicks Reservoir during the 1993 reservoir event. The latter two of these are discussed in more detail in Appendix B.

4.1 HEC-HMS Analysis

The HCFCD maintains and manages hydrology models for each watershed that utilize the HEC-HMS software developed by the U.S. Army Corps of Engineers. These models apply the Green and Ampt Method, a time-based model that simulates infiltration into the soil based upon hydraulic parameters. Some of these parameters are empirical and difficult to measure and characterize, however literature provides initial guidance, and the parameters were adjusted during the calibration of the hydrologic models.

A key parameter in the computation of runoff volume from rainfall is the drainage area and the percentage of the area that is impervious. The Green and Ampt parameters are only applied to the percentage of the area that is impervious, as it is assumed that pervious surfaces convert 100% of the rainfall to runoff.

The impact of various land use changes can be simulated in HEC-HMS by adjusting the percentage of impervious cover. Commercial and industrial land uses have a very high percentage of impervious cover, usually about 85 to 95%, while single family subdivisions typically have an impervious cover between 40 and 50%.

A HEC-HMS model was executed for a 24-hour 50% (2-year) and 1% (100-year) events with a range of impervious cover. The percentage of impervious cover was varied at 10% increments between 0% and 100%. The comparison shows that, for a fully pervious watershed, about two inches are lost (via infiltration) during a 50% (2-year) rainfall event, and about 3 ½ inches are lost during a 1% (100-year) rainfall event. The percentage of rainfall that converts to runoff would vary depending on the amount of rainfall, and this computations show that it varies between 30% and 60% for large events (defined as those greater than a 50% or 2-year event).

Considering the development of a single-family subdivision with an impervious cover of 50%, about one inch is lost during a 50% (2-year) event, and almost two inches are lost during a 1% (100-year) event. Therefore, based upon the HEC-HMS model using the Green and Ampt method, the development of a single-family subdivision would increase the runoff volume by 1.02 inches during a 50% (2-year) event, and by 1.79 inches during a 1% (100-year) event.

A commercial or industrial development with an impervious area of 90% will have a greater impact. For a 50% (2-year) event, only 0.2 inches are lost; and for a 1% (100-year) event, only about 0.4 inches are lost. Based upon the HEC-HMS model using the Green and Ampt method, the development of a commercial or industrial site would increase the runoff volume by 1.83 inches during a 50% (2-year) event, and by 3.21 inches during a 1% (100-year) event.

Table D4.1
Rainfall-Runoff in HEC-HMS (Green & Ampt Method, Addicks Watershed)

Impervious	50% (2-year)				1% (100-year)			
Cover (%)	Rainfall (in)	Runoff (in)	Runoff (%)	Infiltration (in)	Rainfall (in)	Runoff (in)	Runoff (%)	Infiltration (in)
0%	3.38	1.35	40%	2.03	12.17	8.60	71%	3.57
10%	3.38	1.55	46%	1.83	12.17	8.96	74%	3.21
20%	3.38	1.76	52%	1.62	12.17	9.31	76%	2.86
30%	3.38	1.96	58%	1.42	12.17	9.67	79%	2.50
40%	3.38	2.16	64%	1.22	12.17	10.03	82%	2.14
50%	3.38	2.37	70%	1.01	12.17	10.39	85%	1.78
60%	3.38	2.57	76%	0.81	12.17	10.74	88%	1.43
70%	3.38	2.77	82%	0.61	12.17	11.10	91%	1.07
80%	3.38	2.97	88%	0.41	12.17	11.46	94%	0.71
90%	3.38	3.18	94%	0.20	12.17	11.81	97%	0.36
100%	3.38	3.38	100%	0.00	12.17	12.17	100%	0.00

4.2 Rainfall-Runoff Evaluation (R.G. Miller)

In 2012, HCFCD engaged RG Miller Engineers to evaluate observed streamflow data and to compare the resultant runoff volume with the measured precipitation in the upstream watershed. The report is entitled *Rainfall Volume vs. Runoff Volume Evaluation Study.* The goal of this study was to "to develop an improved understanding of a relationship between rainfall and runoff for various intensity storm events."

The results of this analysis are presented in greater detail in Appendix B. The analysis found that the average rainfall to runoff percentage in the Addicks Reservoir, for the full spectrum of events, is 70%. It is difficult to correlate this value to the values in Table D4.1 due to the variability in rainfall amount, percentage of impervious cover, and antecedent moisture condition. However, the results offer no indication of conflict and generally are within expected ranges.

The observed rainfall-runoff relationship in the Upper Cypress Creek watershed is much lower, averaging about 41%. This is not unexpected given the unique topography of the upper Cypress watershed. This is also evidence that the areas of remnant native prairie are retaining a much greater percentage of rainfall.

4.3 Analysis of Addicks Reservoir Inflow Data, 1992

Daily pool elevation and release data from Addicks Reservoir was collected and analyzed as part of a study of the reservoirs described in Appendix B. The daily inflow can be reduced from the daily pool elevation and release volume, and this inflow can be compared to measured rainfall in the watershed. Between December, 1992 and March, 1993 frequent rainfalls during a wet season resulted in the reservoir achieving its record pool elevation.

Section 3.1 of Appendix B summarizes a detailed analysis of the daily data. Among the conclusions from this evaluation is that the rainfall-to-runoff conversion over this period was about 75%. This is slightly higher than the R.G. Miller evaluation of 70%, but within the same order of magnitude. Furthermore, much of the rainfall occurred during a high antecedent moisture condition. As with the R.G. Miller study, there is no indication of conflict with previous studies and understanding.

5.0 Summary

This appendix summarized review and analysis of the conversion of rainfall to runoff for a variety of studies and methods. As part of the Cypress Creek Overflow Management Plan study, the HCFCD is collecting and analyzing data to provide a greater understanding of this relationship. This purpose of this review is to provide interim guidance for the study based upon previous study, computations, and interim data from the HCFCD study.

Based upon this, the following interim guidance criteria is recommended:

- For the 24-hour, 1% (100-year) event, the development of land is expected to result in an increase of between 1.79 inches of runoff (single family residential) and 3.21 inches of runoff (commercial/industrial). For simplicity, a single value of 2 inches may be considered to represent the volume impact of new development.
- Prairie preservation and restoration has a significant impact on runoff volume, as evidence supports the theory that native prairie vegetation increase the infiltrative capacity of soil. Based upon limited data, it appears that one acre of prairie would increase the infiltration capacity of undeveloped land by 3 ½ inches. The restoration of one acre of prairie would offset the volume impact of about two acres of single-family subdivision or about one acre of commercial or retail development.

6.0 References

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Appendix E

Cost Estimates and Benefit/Cost Determination

August 18, 2015

Table of Contents

1.0 Introduction

This appendix describes and summarizes the development of cost estimates and a benefit-cost analysis for the two alternative management plans developed in support of the Cypress Creek Overflow Management Plan. As required in the grant scope, two plans were identified for further study: Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B" and Management Plan 5 – Katy Hockey N – Cypress Reservoir. This appendix summarizes the development of planning level cost estimates of each of these alternatives, as well as the determination of the benefits provided by each. A benefit-to-cost relationship is also presented for each of the management plans.

1.1 Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B"

This strategy involves a reservoir along Mound Creek that would reduce the frequency and magnitude of the overflow. Overflow interceptor channels constructed downstream of the watershed divide would tie in with a conveyance channel to carry overflow to Addicks Reservoir. The interceptor channels will border an area that will continue to experience inundation during overflow events; this area has the potential to provide greater conservation opportunities in addition to management of the Cypress Creek overflow. This management plan would be supplemented by overflow storage in John Paul's Landing, a regional park that will include an amenity lake, as well as development criteria.

Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B" is depicted in Exhibit E1.1. The channel will be expanded to convey 4,500 cfs of discharge into the enlarged Bear Creek channel approximately 7,500 feet upstream of Fry Road. The channel will utilize natural channel design techniques, and will be sufficiently deep to accept drainage from lateral systems. The overflow would be significantly reduced; however some residual overflow would continue to inundate a large area in the upper Addicks Reservoir. Therefore, an additional overflow inundation area of approximately 2,200 acres, which currently experiences the overflow during a 1% annual chance event, would be bounded by interceptor channels that would collect the overflow and direct it towards an outlet into Bear Creek. Approximately 1,580 acres of the 2,200 is privately held land with the remainder currently being held as conservation. The 1,580 acres will be preserved as conservation area, and the collection channels will be located on the south and east perimeters of this conservation area. This approach helps assure that the collection will not influence overflow rates and volume, and also provides for additional conservation area. In addition, it will provide some additional attenuation of overflow.

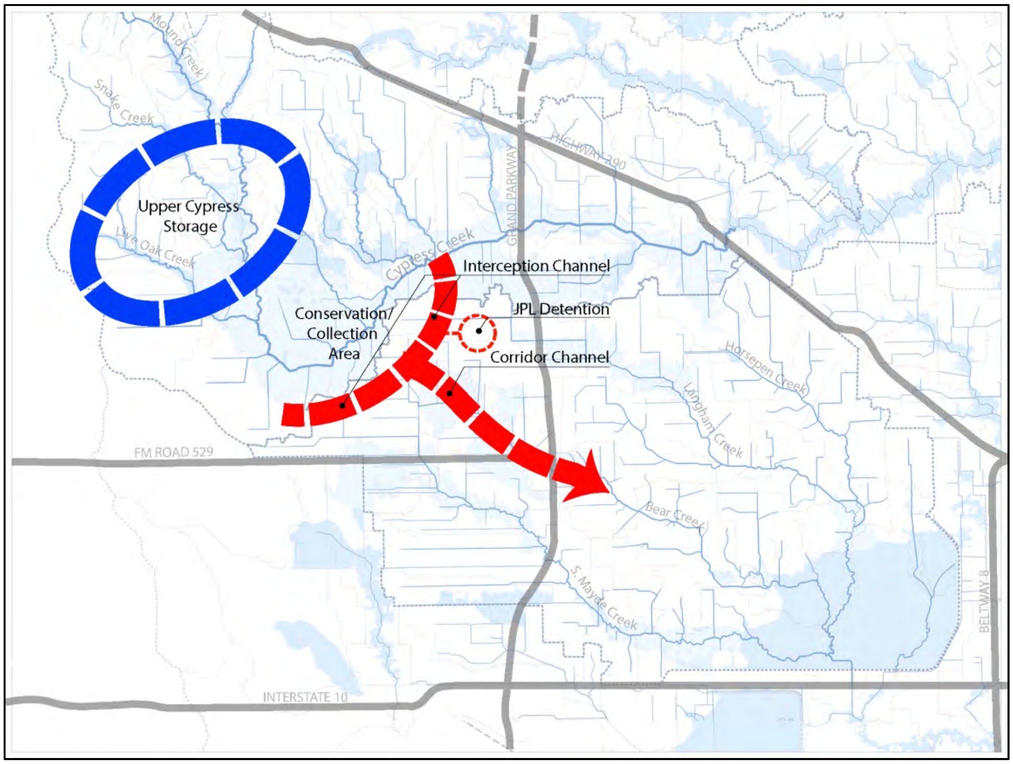

Exhibit E1.1
Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B"

The existing peak 1% (100-year) overflow of 12,500 cfs will be reduced by the construction of the Mound Creek Reservoir. However, since the reservoir will still allow for a considerable overflow, the required storage volume is substantially smaller. The reservoir will flood to a 1% (100-year) pool elevation of 188 feet, will inundate 2,880 acres of land during the 1% (100-year) event, storing 15,730 acre-feet. The maximum storage depth would be 13 feet, with an average depth of seven feet. The reservoir would drain in three to four days. With the reservoir in place, the peak overflow would be reduced to 5,500 cfs. The peak overflow volume would be reduced from 23,355 acre-feet to approximately 17,000 acre-feet.

The reservoir will be controlled by an earthen dam with a maximum height of 22 feet, which would allow for 8 feet of freeboard during a 1% annual chance event and provide sufficient volume to contain the probable maximum flood. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur. The embankment would include a stabilized emergency spillway that would pass events in excess of the 1% (100-year) event. Such flows may exceed the design capacity of existing infrastructure, but would not exceed current flowrates for a similar event.

There would be a primary outlet structure to Mound Creek, and a secondary outlet structure to Live Oak Creek. The Mound Creek outlet would be in the form of an armored open channel, while the Live Oak Creek outfall would be via a boxed structure.

The reservoir footprint encompasses 3,765 acres of land. This includes what is now 1,520 acres of private land and 2,245 acres of conservation land. In addition, the conservation/collection area covers 2,200 acres, including 400 acres of public land (the HCFCD's Hornberger Tract) that is being held in conservation.

Approximately 300 acre-feet of additional detention will be provided within John Paul's Landing (JPL), a regional park that will include a large amenity lake. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome-based, and developers will determine the approach to manage this runoff.

1.2 Management Plan 5 – Katy Hockley N - Cypress Reservoir

This strategy involves construction of a reservoir located in both the Upper Cypress and Addicks watersheds. The reservoir would capture flow along Cypress Creek and the overflow area in one contiguous pool, and includes outlets to Cypress Creek and Bear Creek. Bear Creek would be enlarged between the reservoir and development that is located substantially farther downstream. An internal reservoir balance channel and structure would be constructed to prevent the increase in volume to either Addicks Reservoir or Cypress Creek. This management plan would be supplemented by overflow storage in John Paul's Landing, a regional park that will include an amenity lake, as well as development criteria.

Management Plan 5 – Katy Hockley N - Cypress Reservoir is depicted in Exhibit E1.1. The reservoir would be formed by an earthen berm or dam that extends along Longenbaugh Road, around and outside of Paul Rushing Park, and northward along Katy-Hockley Road across Cypress Creek. The berms would vary in height, with a maximum height of eight feet. They would be constructed using excavated material from within the reservoir. This is the only excavation within the reservoir.

Bear Creek will be enlarged for a distance of about 24,000 feet, from the outlet of the lower pool near the intersection of Longenbaugh Road and West Road, downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel will utilize natural channel design principles within a 500-foot corridor. The channel will be sufficiently deep to accept drainage from lateral channels. The outlet to Bear Creek will be restricted to 2,000 cfs via a boxed conduit. This restriction is necessary to prevent the diversion of additional flow volume from Cypress Creek to Addicks Reservoir during events smaller than the 1% (100-year) event. The outlet to Cypress Creek will be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year) event, the release to Cypress Creek will be restricted to 5,300 cfs. This results in a combined maximum release of 7,300 cfs.

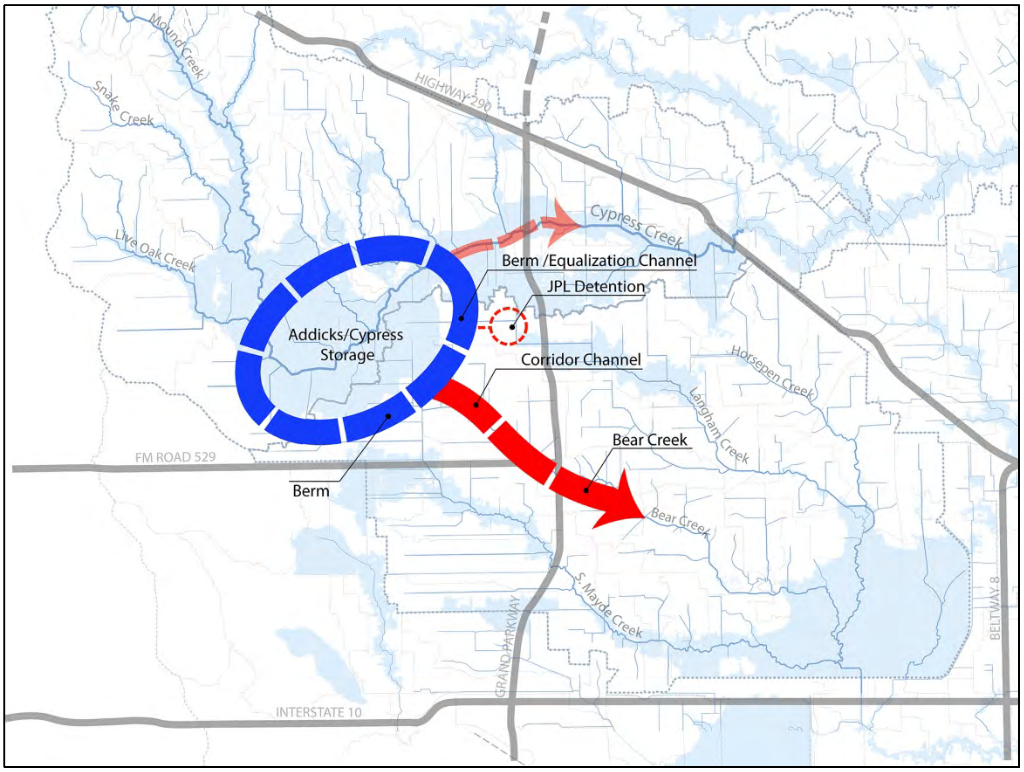

Exhibit E1.1
Management Plan 5 – Katy Hockley N – Cypress Reservoir

The 1% (100-year) reservoir pool elevation is 168 feet, inundating 7,400 acres and providing 26,500 acre-feet of storage. The maximum depth in the basin, excluding existing channels, will be eight feet, with an average depth of four feet for a 1% annual chance event. The reservoir will drain in three days.

The reservoir will be controlled by an earthen dam with a maximum height of 14 feet, however the average height will be about five feet. The embankment would be constructed from excavation within the reservoir. This is the only excavation that would occur. The embankment would include a stabilized emergency spillway that would pass events in excess of the 1% (100-year) event. Such flows may exceed the design capacity of existing infrastructure, but would not exceed current flowrates for a similar event.

There will be a small channel inside the reservoir along the south dam that will direct low flows to the outlet to Bear Creek. In addition, there will be a channel inside the east dam that will allow flows to drain back to the Cypress Creek watershed from the Addicks watershed. This is necessary because the higher elevations along Cypress Creek created by the dam will result in the diversion of additional volume across the watershed, and this channel is necessary to return volume to Cypress Creek. A backflow prevention structure will be constructed near the watershed divide to ensure the channel does not allow for flow from the Cypress Creek watershed to the Addicks Reservoir watershed.

In total, approximately 7,400 acres of land will be inundated during the 1% (100-year) event. This includes 3,540 acres of private land, 3,401 acres of conservation land, and 459 acres of public land (held for conservation).

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

This strategy includes the adoption of Development Criteria that prevents the increase in runoff volume into Addicks Reservoir as the study area develops. The criteria will require developers to manage the volume equivalent of two inches of runoff. The criteria will be outcome-based, and developers will determine the approach to manage this runoff.

2.0 Cost Estimates

Planning-level cost estimates were developed throughout the formulation of plans. Costs were developed for the original "bookend" strategies and six alternative plans as part of the plan evaluation process, and are not presented in this appendix. Cost estimates were developed in slightly greater detail for the final two identified plans. This section provides an overview of the development of the cost estimates. Section 2.1 describes the cost items utilized in the development of costs for all six alternatives. Sections 2.2 and 2.3 provide an overview of the cost estimates for Plan 3 and Plan 5, respectively.

2.1 Cost Items

Costs were developed for the major items included in the various plans. All items were organized under one of three categories: land, construction and professional services. The following sections describe each of these.

The cost estimates were developed in an Excel spreadsheet using a table reference to the cost items. If necessary, a user can adjust individual cost items and the cost spreadsheets will update to reflect the total cost. The cost item summaries presented in this section reflect the tables used in this study.

2.1.1 Land Values

Land costs are the most significant cost item in both plans. In addition, land costs are the most uncertain and most volatile. The opening of the Grand Parkway Segment E, between IH-10 and US-290, in December 2013 has provided critical transportation access to the land in the study area. However, much of this land is subject to flooding from the overflow during a 1% event. It is uncertain how well the impact of the overflow is understood by the land development community, and the potential lack of understanding may result in improper consideration of land values.

Land values were assigned based upon real estate listings and recent transactions that had been performed prior to June 2013. These are considered more pertinent and accurate as compared to the Harris County Appraisal District. Table E2.1 lists the land categories and the assumed cost used in the cost estimates.

Table E2.1
Assumed Land Values

No.	Category	Cost	Unit	Description
L1	Land A	$18,000	ac	Low value - west and north, and/or high flood depth
L2	Land B	$22,500	ac	Medium value - small tracts, and/or south and east
L3	Land C	$30,000	ac	High value - excellent access, not flood prone, close in, and/or near development
L4	Designated Conservation Land	$12,500	ac	Value of inundation easement on conservation land
L5	Conservation Land	$12,500	ac	Value of inundation easement on conservation land
L6	Public Land	$0	ac	No land cost considered
L7	Dedicated Land	$0	ac	No land cost considered
L8	Land B - Temp Esmt	$5,625	ac	Cost of temporary flooding easement on open land
L9	Land B - Convert Temp Esmt to Perm	$16,875	ac	Cost to convert temporary easement to permanent easement and/or fee ownership

Land that is very deep in the existing floodplain, including the floodplain of Cypress Creek and areas very deep in the overflow, were assigned the lowest raw land value, at $18,000 per acre. Nearby land that is generally west of Katy-Hockley Cutoff and North of FM 529 was assigned a value of $22,500 per acre. Closer-in land that is subject to more immediate development pressure was assigned a value of $30,000 per acre.

The projects consider the occasional, infrequent and short-duration inundation of conservation land. For initial cost estimates, it was assumed that flooding easements would be acquired to allow for this inundation at a cost of $12,500 per acre. However, if an in-kind partnership is developed with the conservation interests, this land would fall under dedicated land.

The implementation plans consider a temporary flooding easement on private land in the initial project phases. The subject land falls under category “Land B,” which has a cost of $22,500 per acre. The cost estimates assume the temporary easement would be acquired for $5,625 per acre, which is 25% of the assumed value. Furthermore, the cost estimates assume the remaining $16,875 would be necessary to convert the temporary easements to permanent.

Public land that is owned by HCFCD and Harris County Precinct 3 would be utilized at no cost. For Precinct 3, this refers to detention within John Paul’s Landing.

2.1.2 Construction Costs

There are a number of elements associated with the construction costs of both plans. The largest single cost item is earthwork, which accounts for about 60% of the total construction costs. Other construction items are pipeline adjustment, roadway crossing adjustments, stream mitigation, outfall and control structures, and construction erosion control measures.

Earthwork

Both plans involve the excavation of channels and detention as well as the construction of berms and embankments. The resultant earthwork prices are listed in Table E2.2.

Table E2.2
Earthwork Prices

No.	Item	Price	Unit	Description
E1	No Haul Excavation	$3	cy	Adjacent spoil/source
E2	Medium Haul Excavation	$7.5	cy	nearby disposal/source
E3	Long Haul Excavation	$15	cy	distant disposal truck haul
E4	Training Berm	$5	cy	source adjacent to berm
E5	Berm/Dam	$15	cy	source adjacent, compacted
E6	Key Trench	$7.5	cy	

Much of the project will involve excavation or fill where there is minimal haul distance. Category E1 is for excavation or fill where the source or spoils is immediately adjacent and does not require haul. An example of this would be areas where there is an adjacent spoils area. Category E2 is for short- to medium-haul excavation, such as where excavated material is used to provide fill in very nearby areas. Category E3 is for disposal where trucks must haul material to an offsite disposal site.

Category E4 is for training berms, where the source will be adjacent material. The berms will require shaping. Category E5 is for the construction of the embankments for the reservoirs. This assumes that the material will be primarily from adjacent sites, but some offsite material may be necessary. The embankment must be shaped and compacted. Category E6 is for the key trench for the embankment.

Relocations

The plans involve the widening and deepening of Bear Creek, and this will involve the modification of existing pipeline crossings and roadway crossings. Table E2.3 provides the prices assumed for these crossings.

Table E2.3
Relocation Prices

No.	Item	Price	Unit	Description
R3	Minor Bridge Modification 2	$1,500,000	ea	Widen bridge – 2-lane road
R4	Major Bridge Modification	$3,000,000	ea	Widen bridge – 4-lane road, State Hwy
R6	Major Pipeline	$1,000,000	ea	Adjust pipeline
R7	Minor Bridge Modification 1	$250,000	ea	Excavate under bridge, modify piers

Minor Bridge Modification 1 refers to excavation under an existing bridge, modification to the piers to accommodate the deeper channel, and slope paving the slope underneath the bridge. Minor Bridge Modification 2 involves adjusting the approaches for a widened channel and raising the roadway for a two-lane road. Major Bridge Modification involves adjusting the approaches for a wider channel and replacing the bridge for a four-lane roadway or a State Highway.

Major Pipeline relocation involves adjusting an existing pipeline to accommodate the widened and deepened channel.

Stream Mitigation

The modification of the Bear Creek channel, as well as the Cypress Creek channel near the reservoir outfall structures, will require mitigation to offset habitat impacts to the stream. The potential impacts along Cypress Creek are far greater, however they will only extend for a short distance (approximately 1,000 feet). There are minimal resource concerns for Bear Creek. Table E2.4 summarizes the costs assumed for stream mitigation.

Table E2.4
Stream Mitigation Prices

No.	Item	Price	Unit	Description
M1	Stream Mitigation	$250	lf	Assumes mitigation in place as channel modifications are constructed.

The modifications to Bear Creek will be in a wide corridor that will facilitate natural channel design techniques to manage the bank full flows. These features will allow for mitigation in place. The price recognizes the cost of installing those features in the bottom of the channel. Impacts to Cypress may also be mitigated in place, where possible, however mitigation bank credits may be necessary to offset impacts if utilized mitigation bank is available.

Structures

Structures will be utilized to control the rate of flow from the reservoirs, to control flow into and out of John Paul's Landing, and to provide volume equalization in the Plan 5 reservoir. Table E2.5 summarizes the prices used for structures.

Table E2.5
Structure Prices

No.	Item	Price	Unit	Description
D1	Culvert	$15	sf-lf	Unit is based upon Length vs. Area
D2	Riprap/Slope Protection	$125	sy	
D3	Channel Protection	$250	lf	Toe protection, mild treatments
D4	Drop Structure	$250,000	ea	Sheet pile structure
D5	Back Slope Drainage	$25	lf	Assumes every 800 feet on both side of channel, $10,000 per
D6	JPL Control Structure	$250,000	ea	Inflow/outflow from Bear Creek
D7	Downstream Transition	$500,000	ea	Bear Creek transition at ds end of new modifications
D11	Backflow Prevention	$300,000	ea	For Plan 5 Reservoir
D12	Remove Inline Structure	$50,000	ea	Bear Creek downstream of Fry Rd (Plan 5)

Site, SWPPP and Stabilization

The prices associated with mobilization, setup, erosion and sediment control, and stabilization of the site are listed in Table E2.6

Table E2.6
Site, SWPPP, and Stabilization

No.	Item	Price	Unit	Description
S1	Mobilization	$100,000	ea	Mobilization
S2	Clear and Grub	$7,000	ac	Clear and Grub
S3	Silt Fence	$2	lf	Silt Fence
S4	Care and Control of Water	$30	lf	Care and Control of Water
S5	Hydromulch	$3,000	ac	Hydromulch
S7	Irrigation	$2,500	ac	Irrigation
S8	Construction Entrance	$5,000	ea	Construction Entrance

Contingency

A 25% contingency was added to the total construction cost. This contingency cost considers cost items not identified in this planning level cost summary, and allows for slight price variations.

2.1.3 Professional Costs

Professional costs represent the costs associated with performing engineering designs, obtaining permits, acquiring land and overseeing the construction. Each of these was determined based upon a percentage of the construction cost (not including land acquisition costs).

Engineering and design costs were assumed to be equivalent to 8% of the total construction cost. Environmental studies, permitting and real estate acquisition costs were assumed to be equivalent to 4% of the construction cost. Construction management was assumed to cost 10% of the overall construction costs. Therefore, professional costs were assumed to be, in total, equivalent to 22% of the total construction cost.

2.2 Plan 3 Cost Estimates

Two versions of the cost of Plan 3 were developed. The initial version is the full total cost of the plan. The second version is the total cost of the plan assuming in-kind contributions by conservation interests and by development activity. These in-kind contributions are discussed in Appendix F.

2.2.1 Plan 3 Full Cost

Plan 3 is estimated to cost approximately $271 million. This includes $117 million in land costs, $126 million in construction costs, and $28 million in professional fees. Table E2.7 summarizes the cost estimate, by project element.

Exhibit E2.7
Plan 3 Cost Estimate - Full Cost

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	215	ac	$22,500	$4,837,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - County	415	ac	$0	$0	
	Total - Land					*$15,825,000*
E1	Collection Channel Excavation	785,000	cy	$3	$2,355,000	
D5	Backslope Drains	20,000	lf	$25	$500,000	
E2	Daylight/Bear Ck Channel Excavation	739,400	cy	$7.5	$5,545,500	
R3	Katy-Hockley Road	1	ea	$1,500,000	$1,500,000	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$10,650,500*	
	25% Contingency			25%	$2,662,625	
	Total - Construction					*$13,313,125*
	Engineering/Design			8%	$1,065,050	
	Environmental/Permitting/ROW			4%	$532,525	
	Construction Management			10%	$1,331,313	
	Total - Professional					*$2,928,888*
ELEMENT 1 - TOTAL						**$32,067,013**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Land	295	ac	$30,000	$8,850,000	
	Total - Land					*$8,850,000*
E2	Channel Excavation	2,059,800	cy	$7.5	$15,448,500	
R3	Longenbaugh Road	1	ea	$1,500,000	$1,500,000	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
R3	Stockdick School Rd	1	ea	$1,500,000	$1,500,000	
R6	Major Natural Gas Pipelines	5	ea	$1,000,000	$5,000,000	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	180	ac	$7,000	$1,260,000	
S3	Silt Fence	39,000	lf	$2	$78,000	
S4	Care and Control of Water	19,500	lf	$30	$585,000	
S5	Hydromulch	180	ac	$3,000	$540,000	
D5	Backslope Drains	19,500	lf	$25	$487,500	
M1	Stream Mitigation	26,500	lf	$250	$6,625,000	
	Subtotal - Construction				*$37,637,000*	
	25% Contingency			25%	$9,409,250	
	Total - Construction					*$47,046,250*
	Engineering/Design			8%	$3,763,700	
	Environmental/Permitting/ROW			4%	$1,881,850	
	Construction Management			10%	$4,704,625	
	Total - Professional					*$10,350,175*
ELEMENT 2 TOTAL						**$66,246,425**

Exhibit E2.7 (Continued)
Plan 3 Cost Estimate - Full Cost

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Upper Langham Collection	55	ac	$30,000	$1,650,000	
	Total - Land					*$1,650,000*
E2	Channel Excavation	289,900	cy	$7.5	$2,174,250	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
	Subtotal - Construction				*$8,174,250*	
	25% Contingency			25%	$2,043,563	
	Total - Construction					*$10,530,313*
	Engineering/Design			8%	$842,425	
	Environmental/Permitting/ROW			4%	$421,213	
	Construction Management			10%	$1,053,031	
	Total - Professional					*$2,316,669*
ELEMENT 3 TOTAL						**$14,496,981**

Element 4 - Conservation/Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Collection Channels	90	ac	$22,500	$2,025,000	
L9	Convert Temp Esmt to Permanent	1,580	ac	$16,875	$26,662,500	
L6	County Land	440	ac	$0	$0	
	Total - Land					*$28,687,500*
E1	Excavation	1,573,800	cy	$3	$4,721,400	
D5	Back Slope Drains	13,000	lf	$25	$325,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	230	ac	$7,000	$1,610,000	
S3	Silt Fence	33,000	lf	$2	$66,000	
S5	Hydromulch	230	ac	$3,000	$690,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
	Subtotal - Construction				*$7,527,400*	
	25% Contingency			25%	$1,881,850	
	Total - Construction					*$9,409,250*
	Engineering/Design			8%	$752,740	
	Environmental/Permitting/ROW			4%	$282,278	
	Construction Management			10%	$940,925	
	Total - Professional					*$1,975,943*
ELEMENT 4 TOTAL						**$40,072,693**

Exhibit E2.7 (Continued)
Plan 3 Cost Estimate - Full Cost

Element 5 - Mound Creek Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	1,520	ac	$22,500	$34,200,000	
L5	Conservation land	2,245	ac	$12,500	$28,062,500	
	Total - Land					*$62,262,500*
E6	Key Trench Excavation	106,950	cy	$7.5	$802,125	
E5	Embankment	1,236,950	cy	$15	$18,554,250	
D2	Mound Ck Outfall Rip-Rap/Slope Paving	15,000	sy	$125	$1,875,000	
D3	Spillway	52,000	lf	$250	$13,000,000	
D1	Live Oak 200 lf 1-6'x6' box	7,200	sf-lf	$15	$108,000	
E2	Live Oak Excavation	267	cy	$7.5	$2,000	
D2	Live Oak Rip-Rap/Slope Paving	1,733	sy	$125	$216,666	
S1	Mobilization	1	ea	$100,000.0	$100,000	
S2	Clear and Grub	190	ac	$7,000	$1,330,000	
S3	Silt Fence	27,500	lf	$2	$55,000	
S5	Hydromulch	190	ac	$3,000	$570,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	1,000	lf	$250	$250,000	
	Subtotal - Construction				$36,878,041	
	25% Contingency			25%	$9,219,510	
	Total - Construction					*$46,097,552*
	Engineering/Design			8%	$3,687,804	
	Environmental/Permitting/ROW			4%	$1,843,902	
	Construction Management			10%	$4,609,755	
	Total - Professional					*$10,141,461*
ELEMENT 5 TOTAL						**$118,501,513**

Plan Totals	
Land	$117,275,000
Construction	$126,396,489
Professional	$27,713,135
TOTAL PLAN COST	**$271,384,624**

2.2.2 Plan 3 Effective Cost (With In-Kind Contributions)

With in-kind contributions from the conservation and development community, Plan 3 is estimated to cost approximately $177 million. This includes $79 million in land costs, $79 million in construction costs, and $19 million in professional fees. Table E2.8 summarizes the cost estimate, by project element.

Exhibit E2.8
Plan 3 Cost Estimate – with In-Kind Contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	215	ac	$22,500	$4,837,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - County	415	ac	$0	$0	
	Total - Land					*$15,825,000*
E2	Collection Channel Excavation	785,000	cy	$8	$5,887,500	
E2	Daylight/Bear Ck Channel Excavation	739,400	cy	$8	$5,545,500	
D5	Backslope Drains	20,000	lf	$25	$500,000	
R3	Katy-Hockley Road	1	ea	$1,500,000	$1,500,000	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$14,183,000*	
	25% Contingency			25%	$3,545,750	
	Total - Construction					*$17,728,750*
	Engineering/Design			8%	$1,418,300	
	Environmental/Permitting/ROW			4%	$709,150	
	Construction Management			10%	$1,772,875	
	Total - Professional					*$3,900,325*
ELEMENT 1 - TOTAL						**$37,454,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land Dedicated by Dev	295	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	2,059,800	0	$0.0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
	Subtotal - Construction				*$6,263,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$626,300	
	Environmental/Permitting/ROW			4%	$313,150	
	Construction Management			10%	$782,875	
	Total - Professional					*$1,722,325*
ELEMENT 2 TOTAL						**$9,551,075**

Exhibit E2.8 (Continued)
Plan 3 Cost Estimate – with In-Kind Contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total - Land					*$0*
D6	JPL Control Structure	1	ea	$250,000	$250,000	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,565,750	
	Total - Construction					*$7,828,750*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,750*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Conservation/Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Collection Channels	90	ac	$22,500	$2,025,000	
L9	Convert Temp Esmt to Permanent	1,580	ac	$16,875	$26,662,500	
L6	County Land	440	ac	$0	$0	
	Total - Land					*$28,687,500*
E1	Excavation	1,573,800	cy	$3	$4,721,400	
D5	Back Slope Drains	13,000	lf	$25	$325,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	230	ac	$7,000	$1,610,000	
S3	Silt Fence	33,000	lf	$2	$66,000	
S5	Hydromulch	230	ac	$3,000	$690,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
	Subtotal - Construction				*$7,527,400*	
	25% Contingency			25%	$1,881,850	
	Total - Construction					*$9,409,250*
	Engineering/Design			8%	$752,740	
	Environmental/Permitting/ROW			4%	$376,370	
	Construction Management			10%	$940,925	
	Total - Professional					*$2,070,035*
ELEMENT 4 TOTAL						**$40,166,785**

Exhibit E2.8 (Continued)
Plan 3 Cost Estimate – with In-Kind Contributions

Element 5 - Mound Creek Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	1,520	ac	$22,500	$34,200,000	
L7	Conservation land	2,245	ac	$0	$0	
	Total - Land					*$34,200,000*
E6	Key Trench Excavation	106,950	cy	$7.5	$802,125	
E5	Embankment	1,236,950	cy	$15	$18,554,250	
D2	Mound Ck Outfall Rip-Rap/Slope Paving	15,000	sy	$125	$1,875,000	
D3	Spillway	52,000	lf	$250	$13,000,000	
D1	Live Oak 200 lf 1-6'x6' box	7,200	sf-lf	$15	$108,000	
E2	Live Oak Excavation	267	cy	$7.5	$2,000	
D2	Live Oak Rip-Rap/Slope Paving	1,733	sy	$125	$216,666	
S1	Mobilization	1	ea	$100,000.0	$100,000	
S2	Clear and Grub	190	ac	$7,000	$1,330,000	
S3	Silt Fence	27,500	lf	$2	$55,000	
S5	Hydromulch	190	ac	$3,000	$570,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	1,000	lf	$250	$250,000	
	Subtotal - Construction				$36,878,041	
	25% Contingency			25%	$9,219,510	
	Total - Construction					*$46,097,552*
	Engineering/Design			8%	$3,687,804	
	Environmental/Permitting/ROW			4%	$1,843,902	
	Construction Management			10%	$4,609,755	
	Total - Professional					*$10,141,461*
ELEMENT 5 TOTAL						**$90,439,013**

Plan Totals	
Land	$78,712,500
Construction	$79,467,552
Professional	$19,552,896
TOTAL PLAN COST	**$177,732,948**

2.2 Plan 5 Cost Estimates

Two versions of the cost of Plan 5 were developed. The initial version is the full total cost of the plan. The second version is the total cost of the plan assuming in-kind contributions by conservation interests and by development activity. These in-kind contributions are discussed in Appendix F.

2.2.1 Plan 5 Full Cost

Plan 5 is estimated to cost approximately about $369 million. This includes $206 million in land costs, $134 million in construction costs, and $29 million in professional fees. Table E2.9 summarizes the cost estimate, by project element.

Exhibit E2.9
Plan 3 Cost Estimate - Full Cost

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	285	ac	$22,500	$6,412,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$17,400,000*
E2	Collection Channel Excavation	785,000	cy	$7.5	$5,887,500	
E2	Daylight/Bear Ck Channel	739,400	cy	$7.5	$5,545,500	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$12,183,000*	
	25% Contingency			25%	$3,045,750	
	Total - Construction					*$15,228,750*
	Engineering/Design			8%	$1,218,300	
	Environmental/Permitting/ROW			4%	$609,150	
	Construction Management			10%	$1,522,875	
	Total - Professional					*$3,350,325*
ELEMENT 1 - TOTAL						**$35,979,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Land	295	ac	$30,000	$8,850,000	
	Total - Land					*$8,850,000*
E2	Channel Excavation	2,059,800	cy	$7.5	$15,448,500	
R3	Longenbaugh Road	1	ea	$1,500,000	$1,500,000	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
R3	Stockdick School Rd	1	ea	$1,500,000	$1,500,000	
R6	Major Natural Gas Pipelines	5	ea	$1,000,000	$5,000,000	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	180	ac	$7,000	$1,260,000	
S3	Silt Fence	39,000	lf	$2	$78,000	
S4	Care and Control of Water	19,500	lf	$30	$585,000	
S5	Hydromulch	180	ac	$3,000	$540,000	
D5	Backslope Drains	19,500	lf	$25	$487,500	
M1	Stream Mitigation	26,500	lf	$250	$6,625,000	
S1	Mobilization	1	ea	$100,000	$100,000	
E2	Channel Excavation	80,000	cy	$7.5	$600,000	
D5	Backslope Drains	10,000	lf	$25	$250,000	
S3	Silt Fence	20,000	lf	$2	$40,000	
S5	Hydromulch	28	ac	$3,000	$84,000	
D12	Remove Ex Structure	1	ea	$50,000	$50,000	
R7	Adjust Bridges at Fry and W Little	2	ea	$250,000	$500,000	
	Subtotal - Construction				*$39,261,000*	
	25% Contingency			25%	$9,815,250	
	Total - Construction					*$49,076,250*
	Engineering/Design			8%	$3,926,100	
	Environmental/Permitting/ROW			4%	$1,963,050	
	Construction Management			10%	$4,907,625	
	Total - Professional					*$10,796,775*
ELEMENT 2 TOTAL						**$68,723,025**

Exhibit E2.9 (Continued)
Plan 5 Cost Estimate - Full Cost

Element 3 - JPL Landing Detention						
No	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	Upper Langham Collection	55	ac	$30,000	$1,650,000	
	Total - Land					*$1,650,000*
E2	Channel Excavation	6	cy	$7.5	$2,174,250	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
	Subtotal - Construction				*$8,174,250*	
	25% Contingency			25%	$2,043,563	
	Total - Construction					*$10,530,313*
	Engineering/Design			8%	$842,425	
	Environmental/Permitting/ROW			4%	$421,213	
	Construction Management			10%	$1,053,031	
	Total - Professional					*$2,316,669*
ELEMENT 3 TOTAL						**$14,496,981**

Element 4 - Acquire Land for KH N-Cypress Storage						
No	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	3536	ac	$22,500	$79,560,000	
L5	Conservation land	5,725	ac	$12,500	$71,562,500	
L6	County Land	415	ac	$0	$0	
L9	Land Value B Convert Temp Esmt to Perm	1584	ac	$16,875	$26,730,000	
	Total - Land					*$177,852,500*
	Total - Construction					*$0*
	Engineering/Design			8%	$0	
	Environmental/Permitting/ROW			4%	$0	
	Construction Management			10%	$0	
	Total - Professional					*$0*
ELEMENT 4 TOTAL						**$177,852,500**

Exhibit E2.9 (Continued)
Plan 5 Cost Estimate - Full Cost

Element 5 - Construct KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
	Total - Land					*$0*
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
E6	Key Trench Excavation	89,800	cy	$7.5	$673,500	
E5	Embankment	788,200	cy	$15	$11,823,000	
D2	Cypress Outlet - riprap/slope paving	13,300	sy	$125	$1,662,500	
D3	Cypress Spillway	18,667	lf	$250	$4,666,750	
D3	Bear Creek Spillway	18,667	lf	$250	$4,666,750	
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
D1	S Mayde Ck - 200 lf 1-6'x8' box	9,600	sf-lf	$15	$144,000	
E2	S Mayde Excavation	356	cy	$7.5	$2,667	
D2	S Mayde Rip-Rap/Slope Paving	1,733	sy	$125	$216,667	
D1	Balance Structure 50 lf 9-6x6 box	16,200	sf-lf	$15	$243,000	
D11	Balance Structure Backflow Prevention	6	ea	$300,000	$1,800,000	
E5	Road Emb - Warren Rnch, Hebert	380,000	cy	$15	$5,700,000	
D1	Road Culvert - Warren Rnch, Hebert	180,000	sf-lf	$15	$2,700,000	
L2	Add ROW - Warren Rnch, Hebert	41	ac	$22,500	$922,500	
	Add Pvmt - Warren Rnch, Hebert	120,000	sy	$50	$6,000,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	400	ac	$7,000	$2,800,000	
S3	Silt Fence	53,900	lf	$2	$107,800	
S5	Hydromulch	400	ac	$3,000	$1,200,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	3,000	lf	$250	$750,000	
	Subtotal - Construction				$47,380,933	
	25% Contingency			25%	$11,845,233	
	Total - Construction					*$59,226,167*
	Engineering/Design			8%	$4,738,093	
	Environmental/Permitting/ROW			4%	$2,369,047	
	Construction Management			10%	$5,922,617	
	Total - Professional					*$13,029,757*
ELEMENT 5 TOTAL						**$72,255,923**

Plan Totals	
Land	$205,752,500
Construction	$134,061,479
Professional	$29,493,525
TOTAL PLAN COST	**$369,307,505**

2.2.2 Plan 5 Effective Cost (With In-Kind Contributions)

With in-kind contributions from the conservation and development community, Plan 5 is estimated to cost approximately $243 million. This includes $124 million in land costs, $98 million in construction costs, and $21 million in professional fees. Table E2.10 summarizes the cost estimate, by project element.

Exhibit E2.10
Plan 5 Cost Estimate – with In-Kind Contributions

Element 1 - Initial Collection Area						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L3	7,000' Corridor	70	ac	$30,000	$2,100,000	
L2	Collection Channels	285	ac	$22,500	$6,412,500	
L8	Temporary Flood Esmt - Private	1580	ac	$5,625	$8,887,500	
L6	Temporary Flood Esmt - Hornberger	415	ac	$0	$0	
	Total - Land					*$17,400,000*
E2	Collection Channel Excavation	785,000	cy	$7.5	$5,887,500	
E2	Daylight/Bear Ck Channel	739,400	cy	$7.5	$5,545,500	
	Maintain Irrigation	5	ea	$150,000	$750,000	
	Subtotal - Construction				*$12,183,000*	
	25% Contingency			25%	$3,045,750	
	Total - Construction					*$15,228,750*
	Engineering/Design			8%	$1,218,300	
	Environmental/Permitting/ROW			4%	$609,150	
	Construction Management			10%	$1,522,875	
	Total - Professional					*$3,350,325*
ELEMENT 1 - TOTAL						**$35,979,075**

Element 2 - Bear Creek Channel						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Land	295	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	2,059,800	0	$0	$0	
A1	Longenbaugh Road	1	0	$0	$0	
R4	FM 529	1	ea	$3,000,000	$3,000,000	
A1	Stockdick School Rd	1	0	$0	$0	
A1	Major Natural Gas Pipelines	5	0	$0	$0	
D7	Transition to Downstream	1	ea	$500,000	$500,000	
S1	Mobilization	1	ea	$100,000	$100,000	
S2	Clear and Grub	50	ac	$7,000	$350,000	
S3	Silt Fence	14,000	lf	$2	$28,000	
S4	Care and Control of Water	7,000	lf	$30	$210,000	
S5	Hydromulch	50	ac	$3,000	$150,000	
D5	Backslope Drains	7,000	lf	$25	$175,000	
A1	Mobilization	1	0	$0	$0	
A1	Clear and Grub	180	0	$0	$0	
A1	Silt Fence	39,000	0	$0	$0	
A1	Care and Control of Water	19,500	0	$0	$0	
A1	Hydromulch	180	0	$0	$0	
A1	Backslope Drains	19,500	0	$0	$0	
M1	Stream Mitigation	7,000	lf	$250	$1,750,000	
A1	Stream Mitigation	19,500	0	$0	$0	
S1	Mobilization	1	ea	$100,000	$100,000	
E2	Channel Excavation	80,000	cy	$8	$600,000	
D5	Backslope Drains	10000	lf	$25	$250,000	
S3	Silt Fence	20,000	lf	$2	$40,000	
S5	Hydromulch	28	ac	$3,000	$84,000	
D12	Remove Ex Structure	1	ea	$50,000	$50,000	
R7	Adjust Bridges at Fry and W Little	2	ea	$250,000	$500,000	
	Subtotal - Construction				*$7,887,000*	
	25% Contingency			25%	$1,971,750	
	Total - Construction					*$9,858,750*
	Engineering/Design			8%	$788,700	
	Environmental/Permitting/ROW			4%	$394,350	
	Construction Management			10%	$985,875	
	Total - Professional					*$2,168,925*
ELEMENT 2 TOTAL						**$12,027,675**

Exhibit E2.10 (Continued)
Plan 5 Cost Estimate – with In-Kind Contributions

Element 3 - JPL Landing Detention						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L7	Upper Langham Collection	55	ac	$0	$0	
	Total - Land					*$0*
A1	Channel Excavation	289,900	0	$0.0	$0	
E2	Detention Excavation	800,000	cy	$7.5	$6,000,000	
D6	JPL Control Structure	1	ea	$250,000	$250,000	
	Subtotal - Construction				*$6,250,000*	
	25% Contingency			25%	$1,562,500	
	Total - Construction					*$7,812,500*
	Engineering/Design			8%	$625,000	
	Environmental/Permitting/ROW			4%	$312,500	
	Construction Management			10%	$781,250	
	Total - Professional					*$1,718,7500*
ELEMENT 3 TOTAL						**$9,531,250**

Element 4 - Acquire Land for KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
L2	Land value B	3536	ac	$22,500	$79,560,000	
L3	Land value C	0	ac	$30,000	$0	
L7	Conservation land	5,725	ac	$0	$0	
L6	County Land	415	ac	$0	$0	
L9	Land Value B Convert Temp Esmt to Perm	1,584	ac	$16,875	$26,730,000	
	Total - Land					*$106,290,000*
	Total - Construction					*$0*
	Engineering/Design			8%	$0	
	Environmental/Permitting/ROW			4%	$0	
	Construction Management			10%	$0	
	Total - Professional					*$0*
ELEMENT 4 TOTAL						**$106,290,000**

Exhibit E2.10 (Continued)
Plan 5 Cost Estimate – with In-Kind Contributions

Element 5 - Construct KH N-Cypress Storage						
No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Cost**	**Totals**
	Total - Land					*$0*
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
E6	Key Trench Excavation	89,800	cy	$7.5	$673,500	
E5	Embankment	788,200	cy	$15	$11,823,000	
D2	Cypress Outlet - riprap/slope paving	13,300	sy	$125	$1,662,500	
D3	Cypress Spillway	18,667	lf	$250	$4,666,750	
D3	Bear Ck Spillway	18,667	lf	$250	$4,666,750	
E1	Channel Excavation (Res. Balance Chnl)	197,800	cy	$3	$593,400	
D3	Spillway	18,667	lf	$250	$4,666,667	
D1	S Mayde Ck - 200 lf 1-6'x8' box	9,600	sf-lf	$15	$144,000	
E2	S Mayde Excavation	356	cy	$8	$2,667	
D2	S Mayde Rip-Rap/Slope Paving	1,733	sy	$125	$216,667	
D1	Balance Structure 50 lf 9-6x6 box	16,200	sf-lf	$15	$243,000	
D11	Balance Structure Backflow Prevention	6	ea	300,000	$1,800,000	
E5	Road Emb - Warren Rnch, Hebert	380,000	cy	$15	$5,700,000	
D1	Road Culvert - Warren Rnch, Hebert	180,000	sf-lf	$15	$2,700,000	
L2	Add ROW - Warren Rnch, Hebert	41	ac	$22,500	$922,500	
	Add Pvmt - Warren Rnch, Hebert	120,000	sy	$50	$6,000,000	
S1	Mobilization	1	ea	100,000	$100,000	
S2	Clear and Grub	400	ac	$7,000	$2,800,000	
S3	Silt Fence	53,900	lf	$2	$107,800	
S5	Hydromulch	400	ac	$3,000	$1,200,000	
S8	Construction Entrance	3	ea	$5,000	$15,000	
M1	Stream Mitigation	3,000	lf	$250	$750,000	
	Subtotal - Construction				$52,047,600	
	25% Contingency			25%	$13,011,900	
	Total - Construction					*$69,059,500*
	Engineering/Design			8%	$5,204,760	
	Environmental/Permitting/ROW			4%	$2,602,380	
	Construction Management			10%	$6,505,950	
	Total - Professional					*$143,313,090*
ELEMENT 5 TOTAL						**$79,372,590**

Plan Totals	
Land	$123,690,000
Construction	$97,959,500
Professional	$21,551,090
TOTAL PLAN COST	**$243,200,590**

3.0 Benefit-Cost Analysis

The purpose of the benefit-cost analysis is to identify specific benefits of the respective plans, quantify them in dollar values, and compare them to project costs in the form of a benefit/cost ratio. Some benefits, such as flood damages avoided, can be directly determined. However, this can be more difficult with other benefit categories, such as ecological benefits. This section describes the benefit categories and the determination of economic benefits, as well as the computation of a benefit-cost relationship for each plan.

3.1 Benefit Categories

Both plans provide a number of benefits. They decrease structural flooding in the overflow area. They increase the economic value of the land manifest in development potential. They provide contiguous green space and potential to increase the conservation footprint. They provide protection to Addicks Reservoir via new development policy. They provide recreation opportunities.

The various benefit sections are described below, along with the quantification for each of the two plans.

3.1.1 Reduction to Existing Flood Damages

There are existing flood-prone properties in the study area that will be beneficially impacted by the proposed project. These include properties in the existing overflow area, developments along the Addicks Reservoir tributaries, and properties along Cypress Creek downstream of the overflow.

Cypress Creek Overflow

The HCFCD Structural Inventory Database was used to evaluate properties in the overflow, and the structures subject to flooding are depicted in Exhibit E3.1. During the 1% (100-year) flood event, it is estimated that 107 structures will be subject to flooding. This includes 53 single-family homes, 19 mobile homes, 17 warehouse (or industrial/commercial) buildings, one government or utility structure, and 17 under the category of home/repair use. This last category primarily refers to toolsheds and/or barns adjacent to single-family homes. Table E3.1 summarizes the flood-prone structures during the various events studied.

Table E3.1
Flood-Prone Structures in Overflow

	20% (5-yr)	10% (10-yr)	1% (100-yr)
Single-Family House	7	14	53
Mobile Home	4	5	19
Warehouse/Commercial	3	4	17
Government/Utility	0	0	1
Repair/Home Use	0	3	17

Expected damages for the structure and contents were determined by comparing the computed flood elevation at a location with the estimated elevation of the structure, and then applying a damage estimate determined from curves developed by the U.S. Army Corps of Engineers New Orleans District to the appraised value. These damages were converted to annual average damages using the annual exceedance probability for each event. The present value was developed using a period of 40 years and a discount rate of 3.9% based upon guidance from the Office of Management and Budget (OMB Circular A-94, 2014).

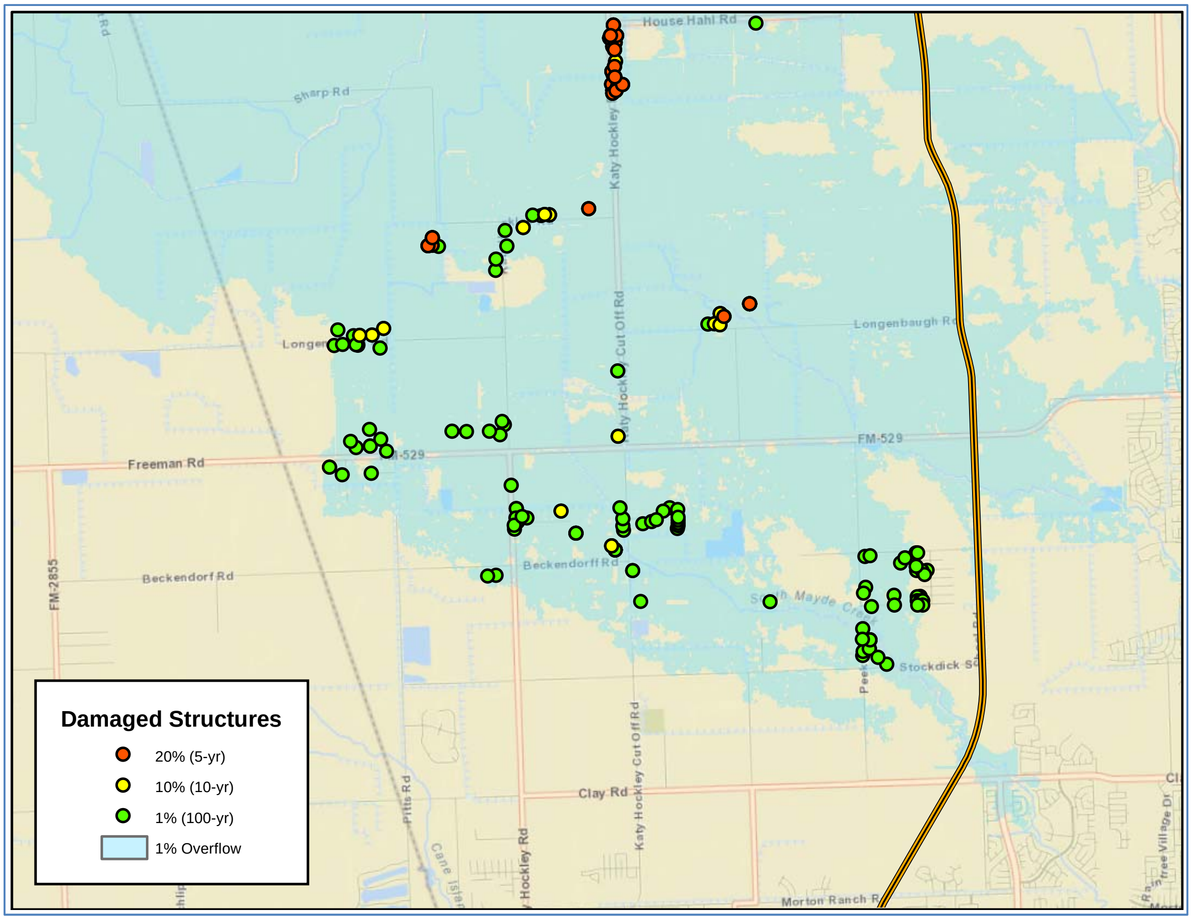

Exhibit E3.1
Flood-Prone Structures in the Cypress Creek Overflow

The damage computations are summarized in Table E3.2. A single 1% (100-year) event is estimated to cause almost $8 million in damages. Over time, damages are estimated to average just over $300,000 per year, resulting in a present value of damages of about $6.5 million.

Table E3.2
Summary of Structural Damages in Overflow

Storm	Probability	Single Event Damages	Average Annual Damages	Incremental Annual Average Damages
5-yr	20%	$863,636	$173,000	$173,000
10-yr	10%	$1,569,000	$157,000	$71,000
100-yr	1%	$7,716,000	$77,000	$61,000
Total Average Annual Damages				**$305,000**
Present Value of Damages				**$6,552,000**

The analysis of structures summarized in Table E3.2 does not include the potential damage to vehicles. The structural database was utilized in the estimated of vehicle damages. While structures are generally assumed to be one foot above natural grade, it is assumed that vehicles will be parked at natural ground. Therefore, the flood depths utilized in the computation of structure damages for each structure were increased by one foot in order to recognize the assumption that vehicles assigned to that structure would be one foot lower than the structure.

A cursory survey was developed by driving through the study area. Vehicles were identified by number, type, and general condition for different types of structures (single-family, public and semi-public, mobile homes, repair and home use, and warehouse and contractor services). A generalized breakdown was developed based upon the survey, and is depicted in Table E3.3. Depth damage curves for vehicles were utilized to evaluate estimated damages, which were then converted to average annual damages and present value damages. Table E3.4 summarizes the computation of vehicle damages. A single 1% (100-year) event is estimated to cause over $1.1 million in vehicle damages. Over time, vehicle damages are estimated to average just over $80,000 per year, resulting in a present value of vehicle damages of almost $1.8 million.

Table E3.3
Assumed Vehicle Values and Inventory Factor

	Sedans	**Pickups**	**SUV**	**Sports**	**Minivans**
Assumed Value	$10,000	$18,000	$20,000	$22,000	$15,000
Structure Type – No. of Vehicles for Each					
Single-Family	0.3	0.9	0.4	0.1	0.3
Public & Semi Public	0.0	1.0	0.0	0.0	0.0
Mobile Home	0.6	0.9	0.3	0.0	0.2
Repairs & Home Use	0.0	1.0	0.0	0.0	0.0
Warehouse & Contractor Services	0.0	2.0	0.0	0.0	0.0

Table E3.4
Summary of Vehicle Damages in Overflow

Storm	**Probability**	**Single Event Damages**	**Average Annual Damages**	**Incremental Annual Average Damages**
5-yr	20%	$338,332	$68,000	$68,000
10-yr	10%	$419,092	$42,000	$8,000
100-yr	1%	$1,126,213	$11,000	$7,000
Total Average Annual Damages				**$83,000**
Present Value of Damages				**$1,783,000**

Both Plan 3 and Plan 5 will eliminate all of the structural flood damages associated with the overflow. Three mobile homes would be acquired as part of the project, and ultimately most, if not all, properties will be acquired by private development interests. Since the cost of the structures was not included in the land cost, the benefit of the flood damage reduction is considered throughout the duration of the project.

Addicks Reservoir Tributaries

There are mapped floodplains along the various tributaries to Addicks Reservoir, including Bear Creek, South Mayde Creek, and Langham Creek. Each of these channels carries runoff generated by the surrounding drainage areas in addition to the Cypress Creek overflow. The local runoff generally reaches these tributaries much more quickly and at higher flow rates than the overflow.

Flooding along these tributaries is generally associated with local runoff; the 1% annual chance floodplain mapped on the effective flood insurance rate maps for these tributaries are based on flow generated by the surrounding drainage area. In some cases, an overflow-only event creates flow rates that result in flooding along these tributaries, but in almost all cases the regulatory floodplain is controlled by the local event.

Plan 5 does include some minor channel modifications along Bear Creek in the vicinity of Fry Road. These improvements will result in a slight reduction in flood elevations. During the 1% (100-year) event, water surface elevations will be reduced by between one-half to one foot. This area was subject to flooding during a recent flood event. The structural inventory does not show any damages for events up to and including the 1% (100-year) event.

There are likely non-quantifiable benefits along Bear Creek as a result of the Plan 5 improvements. These include the reduction of inundation of lower-lying areas of neighborhoods and the associated benefits this would have on mobility and reduction of general nuisance that area residents experience during rain events that flood the neighborhood but do not result in structural flooding.

Cypress Creek

There are many flood-prone areas along Cypress Creek downstream of the study area, which is commonly known as "Lower Cypress Creek." Lower Cypress Creek is surrounded by significantly more development than Upper Cypress Creek and is subject to a double hydrograph peak. There is an initial rise from local runoff in the developed areas of lower Cypress Creek which usually recedes, followed by another rise as the flood wave from Upper Cypress Creek makes its way down the stream. The actual nature of the rainfall determines which of these peaks is the greatest source of flood damage. Measures that address the local runoff, or the first peak, will not affect the second peak; likewise, upstream measures that address the second peak will not affect the first peak.

Both Plan 3 and Plan 5 include storage reservoirs that are similar in character and location to features proposed in the *Cypress Creek Master Drainage Plan,* which was prepared by TC&B and adopted by Harris County Commissioners Court in the 1980s. The measures will reduce, but not eliminate, the peak flow from the Upper Cypress Creek watershed. For rainfall events where this event causes the most flooding, both plans will have a noticeable impact. Because of the nature of the dual peak, it is difficult to quantify the benefit to Lower Cypress Creek, and is considered a non-quantified benefit for this analysis.

3.1.2 Addicks Reservoir

As noted in Appendix B, Addicks Reservoir does not have the capacity to accept additional runoff volume, whether it is from the additional development or from diversions related to a flood control project. The development policy adopted for both plans will offset and prevent additional runoff, and is a benefit when compared to a most likely future condition that does not include such controls. In addition, securing additional land for conservation, via the large storage reservoirs, prevents additional development and controls existing runoff. This will also positively impact Addicks Reservoir.

In the 1990s, the U.S. Army Corps of Engineers conducted a Section 216 Reconnaissance Study of Addicks and Barker Reservoirs. As part of this study, an economic analysis was conducted. No structural damages were computed within the 1% (100-year) reservoir pool. While they did not consider the impact of additional runoff from volume, their conclusions support the notion that the potential for damages is relegated to the very largest events, and is unlikely to substantially impact an economic analysis.

For the reasons described above, the benefits to Addicks Reservoir are considered a non-quantifiable benefit. The measures introduced by both plans will provide significant relief for a very large, but rare, flood event.

3.1.3 Land Intensification

Land intensification relates to the increase in overall land value and potential use as it relates to a project. Both projects will have direct and significant impacts on the development characteristic of the land which is manifest in the land intensification benefit.

Development within the project area is certain. Developers will be left to develop in an ad hoc manner, which will require substantial detention, and therefore land, to maintain the existing overflow attenuation. Management of the overflow would be implemented on a case-by-case basis as each new development is constructed. Results would be focused on the individual developments rather than the region. Individual plans would not necessarily work in concert with each other.

Without Project Mitigation Cost

Two general approaches were utilized to consider land intensification. The initial approach was to estimate the land required for mitigation of the overflow attenuation based upon the total existing "storage volume" of the overflow. Table E3.5 shows the total area for various overflow depths during the 10% (10-year) and 1% (100-year) events. For the 1% (100-year) event, this results in a total area of 20,838 acres and a "storage volume" of 10,938 acre-feet. For these 20,838 acres to develop without impacts, they must either maintain or replace this storage volume. On a prorated basis, this works out to 0.52 acre-feet per acre – in addition to onsite detention requirements. In Harris County, it is not unusual that new developments reserve 10-12% of the project area for detention facilities to primarily serve residential subdivisions.

Table E3.5: Total Area (Acres) of Overflow, by Depth

Overflow Depth (feet)	10% (10-year)	1% (100-year)
0.0 – 0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	8,645	20,838

The available depth of the overflow mitigation is limited by outfall depth. In some cases, development may be able to outfall collected overflow into channel systems, however this would expedite the flow velocity and travel time, requiring substantially more attenuation. Otherwise, the outfall would have to mimic existing hydrology, and would be redistributed into the overflow regime. The deepest overflows are about three feet, so assuming that the available depth is only three feet, this requires 17% of the acreage to be reserved for overflow mitigation, or 3,542 acres (there are many available engineering approaches, including the installation of pumps and other storage and outfall configurations – this analysis assumes a gravity outfall into the existing overflow). Assuming a cost of $30,000 per acre for land, this results in total land costs of about $106 million. In addition, the storage must be excavated. Using an excavation cost of $3 per cubic yard results in an excavation cost of about $117 million. Combining these results in a total mitigation cost of about $223 million.

Development Yield

A second approach was to evaluate the cumulative development yield for the entire study area. This computation assumed a 1,000-acre single-family master-planned community as its prototype. The "with project" condition represents either Plan 3 or Plan 5. In such a case, the land would develop in a manner consistent with other areas that are not influenced by floodplain or an overflow. The development plan assumes 10% of land for detention, 60% for single-family lots, 20% for roads and common areas, 6% for commercial, 2% for school, and 2% for utilities. Income is produced by single-family lots, commercial and school sites. It is assumed that raw land will be purchased for $30,000 per acre, which is the same value used in the project cost estimates. There will be four residential lots per acre of single-family land, and they will sell at $20,000 each. Commercial land and school land will sell at $80,000 per acre. Development construction costs are omitted because they will typically be passed to the municipal utility district.

The "without project" condition is similar, however the detention commitment is increased from 10% to 27% based upon the computation that 17% of land will be required for detention. The resultant acreage for income-producing uses is adjusted accordingly.

Table E3.6
Computation of Land Intensification Based on Use

Item	Without Plan		With Plan (Plan 3 or Plan 5)	
		Income		Income
Acreage	1000 ac		1000 ac	
Raw Land Price	$30,000/ac		$30,000/ac	
Land Cost		$30,000,000		$30,000,000
Single-Family Density	4		4	
Typ Development Breakdown				
% for Detention (Runoff)	10%		10%	
% for Detention (Overflow)	17%		0%	
% SF Lots	39%		50%	
% Roads, Common	20%		25%	
% Commercial	7%		8%	
% School	4%		4%	
% Utility	3%		3%	
Summary				
Area for Lots (ac)	390		500	
No. Lots	1560		2000	
Lot Sale Price (per lot)	$20,000.00		$20,000.00	
Lot Income		$31,200,000		$40,000,000
Area for Commercial (ac)	70		80	
Commercial Sale Price	$80,000.00		$80,000.00	
Commercial Income		$5,600,000		$6,400,000
Area for School (ac)	40		40	
School Sale Price (per ac)	$80,000.00		$80,000.00	
School Site Income		$3,200,000		$3,200,000
TOTAL VALUE (1000 AC)		$10,000,000		$19,600,000
TOTAL VALUE/ac		$10,000		$19,600

This calculation and comparison of the "with project" and "without project" conditions is tabulated in Table E3.6. Based on this table, the "without project" condition produces income of about $10,000 per acre, while the "with project" condition produces income of about $19,600 per acre. The difference between these, $9,600, spread over 18,000 acres, results in a value of approximately $173 million. This is similar to the value of $223 million computed using the first method (the value of land required for additional detention).

3.1.4 Conservation

There is a lot of literature regarding the value of conservation land, including a compilation of studies by the Trust for Public Land. It is difficult to derive a correlation for use in placing a value on conservation land in the project area. There have been a number of land deals to preserve land in the study area, however the financial details of these deals are unavailable. The HCFCD paid about $2,000 per acre in 2003 for property located within the path of the 1%

overflow, downstream of the watershed divide. This equates to $3,100 per acre in 2014 dollars. However, land values have increased considerably since that time. It is estimated that the property would cost $20,000 - 30,000/acre in 2014.

Plans 3 and 5 both present an opportunity to expand the conservation footprint within the area inundated by 1% annual chance overflow. However, it would require that some of the land protected by existing conservation easements participate in the regional overflow management plan and provide the dual use of conservation and drainage. Considering the large opportunity costs foregone by various conservation transactions, a value of $12,500/acre seems reasonable. This is about one-half of the market value, and is the value utilized for conservation land in the cost estimates.

3.1.5 Infrastructure Benefits

The project will provide benefits by alleviating mobility impacts along public roadways when the overflow occurs, which can last for days in some areas that are inundated by the overflow. Not only will a regional plan benefit existing roadways but future roadways as well, which will not be required to address management of the overflow as new infrastructure is constructed to serve future communities. Additionally, the regional management plans that have been identified would provide a much needed drainage artery along Bear Creek.

Roads

Every time there is an overflow event, there are costs associated with the impacts to the public roads. These include damage to the roads and bridges, lost travel time, cleanup, and emergency services. A detailed economic study of all of these is beyond the scope of this study, and these potential benefits have minimal impact on the overall benefit. Instead, this benefit is recognized and not-quantified.

Drainage

As the study area develops, there will need to be a drainage artery along Bear Creek to provide drainage access to the adjacent developments, as well as those developments that drain to laterals to Bear Creek. The project will provide this artery, so the benefit is determined to be the cost of deepening Bear Creek to a 15-foot deep channel, without considerations for additional capacity. The cost of this was determined to be $6 million.

3.1.6 Park Facilities

The project will reduce flooding in Paul Rushing Park, and will provide a means to excavate a portion of lakes in John Paul’s Landing. The John Paul’s Landing impact is neutral as it pertains to benefits. The benefit to Paul Rushing Park is difficult to quantify and relatively small, therefore it is considered a non-quantified benefit.

3.1.7 Greenspace

Studies have indicated that green space and parks increase land values. The relative impacts decrease with distance from the park or open land. There are algorithms to compute this. Both Plan 3 and Plan 5 will increase the conservation and greenspace footprint, and will thus provide a benefit. However, the “without project” condition also has large greenspace reserves, considering the Precinct 3 parks and the existing conservation land. Therefore, the relative impact is small and is considered a non-quantified benefit.

3.1.8 Other Non-Quantified Benefits

The plans deliver additional benefits that are difficult to quantify but that warrant recognition, including:

- Opportunities for mitigation banking
- General recreation
- Quality of life
- Eco-tourism
- Carbon banking

3.2 Comparison of Benefits and Costs

Benefits and costs were assigned throughout the life of the project based upon the implementation plan described in Appendix F. Efforts were made to align costs and benefits based upon this model. For the evaluation of Plan 3 and Plan 5, it is assumed that "with project" development will occur at a rate of 800 acres per year, while "without project" development – using ad hoc solutions – will occur at a rate of 500 acres per year.

The determination of project costs for the benefit-cost comparison was based upon the Plan 3 and Plan 5 cost estimates that assumed in-kind contributions. This is a valid approach because the in-kind contributions do not represent economic costs incurred by any party. For example, the Katy Prairie Conservancy (KPC) allowing the use of conservation land requires no expenditure on their part. The in-kind activities provided by developers are activities they would perform as part of their normal development activity.

The benefits and costs were distributed over 50 years based upon the implementation plans. The costs in each year are based upon 2014 dollars. The expenditures over the life of the project were brought to present value using a discount rate of 2.0%, which is the premium over the annual inflation index (1.9%) cited in OMB Circular A-94 (2014).

3.2.1 BCR - Plan 3

The costs and benefits were distributed over the life of the Plan 3 project, at 2014 present values. This distribution is shown in Table E3.7. The total present-value cost of Plan 3, with in-kind contributions, is $148 million; while the total benefit is $168 million. The largest benefit category is land intensification, which accounts for $120 million, or 71%, of the total quantified benefit. There are other non-quantified benefits as well, such as the value of increasing the conservation footprint in a contiguous manner, that if quantified, would trend the overall benefit upward.

The resultant benefit-to-cost ratio, defined as annualized benefits divided by annualized costs, for Plan 3 is 1.14. This does not consider the non-quantified benefits described above. Full consideration of this would result in a slightly higher benefit-to-cost ratio.

3.2.2 BCR - Plan 5

The costs and benefits were distributed over the life of the Plan 5 project, at 2014 present values. This distribution is shown in Table E3.8. The total present-value cost of Plan 5, with in-kind contributions, is $206 million; while the total benefit is $183 million. The largest benefit category is land intensification, which accounts for $114 million, or 62%, of the total quantified benefit. There are other non-quantified benefits as well.

The resultant benefit-to-cost ratio, defined as annualized benefits divided by annualized costs, for Plan 5 is 0.89. This does not consider the non-quantified benefits described above. Full consideration of this would result in a slightly higher benefit-to-cost ratio.

Table E3.7
Plan 3 Benefit-Cost Calculation

	Start	End	PV Cost	Year (PV Costs and PV Benefits, in thousands)											
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Costs															
Comp 1 - Professional	1	3	$3,862	$1,950	$1,912	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	2	3	$15,515	$0	$15,515	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	3	5	$16,873	$0	$0	$8,520	$8,353	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	7	14	$1,442	$0	$0	$0	$0	$0	$0	$218	$214	$210	$206	$202	$198
Comp 2 - Real Estate	5	8	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	8	19	$6,185	$0	$0	$0	$0	$0	$0	$0	$620	$607	$596	$584	$572
Comp 3 - Professional	3	10	$1,558	$0	$0	$236	$231	$227	$222	$218	$214	$210	$0	$0	$0
Comp 3 - Real Estate	4	7	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	7	13	$6,869	$0	$0	$0	$0	$0	$0	$3,469	$3,401	$0	$0	$0	$0
Comp 4 - Professional	2	13	$1,842	$0	$184	$181	$177	$174	$170	$167	$164	$161	$157	$154	$151
Comp 4 - Real Estate	13	15	$25,524	$0	$2,557	$2,507	$2,458	$2,409	$2,362	$2,316	$2,270	$2,226	$2,182	$2,139	$2,097
Comp 4 - Construction	14	15	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	8	14	$8,407	$0	$0	$0	$0	$0	$0	$0	$1,471	$1,443	$1,414	$1,387	$1,359
Comp 5 - Real Estate	14	18	$25,670	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	18	22	$31,965	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance			$2,185	$0	$0	$10	$9	$9	$9	$13	$17	$21	$25	$29	$48
Total Costs			**$147,898**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Benefits															
Structural Damages Avoided			$6,361	$0	$0	$0	$0	$0	$0	$135	$133	$130	$128	$125	$123
Vehicle Damage Avoided			$1,731	$0	$0	$0	$0	$0	$0	$37	$36	$35	$35	$34	$33
Land Intensification			$120,287	$0	$0	$3,845	$3,769	$3,695	$3,623	$3,552	$3,482	$3,414	$3,347	$3,281	$3,217
Conservation			$33,624	$0	$19,363	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage			$6,000	$0	$0	$0	$0	$0	$0	$0	$545	$545	$545	$545	$545
Total Benefits			**$168,003**	**$0**	**$0**	**$7,536**	**$7,388**	**$7,243**	**$7,101**	**$6,962**	**$6,825**	**$6,691**	**$6,560**	**$6,432**	**$6,305**

Table E3.7 (Continued)
Plan 3 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)													
	13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Costs														
Comp 1 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$194	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$561	$550	$539	$529	$518	$508	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$1,333	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$6,609	$6,480	$6,353	$6,228	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$0	$0	$8,230	$8,069	$7,911	$7,756	$0	$0	$0	$0	$0
Maintenance	$51	$50	$49	$48	$47	$71	$70	$69	$67	$66	$65	$63	$62	$61
Total Costs	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Benefits														
Structural Damages Avoided	$120	$118	$116	$113	$111	$109	$107	$105	$205	$201	$197	$193	$190	$186
Vehicle Damage Avoided	$33	$32	$31	$31	$30	$30	$29	$28	$56	$55	$54	$53	$52	$51
Land Intensification	$3,154	$3,092	$3,032	$2,972	$2,914	$2,857	$2,801	$2,746	$2,692	$2,639	$2,587	$2,537	$2,487	$2,438
Conservation	$0	$3,672	$3,600	$3,529	$3,460	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage	$545	$545	$545	$545	$545	$545	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$6,182**	**$6,061**	**$5,942**	**$5,825**	**$5,711**	**$5,599**	**$5,489**	**$5,382**	**$5,276**	**$5,173**	**$5,071**	**$4,972**	**$4,874**	**$4,779**

Table E3.7 (Continued)
Plan 3 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)													
	27	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Costs														
Comp 1 - Professional	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Costs	**$60**	**$59**	**$57**	**$56**	**$55**	**$54**	**$53**	**$52**	**$51**	**$50**	**$49**	**$48**	**$47**	**$46**
Benefits														
Structural Damages Avoided	$182	$179	$175	$172	$168	$165	$162	$159	$156	$153	$150	$147	$144	$141
Vehicle Damage Avoided	$50	$49	$48	$47	$46	$45	$44	$43	$42	$42	$41	$40	$39	$38
Land Intensification	$2,390	$2,343	$2,297	$2,252	$2,208	$2,165	$2,123	$2,081	$2,040	$2,000	$1,961	$1,922	$1,885	$1,848
Conservation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$4,685**	**$4,593**	**$4,503**	**$4,415**	**$4,328**	**$4,243**	**$4,160**	**$4,079**	**$3,999**	**$3,920**	**$3,843**	**$3,768**	**$3,694**	**$3,622**

Table E3.7 (Continued)
Plan 3 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)									
	41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Costs										
Comp 1 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 41 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	$45	$44	$44	$43	$42	$41	$40	$39	$39	$38
Total Costs	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Benefits										
Structural Damages Avoided	$138	$135	$133	$130	$128	$125	$123	$120	$118	$116
Vehicle Damage Avoided	$38	$37	$36	$35	$35	$34	$33	$33	$32	$31
Land Intensification	$1,812	$1,776	$1,741	$1,707	$1,674	$1,641	$1,609	$1,577	$1,546	$1,516
Conservation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$3,551**	**$3,481**	**$3,413**	**$3,346**	**$3,280**	**$3,216**	**$3,153**	**$3,091**	**$3,030**	**$2,971**

Table E3.8
Plan 5 Benefit-Cost Calculation

	Start	End	PV Cost	Year (PV Costs and PV Benefits, in thousands)											
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Costs															
Comp 1 - Professional	1	3	$3,317	$1,675	$1,642	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	2	3	$17,059	$0	$17,059	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	3	5	$14,494	$0	$0	$7,319	$7,175	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	7	14	$1,816	$0	$0	$0	$0	$0	$0	$275	$270	$264	$259	$254	$249
Comp 2 - Real Estate	5	8	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	8	19	$7,789	$0	$0	$0	$0	$0	$0	$0	$780	$765	$750	$735	$721
Comp 3 - Professional	3	10	$1,526	$0	$0	$0	$0	$0	$519	$509	$499	$0	$0	$0	$0
Comp 3 - Real Estate	4	7	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	7	13	$6,225	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,090	$1,068	$1,047
Comp 4 - Professional	2	13	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	13	15	$92,786	$0	$8,016	$7,859	$7,705	$7,554	$7,405	$7,260	$7,118	$6,978	$6,841	$6,707	$6,576
Comp 5 - Professional	8	14	$11,405	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,996	$1,957	$1,919
Comp 5 - Real Estate	14	18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	18	22	$47,399	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance			$1,895	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Costs			**$205,710**	**$1,675**	**$26,717**	**$15,177**	**$14,880**	**$7,554**	**$7,924**	**$8,044**	**$8,667**	**$8,008**	**$10,936**	**$10,722**	**$10,512**
Benefits															
Structural Damages Avoided			$6,573	$0	$0	$0	$0	$0	$0	$135	$133	$130	$128	$125	$123
Vehicle Damage Avoided			$1,789	$0	$0	$0	$0	$0	$0	$37	$36	$35	$35	$34	$33
Land Intensification			$114,428	$0	$0	$3,691	$3,619	$3,548	$3,478	$3,410	$3,343	$3,277	$3,213	$3,150	$3,088
Conservation			$55,607	$0	$19,363	$3,360	$3,294	$3,230	$3,166	$3,104	$3,043	$2,984	$2,925	$2,868	$2,812
Drainage			$4,740	$0	$0	$0	$0	$0	$0	$0	$475	$466	$456	$447	$439
Total Benefits			**$183,136**	**$0**	**$0**	**$7,536**	**$7,388**	**$7,243**	**$7,101**	**$6,962**	**$6,825**	**$6,691**	**$6,560**	**$6,432**	**$6,305**

Table E3.8 (Continued)
Plan 5 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)													
	13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Costs														
Comp 1 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$244	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$707	$693	$679	$666	$653	$640	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$1,027	$1,007	$987	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	$6,447	$6,320	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$1,881	$1,844	$1,808	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$16,113	$15,797	$15,488	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	$0	$0	$0	$74	$73	$71	$70	$69	$67	$66	$65	$63	$62	$61
Total Costs	**$10,305**	**$9,864**	**$3,474**	**$16,854**	**$16,523**	**$16,199**	**$70**	**$69**	**$67**	**$66**	**$65**	**$63**	**$62**	**$61**
Benefits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Structural Damages Avoided	$33	$32	$31	$31	$30	$30	$58	$57	$56	$55	$54	$53	$52	$51
Vehicle Damage Avoided	$3,028	$2,968	$2,910	$2,853	$2,797	$2,742	$2,689	$2,636	$2,584	$2,534	$2,484	$2,435	$2,387	$2,341
Land Intensification	$2,756	$2,702	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Conservation														
Drainage	$430	$422	$413	$405	$397	$390	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$6,182**	**$6,061**	**$5,942**	**$5,825**	**$5,711**	**$5,599**	**$5,489**	**$5,382**	**$5,276**	**$5,173**	**$5,071**	**$4,972**	**$4,874**	**$4,779**

Table E3.8 (Continued)
Plan 5 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)													
	27	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Costs														
Comp 1 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	$60	$59	$57	$56	$55	$54	$53	$52	$51	$50	$49	$48	$47	$46
Total Costs	**$60**	**$59**	**$57**	**$56**	**$55**	**$54**	**$53**	**$52**	**$51**	**$50**	**$49**	**$48**	**$47**	**$46**
Benefits														
Structural Damages Avoided	$182	$179	$175	$172	$168	$165	$162	$159	$156	$153	$150	$147	$144	$141
Vehicle Damage Avoided	$50	$49	$48	$47	$46	$45	$44	$43	$42	$42	$41	$40	$39	$38
Land Intensification	$2,295	$2,250	$2,206	$2,162	$2,120	$2,078	$2,038	$1,998	$1,959	$1,920	$1,882	$1,846	$1,809	$1,774
Conservation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$4,685**	**$4,593**	**$4,503**	**$4,415**	**$4,328**	**$4,243**	**$4,160**	**$4,079**	**$3,999**	**$3,920**	**$3,843**	**$3,768**	**$3,694**	**$3,622**

Table E3.8 (Continued)
Plan 5 Benefit-Cost Calculation

	Year (PV Costs and PV Benefits, in thousands)									
	41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
Costs										
Comp 1 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 1 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 2 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 3 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 4 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Professional	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Real Estate	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Comp 5 - Construction	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Maintenance	$45	$44	$44	$43	$42	$41	$40	$39	$39	$38
Total Costs	**$45**	**$44**	**$44**	**$43**	**$42**	**$41**	**$40**	**$39**	**$39**	**$38**
Benefits										
Structural Damages Avoided	$138	$135	$133	$130	$128	$125	$123	$120	$118	$116
Vehicle Damage Avoided	$38	$37	$36	$35	$35	$34	$33	$33	$32	$31
Land Intensification	$1,739	$1,705	$1,672	$1,639	$1,607	$1,575	$1,544	$1,514	$1,484	$407
Conservation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drainage	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Benefits	**$3,551**	**$3,481**	**$3,413**	**$3,346**	**$3,280**	**$3,216**	**$3,153**	**$3,091**	**$3,030**	**$832**

Appendix F

Financial Pro Forma

August 18, 2015

Table of Contents

1.0 Introduction

This appendix describes and summarizes the development of implementation strategies and financial pro forma of two management plans. As noted in the report, two plans were identified for further study: Management Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B" and Management Plan 5 – Katy Hockey N – Cypress Reservoir. Appendix E describes the development of cost estimates for each of these two plans.

The implementation and financing of any management strategy is a critical component of the plan. This appendix describes implementation, funding strategies, and presents a cost model to support evaluation of long-term cash flows associated with the plans.

2.0 Implementation Sequence

The study area lies within an area subject to immediate development pressure. However, both of the management plans include large storage components accomplished by constructing berms. The planning, engineering, permitting, and construction of these flood control reservoirs will take years. The implementation strategy considers this, and provides a mechanism to phase in features over time that will incrementally address the overflow and facilitate the near-term demand for land development.

2.1 Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B"

The Mound Creek Reservoir with Overflow Conveyance "B" (Management Plan 3) is depicted in Exhibit F2.1. A reservoir would be formed by an earthen dam that extends across Mound Creek just upstream of the confluence with Live Oak Creek. The primary outfall from the Mound Creek Reservoir will be via Mound Creek, which will remain open through the channel section. The dam will extend near to the edge of the channel banks. During normal flow, Mound Creek will flow as it does today. However, when larger rainfalls result in flows exceeded the banks and occupying the floodplain, the dam will impede this overbank flow and result in the inundation and subsequent attenuation within the reservoir. The outlet to Cypress Creek will be restricted to existing flow rates for all events via a constrained channel section. During the 1% (100-year), the release to Cypress Creek will be restricted to 7,500 cfs. A secondary outfall at Live Oak Creek will be constructed to ensure that flow is maintained along Live Oak Creek.

Within the Addicks Reservoir watershed, there will be collection channels near Katy-Hockley Road and Longenbaugh Road that intercept the residual overflow. The area between these interception channels and Cypress Creek is currently a mix of conservation land protected by easements as well as unrestricted privately owned land. This management plan calls for the access to or acquisition of these lands (either in fee or via flooding and/or drainage easements) in order to preserve a dedicated region to convey and capture the overflow. There is significant potential to increase the overall conservation footprint through the dual use of the area for overflow inundation when needed, as well as additional conservation if the current land use is not maintained. Berms will be constructed along the interception channels and range in height from 3-5 feet, and will ensure that the overflow does not extend past the interception channels should they become full. During larger events, such as the 1% (100-year) event, the inundation channels will become full and the berms will cause a slight rise in the water surface elevation in portions of the land inundated by the overflow upstream of the interceptor channels. Therefore the area acquired for the property will also provide attenuation of the overflow. Existing conservation land will not be affected by this rise in water surface elevation. In total, the conservation/collection area will occupy 2,200 acres – 1,580 acres of private land, 440 acres of public land, and 180 acres of existing conservation land.

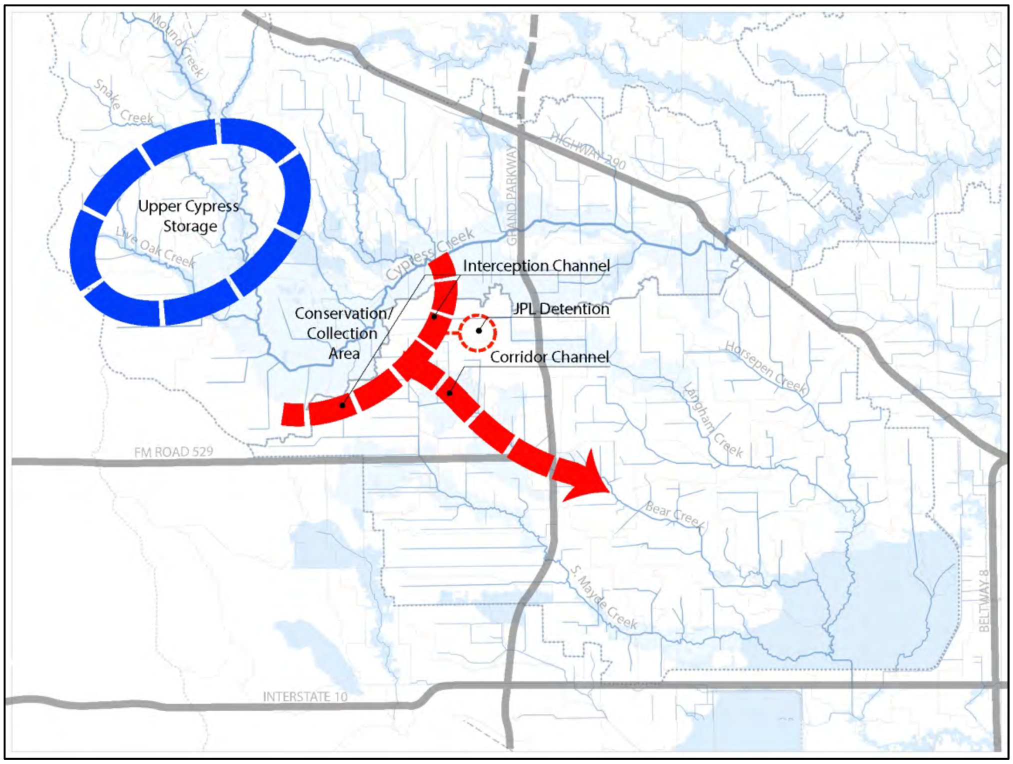

Exhibit F2.1
Plan 3 – Mound Creek Reservoir plus Overflow Conveyance "B"

Bear Creek will be enlarged for a distance of about 24,000 feet, from where the interception/collection channels join Bear Creek downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel will utilize natural channel design principles within a 500-foot corridor. The channel will be sufficiently deep to accept drainage from lateral channels.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL), a regional park established by Harris County Precinct 4 in the vicinity of the proposed overflow management plans. A large amenity lake will be constructed as one of the park features. A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL.

The plan also includes the adoption of development criteria in the study area to ensure that future land development activity does not increase flood risk associated with Addicks Reservoir. Mitigation of potential increases in runoff volume may be in the form of extended detention, retention, low-impact development, prairie restoration, or other measures. It is recommended that developers be given the opportunity to present a method for the consideration of the Flood Control District.

The total cost of Plan 3 is estimated to be $271 million. It will manage the overflow impacts for about 18,500 acres of land in the 1% annual chance overflow inundation area, and will increase the conservation footprint by approximately 3,100 acres. An implementation plan has been developed to facilitate development activity in portions of the study area in an expedient and incremental manner. There are five elements to this implementation, as described in the following sections.

2.1.1 Plan 3, Element 1 – Initial interception

An interim collection channel would be constructed in a north-south orientation, along the Katy-Hockley Cutoff Road. Spoil from this will be used to construct a small berm on the east bank of the channel. The channel and berm will intercept overflow and convey it to the upper end of Bear Creek, which will be deepened for a distance of about 7,000 feet, at a very minimal slope, until it daylights to the bottom of the existing stream.

This initial element will not address overflow west of Bear Creek, but it will remove inundation from areas immediately east of the channel and berm. However, Bear Creek does not have the capacity to convey the flows, and the overflow will maintain current overflow boundaries and patterns downstream of the interim collection channels and north of Bear Creek until channel modifications are constructed along Bear Creek that provide additional channel capacity to accommodate the overflow.

Permitting and environmental investigations necessary to construct the full Management Plan 3 are anticipated to take several years to complete. Therefore, these tasks would begin early in the implementation process and are also initiated as part of Element 1. The permitting would continue throughout the duration of implementation, and are considered within each of the elements as part of Professional Services.

This interim measure would cost about $37 million. This assumes that temporary flooding easements will be obtained on almost 1,600 acres of private land in the collection area, which is property that becomes inundated by the overflow that occurs under existing conditions.

2.1.2 Plan 3, Element 2 – Bear Creek Conveyance Improvements

Plan 3, Element 2 is the reservation of the 500-foot Bear Creek corridor and the construction of the modified channel. Coupled with Element 1, this element will protect 5,800 acres from inundation during the 1 % (100-year) event.

These features will be implemented as development progresses along Bear Creek. Individual development within the 5,500 acres may occur ahead of full implementation; however developments along the corridor will be required to reserve the right of way and construct the channel. This will provide outfall depth to serve drainage infrastructure and fill material for future development, as well as a potential location for limited detention. Depending on the status of the overall project, developments may have to install interim measures to protect against the overflow until the full project is constructed. This may be in the form of fill, levees or channels that protect the development.

Considering in-kind contributions, Element 2 costs approximately $10 million and (coupled with Element 1) will protect approximately 5,800 acres of land from the overflow during a 1% event.

2.1.3 Plan 3, Element 3 –Detention at John Paul's Landing

John Paul's Landing is a Harris County Precinct 3 park located along the east side of Katy-Hockley Cutoff Road. Plans for the park include about 400 surface acres of lakes. These lakes would have a permanent water surface about eight feet below natural ground, and therefore have significant detention capacity. The Upper Langham Creek Master Drainage Plan intends to utilize a portion of the available detention storage, and the remaining storage capacity is to be utilized as part of the Plan 3 concept to collect and store the relatively small volume of overflow east of Katy-Hockley Cutoff Road. Element 3 involves the excavation of this storage, which is about 500 acre-feet.

A channel would be constructed north of the park near the watershed divide, and this channel will collect overflow east of Katy-Hockley Cutoff and convey it to the JPL detention basins.

The implementation of Element 3 will require coordination with park construction and activity associated with the Upper Langham Creek Master Drainage Plan. With in-kind contributions, this element will cost approximately $9 million, and will protect an additional area of approximately 3,500 acres from the 1% overflow.

2.1.4 Plan 3, Element 4 – Acquire Conservation/Collection Area

The implementation of Element 1 required obtaining temporary flood easements across about 1,600 acres of land utilized in the collection of the overflow and the construction of the east-west collection channel. Element 4 involves the conversion of these temporary easements into permanent easements or fee ownership. It also includes the construction of an east-west collection channel; however this channel cannot be constructed until Element 5, the Mound Creek Reservoir, is constructed.

Element 4 will cost approximately $90 million. This element does not recover overflow land without the Mound Creek Reservoir (Element 5); therefore land recovery is discussed with that element.

2.1.5 Plan 3, Element 5 – Mound Creek Reservoir

This element involves the acquisition of land for the Mound Creek Reservoir as well the construction of a berm that would occasionally impound water for a very short duration. This storage area will decrease the frequency and magnitude of the overflow. Element 5 will cost approximately $90 million. Together, Elements 4 and 5 will recover about 9,500 acres from the overflow.

2.2 Plan 5 – Katy Hockley N – Cypress Reservoir

The Katy Hockley N – Cypress Reservoir plan is depicted in Exhibit F2.2. A reservoir would be formed by an earthen dam that extends across both Cypress Creek and the Addicks Reservoir/Cypress Creek watershed divide. There will be outfalls to both Cypress Creek and Bear Creek. The outlet to Cypress Creek will be restricted to existing flow rates for all events via a box structure. The outlet to Bear Creek will further restrict flows to about 2,000 cfs. This is less than the existing flow rate but is necessary to ensure that a greater volume of stormwater is not transferred from the Cypress Creek watershed to the Addicks Reservoir watershed than occurs under existing conditions. In addition, an internal channel will be constructed to allow flow from the Addicks Reservoir watershed back into the Cypress Creek watershed. This channel will have a structure with a backflow prevention device at the watershed divide to prevent flow from traveling in the channel from the Cypress Creek watershed to the Addicks Reservoir watershed.

Bear Creek will be enlarged for a distance of about 24,000 feet, from where the interception/collection channels join Bear Creek downstream to the existing enlarged channel (approximately 7,500 feet west of Fry Road). This enlarged channel will utilize natural channel design principles within a 500-foot corridor. The channel will be sufficiently deep to accept drainage from lateral channels.

Approximately 300 acre-feet of detention would be provided within John Paul's Landing (JPL). A channel would be constructed to collect residual overflow downstream of Katy-Hockley Road and to convey this overflow into JPL. In addition, a channel would be constructed to convey flow from Bear Creek to JPL in order to provide additional flow reduction along Bear Creek.

The plan also include the adoption of development criteria in the study area to ensure that future land development activity does not increase flood risk associated with Addicks Reservoir. Mitigation of potential increases in runoff volume may be in the form of extended detention, retention, low impact development, prairie restoration, or other measures. It is recommended that developers be given the opportunity to present a method for the consideration of the Flood Control District.

The total cost of Plan 3 is estimated to be about $370 million. It will remove the overflow from about 17,000 acres of land, and will increase the conservation footprint by 5,000 acres. An implementation plan has been developed to facilitate development activity in portions of the study area in an expedient and incremental manner. There are five elements to this implementation, as described in the following sections.

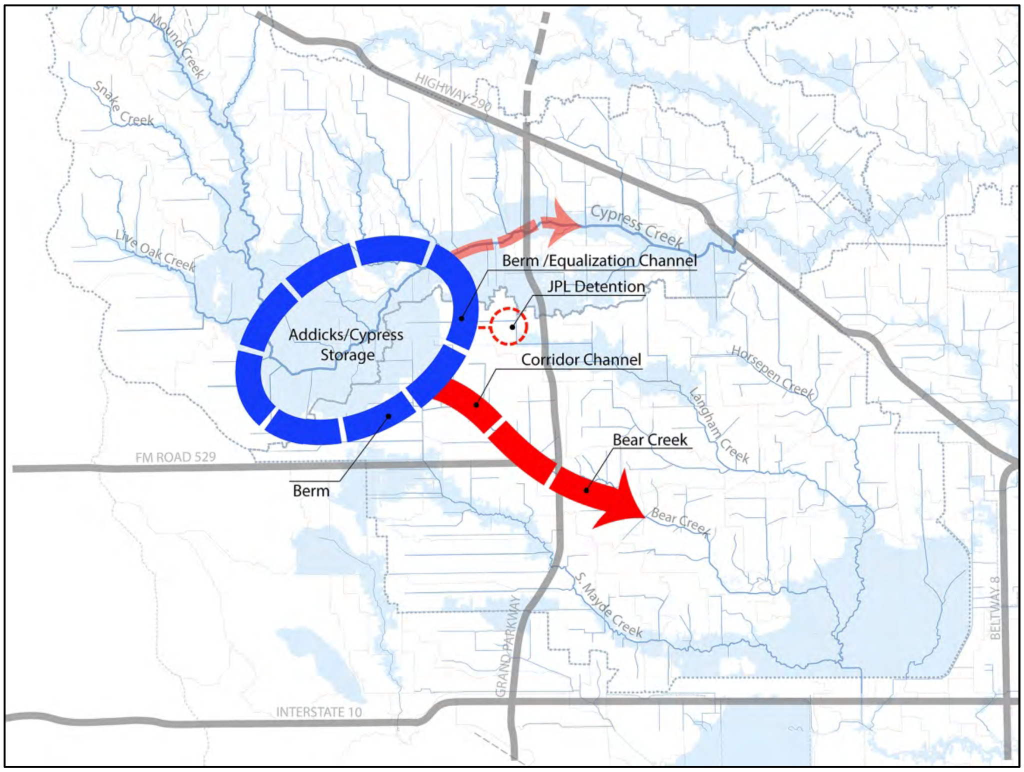

Exhibit F2.2
Plan 5 – Katy Hockley N – Cypress Reservoir

2.2.1 Plan 5, Element 1 – Initial interception

An interim collection channel would be constructed on an east-west orientation that will intercept overflow west of Katy-Hockley Cutoff Road. Spoil from this will be used to construct a small berm on the right bank of the channel. The channel and berm will intercept overflow and convey it to the upper end of Bear Creek, which will be deepened for a distance of about 7,000 feet, at very minimal slope, until it daylights to the bottom of the existing stream.

This initial element will not address overflow east and north of Bear Creek, but it will remove inundation from areas immediately south of the interim collection channel and adjacent berm. Bear Creek does not have the capacity to convey the flows, and the overflow will eventually exceed the channel and maintain current overflow boundaries and patterns downstream of the interim collection channels until channel modifications are constructed along Bear Creek that provide additional channel capacity to accommodate the overflow.

Permitting and environmental investigations necessary to construct the full Management Plan 5 are anticipated to take several years to complete. Therefore, these tasks would begin early in the implementation process and are also included as part of Element 1.

This interim measure would cost about $36 million. This assumes that temporary flooding easements will be obtained on almost 1,600 acres of private land in the collection area, which is property that becomes inundated by the overflow that occurs under existing conditions.

2.2.2 Plan 5, Element 2 – Bear Creek Conveyance Improvements

Plan 5, Element 2 is the reservation of the 500-foot Bear Creek corridor and the construction of the modified channel. Coupled with Element 1, this element will protect 10,100 acres from inundation during the 1 % (100-year) event. These features will be implemented as development progresses along Bear Creek. Individual development within the 9,000 acres may occur ahead of full implementation; however those developments along the corridor will be required to reserve the right of way and construct the channel. This will provide outfall depth to serve drainage infrastructure and fill material for future development, as well as a potential location for limited detention. Depending on the status of the overall project, developments may have to install interim measures to protect against the overflow until the full project is constructed. This may be in the form of fill, levees or channels that protect the development.

As the channel enlargements are completed, the peak overflow discharge in the channel may eventually exceed current peak overflow discharges in Bear Creek as it passes through developed areas. While the resultant 1 % (100-year) overflow flow rate is less than the 1 % (100-year) flow rate from a local rainfall event, this would result in a temporary slight increase in flood risk through this reach. To offset this, Element 2 includes about one mile of channel enlargement, generally between Fry Road and West Little York Road. The enlargements would extend upstream of the sheet pile transition structure located downstream of Fry Road, and would extend upstream to just past West Little York Road. Minor modifications to the bridge structures may be necessary to accommodate the enlarged and deepened channel. This channel widening would be accommodated within the existing channel right-of-way.

Considering in-kind contributions, Element 2 costs approximately $12 million and (coupled with Element 1) will protect approximately 9,000 acres of land from the overflow during a 1 % event.

2.2.3 Plan 5, Element 3 – JPL Detention

John Paul’s Landing is a Harris County Precinct 3 park located along, and east of, Katy-Hockley Cutoff Road. Plans for the park include about 400 surface acres of lakes. These lakes would have a permanent water surface about eight feet below natural ground, and therefore have significant detention capacity. The Upper Langham Creek Master Drainage Plan intends to utilize a portion of the available detention storage, and the remaining storage capacity is to be utilized as part of the Plan 3 concept to collect and store the relatively small volume of overflow east of Katy-Hockley Cutoff Road. Element 3 involves the excavation of this storage, which is about 300 acre-feet.

A channel would be constructed north of the park near the watershed divide, and this channel will collect overflow east of Katy-Hockley Cutoff and convey it to the JPL detention basins.

The implementation of Element 3 will require coordination with park construction and activity associated with the Upper Langham Creek Master Drainage Plan. With in-kind contributions, this element will cost approximately $9 million, and will protect an additional area of about 3,500 acres from the 1 % overflow.

2.2.4 Plan 5, Element 4 – Acquire Land for Construct Katy Hockley N – Cypress Reservoir

The implementation of Element 1 required obtaining flood easements across about 1,600 acres of land utilized in the collection of the overflow and the construction of the east-west collection channel. Element 4 requires the conversion of these temporary easements to permanent easements and/or fee ownership, as well as the securing of additional land for the reservoir.

With in-kind contributions, Element 4 will cost approximately $106 million. There is no land recovery singularly associated with Element 4.

2.2.5 Plan 5, Element 5 – Construct Katy Hockley N – Cypress Reservoir

This element involves the construction of the berms necessary to occasionally impound water in the Katy Hockley N – Cypress Reservoir, as well as the necessary outfall and equalization structures.

Element 5 will cost approximately $79 million. Together, Elements 4 and 5 will protect an additional area of almost 5,500 acres from the 1 % overflow.

Exhibit 8.8 illustrates Elements 4 and 5 for Plan 5.

3.0 Funding and Finance Considerations

The development of a funding and financing plan is critical to the potential success of a project. This consideration will ultimately define the ability to implement the plan. Elements of this would be developed further in the overall process – this document presents only a general framework and presents various options and strategies.

Ultimately, the goal of a funding program is to (1) develop a mechanism whereby the beneficiaries of the project pay an appropriate share of the project, and (2) develop a means to finance the initial project "seed" activity.

3.1 Funding Mechanism

The State of Texas makes available a number of potential infrastructure funding and financing vehicles. The primarily economic benefit of the plan is to increase the efficiency of land development activity. As such, a considerable share of the project cost will be borne by land interests. There exist a number of finance plans that utilize the resultant development as its basis. Many of these, such as special purpose districts, issue debt and retire that debt through ad valorem taxes within the defined district. Impact fees may be collected to offset the cost of infrastructure provided for land development. Local government corporations can be established to oversee various layers of revenue sources, which may include ad valorem taxes in utility districts, one penny of sales tax (if not already claimed), and impact fees. In any of these, one party must act as the project sponsor and banker – in that they oversee the construction and operation of the project, secure the initial investment, and recover the investment through various revenue streams.

This study does not include an in-depth evaluation of these various approaches. Instead, the study considers a cost per acre for the land development share of the cost. While this is presented in a manner consistent with an impact fee, and can be thought of that way, the primary purpose is to establish a project cost per acre of developed land. This can then be utilized in the consideration of various funding and finance opportunities.

3.2 In-Kind Contributions

In addition to the contribution by the land interests, there are opportunities for in-kind contributions. The development of land presents an opportunity for acquisition of the Bear Creek corridor, whereby developers will dedicate the 500-foot right of way as part of their development platting. They would typically desire to deepen Bear Creek, and to excavate it as a source of material, therefore the channel construction would be provided by developers as they work along the corridor. In addition, the corridor provides an opportunity for on-line detention and/or excavated detention.

Both Plan 3 and Plan 5 substantially increase the conservation footprint. One of the primary missions of conservation efforts in the study area is to secure conservation land in the Katy Prairie. The reservoirs both include land adjacent to existing conservation land, and they propose occasional and short duration inundation of existing conservation land. This inundation would not be of significantly different character than current inundation, and would not affect the ultimate ecology or health of the land. In particular, the inundation associated with Plan 5 is very infrequent, as the existing conservation land is almost entirely outside of the 1% (100-year) pool, and the land that is within this pool would be subject to very shallow inundation. If the project were allowed to occasionally inundate this land, as described, in exchange for the addition to the overall conservation footprint, this would substantially reduce the land cost associated with the plan.

Harris County Precinct 3 would benefit by gaining construction of lakes in John Paul’s Landing as well as a potential source of water from Bear Creek and the interceptor channel to the north. Their contribution to the plan is the allowance of the use of John Paul’s Landing for detention.

3.3 Harris County Flood Control District (HCFCD)

HCFCD, as the recipient of the TWDB grant, supported the project and contributed funding to the overall study. The role of HCFCD in the ultimate implementation is not certain. There is a need for an overall project sponsor to oversee the implementation of any management plan. This role may be fulfilled by HCFCD or perhaps by another party, such as a special purpose district.

The project does require initial seed funding of about $50 million. This is necessary to implement the initial plan element. Once this initial element is constructed, developers may begin to recover land for development by implementing the second plan element, therefore allowing for the land interests contribution as described in Section 3.1. HCFCD benefits by providing a higher standard of flood control and management in the watershed, by reducing flood damages to existing property, and by potentially reducing flood flows in Cypress Creek and Bear Creek.

The TWDB provides funding to communities through low interest loans to support various water resources development activities. The TWDB may be a viable source to assist HCFCD in this funding.

3.4 Other Interests

The U.S. Army Corps of Engineers benefits from the development policy that manages runoff volume to Addicks Reservoir, and also benefits from the expanded conservation footprint that protects land from future development. Funding support from the U.S. Army Corps of Engineers is possible; however it would likely require a congressional appropriation.

Waller County benefits by the removal of some overflow in Cane Island Branch as well as the certainty that comes with an established management plan in the Cypress Creek watershed. Plan 3 would provide opportunity for county park facilities in the portion of the reservoir land that is not already dedicated to conservation. Waller County may contribute to the plan by adopting the development criteria recommended as part of both plans.

4.0 Financial Model

A cash flow model was developed to assist in the evaluation of the two plans. This model establishes a funding basis, computes a per-acre cost basis, tracks an implementation schedule, and develops different pro charts that assist in evaluating the project. The model presented in this section assumes the in-kind contribution described in Section 3.2, and assumes that 70% of the remaining project cost would be borne by the land interests and 30% would be borne by the project sponsor. However, these assumptions can easily be modified in the model input.

The model, as developed, provides a useful planning tool and could also be utilized throughout implementation. The model is in the form of an MS Excel spreadsheet.

4.1 Model Inputs

The inputs for the financial model are described in this section. They include Basic Input, Schedule Input, and Cost input.

4.1.1 Basic Input

The Basic Input includes general items related to the model. Table F4.1 lists and describes the Basic Input parameters. Table F4.2 lists the inputs utilized for the Plan 3 and Plan 5 models described in this Appendix. As noted in Table F4.2, the models used in this analysis assume in-kind contribution (Line 20) and sponsor contribution of 30% of the remaining project cost (Line 30). The analysis assumes that 85% of the service area will develop and contribute to the project (Line 60) through an impact fee. However, the revenue source can be changed to match alternative funding sources if a different revenue stream other than impact fees associated with new development is used in the future.

The model utilizes current-year dollar values, therefore Lines 190, 200, and 210 are zero. The model is not being used to evaluate bond financing (Line 250 equal to zero) or financing through existing ad valorem tax base (Line 310). However, these two items were included in the financial model in order to provide flexibility for future use, should the need arise. As such, the model considers the contribution from impact fees associated with development for this study.

Table F4.1
Basic Model Inputs

Line	Parameter	Entry	Comment/Description
20	In-Kind Contribution from Partner/Sponsor	Y/N	Y if project cost is reduced by in-kind contributions
30	Sponsor Contribution	%	% of project funded by sponsor (remainder by land interests)
50	Service Area	Ac	Reduction in 1% overflow inundation area
60	Service Area Developed	%	Percentage of service area expected to contribute to project
80	Development Rate	Ac/Yr	Rate of development in the service area
90	Population Density	People/Ac	
100	Impact Fee Lead Time	Year No.	Years start of impact fee collection will precede service provided
110	Lead Time for Phase [1]	Years	Not Used
120	Last CIP Update [2]	Year No.	Not Used
190	Annual Cost Escalation	%	Use 0% for base year dollars
200	Annual Land Contribution Value Escalation	%	Use 0% for base year dollars
210	Annual Tax Base Escalation	%	Use 0% for base year dollars
230	Bond Premium[3]	%	Not used - Discount rate of bonds less annual inflation
240	Bond Retirement Period[3]	Years	Not used - Years to retire bonds issued for project
250	Amount of Project Financed[3]	%	Not Used - Percentage of project cost that is financed through bonds
260	Average single-family home value	$	
270	Development density	Lots/ac	Average units per acre, all residential development types
280	HCFCD tax rate	$/$100	
310	% financed by existing tax revenue	%	
330	Harris County Tax Rate	$/$100	
340	Finance Period	Years	

Notes: 1. Reserved for evaluation of Sec 395 Impact Fee with project phasing
2. Reserved for evaluation of Sec 395 Impact Fee funding
3. Used for analysis of funding through issuance of bond debt

4.1.2 Schedule Input

The Schedule Input is used to inset the start and duration of the individual plan elements. Some start dates are contingent on other activities, and the user does not have the option of adjusting those. However, most start dates are input-driven. Table F4.2 shows the Schedule Input for Plan 3, while Table F4.3 shows the Schedule Input for Plan 5. The user may insert dates and duration for professional services, real estate, and construction activity. The fields highlighted in yellow are those that may be adjusted.

4.1.3 Cost Input

The model includes cost estimate data from the cost estimates described in Appendix E. The cost is broken down by phase, with a separate tabulation for in-kind considerations. There is also reference table with unit prices. The user may adjust the cost items, in-kind distribution, and unit prices for the various features.

Table F4.2
Basic Model Inputs – Plan 3 and Plan 5

Line	Parameter	Plan 3	Plan 5
20	In-Kind	Y	Y
30	Sponsor Contribution	30%	30%
50	Service Area	18,190 ac	18,190 ac
60	Service Area Developed	85%	85%
80	Development Rate	800 ac/yr	800 ac/yr
90	Population Density	9 persons/ac	9 persons/ac
100	Start Land Contribution	2 yrs	2 yrs
110	Lead Time for Phase	Not used	Not used
120	Last CIP Update	Not used	Not used
190	Annual Cost Escalation	0%	0%
200	Annual Land Contribution Escalation	0%	0%
210	Annual Tax Base Escalation	0%	0%
230	Bond Premium	2%	2%
240	Bond Retirement Period	20 yrs	20 yrs
250	Amount of Project Financed	0%	0%
260	Average single-family home value	$250,000	$250,000
270	Development density	2 lots/ac	2 lots/ac
280	HCFCD tax rate	$0.03/$100	$0.03/$100
310	% financed by existing tax revenue	0%	0%
330	Harris County Tax Rate	$0.03/$100	$0.03/$100
340	Finance Period	30 years	30 years

Table F4.3
Plan 3 – Schedule Input

Component	Description	Start (BOY)	Duration	End (BOY)
1	Collection channels without overflow containment, upstream portion of 1000' bermed conveyance - to daylight (about 7,000 feet)	1	4	5
	Professional	1	2	3
	Real Estate	2	1	3
	Construction	3	2	5
2	Bermed overflow conveyance area (initially piecemeal, as development occurs)	5	14	19
	Professional	7	7	14
	Real Estate	5	3	8
	Construction	8	11	19
3	JPL detention, OF conveyance east of KH, Bear diversion to JPL	5	8	13
	Professional	5	2	7
	Real Estate	6	1	7
	Construction	7	6	13
4	Acquire 2200 ac conservation/collection area	2	14	16
	Professional	2	11	13
	Real Estate	2	11	13
	Construction	13	3	16
5	Mound Creek Storage Area	8	13	21
	Professional	8	5	13
	Real Estate	13	4	17
	Construction	17	4	21

Table F4.4
Plan 5 – Schedule Input

Component	Description	Start (BOY)	Duration	End (BOY)
1	Collection channel along Katy Hockley (future equalization channel), Bear Creek channel to dayligh (about 7,000 feet)	1	4	5
	Professional	1	2	3
	Real Estate	2	1	3
	Construction	3	2	5
2	Outfall Channel to Bear Creek (Downstream to Upstream, as development occurs)	4	12	16
	Professional	4	7	11
	Real Estate	4	4	8
	Construction	5	11	16
3	JPL detention, OF conveyance east of KH, Bear diversion to JPL	6	10	16
	Professional	6	3	9
	Real Estate	7	3	10
	Construction	10	6	16
4	Acquire Land for Storage Area	2	13	15
	Professional	2	13	15
	Real Estate	2	13	15
5	Construction of Storage Area	10	9	19
	Professional	10	6	16
	Real Estate	16	0	16
	Construction	16	3	19

4.2 Model Outputs

The model uses the data to develop tabular data on an annual basis. A number of graphs are available for output, as well as a visual schedule. Outputs used in the analysis of Plan 3 and Plan 5 are presented in this section.

4.2.1 Schedule Output

Table F4.5 shows an implementation schedule for Plan 3, and Table F4.6 shows an implementation schedule for Plan 5.

Table F4.5
Plan 3 – Implementation Schedule

Component	Description	Start (BOY)	Duration	End (BOY)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		1	4	5																				
	Professional	1	2	3																				
	Real Estate	2	1	3																				
	Construction	3	2	5																				
2		5	14	19																				
	Professional	7	7	14																				
	Real Estate	5	3	8																				
	Construction	8	11	19																				
3		3	7	10																				
	Professional	3	7	10																				
	Real Estate	4	3	7																				
	Construction	7	2	9																				
4		2	13	15																				
	Professional	2	11	13																				
	Real Estate	2	11	13																				
	Construction	13	2	15																				
5		8	12	20																				
	Professional	8	6	14																				
	Real Estate	12	4	16																				
	Construction	16	4	20																				

Table F4.6
Plan 5 – Implementation Schedule

Component	Activity	Start (BOY)	Duration	End (BOY)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		1	4	5																				
	Professional	1	2	3																				
	Real Estate	2	1	3																				
	Construction	3	2	5																				
2		5	14	19																				
	Professional	7	7	14																				
	Real Estate	5	3	8																				
	Construction	8	11	19																				
3		6	10	16																				
	Professional	6	3	9																				
	Real Estate	7	3	10																				
	Construction	10	6	16																				
4		2	13	15																				
	Professional	2	13	15																				
	Real Estate	2	13	15																				
5		10	9	19																				
	Professional	10	6	16																				
	Real Estate	16	0	16																				
	Construction	16	3	19																				

The schedules shown depict an 18- to 20-year implementation for both management plans. Ultimately, the schedule depends upon the time necessary to complete the engineering, permitting, land acquisition, and construction. Additional considerations include available funding and available cash flows.

4.2.2 Land Recovery

Exhibit F4.1 depicts land recovery vs. development demand over time for Plan 3, and Exhibit F4.2 depicts the same for Plan 5. These charts are based upon the development rate provided in the Basic Input as well as the Schedule Input. The implement schedule presented was based upon an average development rate of 800 acres per year, which was determined from investigating the development trends in other large communities developed within and surrounding Harris County, such as The Woodlands as well the Katy-Fulshear corridor west of State Highway 99 (the Grand Parkway).

To be effective, the management plan must be able to recover land at a rate necessary to meet the overall demand. In implementation, the model allows for the adjustment of the implementation schedule to attempt to meet this demand, within the constraints of engineering, permitting, land acquisition and construction.

The models indicate that the implementation of the initial elements meets the demand in a manner that allows for the necessary time to provide the engineering, permitting, land acquisition and construction.

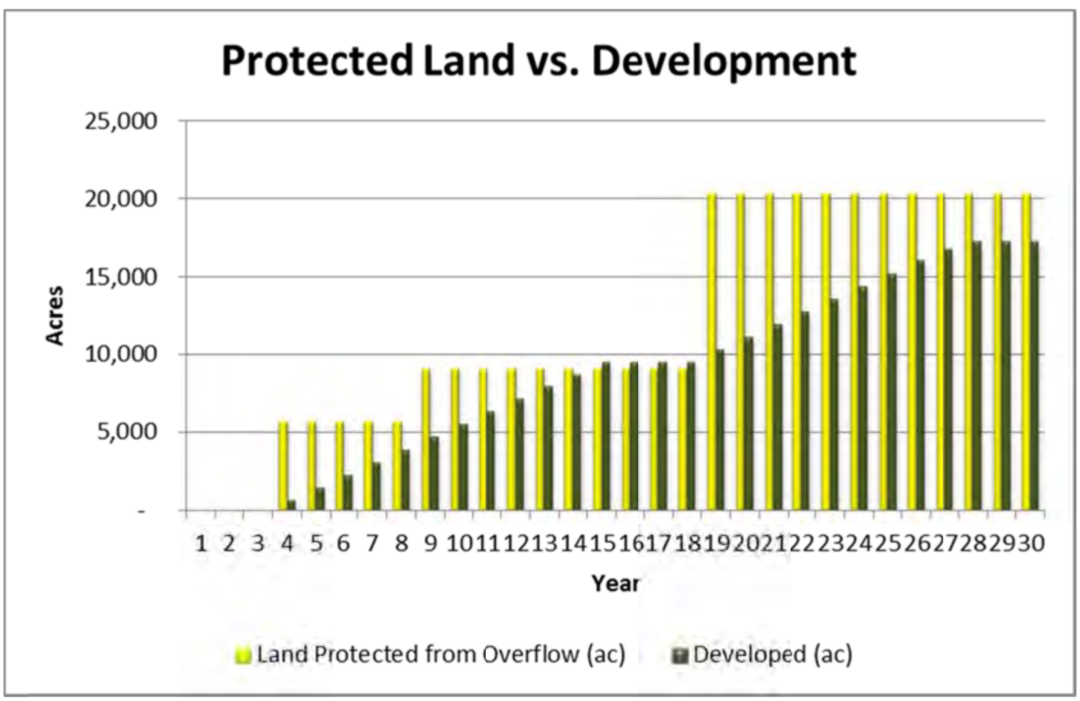

Exhibit F4.1
Plan 3 – Land Recovery vs. Development Demand

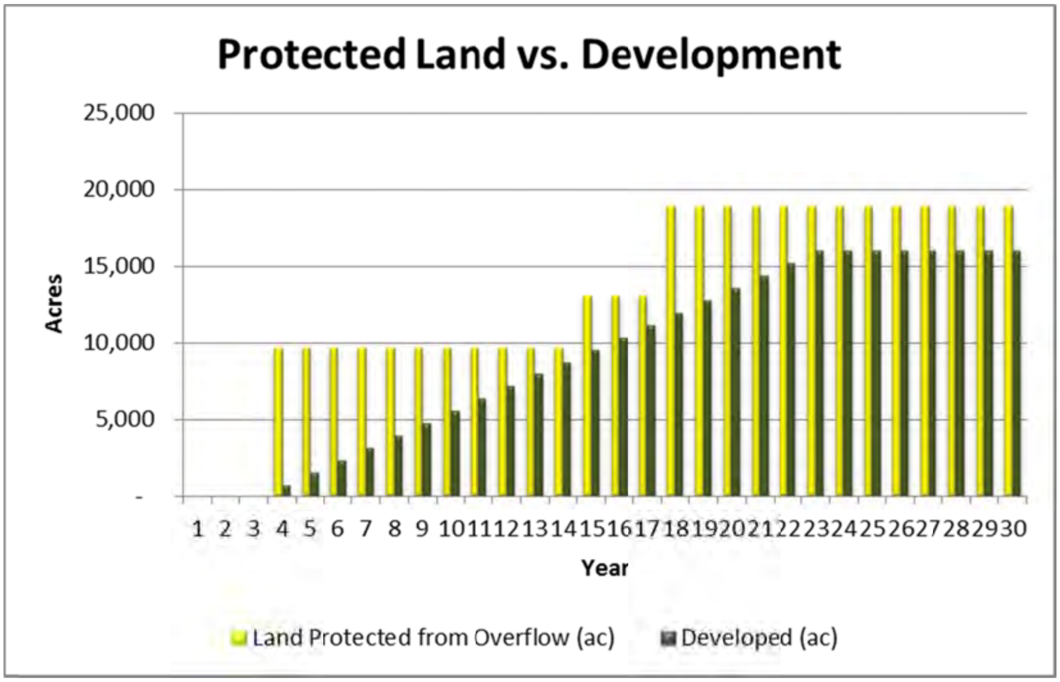

Exhibit F4.2
Plan 5 – Land Recovery vs. Development Demand

4.2.3 Annual Project Cost by Element (Component)

The model provides a chart that depicts the annual project cost by element over the implementation schedule. This is shown on Exhibit F4.3 for Plan 3 and Exhibit F4.4 for Plan 5. The implementation schedule was developed in a manner that attempts to maintain a level cost throughout the implementation. There is a higher cost in the second year because of the need to secure land in the initial collection area associated with Element 1 in both plans. This represents a portion of the initial project investment that must be made.

4.2.4 Project Cost vs. Land Revenue

The management plans will provide a regional management strategy and eliminate the need for development to construct individual onsite overflow management facilities. Therefore, as the land develops, it will contribute to the project cost. There are various methods for this to occur, and the Basic Input allows for the consideration of various funding mechanisms. This section presents the results of an impact fee model, which considers development impact fees paid as land develops. The model determines an impact fee from the Basic Input parameters. For Plan 3, the computed impact fee is $9,454 per acre; and for Plan 5, the computed impact fee is $11,708 per acre.

Exhibit F4.5 shows the annual project cost against the annual project revenue, based on an impact fee model, for Plan 3. Exhibit F4.6 shows the same for Plan 5. The revenue stream from the project will change based upon the development rate and the impact fee.

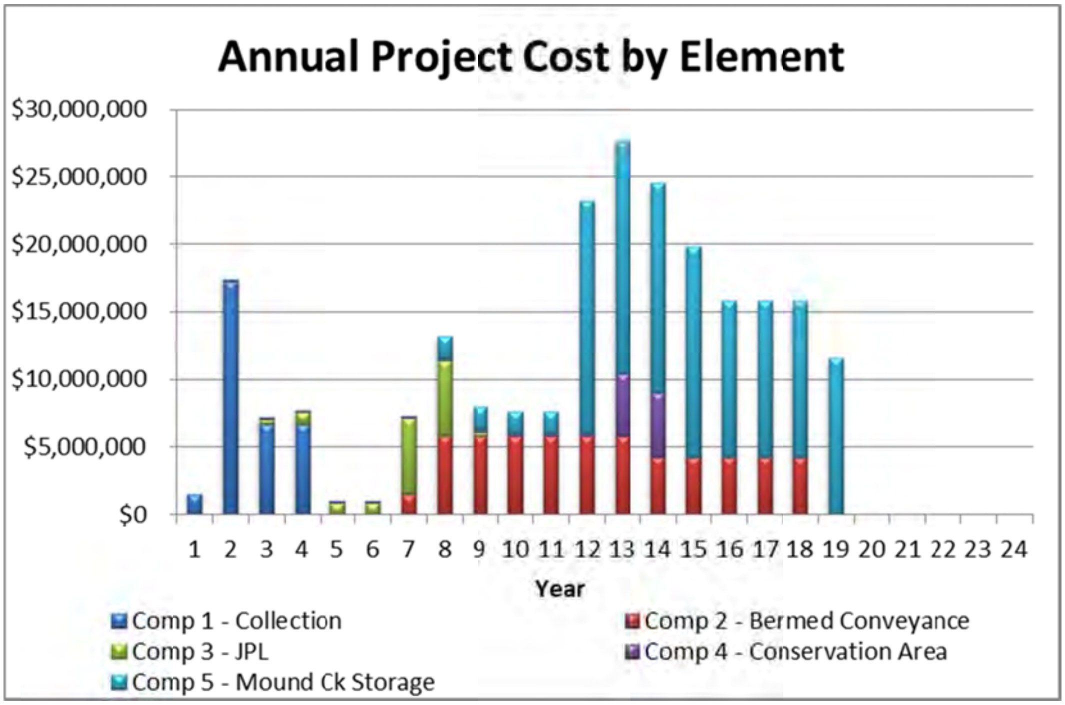

Exhibit F4.3
Plan 3 – Annual Project Cost by Element

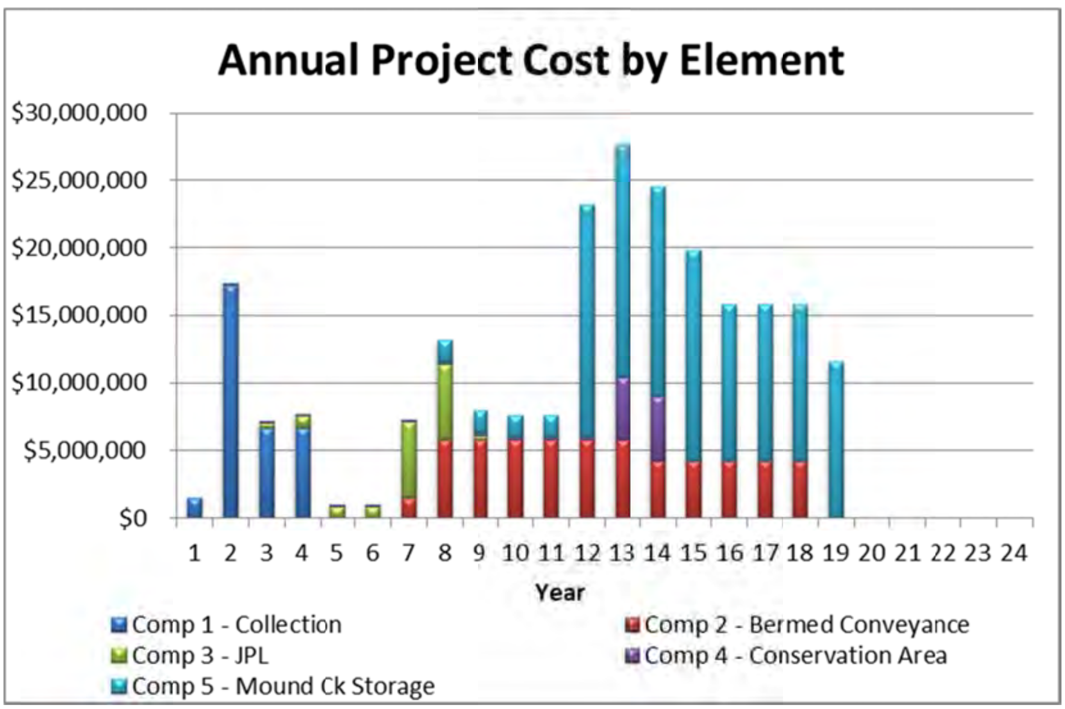

Exhibit F4.4
Plan 5 – Annual Project Cost by Element

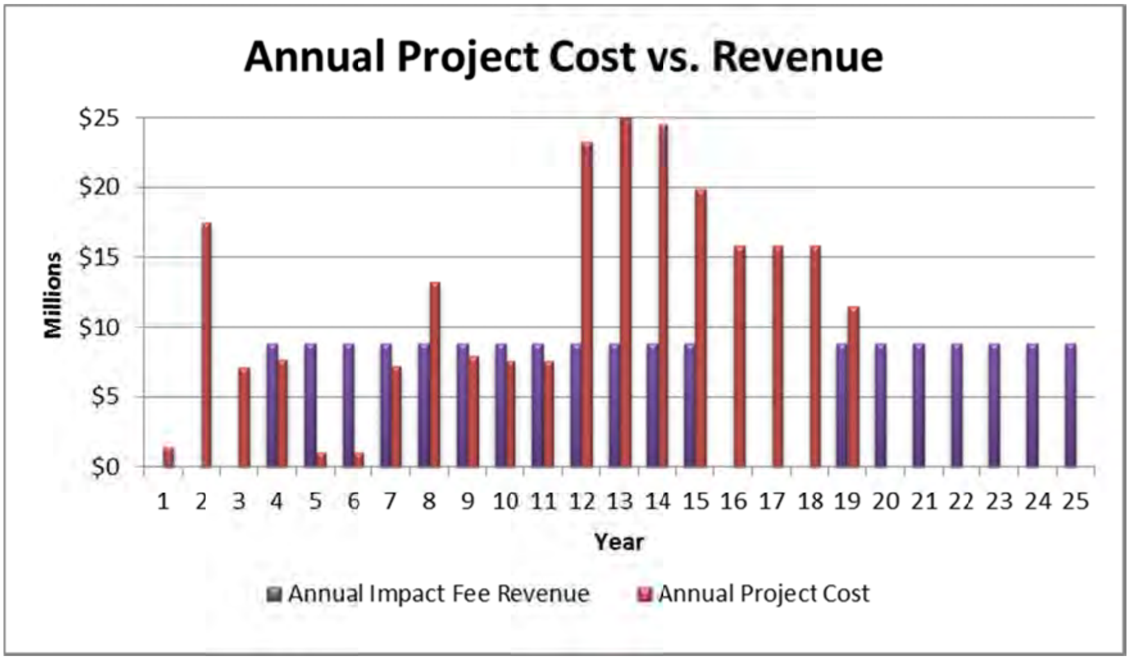

Exhibit F4.5
Plan 3 – Annual Project Cost vs. Land Revenue (Impact Fee Model)

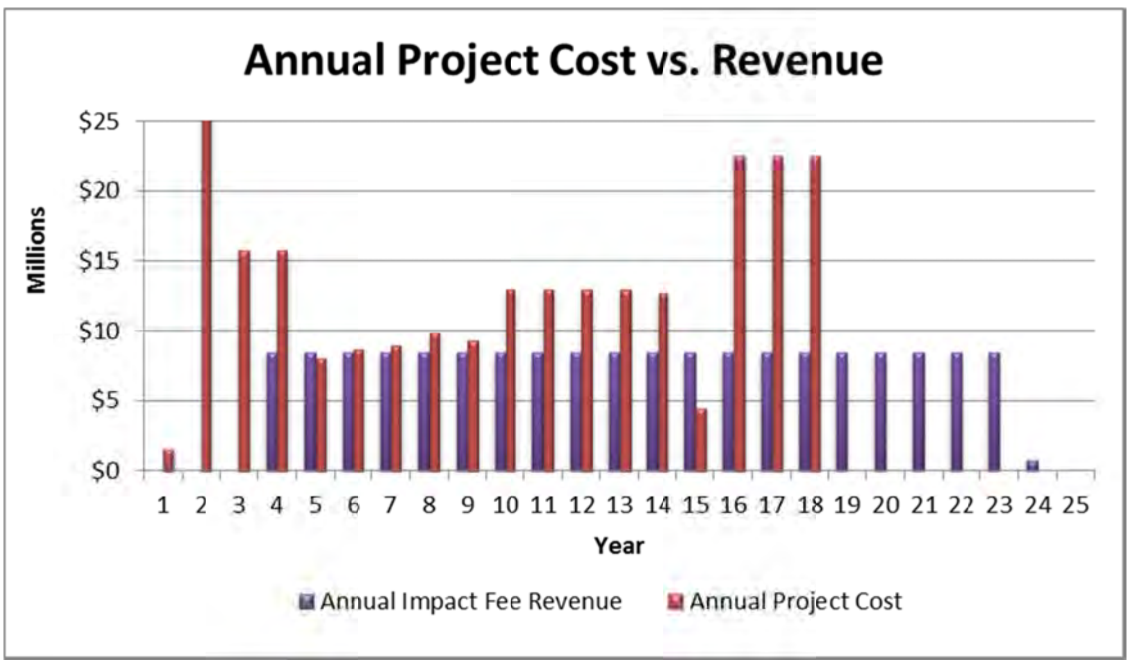

Exhibit F4.6
Plan 5 – Annual Project Cost vs. Land Revenue (Impact Fee Model)

The comparisons presented in Exhibits F4.5 and F4.6 provides insight into annual costs and revenue; however they do not clearly reflect the overall financial structure of the implementation. Exhibits F4.7 and F4.8 compare the cumulative annual costs and revenue of both plans. The red bars in both graphs represent the project costs in excess of the revenue that would be borne by the project sponsor. This includes the investment in the initial years in addition to the funds needed to complete the project once the land is fully developed and revenue streams cease.

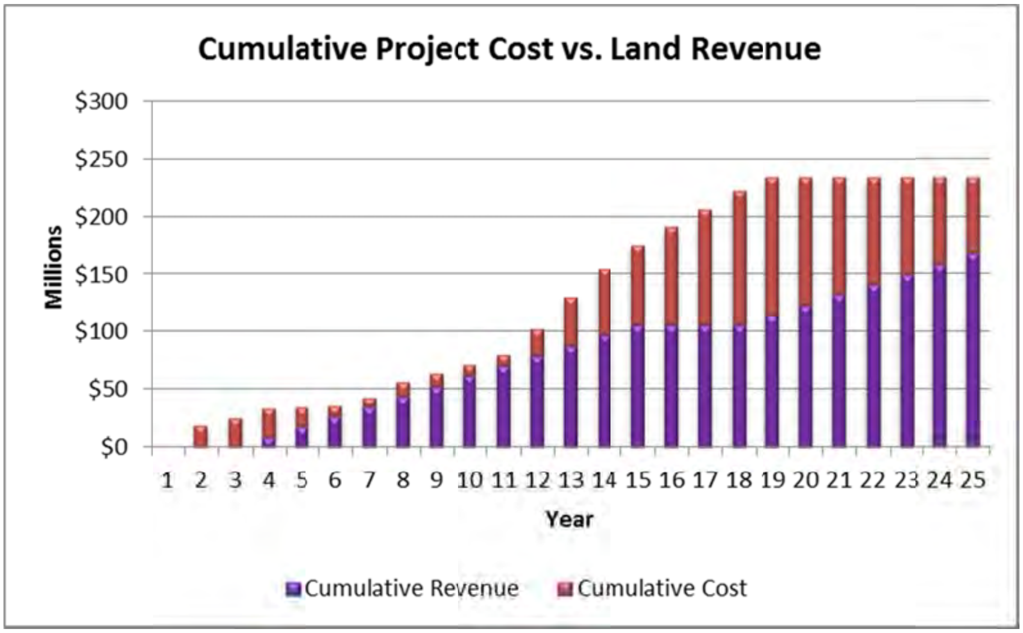

Exhibit F4.7
Plan 3 – Cumulative Project Cost vs. Land Revenue (Impact Fee Model)

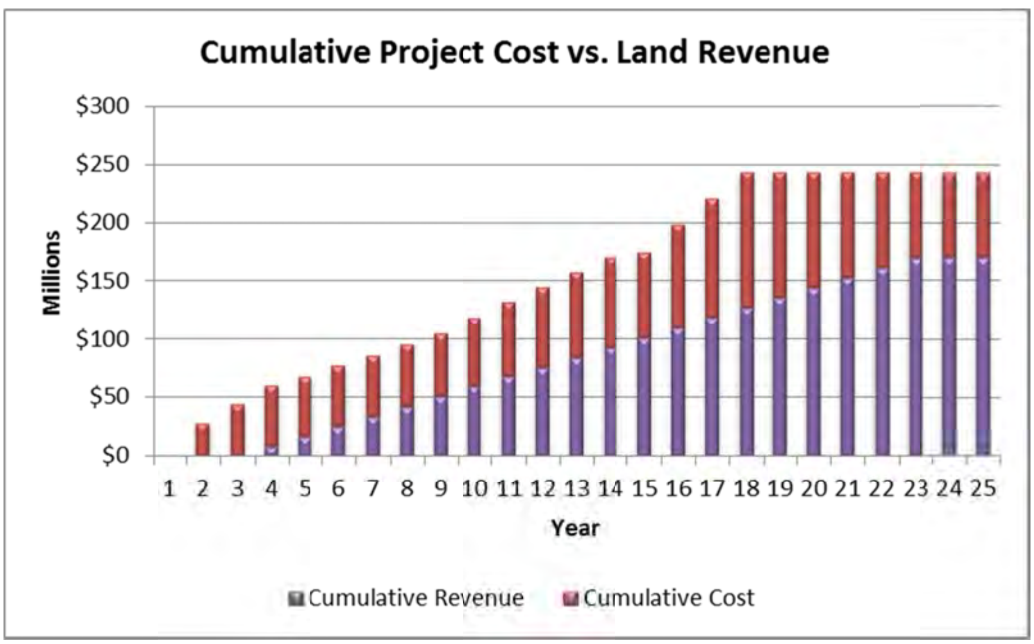

Exhibit F4.8
Plan 5 – Cumulative Project Cost vs. Land Revenue (Impact Fee Model)

4.2.5 Summary

The cash flow model has additional outputs available to consider impacts to tax revenue and other potential funding scenarios; however these outputs were not developed for this plan.

The various charts presented in this report indicate the viability of the implementation of each alternative if the assumed land revenue and in-kind contributions were provided. The charts also demonstrate how the Schedule Input can be adjusted to balance the annual costs, meet the land development demand, and manage overall implementation.

Appendix G

Supplemental Guidelines and Criteria for Developing in the Addicks/Barker Watershed(s) and the Upper Cypress Creek Watershed Upstream of US 290

August 10, 2015

TABLE OF CONTENTS

DRAFT SUPPLEMENTAL GUIDELINES AND CRITERIA FOR DEVELOPING IN THE ADDICKS/BARKER WATERSHED(S) AND THE UPPER CYPRESS CREEK WATERSHED UPSTREAM OF US 290

September 25, 2014

Introduction

I.1 Introduction

These supplemental guidelines and criteria to the Harris County Flood Control District's (HCFCD) Policy Criteria and Procedures Manual (PCPM) are intended to provide direction for the engineering community and HCFCD staff to comply with the HCFCD no-adverse impact policy associated with management of stormwater runoff from land development and infrastructure projects in the upper Cypress Creek, Addicks Reservoir and Barker Reservoir watersheds. Current Harris County Flood Control District policy, criteria, procedures, and requirements for land development will continue to apply except as noted with these supplemental guidelines and criteria.

The unique hydrological phenomenon that prompted this supplement is the stormwater overflow from Cypress Creek to the Addicks and Barker Reservoir watersheds and the storage capacity of the reservoirs. Overflow initiates between the 20 percent (5-year) and 10 percent (10-year) probability events.

I.2 Overview

These supplemental guidelines and criteria include:

1. Impact analyses demonstrating no adverse impacts associated with development of properties or infrastructure projects that are affected by, or contribute to the Cypress Creek overflow.
2. Dedication and construction of overflow conveyance facilities
3. Stormwater runoff volume control (retention volume) for properties located within the Addicks and Barker Reservoir watersheds, as well as the upper Cypress Creek watershed.
4. Revised Site-Runoff Curve equations for the upper Cypress Creek watershed.
5. Revised minimum detention requirements within the upper Cypress Creek, Addicks Reservoir and Barker Reservoir watersheds.

The following table shows which of these guidelines and criteria apply to which watershed. Additionally, Exhibits 1-5 illustrate the area of application for these guidelines and criteria.

Continued on next page

I.2
Overview
(continued)

Table 1: Application of the Supplemental Drainage Guidelines and Criteria

Supplemental Guidelines and Criteria[1]	Cypress Creek Watershed Upstream of US 290[2]	Addicks Reservoir Watershed[2]	Barker Reservoir Watershed[2]
Overflow Impact Analyses (Section 1.1)	X	X	X
Overflow Conveyance Facilities (Section 1.2)	X	X	
Stormwater Retention (Section 1.3)	X	X	X
Revised Site Runoff Curve Equations (Section 1.4)	X		
Revised Minimum Detention Volume Requirements (Section 1.5)	X	X	X

Notes:
1. *Exceptions to the supplemental guidelines and criteria are presented in Section 1.6.*
2. *These guidelines and criteria are applicable to those portions of the Addicks Reservoir, Barker Reservoir and Cypress Creek Watersheds located in Harris County.*

I.3
Initial Coordination Meeting

It is essential that the engineer meet with the HCFCD during the Preliminary Assessment (PCPM, Section 2.8.4) and prior to initiating any technical hydrologic investigation for new or modified projects. The purpose of the meeting is for the design engineer to describe the methodology and types of facilities that are proposed to address the requirements outlined within these supplemental criteria, obtain concurrence from HCFCD of the proposed analytical approach, and confirm understanding of the requirements. Documentation by the engineer of the understandings and concurrence by the HCFCD is strongly recommended.

Section 1 – Supplemental Guidelines and Criteria

1.1 Overflow Impact Analyses

Projects located in areas that are affected by or influenced by the Cypress Creek Overflow are subject to additional requirements for impact analyses. The region in Harris County requiring overflow impact analysis include portions of the upper Cypress Creek watershed, Addicks Reservoir watershed, and a small portion of the Barker Reservoir watershed as shown on Exhibit 1.

During the initial coordination meeting with the HCFCD and engineer, topics will include but not be limited to which model(s) to use, the watershed and hydraulic conditions to analyze, and the analytical approach. These conditions may vary based on the physical location of the property relative to the overflow zone. Information provided by the HCFCD will include additional guidelines for performing overflow impact analyses for proposed developments. The following list provides an overview of the guidelines that will be required for overflow impact analysis:

1. The HCFCD has developed a 1-Dimensional/2-Dimensional coupled SWMM model of the Cypress Creek overflow (Cypress Creek overflow model) that reflects flooding depths, discharges, flow direction, and base flood elevations associated with the overflow. Utilize the results from the current Cypress Creek overflow model as the best available data unless otherwise directed by the HCFCD.
2. The HCFCD will update the Cypress Creek overflow model from time to time to reflect changes in the overflow conditions as changes in land use occur.
3. The engineer may use their own numerical model to calculate the mitigation needs for the development project, provided that the model results are realistic and reflects the boundary conditions in the Cypress Creek overflow model and/or is coordinated with the HCFCD for the overflow and receiving water surface elevation downstream. Overflow impact analyses must be performed using FEMA accepted modeling software when computer models are used.

Continued on next page

1.1 Overflow Impact Analyses (continued)

4. Any applicant who plans to develop in the overflow area must demonstrate how to convey the existing overflow without adversely impacting upstream or downstream properties. Clearly explain the analytical approach and show the proposed physical features in the Impact Analysis report submitted to the HCFCD for review and approval. Since the amount, duration, etc. of overflow varies with rainfall intensity and duration, evaluate the conditions of both a 10 percent (10-year) and 1 percent (100-year) event for a 24-hour duration, as well as the 1 percent (100-year) overflow condition without the local flood event, i.e., overflow event only.
5. If a proposed project is part of a larger master plan, an overflow impact analysis will be required for the overall master plan as well as the proposed phasing plan.

1.1.2 Modeling Exemptions

Small projects (less than 20 acres in size) are generally exempt from overflow impact analysis modeling requirements if all of the following conditions apply:

1. The project is located within an area that experiences inundation depths of 6 inches or less during a 1 percent (100-year) overflow occurrence. Coordination with HCFCD will be required to determine depth of overflow at applicant's project site.
2. The project is located outside a designated "local floodway" (see Exhibit 2).
3. The total project area is less than 20 acres in size and is not part of a larger master-planned project. If the project is part of a larger master plan, an overflow impact analysis will be required for the overall master plan and proposed phasing plan.
4. If located within an area that experiences overflow during the 1 percent annual chance event, an overflow conveyance management plan will be required in addition to satisfying Harris County and HCFCD drainage requirements.

Continued on next page

1.1.2 Modeling Exemptions (continued)

These exemptions attempt to simplify the required analyses for small tracts; however, circumstances may exist that would still require a detailed, overflow impact analysis using numerical models. Therefore, small tract developments are encouraged to meet with HCFCD prior to plan development.

1.2 Overflow Conveyance Facilities

New development will be required to dedicate to the HCFCD in fee, any property used to convey the overflow. In addition to new facilities that will be constructed to convey the overflow, dedication of property along and including Bear Creek (Channel U102-00-00) will also be required upstream of channel U102-18-00 (see Exhibit 3). To the extent that new developments are adjacent to the existing Bear Creek stream alignment, the applicant will be allowed to use the property for local flood mitigation provided the local mitigation does not reduce the ability to convey the overflow.

In addition to dedication of property along and including Bear Creek, the following criteria also apply to development along Bear Creek:

1. Unless the local drainage requirements dictate otherwise, the minimum corridor width along Bear Creek shall be 500 feet. This is based upon the assumption of an overflow rate of 6,500 cfs within the channel, as well as target water surface profiles for the 10 percent and 1 percent events.
2. Coordinate channel modifications constructed along Bear Creek with the HCFCD, who will provide guidance on incorporating the following elements into the channel design:
    - Channel elevation, depth, cross-section requirements,
    - Location and size of drop structures (if needed),
    - Discharge-storage relationships, and
    - Natural channel design features.

Continued on next page

1.2 Overflow Conveyance Facilities (continued)

3. An applicant whose property is adjacent to Bear Creek, upstream of HCFCD Channel U102-18-00 (see Exhibit 3), will be required to convey to the HCFCD, in fee, a 250-foot-wide corridor on both sides of the centerline of the creek, unless a regional drainage plan is adopted by Harris County Commissioner's Court that requires a different dedication width or the applicant's property boundaries do not allow for the complete dedication.
4. If natural topographic conditions are such that an alignment shift of the 500-foot corridor channel off the existing channel centerline is feasible and prudent, the appropriate modifications will be considered by the HCFCD provided the applicant has control of the property and can match the corridor requirements.
5. Alternatively, if conditions are such that it is more feasible to construct an alternate overflow conveyance channel parallel to the existing channel, the applicant must meet the requirements previously mentioned (criteria #2 in this list) for channel modifications along Bear Creek and:
    - Have control of the property,
    - Match the corridor limits to the adjacent property, and
    - Provide a minimum 500-foot-wide corridor.

Clearly document the proposed alignment and configuration of the overflow corridor channel in the Impact Analysis Report. The HCFCD is available to review options and provide feedback.

Continued on next page

1.3 Stormwater Retention

In order to avoid increased stormwater runoff volume from new developments into Addicks and Barker reservoirs, stormwater retention will be required for new development within the Addicks and Barker Reservoir watersheds and as well as the upper Cypress Creek watershed west of Katy-Hockley Road (Exhibit 4). Stormwater retention will be used to capture a portion of stormwater runoff leaving new developments and hold it for an indefinite period of time. Techniques such as reuse, infiltration and evaporation can be used to dispose of the retained stormwater.

The PCPM requires use of detention to temporarily store stormwater in order to restrict discharge from new developments to the pre-project discharge rate; however, the use of detention does not address the volume of stormwater draining from new developments. Applicants with new projects in the upper Cypress Creek, Addicks Reservoir and Barker Reservoir watersheds will be required to comply with stormwater retention and stormwater detention criteria.

The applicant is expected to comply with all other current Harris County and HCFCD criteria and policies for stormwater management and mitigation of land development and infrastructure projects (HCFCD PCPM and Harris County Regulations). The volume of runoff captured to provide retention volume will not be considered part of the minimum detention storage requirements provided in Section 6.9 of the PCPM and Section 1.3 of these supplemental criteria.

The following discussion provides criteria on how to determine the increased volume of stormwater runoff to be mitigated, as well as techniques that can be used to provide the required retention.

1.3.1 Determination of Retention Volume

Refer to the PCPM for the impervious cover values for common land use categories (PCPM section 3.5.1), along with the depth of direct runoff (PCPM section 3.6.7), needed to calculate the runoff volume. Provide a detailed description of the area to be developed that includes acreages and maps of existing and post-development land use/land cover types.

Continued on next page

1.3.1 Determination of Retention Volume (continued)

The minimum retention rate shall be no less than 0.1 ac-ft per acre with a detailed analysis. Absent a detailed analysis, provide the following retention storage to avoid additional runoff into Addicks and Barker reservoirs during a rainfall event:

Land Use	Runoff Depth (inches)	Retention Rate (acre-feet/acre)
Single Family Residential	2.1	0.17
Light Industrial	2.9	0.24
Dense Commercial	3.9	0.32

Certain Low Impact Development (LID) techniques may be used to reduce stormwater runoff volume. The use of LID practices may be considered in the retention volume calculations. However, LID techniques must comply with the Harris County Low Impact Development and Green Infrastructure Design Criteria for Storm Water Management.

A clear explanation describing how the retention volume was determined should be included in the Impact Analysis Report. Two examples of approaches are in Section 3 of these criteria.

1.3.2 Retention Volume Techniques

Capture and retain the initial stormwater runoff to satisfy the retention volume mitigation. Acceptable methods for satisfying the retention volume requirement include but are not limited to:

1. Demonstrate how the stored retention volume will be drained through reuse methods such as irrigation, or a combination of reuse, infiltration and/or evaporation techniques.
2. Contribute funds to a conservation area dedicated to restoring prairie grasslands in the watershed on an acre-per-acre basis. This could take the form of third-party agreement that outlines the contribution.

Continued on next page

1.3.2 Retention Volume Techniques (continued)

3. If retained stormwater cannot be drained or stored through methods listed above, conditional release into a receiving stream is possible. However, the following conditions must be met:

   a. In coordination with the Corps of Engineers, Galveston District, the HCFCD will provide information to retention basin owners, engineers, and operators via the Harris County Flood Warning System website: (http://www.harriscountyfws.org) as to when the retained stormwater can be released into the outfall channel.

      i. For the Cypress Creek watershed west of Katy-Hockley Road, the factors affecting the release include current and forecasted water levels in Cypress Creek and rainfall forecasts.

      ii. For Addicks and Barker watersheds, the factors include current and forecasted water levels in the reservoirs, release rates from the reservoirs, and rainfall forecasts.

   b. Coordinate the discharge control method from the retention basin with the HCFCD. Options include valves, gates, pumps, etc. that are operated manually or automatically.

   c. Retention basin owners may be required to control retention discharge through the use of a programmable process control system, such as Supervisory Control and Data Acquisition (SCADA), in conjunction with internet technology. The system must be programmed to gather retention release conditions from the HCFCD Flood Warning System website and control release of the retained stormwater accordingly.

4. Pumped detention facilities are required to drain at least 50 percent of the detention volume by gravity. The additional retention volume needed for runoff volume mitigation can be added to the pumped detention volume, and will not increase the volume of stormwater that would be required to drain through a gravity outfall. However, the retention volume must be managed using the runoff volume mitigation techniques 1-3 listed above.

Continued on next page

1.3.2 Retention Volume Techniques (continued)

5. The applicant may pay a fee to purchase retention volume within a regional stormwater volume mitigation basin in lieu of constructing on-site retention volume measures if such a regional facility becomes available and is approved by the HCFCD.

1.4 Revised Site Runoff Curve Equations

Section 3.3 in the PCPM provides an equation that can be used to determine peak discharge rates for small to moderate drainage areas (areas less than 640 acres in size):

$$Q = bA^m$$

An adjustment to the standard Harris County site runoff curves is required for estimating peak runoff rates for small to moderate areas (areas less than 640 aces) in the upper Cypress Creek watershed, with the exception of the Mound Creek drainage area (see Exhibit 5), the following ponding adjustment should be used:

Upper Cypress Creek Modified Site Runoff Equation: $Q = p*bA^m$

p = ponding adjustment factor

If percent impervious (IMP) $\geq$40%, p = 1.0

If percent impervious (IMP)< 40%, see below

For locations west of Katy-Hockley Road(excluding the Mound Creek watershed (Exhibit 5), use the following equations to calculate the ponding adjustment factor:

10-yr event: $p = 0.30 + 0.0175*(IMP)$

100-yr event: $p = 0.49 + 0.0128*(IMP)$

For locations between Fry Road and Katy-Hockley Road (Exhibit 5), use the following equations to calculate the ponding adjustment factor:

10-yr event: $p = 0.38 + 0.0155*(IMP)$

100-yr event: $p = 0.56 + 0.0110*(IMP)$

Continued on next page

1.5 Minimum Detention Volume Requirements

Minimum detention volume requirements used to mitigate peak discharge rates from new developments within the upper Cypress Creek, Addicks Reservoir and Barker Reservoir watersheds are revised as follows:

- Upper Cypress Creek Watershed:
  - The volume as calculated using Method 1 or 2 as described in the PCPM, but not less than 0.65 acre-feet per acre of new development, or as defined in a watershed with an adopted regional plan.
  - The volume as calculated using the Optional Project Routing Technique or the Method 3 Technique, but not less than 0.55 acre-feet per acre of new development.
- In the Addicks Reservoir and Barker Reservoir watersheds, the volume as calculated using any method described in the PCPM Section 6.9, Detention Volume, but not less than 0.55 acre-feet per acre of new development regardless of method used.

Section 2 – Exceptions to the Supplemental Guidelines and Criteria

2.1 Exceptions to the Criteria

Under certain circumstances, these supplemental guidelines and criteria will not be applicable. Those circumstances include:

- In the event a Regional Overflow Management Plan is defined and formally adopted by Harris County Commissioner's Court, the applicant will comply with the terms of that plan.
- Projects with a master impact study or master drainage plan approved by the HCFCD prior to adoption of these criteria are exempt from these new requirements and may continue to develop under the same previously approved drainage criteria provided approval of the master plan is current and has not expired (see PCPM. Section 2.3.5, Signature Expiration).
- Properties located in the upper Cypress Creek watershed must comply with PCPM, Section 2.15, Regional Flood Control Projects and provide retention volume sufficient to comply with these criteria.
- Properties located within the boundaries of the Upper Langham Creek Capital Improvement and Impact Fee Utilization Plan must comply with PCPM Section 2.15.10, Upper Langham Creek, and are exempt from these supplemental guidelines and criteria.
- Any Harris County road, bridge or park project may adhere to these supplemental guidelines and criteria. In the event a County road, bridge or park project elects not to participate in the supplemental guidelines and criteria, that project will continue to comply with the requirements of the PCPM.
- New residential developments with limited on-site drainage improvements and relatively small amounts of impervious cover (less than or equal to 15 percent) will be exempt from these supplemental detention requirements.

Continued on next page

2.1 Exceptions to the Criteria (continued)

- Cypress Creek overflows into the Addicks Reservoir watershed between the 20 percent (5-year) to 10 percent (10-year) annual chance storm event. New developments in the upper Cypress Creek watershed that construct drainage facilities with a design peak discharge rate for the 1 percent (100-year) event at or below the pre-project 5-year discharge rate will not be required to provide stormwater retention volume. It is anticipated that Cypress Creek floodplain will have sufficient capacity to accommodate the pre-project 5-year flow rate without overflowing into the Addicks Reservoir watershed.

Section 3 - Examples

Example 1

Project Size:	500 acres
Project Location:	Addicks Reservoir Watershed
Documentation provided:	Aerial photography of land cover
	Summary of existing land use
	Soils map
	Proposed land plan and written description
	(450 acres of residential development with a gross lot density of 2.3 units/acre and 50 acres of commercial development)

Peak Flow Rate Impact Analysis

The HCFCD Method 3 for detention volume calculations was used to determine the appropriate detention volume to mitigate increases in peak discharge rates from the development. Total detention rate calculated to be 0.55 ac-ft/acre to control peak discharge rates from the development for the 10 percent (10-year) and 1 percent (100-year) annual chance storm events. Detention volume = 275 acre-feet.

Stormwater Retention Volume Analysis (Based on information provided in Sections 3.5 and 3.6 of the PCPM):

The goal of this preferred analysis approach is to match the impervious cover and runoff depths provided in the PCPM with the existing and proposed land uses at the project location, and to calculate the stormwater runoff volume that will need to be mitigated. Doing so results in the following findings:

Continued on next page

Example 1, (Continued)

Existing Land Use	Impervious Cover (%)	Runoff Depth (in) 10%	Runoff Depth (in) 1%	Project Drainage Area (Ac)	Runoff Volume (ac-ft) 10%	Runoff Volume (ac-ft) 1%
Rangeland	0	3.5	7.9	200	58.3	131.7
Grasslands	0	3.5	7.9	50	14.6	32.9
Agriculture	0	3.5	7.9	250	72.9	164.6
			Total	***500***	***145.8***	***329.2***

Proposed Land Use	Impervious Cover (%)	Runoff Depth (in) 10%	Runoff Depth (in) 1%	Project Drainage Area (Ac)	Runoff Volume (ac-ft) 10%	Runoff Volume (ac-ft) 1%
1/3 Ac Residential	30	4.6	9.3	250	95.8	193.8
1/4 Ac Residential	40	4.9	9.7	105	42.9	84.9
1 Ac Residential	20	4.2	8.8	105	36.8	77.0
Detention Facilities	100	7.1	12.4	40	23.7	41.3
			Total	***500***	***199.1***	***397.0***

Change in Runoff Volume (Acre-Feet)	10%	53.3
	1%	67.8
Retention Volume Required (acre-feet)		67.8
Retention Volume Rate (acre-feet/acre)		0.14

The 0.14 acre-ft/acre is less than the default value of 0.17 acre-feet/acre. A retention volume of 67.8 acre-feet will be constructed to serve the 500-acre development, in addition to the 275 acre-feet of detention that will be required to mitigate peak flow rates draining from the site.

Note: *The development is retaining 0.14 acre-feet of stormwater for each acre of development because detailed calculations were performed to determine a suitable storage coefficient for runoff mitigation. Had this not been done, the development would have been required to retain 0.17 acre-feet of stormwater per acre of development.*

Stormwater Mitigation Facility Design and Operation

A dual use basin will be constructed to provide the necessary detention and retention storage. The basin will be designed such that the detention volume will drain into Bear Creek using gravity flow through an ungated discharge pipe. The 0.14 acre-feet per acre of runoff captured for stormwater retention volume will be released into Bear Creek through a separate, gated outlet installed at a lower elevation than the outlet serving the detention storage. The basins will be maintained by a municipal utility district, which will monitor the retention release conditions on the Harris County Flood Warning System website.

Continued on next page

Example 2

<u>Project size</u>: 125 acres

<u>Project Location:</u> Upper Cypress Creek Watershed

<u>Documentation provided</u>: Aerial photography of land cover

Summary of existing land use

Proposed land plan map and written description

Stormwater Runoff Volume Impact Analysis:

Applicant elects to not perform any analysis of retention rate. The default retention rate is set at 0.17 acre-feet/acre for residential development, 0.32 acre-feet/acre of commercial development and 0.24 acre-feet/acre of industrial development.

Existing Land Use	Impervious Cover (%)	Retention Rate Acre-feet/Acre	Project Drainage Area (Ac)	Retention Volume (Ac-Ft) 10%	Retention Volume (Ac-Ft) 1%
High Density Commercial	85	0.32	5	1.60	1.60
Light Industrial	60	0.24	8	1.92	1.92
Residential (1/4 ac lots)	40	0.17	112	19.04	19.04
Combined Total		***0.18***	***125***	***22.56***	***22.56***

Stormwater Mitigation Facility Design and Operation

The developer elects to build two basins. The smaller basin, designed using a storage rate of 0.18 acre-feet/acre of development will be used for retained water and will be used to irrigate green spaces. The larger detention basin will be designed according to existing criteria, with the 0.65 acre-feet per acre requirement in the upper Cypress Creek watershed west of Katy-Hockley Road. A shallow swale will be used to connect the two basins in the event the smaller basin holding retained water overfills.

Appendix H

Public Outreach Program

Contents

1 Introduction to Appendix H

This appendix provides documentation to accompany Chapter 9 of the final study report for the Cypress Creek Overflow Management Plan. Much of the material also is available on the Harris County Flood Control District (HCFCD or District) website. The study page is located at: HCFCD.org/cypresscreekoverflow.

2 Steering Committee Agendas

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: June 28, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting – Organizational Meeting

Place: HCFCD Office, 9900 NW Fwy.

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
Alem Gebriel (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)

Items to be Discussed:

Introductions

Presentation by Flood Control District

Flood Control District interest in the project

Purpose and role of the Steering Committee

Role and identification of other stakeholders

Project Approach

Questions and Discussion

Beginning to define issues

MEETING AGENDA

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: July 12, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting – Organizational Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
Alem Gebriel (HCFCD)
Beth Walters (HCFCD)
Mary Anne Piacentini (KPC)
Raymond Anderson (HCPID)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)

Items to be Discussed:

Introductions

Presentations by Flood Control District:

Overview of flooding in the Addicks Reservoir watershed (Jeff Lindner)

Floodplain map revision of the Addicks Reservoir watershed (Gary Bezemek)

History of USACE Projects in West Harris County (Richard Long)

Selection of Additional Steering Committee Members and Agencies

Questions and Discussion

Beginning to define issues

A Division of Harris County Public Infrastructure Department

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: July 26, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting – Organizational Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
Alem Gebriel (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
David Randolph (HCFCD)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)

Items to be Discussed:

Introductions

Presentations by Flood Control District:

Addicks Reservoir watershed update(David Randolph)

Langham Creek Plan (David Saha, Alan Potok)

Begin to define issues

Next meeting: 1:30pm, Tuesday, August 9, 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: August 9, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Wesley Newman (KPC)
Joshua Stuckey (HCPID)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)

Items to be Discussed:

Introductions

Discuss the issues identified by the steering committee members in the June 28, 2011 meeting. (separate handout)

Project Sharepoint Site - http://portal/extranet/CCOverflow/CCO/Pages/default.aspx

Next meeting: 1:30pm, Tuesday, August 23, 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: August 23, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Debbie Jones (HCFCD)

Items to be Discussed:

Introductions

Presentations:

Katy Prairie Conservancy (Mary Anne Piacentini)

West Houston Association (Roger Hord)

Waller County (Stephen Reiter/Yancy Scott)

Additional discussion

Next meeting: 1:30pm, Tuesday, September 13, 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: September 13, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Persons Attending:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Fred Garcia (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Debbie Jones (HCFCD)
Ingrid Fairchild (HCFCD)

Items to be Discussed:

Introductions

Discuss items for consultant scope of work

Next meeting: 1:30pm, Tuesday, October 11, 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: September 27, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Invitees:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Janice Gray (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
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Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)
Ingrid Fairchild (HCFCD)

Items to be Discussed:

- Introductions
- Sharepoint Site https://fc92gsp.hcfcd.net/vpn/index.html
- Presentations

  HCFCD Overflow Study (Carl Woodward)

  Cypress Creek Overflow Studies (Costello Inc.)

  Addicks and Cypress Creek Studies (Brown & Gay Engineers, Inc.)

- Mapping Conceptual Mitigation Scenarios

Next meeting: 1:30pm, Tuesday, October 11, 2011
Harris County Permits Building
10555 Northwest Freeway Suite 170

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: October 11, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Invitees:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Janice Gray (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)
Ingrid Fairchild (HCFCD)

Items to be Discussed:

- Introductions
- Discuss Mitigation Alternatives from Previous Studies

  For each alternative, Steering Committee members can provide input regarding how the mitigation concept should be modified to satisfy the concerns and objectives of the different groups and organizations represented on the Steering Committee

Next meeting: 1:30pm, Tuesday, October 25, 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: October 25, 2011

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Invitees:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Janice Gray (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
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Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)
Ingrid Fairchild (HCFCD)

Items to be Discussed:

- Introductions
- Sharepoint website for Cypress Creek Overflow Management Plan
  - Software Installation
  - Navigating the website
  - Suggestions and comments

Next meeting: 1:30pm, Tuesday, ~~September 13,~~ November 8 2011
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County
Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: January 24, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Invitees:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Janice Gray (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Carl Woodward (HCFCD)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)
Ingrid Fairchild (HCFCD)

Items to be Discussed:

- Introductions
- Grant application to Texas Water Development Board
- Additional scope of service items not covered in the grant application
- Consultant team

Next meeting: 1:30pm, Tuesday, February 14, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
713 684-4000

Date: June 26, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan Steering Committee Meeting

Place: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Invitees:

Alan Potok (HCFCD)
Mike Talbott (HCFCD)
David Saha (HCFCD)
Janice Gray (HCFCD/Pct. 3)
David Randolph (HCFCD)
Glenda Callaway (HCFCD)
Heather Saucier (HCFCD)
Ty Kelly (BPA)
Mary Anne Piacentini (KPC)
Joshua Stuckey (HCPID)
Yancy Scott (Waller Co.)
Carl Woodward (HCFCD)
Kevin Shanley (SWA Group)
Michael Schaffer (City of Houston)
Pamela Rocchi (Harris Co. Pct. 4)
Richard Long (USACE)
Russ Poppe (HCPID)
Peter Houghton (Howard Hughes Corp.)
Roger Hord (West Houston Assoc.)
Mark Kilkenny (Mischer)
Stephen Reiter (Halff/Waller Co.)
Raymond Anderson (HCPID)
Shandra Puckett (HCFCD)
Ingrid Fairchild (HCFCD)
Mike Garmon (HCFCD)
Burton Johnson (Michael Baker Inc.)

Items to be Discussed:

- Introductions
- HCFCD consultant team
- Brief review of the following items:
  - HCFCD grant application scope of work and timeline (Mike Garmon)
  - Prairiegrass study (Mary Anne Piacentini)
  - Addicks reservoir repairs (Richard Long)
  - Waller County drainage criteria update (Stephen Reiter)
- Summary of the general issues and goals of the West Houston Association, KPC, Waller County, USACE, City of Houston, and HCPID

Next meeting: 1:30pm, Tuesday, July 10, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: July 10, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Introductions

Items to be Discussed:

- Prairiegrass study update (Mary Anne Piacentini)
- Addicks Reservoir Repairs update (Richard Long)
- Mapping areas of special concern (Everyone):
  - Environmentally sensitive areas
  - Major infrastructure project locations
  - Potential drainage project locations (detention, channels, etc.)
  - Prime development areas

Next meeting: 1:30pm, Tuesday, July 24, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: July 24, 2012

Time: 2:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Introductions

Items to be Discussed:

- Cypress Creek Overflow Hydrology presentation (Baker)
- Data from the July 2012 flooding event on Cypress Creek (HCFCD)
- Constraints on widening channels into Addicks Reservoir (SWA)
- Planning concepts for overflow storage in upper Addicks watershed (SWA)
- Feedback from Steering Committee

Next meeting: 1:30pm, Tuesday, August 14, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: August 14, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Environmental issues presentation (HCFCD – Ingrid Fairchild)
- Waller County presentation and discussion (Halff Assoc.)
- KPC Discussion of prairie inundation (KPC)
- Public meeting (August 15, 2012) overview (HCFCD)

Next meeting: 1:30pm., Tuesday, August 28, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: August 28, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Project Schedule
  - Milestones
  - Deliverables
  - Wrap up
- Mound Creek Base Plan
  - Presentation of the scenario
  - Discussion
- Choose the next conceptual plan for analysis
- Outcome of the public meeting held on August 16, 2012

Next meeting: 1:30pm, Tuesday, September 11, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: September 11, 2012

Time: 1:30 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Acquisition of the overflow AO Zone
- Bear Creek Conveyance Corridor Base Plan
- Choose the next conceptual plan for analysis
- Outcome of the public meeting held on August 16, 2012

Next meeting: 1:30pm, Tuesday, September 25, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY
FLOOD
CONTROL
DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: September 25, 2012

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Alternate Bear Creek Conveyance Channel Concept
- Katy-Hockley Storage Reservoir Concept
- Discuss objectives for comparing conceptual plans

Next meeting: 2:00pm, Tuesday,October 9, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: October 9, 2012

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Cost Estimate for Katy-Hockley Storage Strategy
- Improved Cost Estimate for Mound Creek Strategy
- Discussion of Hydrology and Hydraulic Considerations for the Channel Conveyance Strategy Considering Ultimate Development Conditions
- Planning Objectives for Evaluating the Strategies

Next meeting: 2:00pm, Tuesday,October 23, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: November 13, 2012

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

2:00pm Intro

2:05 Project schedule

Where we are

Discuss tasks for next several steering committee meetings

2:20 Discuss formation of stakeholder group and meeting

2:40 Environmental tasks update and presentation

3:00 Refined cost estimates presentation

3:15 2-dimensional hydraulic model presentation

3:45 Presentation of draft strategy evaluation objectives

4:00 End

Next meeting:

2:00pm, Tuesday,November 27, 2012
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT

Cypress Creek Overflow Study

JANUARY 22 WORKSHOP

AGENDA

2:00	Introduction
2:15	Group 1 + 2 Work Session
3:45	Group 1 + 2 Summary and Discussion of Results
4:20	Wrap Up / Next Steps
4:30	Adjourn

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: March 26, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

- Update on progress since last meeting
- Discuss the concept of what a complete management plan contains
- Discuss the plan evaluation criteria list
- Present the proposed plan
- Discuss how the plan addresses the interests of the entities represented in the steering committee
- Steering committee input

Next meeting:

2:00pm, Tuesday, April 9, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT

Cypress Creek Overflow Study

Steering Committee Meeting

April 9, 2013

AGENDA

2:00 Introductions

2:15 Summary of meetings with representatives of :
- U.S. Army Corps of Engineers
- West Houston Association
- Waller County
- Katy Prairie Conservancy

3:15 Discuss Steering Committee Interests and Concerns

4:20 Wrap Up / Next Steps

4:30 Adjourn

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000
www.hcfcd.org

MEETING AGENDA

Date: April 24, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

I. Summary of April 12, 2013 meeting with Corps of Engineers

II. Continued review of Management Plan #1
- Discussion of 1999 study by TAMU
- Discussion of recent rainfall/runoff comparisons
- Comments on proposed guidelines (pros and cons)
- Comments on proposed management plan physical features (pros and cons)

II. Introduction of Management Plan #2
- Overflow management in Cypress Watershed

III. Environmental Mitigation Limitations within the Addicks and Barker Project Area

Next meeting:

2:00pm, Tuesday, May 14, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

Date: May 14, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

Items to be Discussed:

2:00 pm Intro

2:05 Summary of data from rainfall on prairie, open space and developed area test sites

2:30 Discuss Management Plan #2
- Mound Creek Reservoir location/size
- Other Elements of Plan #2
- Strengths/Weaknesses of Plan #2

3:15 Discuss differences in drainage requirements between Management Plan #1 and #2

3:30 Discuss cost estimates for Management Plan #1 and #2

3:45 Next Steps/Path Forward

4:00 End

Next meeting:

2:00pm, Tuesday, May 28, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

DATE: June 11, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

DISCUSSIONS TOPICS

2:00 Introduction and Handouts

2:05 Management Plan #2 – Updates
- Revisions made since the May 14, 2013 meeting

2:15 Management Plan #3 (Private Sector Strategy)

2:45 Management Plan #4 (Addicks-Cypress Reservoir)

3:15 Management Plan #5 (Master Plan Strategy)

3:45 Study Schedule and Next Steps

NEXT MEETING: 2:00pm, Tuesday, June 25, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

MEETING AGENDA

DATE: June 25, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170
10555 Northwest Freeway

DISCUSSIONS TOPICS

2:00 Introduction and Handouts

2:05 Review of the Management Strategy Options

2:35 Individual Assignment

2:45 Group Discussion
- Goal is to identify 2 preferred options

NEXT STEPS:

- Preferred options:
  - Refine the 2 preferred options
  - Perform financial analysis
  - Develop implementation plans
- Draft interim development criteria for the upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Stakeholder meeting
- Public meeting

NEXT MEETING:

2:00 pm, Tuesday, July 9, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: July 23, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSIONS TOPICS

2:00 Introductions

2:05 Brief Review of Management Strategy Alternatives

2:20 Consider and Prioritize Management Strategies

2:40 Addicks Reservoir Watershed Update

2:55 Choose Two Preferred Management Strategies for Further Study

3:15 Stormwater Runoff Volume Assessment

NEXT STEPS:

- Preferred Management Strategies:
  - Refine the two preferred Management Strategies
  - Perform financial analysis
  - Develop implementation plans
- Finalize draft interim development criteria for the upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Stakeholder meeting (late summer/fall)
- Public meeting (fall)

NEXT MEETING:

2:00 pm, Tuesday, August 13, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: August 13, 2013

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSIONS TOPICS

2:00 Analysis of Future Conditions

2:15 HCFCD View on Need for a Regional Plan

2:30 Refinement of Plans #3 and #5

2:40 Implementation Strategy

3:15 Next Steps
- Further explore funding strategies
- Refine the implementation strategy

UPCOMING STEPS:

- Finalize draft interim development criteria for the upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Stakeholder meeting (late summer/fall)
- Public meeting (fall)

NEXT MEETING:

2:00 pm, Tuesday, August 27, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

DATE:	September 10, 2013
Time:	2:00 pm
Topic:	Cypress Creek Overflow Management Plan Steering Committee Meeting
Location:	Harris County Permits Building, Suite 170 (Room 123) 10555 Northwest Freeway

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DISCUSSIONS TOPICS

2:00 Welcome

2:10 Implementation Strategy

2:30 Cash Flow Analysis

3:15 Completion

UPCOMING STEPS:

- Finalize draft interim development criteria for the upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Benefit-Cost Analysis
- Stakeholder meeting (fall)
- Public meeting (fall)

NEXT MEETING:

2:00 pm, Tuesday, September 27, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: September 24, 2013

Time: 2:00 p.m.

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSION TOPICS

2:00 Welcome

2:10 Conservation and Environmental Mitigation

2:30 Implementation Strategy & Cash Flow Analysis (Management Plan 5)

3:15 Completion

UPCOMING STEPS:

- Public meeting (November 7, 2013)
- Finalize Draft Interim Development Criteria for the Upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Benefit-Cost Analysis
- Stakeholder meeting (fall)

NEXT MEETING:

2:00 p.m., Tuesday,October 8, 2013
Harris County Permits Building
10555 Northwest Freeway, Suite 170

DRAFT MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: October 8, 2013

Time: 2:00 p.m.

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSION TOPICS

2:00 Welcome

2:05 Bear Creek Overflow Conveyance Corridor

2:25 Community Value of the Regional Management Plans

3:20 Cash Flow Analysis – Alternative Participation Scenario

UPCOMING STEPS:

- Public meeting (November 7, 2013)
- Finalize Draft Interim Development Criteria for the Upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Benefit-Cost Analysis
- Stakeholder meeting (fall)

NEXT MEETING:

TBD
Harris County Permits Building
10555 Northwest Freeway, Suite 170

DRAFT MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: October 23, 2013

Time: 10:00 a.m.

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSION TOPICS

10:00 Welcome

10:05 Cash Flow Analysis –Alternative Participation Scenario

10:30 Alternative Funding Strategy – Special Purpose District

UPCOMING STEPS:

- Public meeting (November 7, 2013)
- Finalize Draft Interim Development Criteria for the Upper Cypress Creek and Addicks Reservoir watersheds within Harris County
- Benefit-Cost Analysis
- Stakeholder meeting (Fall)

NEXT MEETING:

TBD
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

DATE: November 26, 2013

Time: 2:00 p.m.

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DISCUSSION TOPICS

2:00 Welcome

2:05 Cash Flow Analysis

2:25 Plans 3 & 5 - Inundation Depth and Duration

2:45 Next Steps

- Prepare the draft report for TWDB
- Prepare a draft *Pathway for Implementation*
- Supplemental development criteria

NEXT MEETING:

January 21, 2014 (2nd Tuesday of the month)
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: February 4, 2014

Time: 2:00 p.m.

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSION TOPICS

2:00 Welcome

2:05 Consensus for a Regional Plan

2:55 Study Schedule Update

NEXT MEETING:

TBD
Harris County Permits Building
10555 Northwest Freeway, Suite 170

MEETING AGENDA

HARRIS COUNTY FLOOD CONTROL DISTRICT

9900 Northwest Freeway
Houston, TX 77092
713-684-4000

DATE: September 08, 2014

Time: 2:00 pm

Topic: Cypress Creek Overflow Management Plan
Steering Committee Meeting

Location: Harris County Permits Building, Suite 170 (Room 123)
10555 Northwest Freeway

DISCUSSIONS TOPICS

- Welcome
- Brief Review of Preferred Regional Management Plans
- Study Update
    - Benefit-Cost Ratio
    - Critical Conservation Area
    - Rainfall-Runoff Study
    - Development Guidelines
- Moving Forward with a Regional Plan
- Thank you

UPCOMING STEPS:

- Public meeting (September 25, 2014)
- Steering Committee Appreciation Event – October (date to be set)
- Submit draft report to TWDB (October 31, 2014)
- Development Guidelines to Commissioners Court (Fall 2014)
- Technical Plan to Commissioners Court (Year-End)

3 Stakeholder Meetings

3.1 February 2013 Stakeholder Meeting

3.1.1 Stakeholders Meeting Agenda

Cypress Creek Overflow Management Plan Stakeholder Meeting

February 12, 2013, 4:00-6:30 p.m.

Harris County Flood Control District North Service Center Pavilion

AGENDA

1. Introduction and Overview (Mike Garmon)
2. Magnitude of Overflow Problem (Burton Johnson)
3. Constraints (Burton Johnson)
4. Environmental Studies (Burton Johnson)
5. Strategies (Kevin Shanley)

BREAK

REVIEW HANDOUTS

6. Q&A and Discussion (Moderator – Mike Garmon; Panel - Alan Potok, Mike Garmon, Burton Johnson, Kevin Shanley)

Cypress Creek Overflow Management Plan

Stakeholder Meeting
February 12, 2013

Texas Water Development Board

Purpose of this Meeting

1. Report the current status of the study
2. Inform interested stakeholders about concepts being considered
3. Hear comments back
4. Respond to questions to the best of our ability

Texas Water Development Board

Reasons for the Planning Effort

- Development is inevitable
- Complex flooding problem
- Limited drainage network
- District's role in management of drainage network
- Need to balance development with other environmental and community interests

Texas Water Development Board

Texas Water Development Board Grant

- Applied for TWDB Flood Protection Planning Grant on January 11, 2012
- Timeframe for completion: February 2014
- 50-50 Costshare: TWDB $750k and HCFCD $750k

Texas Water Development Board

Planning Effort - Engineering

- Quantify and delineate flood risk
- Estimate flood mitigation requirements
- Set basic goals for regional strategy

Texas Water Development Board

Planning Effort - Environmental

- Estimate benefits of prairie restoration for flood control
- Identify critical conservation areas
- Investigate mitigation bank requirements and options
- Consideration of regional/community enhancements

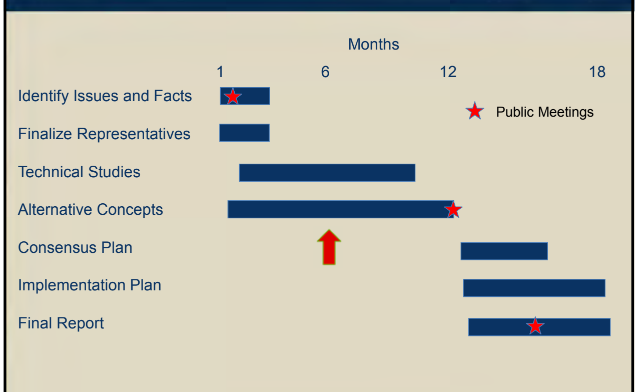
Texas Water Development Board

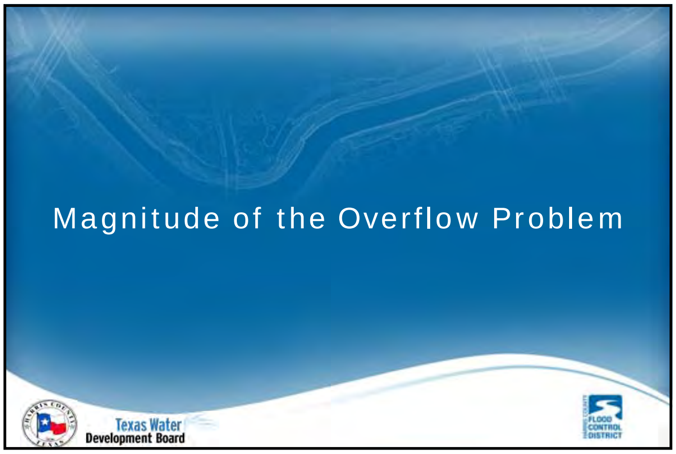
Planning Effort – Business Plan

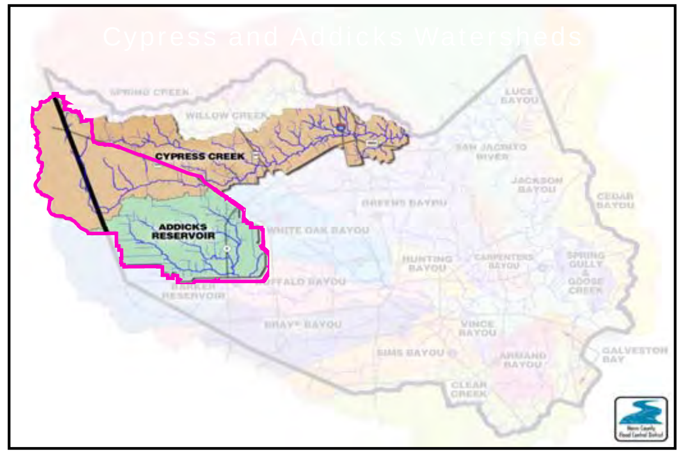
- Cost pro forma – eligible regional facilities
- Cash flow analysis
- Roles and responsibilities
- Land acquisition
- Guidelines for development
- Implementation Plan

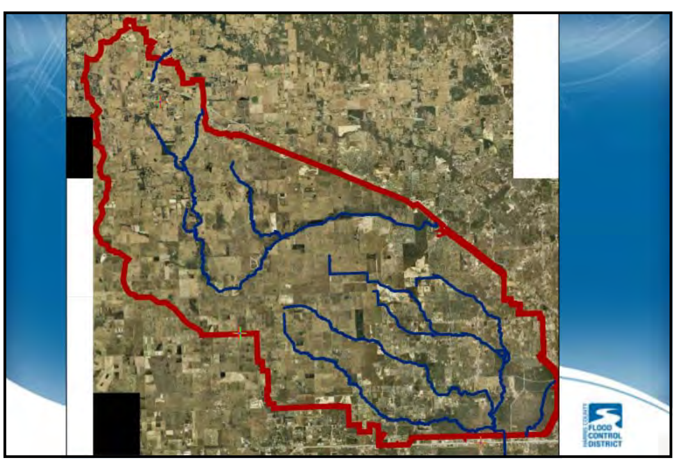
Texas Water Development Board

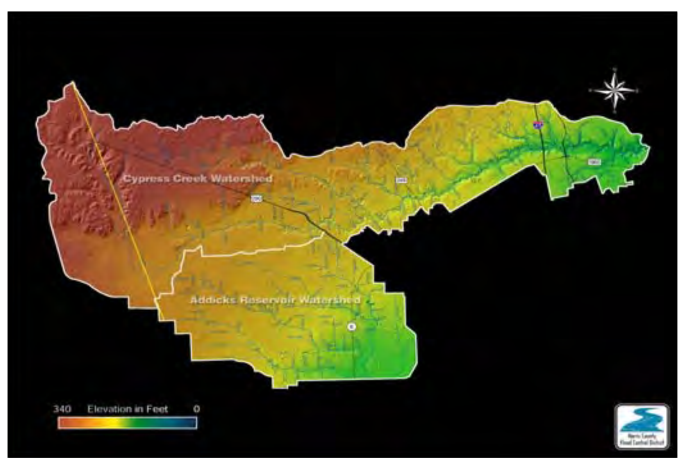
Planning Effort Schedule

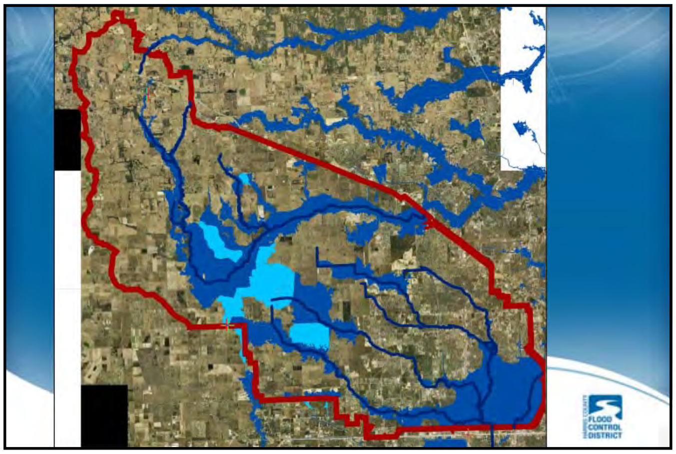


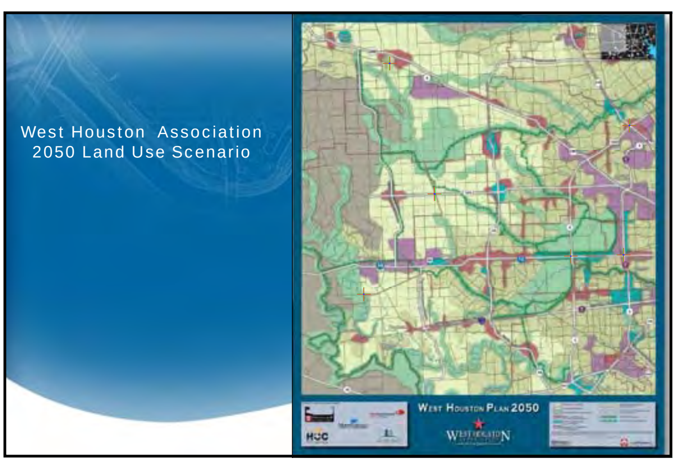

Magnitude of the Overflow Problem
Texas Water
Development Board
FLOOD
CONTROL
DISTRICT

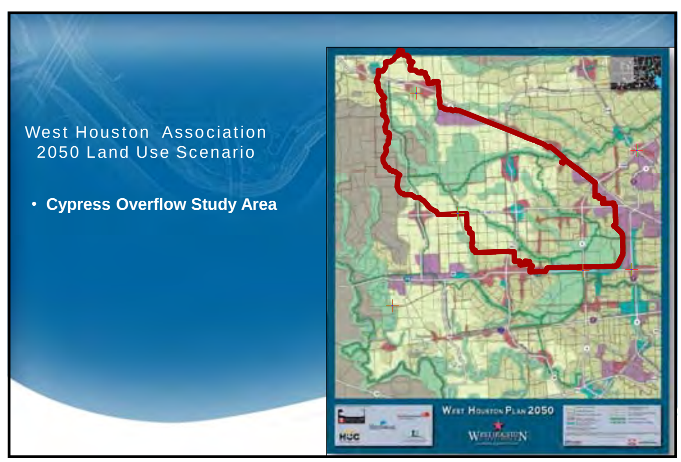

Cypress and Addicks Watersheds
SPRING CREEK
WILLOW CREEK
CYPRESS CREEK
ADDICKS
RESERVOIR
LUCE
BAYOU
SAN JACINTO
RIVER
JACKSON
BAYOU
CEDAR
BAYOU
GREENS BAYOU
WHITE OAK BAYOU
HUNTING
BAYOU
CARPENTERS
BAYOU
SPRING
GULLY
&
GOOSE
CREEK
BARKER
RESERVOIR
BRAYS BAYOU
VINCE
BAYOU
SIMS BAYOU
ARMAND
BAYOU
GALVESTON
BAY
CLEAR
CREEK

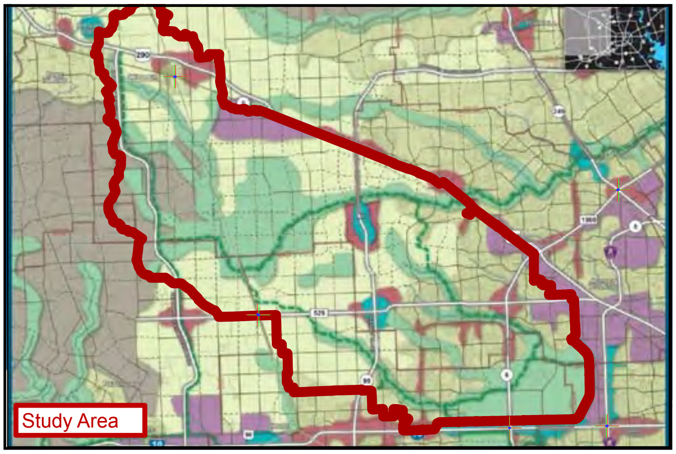

FLOOD
CONTROL
DISTRICT

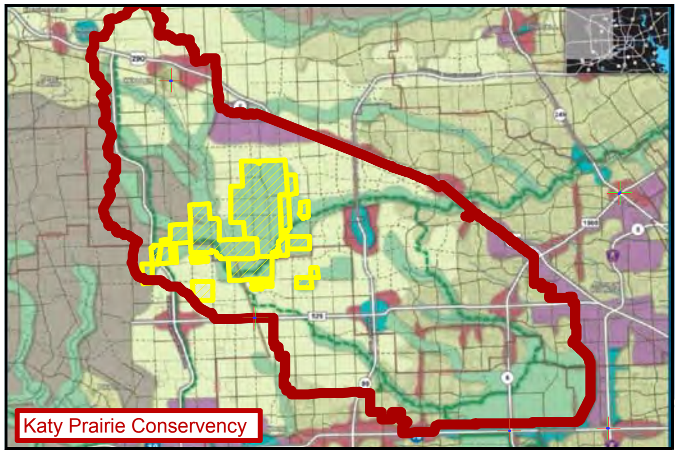

Cypress Creek Watershed
Addicks Reservoir Watershed
340 Elevation in Feet 0

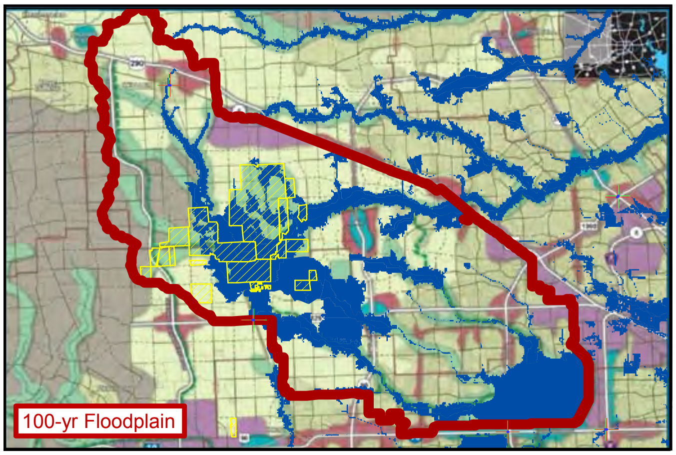

FLOOD
CONTROL
DISTRICT

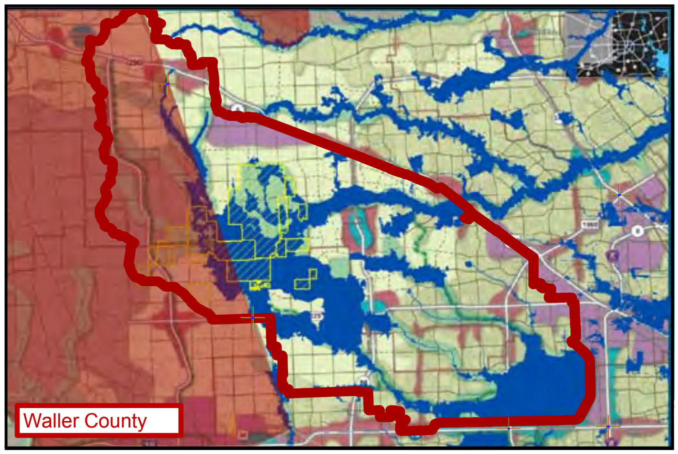

West Houston Association
2050 Land Use Scenario
West Houston Plan 2050

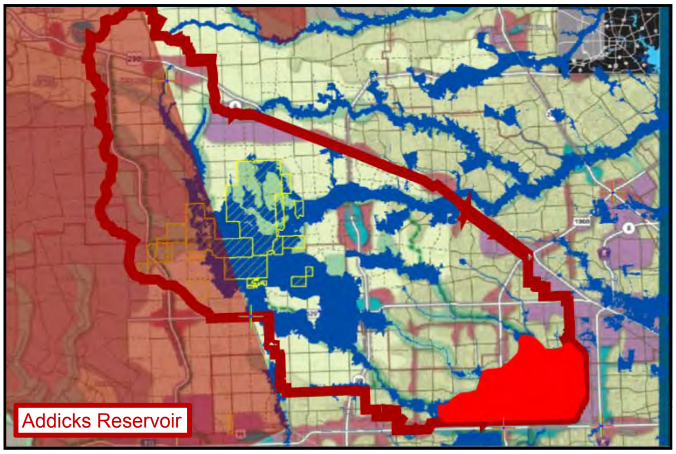

West Houston Association
2050 Land Use Scenario
• Cypress Overflow Study Area
West Houston Plan 2050

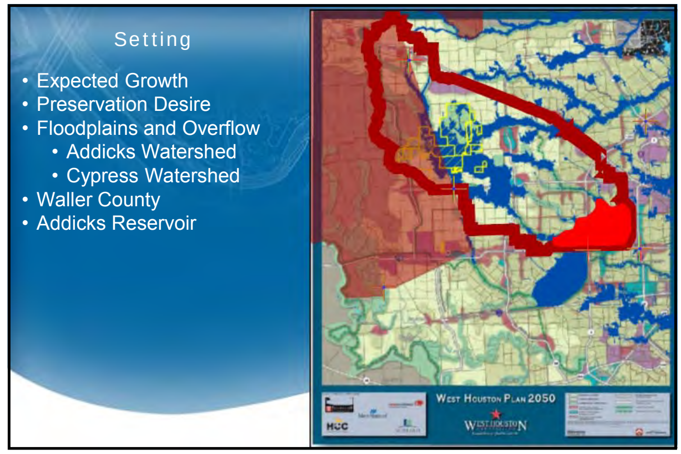

Study Area

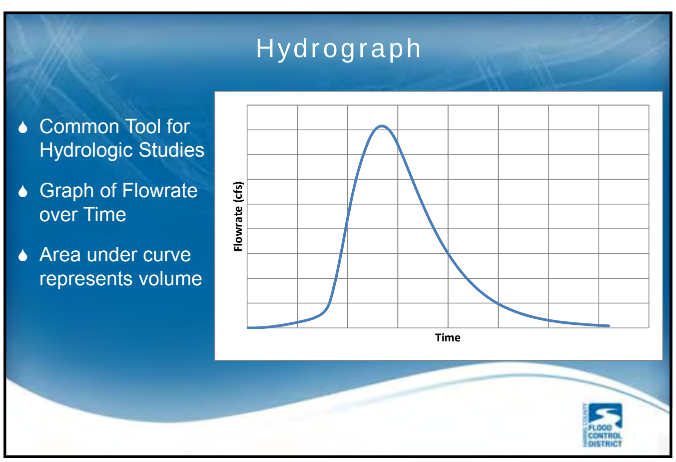

Katy Prairie Conservency

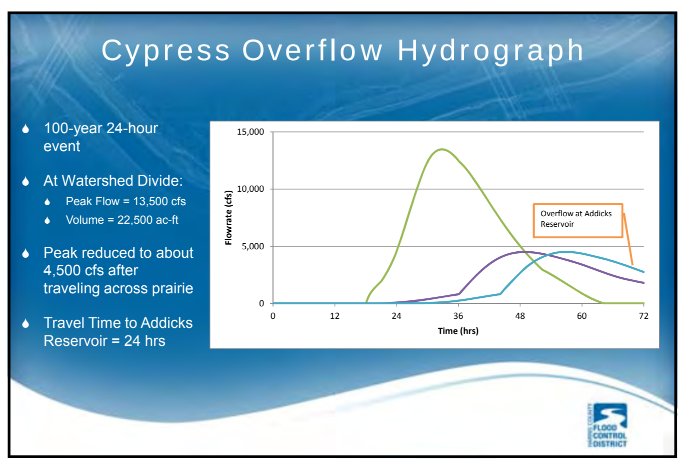

100-yr Floodplain


Waller County


Addicks Reservoir

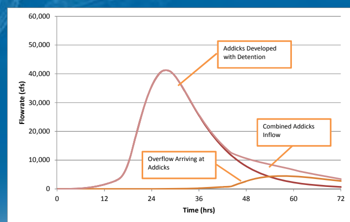

Setting
• Expected Growth
• Preservation Desire
• Floodplains and Overflow
• Addicks Watershed
• Cypress Watershed
• Waller County
• Addicks Reservoir
West Houston Plan 2050


Hydrograph
Common Tool for Hydrologic Studies
Graph of Flowrate over Time
Area under curve represents volume
Flowrate (cfs)
Time


Cypress Overflow Hydrograph
100-year 24-hour event
At Watershed Divide:
Peak Flow = 13,500 cfs
Volume = 22,500 ac-ft
Peak reduced to about 4,500 cfs after traveling across prairie
Travel Time to Addicks Reservoir = 24 hrs
15,000
10,000
5,000
0
Flowrate (cfs)
0
12
24
36
48
60
72
Time (hrs)
Overflow at Addicks Reservoir

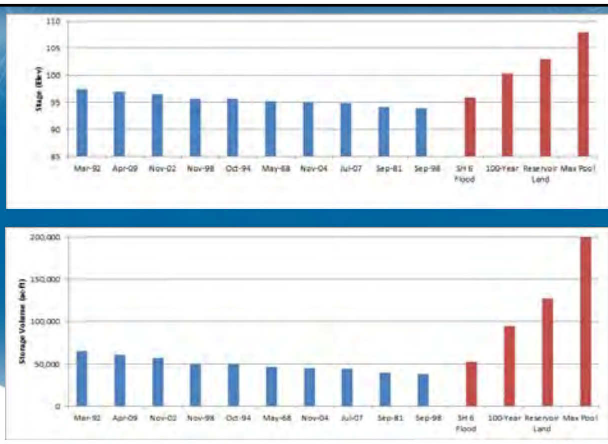
Total Reservoir Inflow Interaction

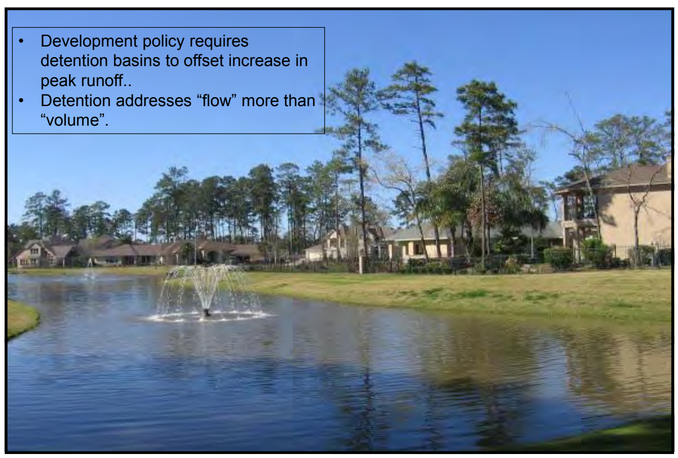
- 100-year 24-hour Event
- Combined hydrographs from Addicks and Overflow
- Addicks Watershed Peak Flow – about 41,000 cfs
- Local runoff about one day ahead of overflow hydrograph



Constraints

- Addicks Reservoir Tributary Channels
  - Bear Creek, S. Mayde Creek, Langham Creek
- Cypress Creek
- Addicks Reservoir
- Waller County
- FEMA Requirements
- Environmental Policy
- Economic



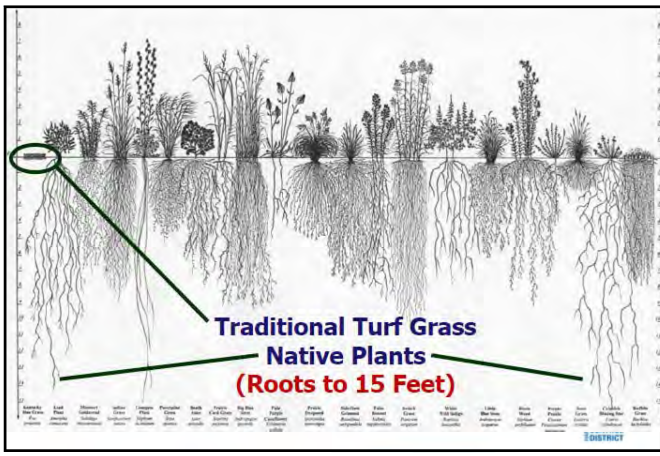


Constraints

Constraints

- Addicks Reservoir Tributary Channels
  - Bear Creek, S. Mayde Creek, Langham Creek
- Cypress Creek
- Addicks Reservoir
- Waller County
- FEMA Requirements
- Environmental Policy
- Economic

Environmental Studies



Effect of Prairie Grass on Runoff Literature Review

- Often cited – native prairie grass increases infiltration capacity of soil
- All citations point back to only two studies
  - Both studies were related to agricultural impact on soil infiltration
  - Compared to native prairie and restored prairie
- Our study could be significant

Preliminary Conclusions

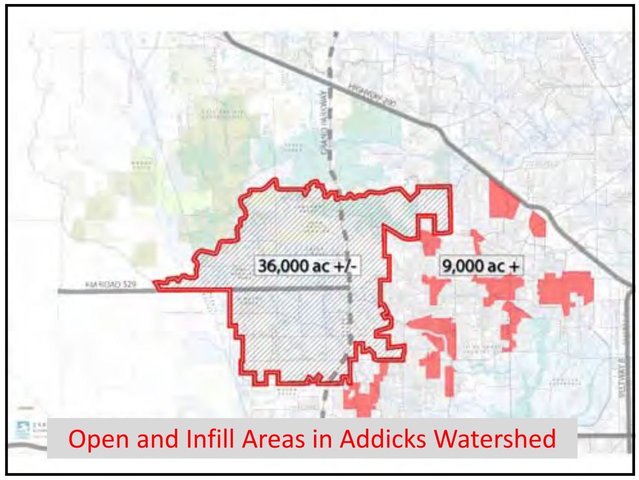
- Research suggests that native prairie has substantially better absorption capability, even in “poorly draining” soil
- The ability to achieve this through restoration is uncertain
- The timeline to establish through restoration is uncertain
- Agricultural activity (row crops, grazing) has a substantial and adverse impact to soil infiltration
- Prairie restoration has the potential to notably increase soil infiltration – Estimate a 1:1 development/mitigation ratio

Strategies

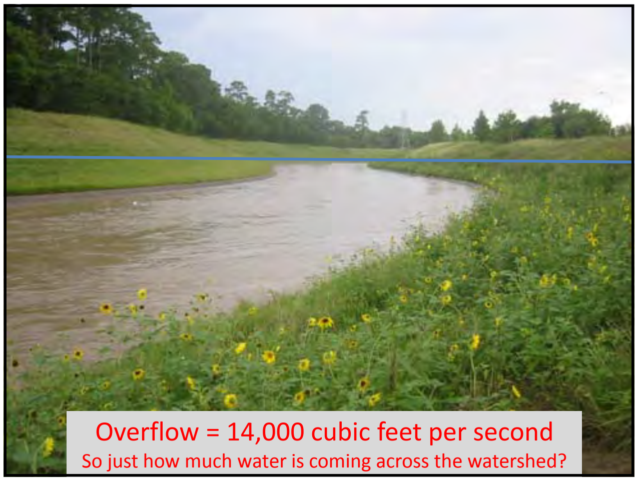
Scales

Overflow Management Strategies

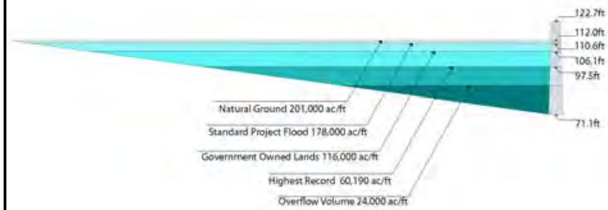
- First prepare “Bookend” approaches
- Evaluate each Bookend approach separately
- Consider combinations of approaches
- Develop recommended approach



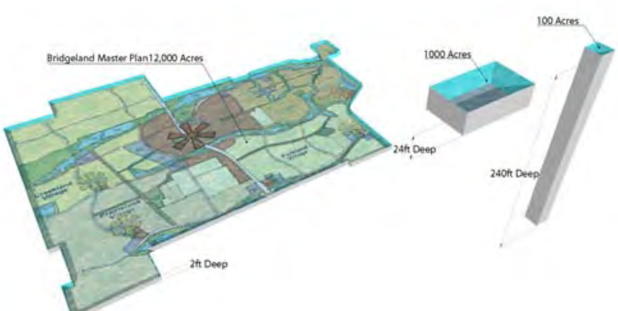
Open and Infill Areas in Addicks Watershed



Overflow = 14,000 cubic feet per second
So just how much water is coming across the watershed?



Addicks Reservoir Capacity
Just how much room is there in the reservoir?



24,000 acre/feet
Just how much water is that?

Approaches

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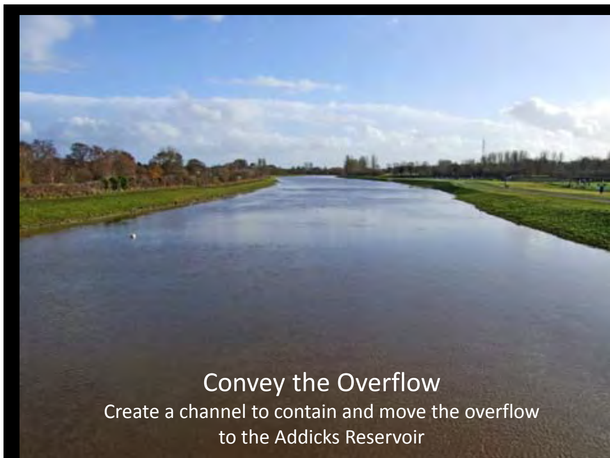
Bookend Solutions

Each one a single approach – like a story



Convey the Overflow

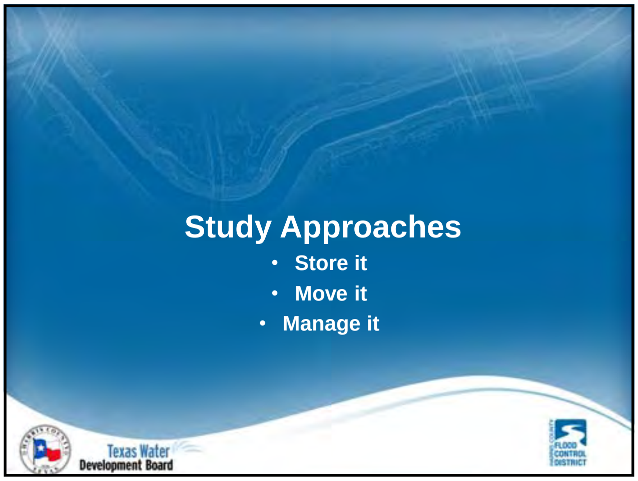
Create a channel to contain and move the overflow to the Addicks Reservoir

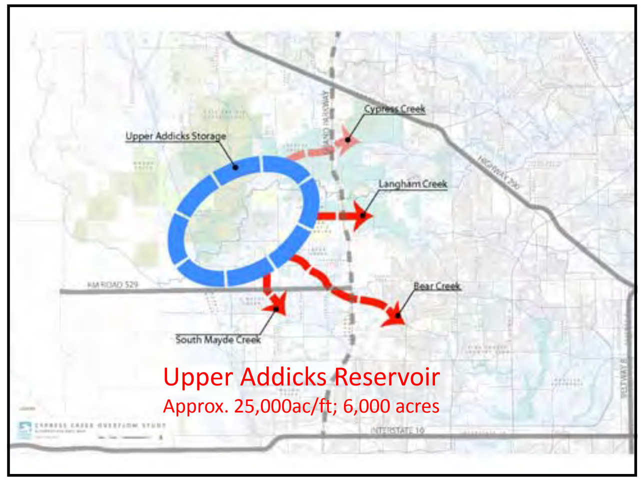
Store the Overflow

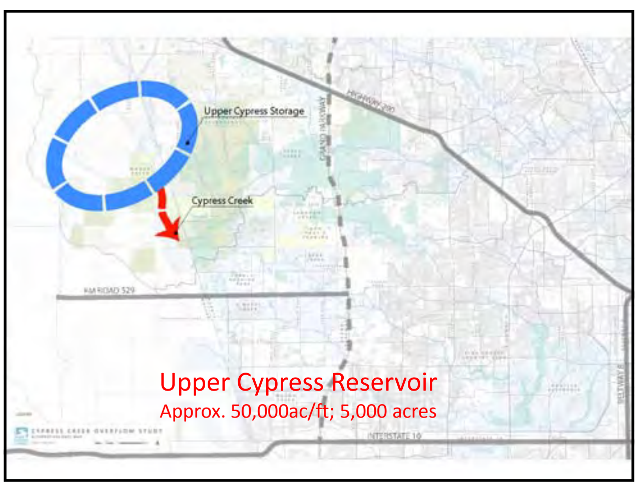
Create a reservoir to act as a giant detention basin

Manage the Overflow

Create development standards and stormwater regulations to allow continued development in the watershed

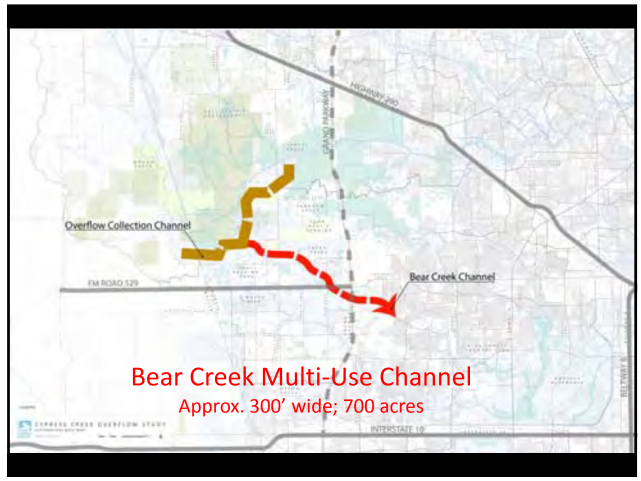

Study Approaches
• Store it
• Move it
• Manage it
Texas Water Development Board
FLOOD CONTROL DISTRICT


Upper Addicks Storage
Cypress Creek
Langham Creek
Bear Creek
South Mayde Creek
FM ROAD 529
Upper Addicks Reservoir
Approx. 25,000ac/ft; 6,000 acres

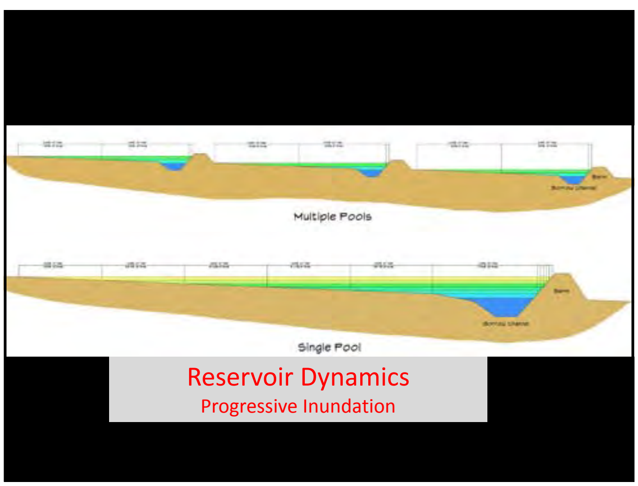

Upper Cypress Storage
Cypress Creek
HIGHWAY 290
FM ROAD 529
Upper Cypress Reservoir
Approx. 50,000ac/ft; 5,000 acres


Reservoir
(Dry almost all of the time)

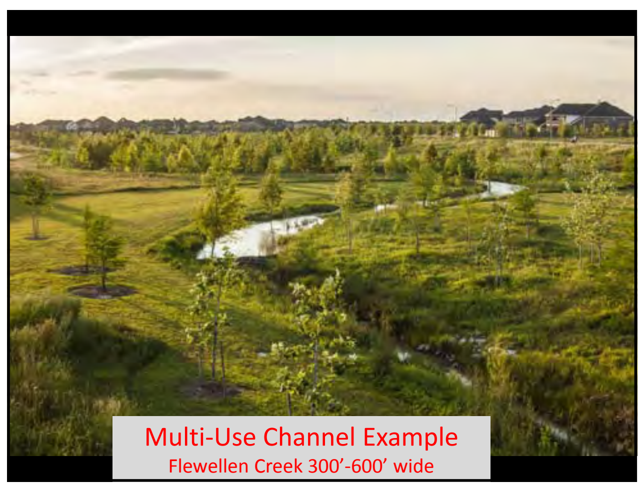
Reservoir
(Filling only very rarely)



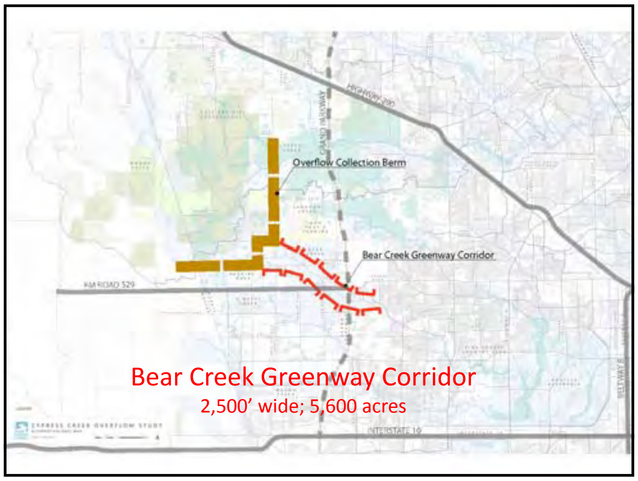
Bear Creek Multi-Use Channel
Approx. 300' wide; 700 acres



Reservoir Dynamics
Progressive Inundation



Multi-Use Channel Example
Flewellen Creek 300'-600' wide



Non-Structural Approaches

- Overflow Area Preservation
- Overflow Development Criteria
- Overflow Protection Zone

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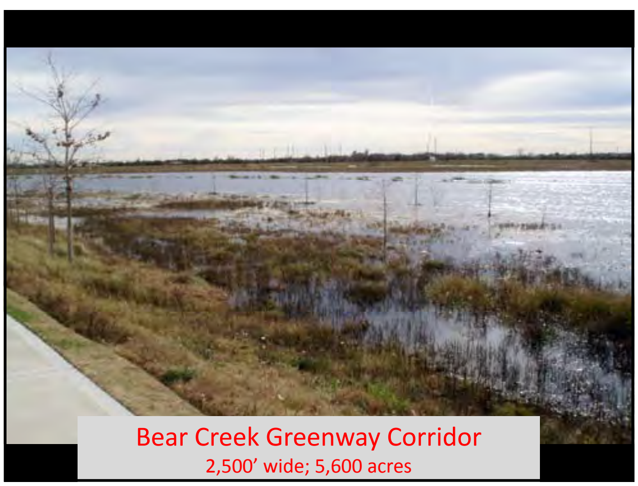
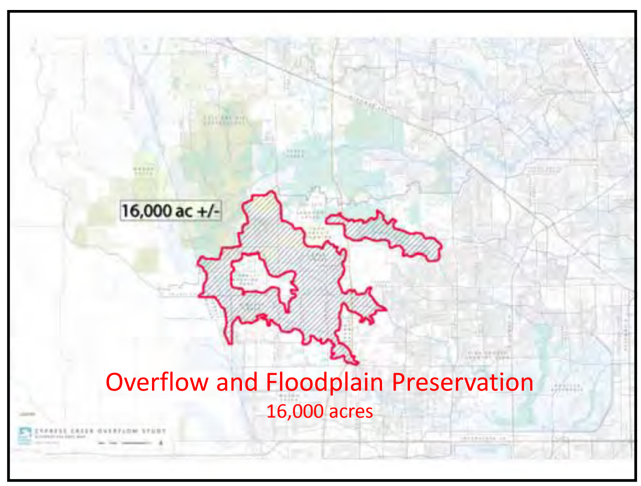
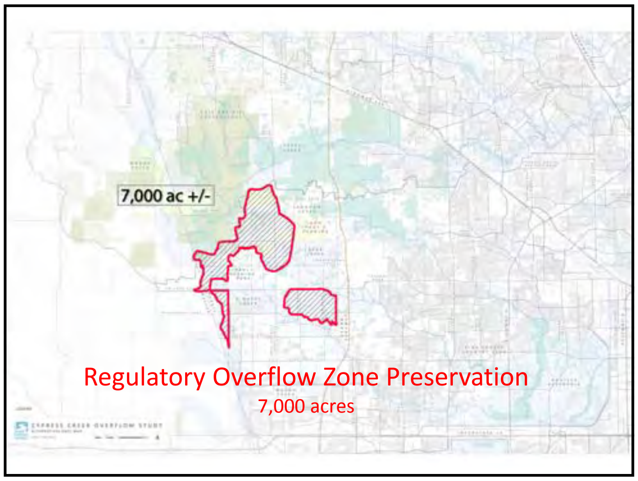
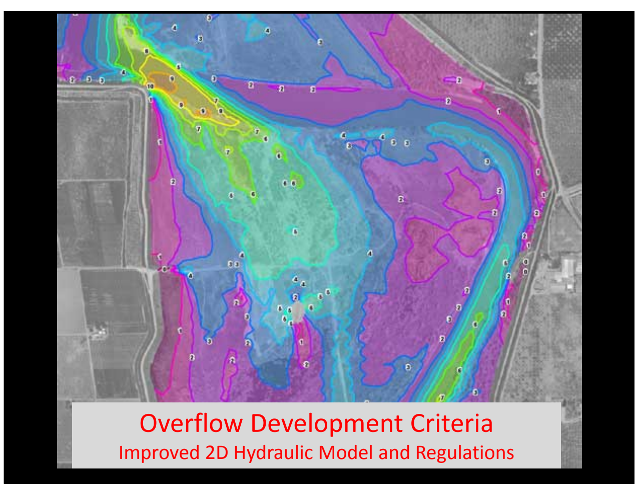
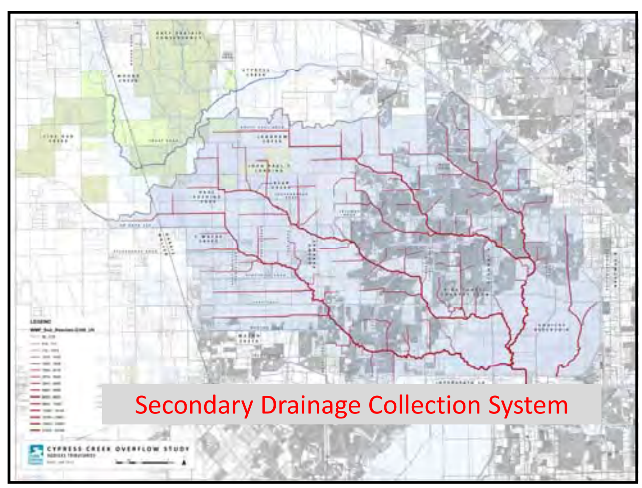





7,000 ac +/-
Regulatory Overflow Zone Preservation
7,000 acres


Overflow Protection Zone
Manage overflow zone like a traditional floodway


Overflow Development Criteria
Improved 2D Hydraulic Model and Regulations


Secondary Drainage Collection System

Non-Structural Supplemental Approaches

- Volume Management:
  - Prairie Restoration
  - Addicks Watershed High Flow Retention
- Flow Rate Management:
  - Upper Cypress Extended Detention
  - Runoff Reduction Incentives

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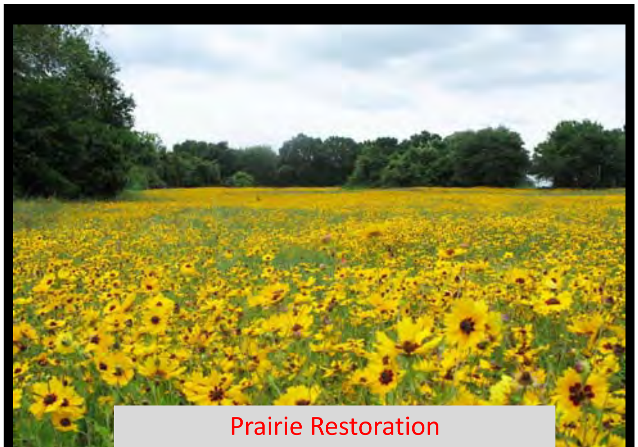
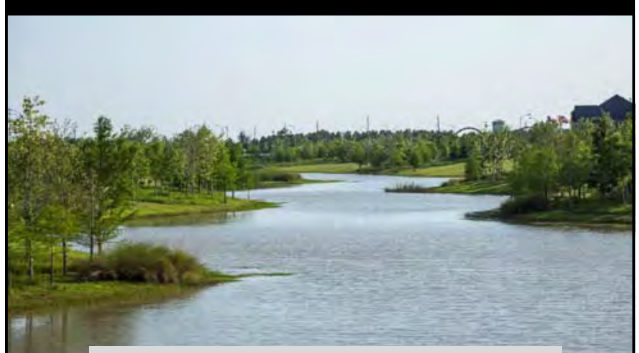
Addicks High Flow Retention
Evaporate/transpire development mitigation volume



Prairie Restoration
Reduces volume of runoff



Upper Cypress Extended Detention
Reduce overflow with reduced peak flows


Break….
Questions & Discussion
Wrap-up
Texas Water
Development Board
FLOOD
CONTROL
DISTRICT

3.1.3 Stakeholders Meeting List of Invitees

CCOMP Meeting of Interested Stakeholders
Invitees

FIRST NAME	LAST NAME	ORGANIZATION	CITY	STATE	ZIP
Russ	Poppe	HCPID	Houston	TX	77002
Jennifer	Lorenz	Bayou Land Conservancy	Houston	TX	77070
Richard	Long	US Army Corps of Engineers	Houston	TX	77077
Joshua	Stuckey	HCPID	Houston	TX	77092
Mike	Fitzgerald	Brown & Gay Engineers, Inc.	Houston	TX	77042
Randy	Jones	Terra Visions, LLC	Houston	TX	77055
Gene	Schmidt	City of Waller, Floodplain Administrator	Waller	TX	77484
Claude	Yoas	Cypress Fairbanks ISD	Houston	TX	77064
Melvin G.	Spinks	Cy-Fair Chamber of Commerce	Cypress	TX	77429
Jack	Sakolosky	Cypress Creek Flood Control Coalition/Bayou Preservation Association	Houston	TX	77070
Jim	Robertson	Cypress Creek Greenway Coalition	Houston	TX	77070
Dick	Smith	Cypress Creek Flood Control Coalition	Cypress	TX	77429
Brad	Tucker	Mustang Tractor & Equipment	Houston	TX	77040
Randal	Arbuckle	Lario Land Consultants	Houston	TX	77043
Mike	Voinis	Halff Associates	Houston	TX	77079
Raymond	DeBock	Harris Co. UD #6	Houston	TX	77084
Charles	Smith	Bear Creek Homeowner	Houston	TX	77084
Randy	Schilhab	Commissioner Radack, Harris County Precinct 3	Houston	TX	77084
Pamela	Rocchi	Commissioner Cagle, Harris County Precinct 4	Houston	TX	77067
Mike	Owens	MUD 374	Cypress	TX	77433
Lorna	Winoske	Morton Road MUD	Houston	TX	77084
David	Molina	HC MUD 165	Cypress	TX	77433
Peter	Houghton	Howard Hughes Corporation	Cypress	TX	77433
David	Nelson	Nelson Farms	Bellville	TX	77418
Mary Anne	Piacentini	Katy Prairie Conservancy	Houston	TX	77098

Wesley	Newman	Katy Prairie Conservancy	Waller	TX	77484
Wes	Birdwell	Halff Associates	Austin	TX	78759
Pat	Nguyen		Houston	TX	77084
Helen	Drummond	Houston Audubon Society	Houston	TX	77079
George	Carmichael	Carmichael Development Company	Houston	TX	77027
Donald	Durgin	Bear Creek Resident	Houston	TX	77084
Mary	Sullivan	NWHC MUD 12	Katy	TX	77449
Jim	Coody	Wetlands Professional Services	Houston	TX	77041
Brandt	Mannchen	Houston Sierra Club	Houston	TX	77096
Michael	Schaffer	City of Houston Planning and Development	Houston	TX	77002
Evelyn	Merz	Houston Sierra Club	Houston	TX	77061
Yancy	Scott	Waller County	Hempstead	TX	77445
Kent	Puckett	Caldwell Companies	Houston	TX	77064
Roger	Hord	West Houston Association	Houston	TX	77024
Ty	Kelly	Bayou Preservation Association	Houston	TX	77046
William	Drohan	City of Katy	Katy	TX	77493
Stephen	Wilcox	Costello. Inc.	Houston	TX	77042
Stephen	Costello	Costello, Inc.	Houston	TX	77042
Jim	Willis	Wildlife Habitat Federation	Cat Spring	TX	78933
Bradford	Wilcox	Texas A&M University Ecosystem Science & Mgt	College Station	TX	77843
Mark	Kilkenny	Mischer Investments	Houston	TX	77046
Gilbert	Ward	Texas Water Development Board, Flood Mitigation Planning	Austin	TX	78711
David	Poteet		Katy	TX	77491

SUPPORT TEAM

Mohamed	Bagha	Michael Baker Jr. Inc.			
Stephen	Benigno	HCFCD			
Gary	Bezemek	HCFCD			
Glenda	Callaway	HCFCD			
Ingrid	Fairchild	HCFCD			
Fred	Garcia	HCFCD			
Mike	Garmon	HCFCD			
Alem	Gebriel	HCFCD			
Janice	Gray	HCFCD			
Ataul	Hannan	HCFCD			
Kim	Jackson	HCFCD			
Burton	Johnson	Michael Baker Jr. Inc.			
Glenn	Laird	HCFCD			
Hannah	Pietsch	HCFCD			

Alan	Potok	HCFCD			
Shandra	Puckett	HCFCD			
David	Randolph	HCFCD			
David	Saha	HCFCD			
Kevin	Shanley	SWA			
Mike	Talbott	HCFCD			
James	Vick	SWA			
Beth	Walters	HCFCD			
Carl	Woodward	HCFCD			

3.1.4 *Stakeholders Meeting List of Attendees*

CCOMP Meeting of Interested Stakeholders Attendees

FIRST NAME	LAST NAME	ORGANIZATION
Wes	Birdwell	Halff Associates
Raymond	DeBock	Harris Co. UD #6
Helen	Drummond	Houston Audubon Society
Roger	Hord	West Houston Association
Deborah	January-Bevers	Regional Land and Water Task Force
Ty	Kelly	Bayou Preservation Association
Richard	Long	US Army Corps of Engineers
Wesley	Newman	Katy Prairie Conservancy
Robert	Rayburn	Bayou Preservation Association
Jim	Robertson	Cypress Creek Greenway Coalition
Pamela	Rocchi	Commissioner Cagle, Harris County Precinct 4
Jack	Sakolosky	Cypress Creek Flood Control Coalition/Bayou Preservation Association
Yancy	Scott	Waller County
Dick	Smith	Cypress Creek Flood Control Coalition
Pete	Smullen	Cypress Creek Flood Control Coalition
Melvin G.	Spinks	Cy-Fair Chamber of Commerce
Joshua	Stuckey	HCPID
Mary	Sullivan	NWHC MUD 12
Mike	Voinis	Halff Associates
Stephen	Benigno	HCFCD
Glenda	Callaway	HCFCD
Fred	Garcia	HCFCD
Mike	Garmon	HCFCD
Janice	Gray	HCFCD
Burton	Johnson	Michael Baker Jr. Inc.
Hannah	Pietsch	HCFCD
Alan	Potok	HCFCD
Shandra	Puckett	HCFCD
David	Saha	HCFCD
Kevin	Shanley	SWA
Mike	Talbott	HCFCD
James	Vick	SWA
Beth	Walters	HCFCD
Carl	Woodward	HCFCD

3.2 May 2014 Stakeholders Meeting

3.2.1 Cypress Creek Overflow Management Plan Stakeholder Meeting

May 20, 2014, 2:00 – 4:00 p.m.

Harris County Flood Control District North Service Center Pavilion

AGENDA

1. Welcome (Mike Talbott)
2. Introduction and Overview (Dena Green)
3. Presentation (Burton Johnson)
    - Rainfall/Runoff Study
    - Technical Plan
    - Funding and Implementation Plan
    - Supplemental Development Criteria
4. Q&A and Discussion (Dena Green)

Meeting Format

- Welcome and Introductions
- Presentation
- Q&A and Comments

Texas Water Development Board

Texas Water Development Board Grant

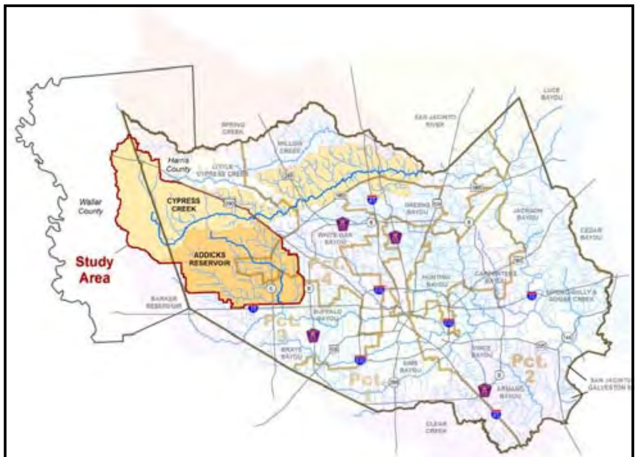
- Grant to Harris County and Harris County Flood Control District
- Contract initiation date : April 19, 2012
- Executed contract: July 2, 2012
- Contract completion date: October 31, 2014
- 50-50 Cost-share: TWDB $750k | HCFCD $750k

Texas Water Development Board

Presentation Topics

- Background
- Rainfall/Runoff Study
- Technical Plan
- Funding and Implementation Plan
- Supplemental Development Criteria

Texas Water Development Board

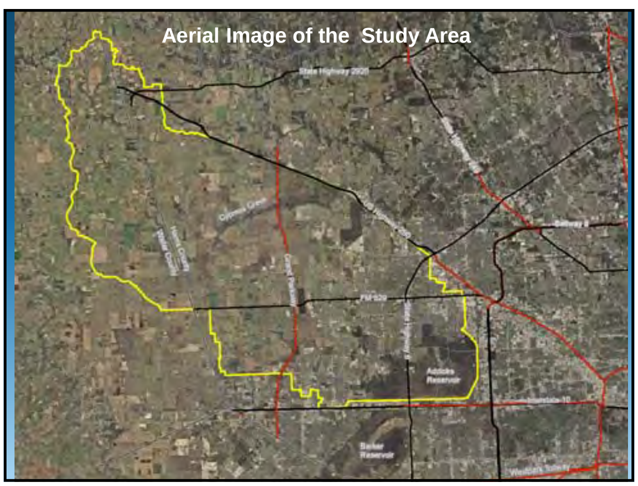


Study Area = 277 square miles

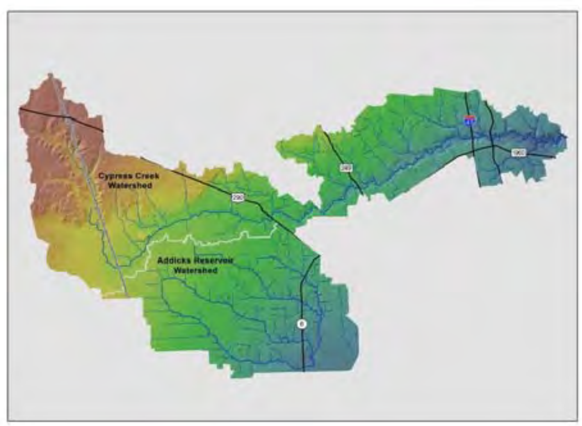
Objectives of this Planning Effort

- Identify a regional plan to manage overflow from Cypress Creek to help mitigate flood risk.
- Balance competing interests of land use preservation, business interests, reservoir operations and environmental mitigation needs during the process.
- Develop a business plan to implement regional strategies.
- Implement appropriate policies to manage the unique hydrologic conditions.

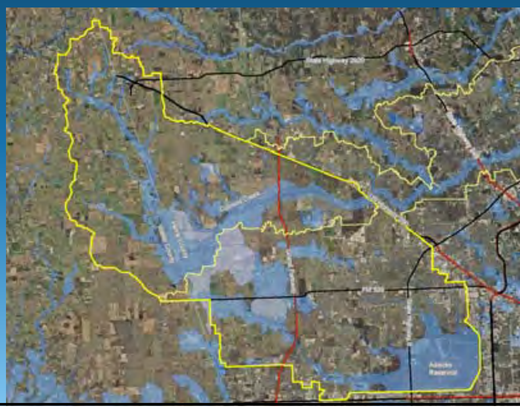
Texas Water Development Board



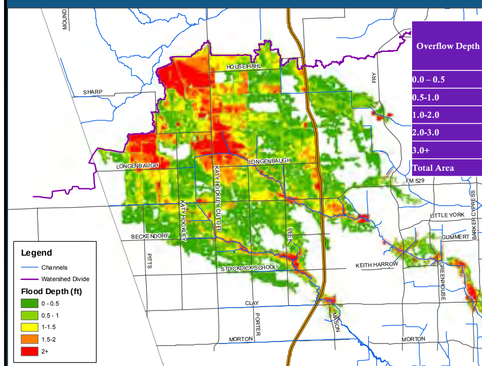
Why the Overflow Occurs



Effective Floodplains and Overflow Map (1% Annual Chance Event)

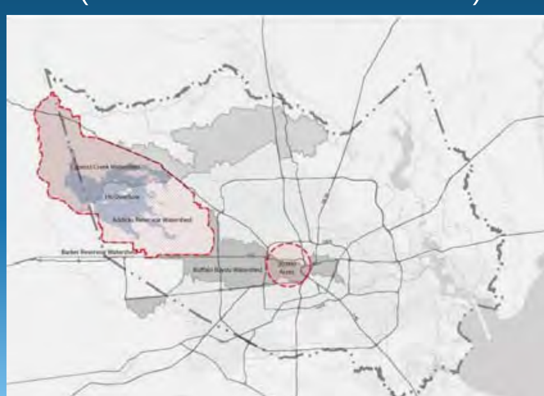


Depth Extent of the Overflow (1% Annual Chance)

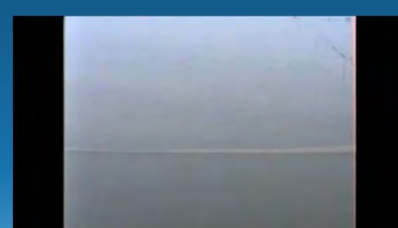


Overflow Depth (feet)	10% (10-year) (acres)	1% (100-year) (acres)
0.0 – 0.5	4,376	7,695
0.5-1.0	1,980	5,045
1.0-2.0	1,993	5,485
2.0-3.0	190	1,672
3.0+	67	941
Total Area	8,645	20,838

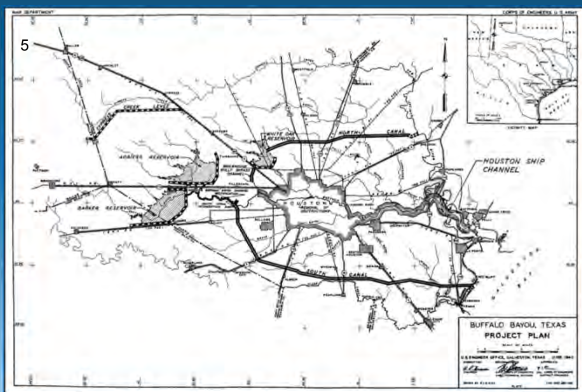
Magnitude of the Overflow Area (1% Annual Chance Event)



Video of October 1998 Overflow

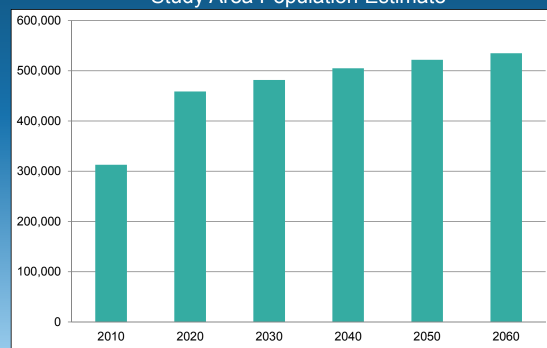


1940 Corps Project Plan

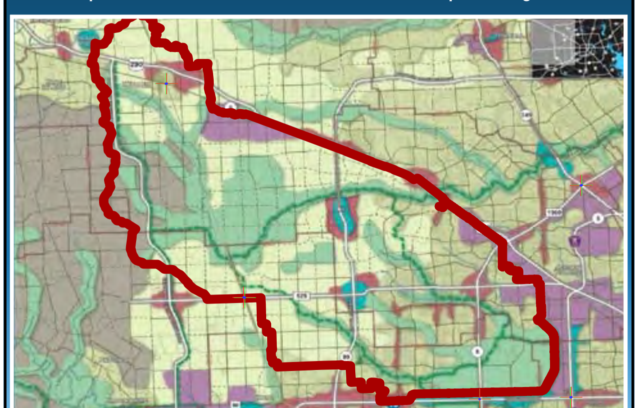


Anticipated Growth

(Region H Water Planning Group Population Projections)



Excerpt from 2010 WHA's 2050 Land Use Scenario Map as Background



HCFCD's Interest in the Overflow

- Dramatic land use changes are predicted
- Unique hydrologic conditions in study area:
  - Existing overflow
  - Drains to reservoirs with finite capacity
    - When water is released, can affect downstream flooding
    - When water is not released, can affect upstream flooding
- Confirm current design criteria are applicable
- Preserve the flood attenuation provided by current land cover (or replace it)
- No Adverse Impact on existing communities within or downstream of the study area.

Steering Committee

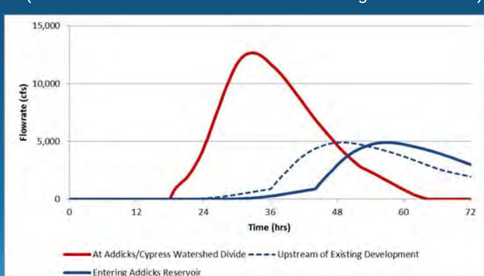
- Harris County Flood Control District
- Harris County Public Infrastructure Department
- Harris County Precinct 3
- Harris County Precinct 4
- City of Houston
- Waller County
- Corps of Engineers
- Bayou Preservation Association
- Katy Prairie Conservancy
- West Houston Association

Presentation Topics

- Background
- Rainfall/Runoff Study
- Technical Plan
- Funding and Implementation Plan
- Supplemental Development Criteria

Cypress Creek Overflow Hydrograph

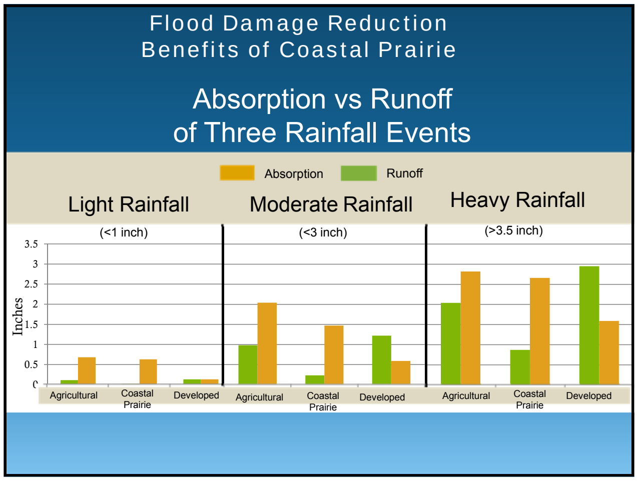
(1% Annual Chance Event – Existing Conditions)



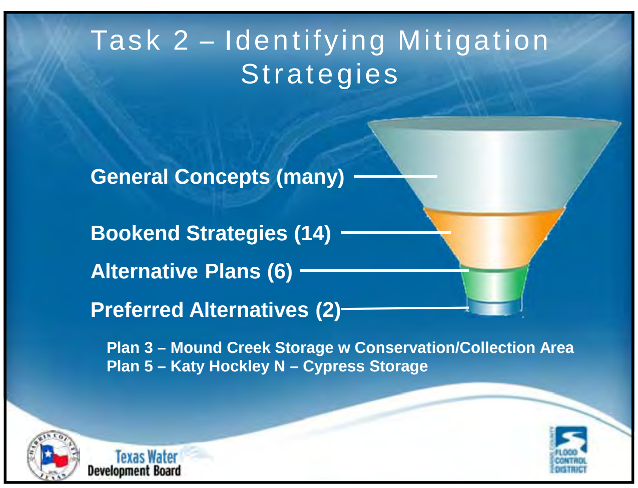
- Overflow at the Watershed Divide = 12,700 cfs
- Peak reduced to about 5,000 cfs after traveling across open space
- Travel Time to Addicks Reservoir = 24 hrs.
- Volume of Overflow = 23,000 acre-feet

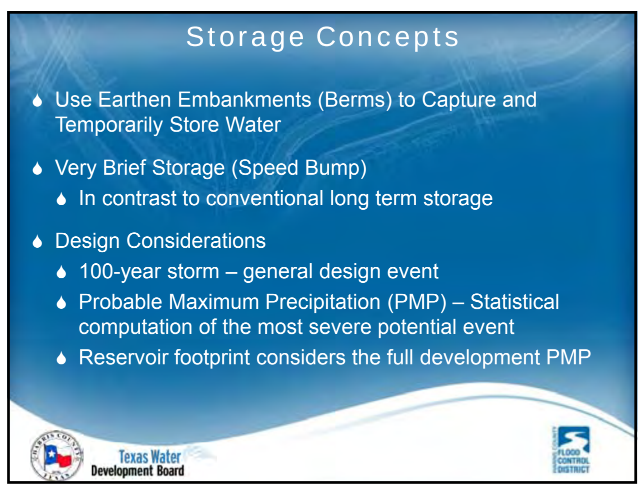
Benefits of Prairie Restoration for Flood Control

- Three land cover types: Native Prairie, Open Space, Developed
- Each site equipped with rainfall/runoff measuring gauges


Flood Damage Reduction
Benefits of Coastal Prairie
Absorption vs Runoff
of Three Rainfall Events
Absorption
Runoff
Light Rainfall
Moderate Rainfall
Heavy Rainfall
(<1 inch)
(<3 inch)
(>3.5 inch)
Inches
3.5
3
2.5
2
1.5
1
0.5
0
Agricultural
Coastal Prairie
Developed
Agricultural
Coastal Prairie
Developed
Agricultural
Coastal Prairie
Developed


Presentation Topics
Background
Rainfall/Runoff Study
Technical Plan
Funding and Implementation Plan
Supplemental Development Criteria
Texas Water Development Board
Flood Control District


Task 2 – Identifying Mitigation Strategies
General Concepts (many)
Bookend Strategies (14)
Alternative Plans (6)
Preferred Alternatives (2)
Plan 3 – Mound Creek Storage w Conservation/Collection Area
Plan 5 – Katy Hockley N – Cypress Storage
Texas Water Development Board
Flood Control District


Storage Concepts
Use Earthen Embankments (Berms) to Capture and Temporarily Store Water
Very Brief Storage (Speed Bump)
In contrast to conventional long term storage
Design Considerations
100-year storm – general design event
Probable Maximum Precipitation (PMP) – Statistical computation of the most severe potential event
Reservoir footprint considers the full development PMP
Texas Water Development Board
Flood Control District

Reservoir
(Dry most of the time)

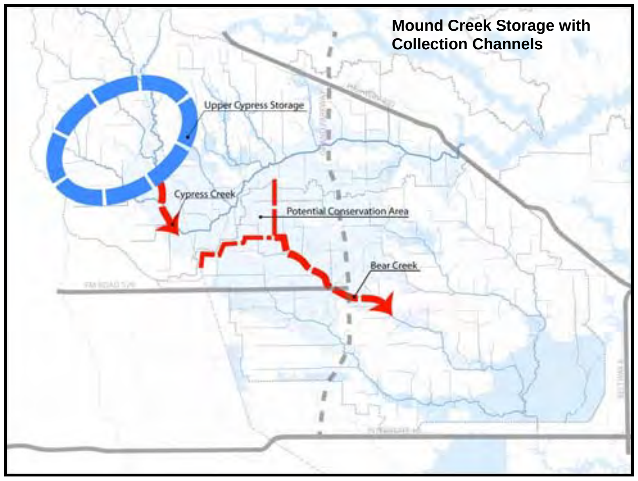
Reservoir
(Fills Infrequently)

Conveyance Channel Concepts

- "Stream Corridor" Concept
  - Wide corridor
  - Could not be used in developed areas
- Low Flow Channel
  - Meandering
  - Design to incorporate natural channel features
- Potential for on-line storage
- Potential for multi-use

Texas Water Development Board

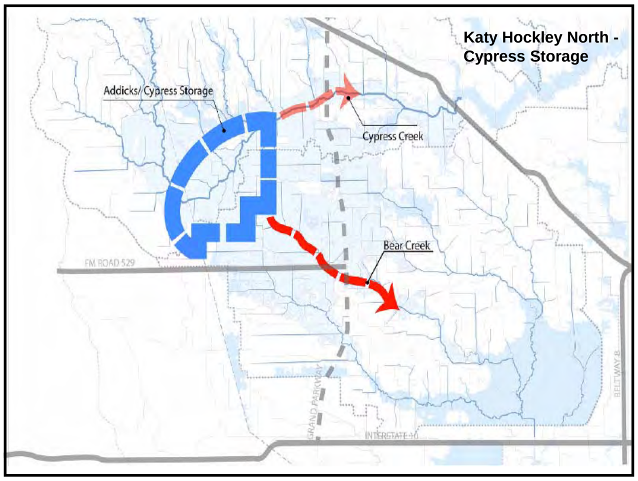
Multi-Use Channel Example
Flewellen Creek 300'-600' wide



Plan 3 – Mound Creek Storage with Conservation/Collection Area

Collection Area and Channel

- Collection area intercepts overflow and funnels it to Bear Creek
  - Conservation opportunities
  - Additional storage
- Detention in John Paul's Landing
- Bear Creek – 500' Corridor
  - Natural Channel Design
  - "Stream Corridor" Concept
  - Convey 4,500 cfs
  - Regional Detention/Retention
  - No modification to Horsepen Creek or S. Mayde Creek



Plan 5 – Katy Hockley N – Cypress Storage
Storage Area

- No diversion of overflow volume
  - Outfalls to Cypress Creek (5,300 cfs) and Bear Creek (2,000 cfs)
  - Equalization Channel with Backflow Preventer
- 1% (100-yr) Event
  - Storage: 26,500 Ac-Ft
  - Inundation: 7,400 Ac
  - Depth: 4' (Avg), 8' (Max)
  - Drain Time: 4-8 days
- Would manage ultimate development Probable Maximum Precipitation

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Plan 5 – Katy Hockley N – Cypress Storage
Channel

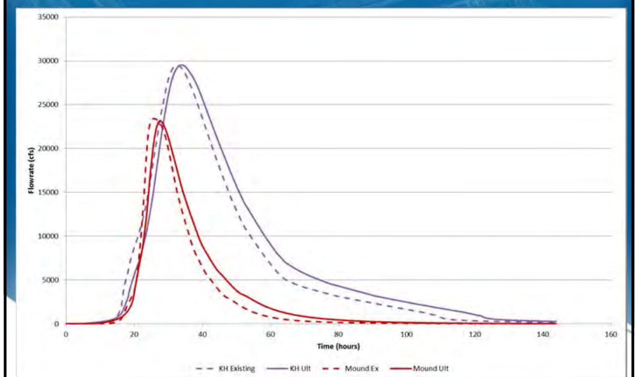
- Corridor
  - Natural Channel Design
  - "Stream Corridor" concept
  - Convey 4,500 cfs (2,000 cfs outfall, 4,500 cfs from local)
  - Regional detention/retention system
  - No modifications to Horsepen Creek or S Mayde Creek
- Removes overflow draining to Langham Creek
- Additional detention in John Paul's Landing

Texas Water Development Board

Plan 5 Additional Information

- Katy-Hockley N. Cypress Storage Area
  - 5,155 of private land
  - 390 ac of HCFCD land
  - 5,725 ac of KPC/Conservation land
- Enlarge Bear Creek from reservoir to existing development near Fry Road (about 7,500')
  - 500-foot right-of-way
  - Regional detention/retention system
  - 2,000 cfs outfall from reservoir (4,500 cfs from local)
  - Avoid modification to S Mayde & Horsepen creeks
- Storage in John Paul's Landing
- Removes overflow along Langham Creek
- Additional development criteria in Addicks and upper Cypress Watersheds

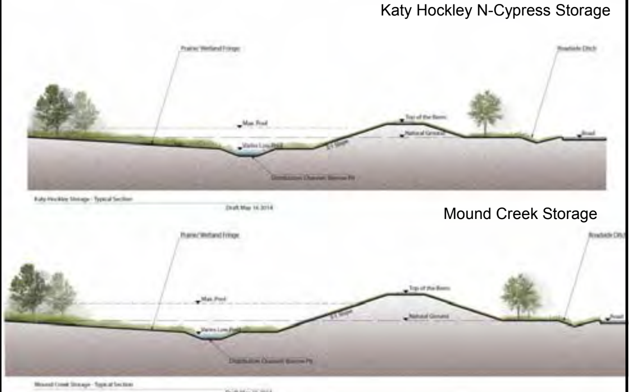
Full Development Hydrographs to Reservoirs



Plan Comparisons

Texas Water Development Board

Typical Sections of the Storage Facility Berms



Plan Comparisons

	Plan 3	Plan 5
Managed Storage Volume (ac-ft) *(Addicks Reservoir Manages 200,800 ac-ft over 16,400 acres)*	15,700 ac-ft	26,500 ac-ft
Storage Facility Area		
Private Land	1,460 ac	5,155 ac
KPC/Conservation Land	2,305 ac	5,725 ac
HCFCD Land	0 ac	390 ac
Collection/Conservation Area		
Private Land	1,585 ac	n/a
HCFCD Land	390 ac	n/a
Relative Land Value	Low/Moderate	Moderate/High
Change in Overflow Volume	Slight Decrease	None
Storage Area Characteristics - 100-yr Event		
Inundation Depth	13' Max, 7' Avg	8' Max, 4' Avg
Drain Time	3 days	6-8 days
Land Removed from 100-yr Overflow	18,592 ac	18,032 ac
Conservation Footprint		
Existing	18,000 ac	18,000 ac
With Plan	21,000 ac	23,000 ac
Cost	$276,500,000	$369,400,000

Presentation Topics

- Background
- Rainfall/Runoff Study
- Technical Plan
- Funding and Implementation Plan
- Supplemental Development Criteria

Texas Water Development Board

Funding Alternatives

- **Partnerships**
- Impact Fee (Collected during Platting)
- Ad Valorem Methods
  - Special District
  - MUDs
- Tax Increment Reinvestment Zone (TIRZ)
- Local Government Corporation

Current Funding Models Consider an Impact Fee Model

Plan Costs

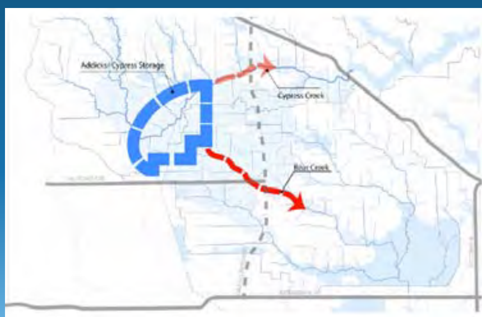
Item	Full Cost	With Partner	
		Partner Contribution	Project Contribution
Plan 3			
Land	$117,300,000	$38,600,000	$78,700,000
Construction	$130,500,000	$41,600,000	$88,900,000
Professional	$28,700,000	$9,200,000	$19,500,000
TOTAL	**$276,500,000**	**$89,400,000**	**$187,100,000**
Plan 5			
Land	$205,800,000	$82,100,000	$123,700,000
Construction	$134,100,000	$35,300,000	$98,800,000
Professional	$29,500,000	$7,800,000	$21,700,000
TOTAL	**$369,400,000**	**$125,200,000**	**$244,200,000**

Funding Alternatives

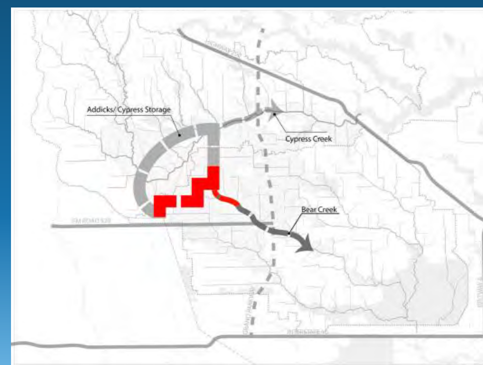
- Partnerships
- Impact Fee (Collected during Platting)
- Ad Valorem Methods
  - Special District
  - MUDs
- Tax Increment Reinvestment Zone (TIRZ)
- Local Government Corporation

Current Funding Models Consider an Impact Fee Model

Implementation and Phasing

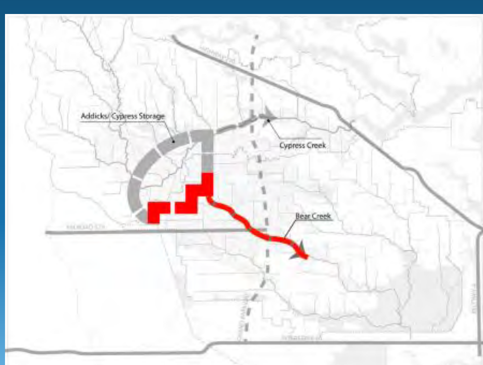


Implementation – Step 1



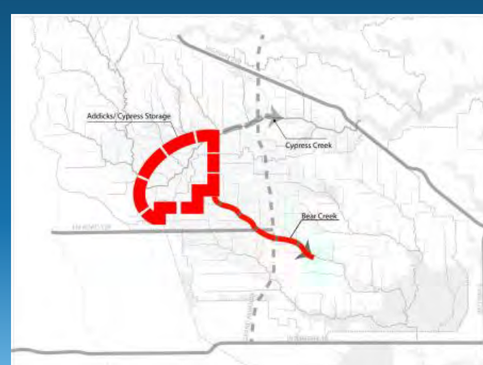
Step 1 Estimated Implementation: Years 1-5

Implementation – Step 2



Step 2 Estimated Implementation: Years 5-16

Implementation – Step 3



Step 3 Estimated Implementation: Years 16-20

Implementation Sequencing

- Each phase helps manage the path of the overflow and reduces its footprint.
- Potential for Development to help pay for implementation of a regional plan rather than smaller, disconnected management facilities that would occur without a regional plan.
- There is a shortfall of funding upfront – regardless of strategy employed.

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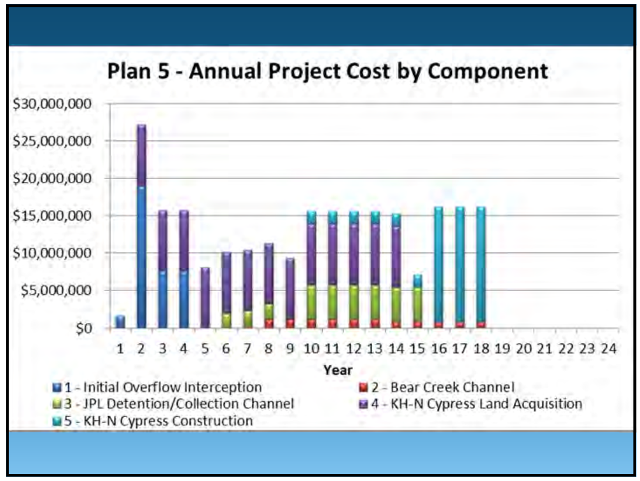

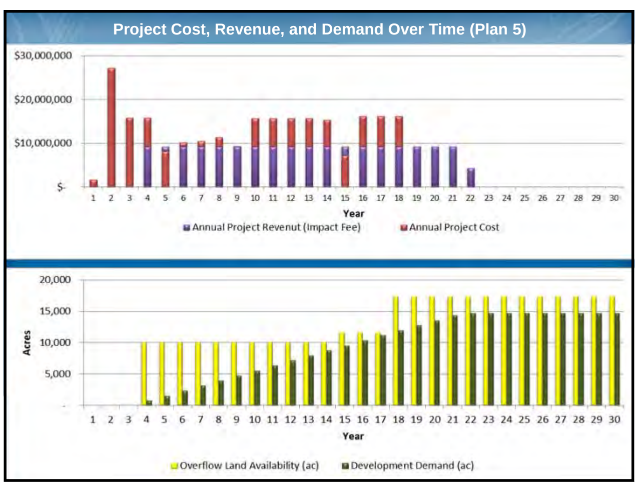

Presentation Topics

- Background
- Rainfall/Runoff Study
- Technical Plan
- Funding and Implementation Plan
- Supplemental Development Criteria

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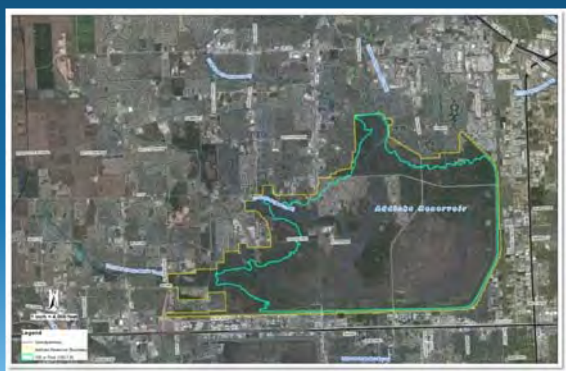
Current Development Around Addicks Reservoir



Supplemental Development Criteria as Part of Management Strategy

Land development increases volume of runoff as well as peak rate of runoff

- As much as 2 inches of additional runoff is expected
- Volume typically not an issue in open channel systems
- Current criteria effective in controlling runoff flow rate but not volume

Cypress Creek & Addicks watersheds are unique

- Increase in volume in the Cypress Creek watershed will lead to increase in overflow
- Every rainfall in Addicks watershed flows into reservoir
- Increased volume of inflow into the reservoir will increase pool elevation
- Potentially affects operating conditions
- Increases flood risk to properties upstream and downstream of reservoirs

Texas Water Development Board

Proposed Changes to Current Criteria

- Increase minimum detention rate from 0.45 acre-feet/acre to 0.55 acre-feet/acre
- Add a 2-inch (0.17 acre-feet/acre) “retention” criteria
- Offer incentives for LID or irrigation use of runoff
- Offer incentives to create prairie

Texas Water Development Board

Next Steps Forward

- Submit Draft Report to the Texas Water Development Board
- Submit Recommended Supplemental Development Guidelines to Harris County Commissioners Court
- Public Meeting Summer 2014

Texas Water Development Board


Cypress Creek Overflow Management Plan
Stakeholder Meeting


Discussion
Texas Water
Development Board

3.2.3 *Stakeholders Meeting List of Invitees*

FIRST NAME	LAST NAME	ORGANIZATION	CITY	STATE	ZIP
Randal	Arbuckle	Lario Land Consultants	Houston	TX	77043
Alan	Bauer	Newland Communities	Houston	TX	77040
Wes	Birdwell	Halff Associates	Austin	TX	78759
Tim	Buscha	IDS Engineering Group	Houston	TX	77040
George	Carmichael	Carmichael Development Company	Houston	TX	77027
Jim	Coody	Wetlands Professional Services	Houston	TX	77041
Stephen	Costello	Costello, Inc.	Houston	TX	77042
Perri	d'Armond	West Houston Association	Houston	TX	77024
Raymond	DeBock	Harris Co. UD #6	Houston	TX	77084
William	Drohan	City of Katy	Katy	TX	77493
Helen	Drummond	Houston Audubon Society	Houston	TX	77079
Donald	Durgin	Bear Creek Resident	Houston	TX	77084
Mike	Fitzgerald	Brown & Gay Engineers, Inc.	Houston	TX	77042
Peter	Houghton	Howard Hughes Corporation	Cypress	TX	77433
Steve	Hupp	Bayou Preservation Association	Houston	TX	77019
Randy	Jones	Terra Visions, LLC	Houston	TX	77055
James Tynan	Kelly	Bayou Preservation Association	Houston	TX	77027
Mark	Kilkenny	Mischer Investments	Houston	TX	77046
Richard	Long	US Army Corps of Engineers	Houston	TX	77077
Jennifer	Lorenz	Bayou Land Conservancy	Houston	TX	77070
David	Lowe	Brown & Gay Engineers, Inc.	Houston	TX	77042
Brandt	Mannchen	Houston Sierra Club	Houston	TX	77096
Evelyn	Merz	Houston Sierra Club	Houston	TX	77061
David	Molina	HC MUD 165	Cypress	TX	77433
Marco	Montes	Commissioner Cagle, Harris County Precinct 4	Houston	TX	77067
David	Nelson	Nelson Farms	Bellville	TX	77418
Wesley	Newman	Katy Prairie Conservancy	Waller	TX	77484
Pat	Nguyen		Houston	TX	77084
Mike	Owens	MUD 374	Cypress	TX	77433
Mary Anne	Piacentini	Katy Prairie Conservancy	Houston	TX	77098
David	Poteet		Katy	TX	77491
Kent	Puckett	Caldwell Companies	Houston	TX	77064
Robert	Rayburn	BPA	Houston	TX	77079

Jim	Robertson	Cypress Creek Greenway Coalition	Houston	TX	77070
Pamela	Rocchi	Commissioner Cagle, Harris County Precinct 4	Houston	TX	77067
Jack	Sakolosky	Cypress Creek Flood Control Coalition/Bayou Preservation Association	Houston	TX	77070
Michael	Schaffer	City of Houston Planning and Development	Houston	TX	77002
Randy	Schilhab	Commissioner Radack, Harris County Precinct 3	Houston	TX	77084
Gene	Schmidt	City of Waller, Floodplain Administrator	Waller	TX	77484
Yancy	Scott	Waller County	Hempstead	TX	77445
Charles	Smith	Bear Creek Homeowner	Houston	TX	77084
Dick	Smith	Cypress Creek Flood Control Coalition	Cypress	TX	77429
Melvin G.	Spinks	Cy-Fair Chamber of Commerce	Cypress	TX	77429
Joshua	Stuckey	HCPID	Houston	TX	77092
Shawn	Sturhan	Harris County PID	Houston	TX	77002
Mary	Sullivan	NWHC MUD 12	Katy	TX	77449
Brad	Tucker	Mustang Tractor & Equipment	Houston	TX	77040
Mike	Voinis	Halff Associates	Houston	TX	77079
Gilbert	Ward	Texas Water Development Board, Flood Mitigation Planning	Austin	TX	78711
Bradford	Wilcox	Texas A&M University Ecosystem Science & Mgt	College Station	TX	77843
Stephen	Wilcox	Costello. Inc.	Houston	TX	77042
Jim	Willis	Wildlife Habitat Federation	Cat Spring	TX	78933
Lorna	Winoske	Morton Road MUD	Houston	TX	77084
Claude	Yoas	Cypress Fairbanks ISD	Houston	TX	77064

3.2.4 Stakeholders Meeting List of Attendees

FIRST NAME	LAST NAME	ORGANIZATION
Stephen	Costello	Costello, Inc.
Jennifer	Lorenz	Bayou Land Conservancy
Marco	Montes	Commissioner Cagle, Harris County Precinct 4
Wesley	Newman	Katy Prairie Conservancy
Mary Anne	Piacentini	Katy Prairie Conservancy
Jim	Robertson	Cypress Creek Greenway Coalition
Jack	Sakolosky	Lakewood Forest Utility District
Dick	Smith	Cypress Creek Flood Control Coalition / Timberlake Improvement District
Stephen	Wilcox	Costello. Inc.
Peter	Smullen	Ravensway - Saracen HOA & CCFC
Larry	Dunbar	Cypress Creek Flood Control Coalition
Will	Gutowsky	Brown & Gay Engineers, Inc.
Mark	Gehringer	Bridgeland

4 Public Meetings

4 Public Meetings

4.1 August 2012 Public Meeting

4.1.1 Newspaper Notice, Houston Chronicle, July 26, 2012

PUBLIC MEETING NOTICE

The Harris County Flood Control District is beginning a study to develop a consensus plan to manage flood risks in the area that experiences overflows from the Cypress Creek watershed. The objective of the study is to establish a set of policies, technical criteria and guidelines that will allow the Flood Control District to plan for and implement programs that reduce flood risks that reflect the unique hydrologic conditions in upper Cypress Creek (upstream of US 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County have received a flood protection planning grant from the Texas Water Development Board to partially support this effort.

A Public Meeting will be held on August 16, 2012 from 3:30 p.m. – 5:00 p.m., at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084. A brief presentation will be made by the study manager, followed by receipt of comments from the public. Written comments may also be made online at www.hcfcd.org/cypressoverflow or mailed to the District at: 9900 Northwest Freeway, Houston, Texas 77092. Written comments should be received by September 30, 2012.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District at 713-684-4000 or online at www.hcfcd.org/cypressoverflow.

4.1.2 Letter to Invitees

PUBLIC MEETING
Cypress Creek Overflow Management Study

Date: August 16, 2012

Time: 3:30 – 5:30 p.m.

Place: Harris County Precinct 3, Bear Creek Community Center
3055 Bear Creek Drive, Houston, Texas 77084
(Directions to the Community Center are available at: www.pct3.hctx.net/cc_bearcreek.)

The Harris County Flood Control District is beginning a study to develop a consensus plan to reduce flood risks in the study area. The Flood Control District and Harris County have received a flood protection planning grant from the Texas Water Development Board to partially support this effort. The objective of the study is to establish a set of policies, technical criteria and guidelines that will allow the Flood Control District to plan for and implement programs that reduce flood risks that reflect the unique hydrologic conditions in upper Cypress Creek (upstream of US 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County.

You are invited to attend a Public Meeting to learn more about the study and to provide comments on the planning effort. A brief presentation will be made by the Study Manager, followed by comments from the public. Written comments may also be made online at www.hcfcd.org/cypressoverflow or mailed to the District at: 9900 Northwest Freeway, Houston, Texas 77092. Written comments should be received by September 30, 2012.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District at 713-684-4000 or online at www.hcfcd.org/cypressoverflow.

Cypress Creek Overflow Management Plan Public Meeting

Bear Creek Community Center, Thursday, August 16, 2012

Attendees

LAST NAME	FIRST NAME	ORGANIZATION
Ahrendt	Carl	Cobb Fendley & Associates
Anderson	Andy	
Anderson	Lonnie	AECOM
Arbuckle	Randal	Laro Land Consultants
Atkinson	Robert	EHRA
Bagha	Mohamed	Michael Baker
Bethke	Trey	USDA-NRCS
Birdwell	Wes	Halff Associates
Bolton	Michael	Hearthstone Flood Coalition
Boudloche	Larry	
Brooks	Ron	Chesmar Homes
Broun	Taylor	NW MUD #10
Carmichael	George	Carmichael Dev. Co.
Carter	Pat	
Chovanec	Brian	Benchmark Engineering Corp.
Coody	Jim	Wetlands Professional Svcs.
Costello	Stephen	Costello, Inc.
Daniel	Roger	
Davidson	Janet	HC MUD 165
DeBock	Raymond	Harris Co. UD #6
Delisle	Nathan	AEI Engineering
Denny	Kleki	
Drohan	William	City of Katy
Durgin	Donald	Bear Creek Resident
Elliott	Shiree	
Ferguson	Linda	
Fitzgerald	Mike	Brown & Gay Engineering
Flores	Al	DEC
Fontana	Leon	
Foster	Joan	
Foster	Paul	Bear Creek Homeowner
Freeman	Jacque	Ricewood Mud
Fritsche	Mike	
Froehlich	Mark	BGE
Gallegos	Rica	Costello, Inc.
Garcia	Fred	HCFCD Pct 4 Coordinator
Gibson	Brian	Friendswood Dev. Co.
Glenson	David	
Goodart	Gary	H UD #6
Goodson	Matt	CenterPoint Energy
Gray	Janice	HCFCD Pct 3 Coordinator
Griffith	Jordan	IDS Engineering Group
Grounds	John	Grounds Anderson, LLC
Grundy	Robert S.	Self
Gunn	Taylor	Perry Homes
Hallimore	Angie	R G Miller
Hejducek	Julie	B.C. Flood Central
Hesterly	Rosemary	
Hillin	Wayne	MUD 255
Hinojosa	Sam	Halff Associates
Hirshman	Alan	Dannenbaum Eng. Corp
Humble	Sean	Sherrington, Inc.
Jang	Jung	R. G. Miller Engineers
Johnson	Burton	Baker
Jones	Randy	Terra Visions, LLC
King	Gary B.	Hendricks Interest
Langford	William	WML
Leite	Betty	KBR
Leyendecker	David	City of Katy, Clay & Leyendecker, Inc.
Long	Richard	Corps of Engineers
Mahaffey	Steve	
Malek	Gloria	NW HC MUD #10
Maler	Debbie	

Mannchen	Brandt	Houston Sierra Club
Maxwell	Troy	Woodcreek
Mays	Jennifer	BGE and Harris Co. MUD 81
McKee	Alan	LJA
Merz	Evelyn	Houston Sierra Club
Molina	David	HC MUD 165
Nguyen	Hanh	COH
Nguyen	Pat	
Nguyen	Truyen	
Ortega	Katrina	MUD 127
Owens	Mike	MUD 374
Palermo	Andy	EHRA
Palomo	Carlos	Self
Panthi	Nawa	A & S Engineers
Patel	Kirti	Richfield Investment
Phillips	David	B.C. Homeowner
Poppe	Russ	HCPID
Preston	Jerry	EHRA, Inc.
Prudhomme	Carrie	Ricewood MUD
Puckett	Pam	Costello, Inc.
Rayburn	Robert	Energy Corridor
Reiter	Stephen	Jones & Carter
Riemersma	Nicole	IDS Engineering Group
Robertson	Jim	Cypress Creek Flood Control Coalition
Rocchi	Pamela	Commissioner Cagle, HC Pct.4
Rose	Mike	RPI
Salzhanover	Frank	Endangered Species Media Project
Scheffler	Charles	COE
Scheffler	Mary	
Schwartz	Gerry	Taxpayer
Scott	Yancy	Waller County
Smith	Charles	Bear Creek Homeowner
Smith	Richard D.	Cypress Creek Flood Control Coalition
Smith	Susan	
Smullen	Peter	CCFCC
Spinks	Melvin	CivilTech
Stuckey	Josh	HCPID
Sullivan	Mary	NWHC MUD 12
Sykes	Joe	HC MUD 374
Thompson	Linda	Self
Tomczyszyn	Sam	CNP
Turner	Lois	
Villarreal	Raul	USDA - NRCS
Vogel	Kevin	Dodson-Walter P. Moore
Vogler	Jeff	VanDeWiele & Volger
Voinis	Mike	Halff Associates
Ward	Gilbert	Texas Water Development Board
Welling	Donald	Self
Wilcox	Stephen	Costello
Wilcoxson	Char	
Winoske	Lorna	Morton Road MUD
Yharte	Junior	NW Harris #10
Yoas	Claude	Cypress Fairbanks ISD
Young	Crayton	Twin Lakes
Young	Jim	HC MUD 255
Yuhnke	Clydell	
Yuhnke	Jim	HC UD #6 Resident
Yurchevich	Pamela	Self

Cypress Creek Overflow Management Plan

Public Meeting
August 16, 2012

Texas Water Development Board

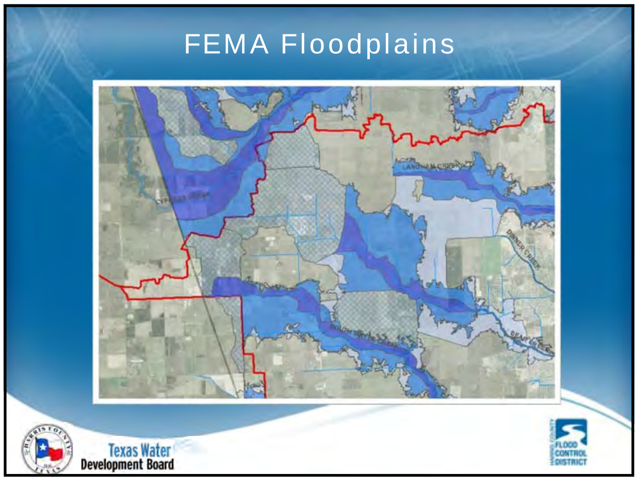
Meeting Format

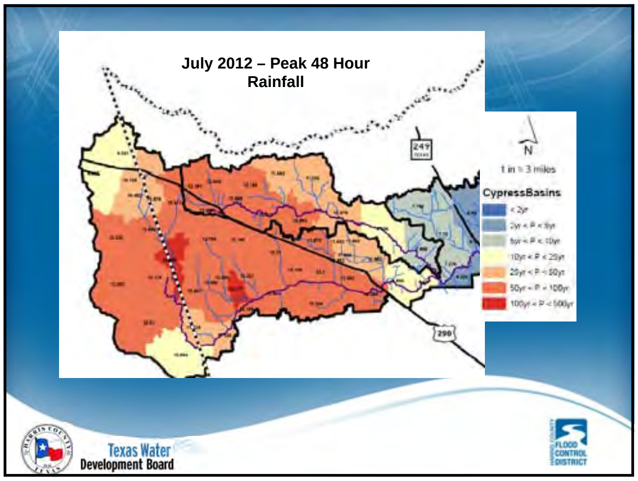
- Welcome and introductions
- Formal Presentation presenting TWDB grant
- Public comments

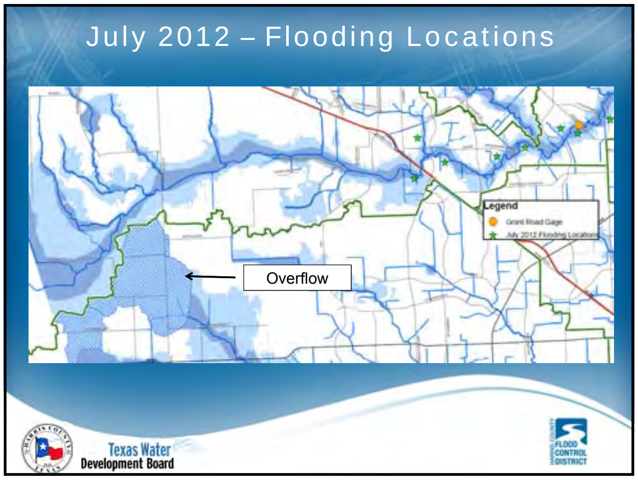
Presentation Topics

1. What is the Cypress Creek overflow?
2. The need for planning
3. Discussion of Steering Committee
4. Critical success factors
5. Discussion of the study
6. Timeline for study
7. Stakeholder interaction

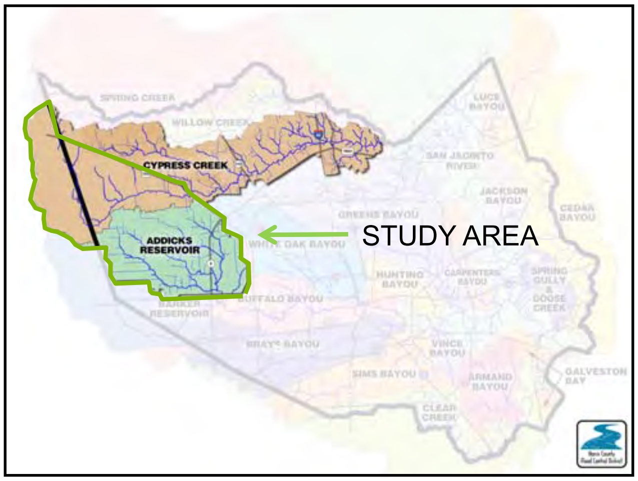
Cypress and Addicks Watersheds

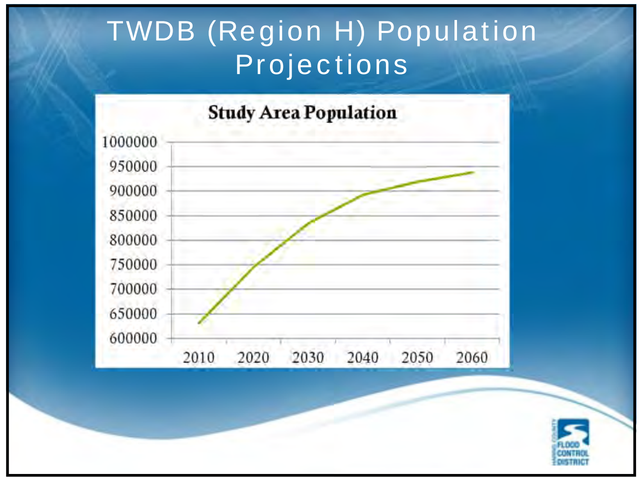

FEMA Floodplains
Texas Water Development Board
FLOOD CONTROL DISTRICT


July 2012 – Peak 48 Hour Rainfall
N
CypressBasins
Texas Water Development Board
FLOOD CONTROL DISTRICT


July 2012 – Flooding Locations
Legend
Overflow
Texas Water Development Board
FLOOD CONTROL DISTRICT


Overflow - Sharp Road
Texas Water Development Board
FLOOD CONTROL DISTRICT


CYPRESS CREEK
ADDICKS RESERVOIR
STUDY AREA
SPRING CREEK
WILLOW CREEK
SAN JACINTO RIVER
JACKSON BAYOU
GREENS BAYOU
CEDAR BAYOU
HUNTING BAYOU
CARPENTERS BAYOU
SPRING GULLY & GOOSE CREEK
BUFFALO BAYOU
BARKER RESERVOIR
BRAYS BAYOU
VINCE BAYOU
SIMS BAYOU
ARMAND BAYOU
GALVESTON BAY
CLEAR CREEK


TWDB (Region H) Population Projections
Study Area Population
1000000
950000
900000
850000
800000
750000
700000
650000
600000
2010
2020
2030
2040
2050
2060
FLOOD CONTROL DISTRICT


The Need for Planning
PROTECTION OF EXISTING POPULACE
LAND DEVELOPMENT PRESSURES
LIMITED DRAINAGE NETWORK
FLOOD CONTROL DISTRICT'S MISSION
OTHER COMMUNITY INTERESTS
LAND PRESERVATION ENVIRONMENTAL MITIGATION
Texas Water Development Board
FLOOD CONTROL DISTRICT


Steering Committee Member
Has major investment in property in the watershed(s).
Makes regulatory policy affecting land use in the watershed(s).
Has developed a master plan for a major portion of the watershed(s).
Able to construct major public infrastructure projects in the watershed(s).
Willing to collaborate with other steering committee members to reach a consensus regarding future plans for drainage and flood control.
Can dedicate the time to complete the study on schedule.
Texas Water Development Board
FLOOD CONTROL DISTRICT

Current Steering Committee Members

- Harris County Flood Control District
- West Houston Association
- Harris County PID
- Harris County Pct 3 & 4
- City of Houston
- Waller County
- Katy Prairie Conservancy
- Bayou Preservation Association
- US Army Corps of Engineers

Texas Water Development Board

FLOOD CONTROL DISTRICT

Critical Success Factors

- The plan must be a workable solution that allows the Flood Control District to fulfill its mission.
- The plan must define the roles and responsibilities of all parties to support the plan both economically and from a policy perspective.
- The plan must respond to conflicting priorities between the environment and business interests.
- The plan should be completed in advance of future land development.
- The plan has to incorporate major planned public infrastructure projects (roadway and thoroughfares, major water pipelines, etc.)

Texas Water Development Board

FLOOD CONTROL DISTRICT

Texas Water Development Board Grant

- Applied for TWDB Flood Protection Planning Grant on January 11, 2012
- Notified of acceptance of grant on April 10, 2012
- Contract initiation date : April 19, 2012
- Executed contract July 2, 2012
- Study completion date: October 31, 2014
- 50-50 Costshare: TWDB $750k and HCFCD $750k

Texas Water Development Board

FLOOD CONTROL DISTRICT

Goals

- Gain consensus on the facts relating to flooding, flood volumes, flood peaks and flood risk.
- Gain understanding of the needs and objectives.
- Develop a consensus plan for flood risk reduction that incorporates the needs and objectives.
- Establish interim criteria while adoption of the final consensus plan is ongoing.
- Design a business plan to implement the strategies, including the roles and responsibilities.
- Adoption of the consensus plan and the business plan by Harris County Commissioners Court.

Texas Water Development Board

FLOOD CONTROL DISTRICT

Planning Effort - Engineering

- Quantify and delineate flood risk
- Estimate flood mitigation requirements
- Set basic goals for regional strategy

Texas Water Development Board

Planning Effort - Environmental

- Estimate benefits of prairie restoration for flood control
- Identify critical conservation areas
- Investigate mitigation bank requirements and options
- Consideration of regional/community enhancements

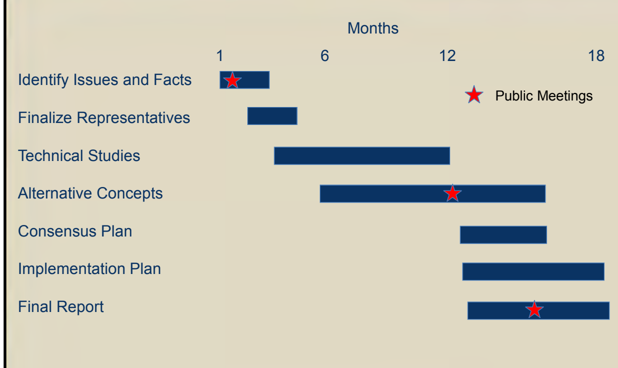
Texas Water Development Board

Planning Effort – Business Plan

- Cost pro forma – eligible regional facilities
- Cash flow analysis
- Roles and responsibilities
- Land acquisition
- Guidelines for development
- Implementation Plan

Texas Water Development Board

Planning Effort Schedule



Stakeholder Interaction

- **Project Website -** www.hcfcd.org/cypressoverflow
- **Copy of Grant Application**
- **Steering Committee Meeting Summaries**
- **Project Deliverables**
- **Public Comments**
- **Your Input**

Harris County Flood Control Information

Harris County Flood Control District

9900 Northwest Freeway

Houston, TX 77092

Attn: Cypress Creek Overflow

(713)684-4000

Purpose: Receive Public Comments

- **Comments will be recorded; transcript on study website**
- **Names will be called from comment cards**
- **Three minutes per speaker**
- **Meeting concluded by 5 p.m.**

Cypress Creek Overflow Management Plan

Public Meeting
August 16, 2012

Harris County Flood Control District

Cypress Creek Overflow Management Plan

Transcript including Verbal Comments
Public Meeting, August 16, 2012

CYPRESS CREEK

OVERFLOW MANAGEMENT

PUBLIC MEETING

THURSDAY, AUGUST 16, 2012

BEAR CREEK COMMUNITY CENTER

3:30 P.M.

Transcript provided by:
The Captioning Company, Inc.
565 South Mason Road, Suite 358
Katy, Texas 77450
281-684-8973 (phone)
281-347-881 (fax)
captioningcompany@comcast.net

P R O C E E D I N G S

(Meeting began at 3:30 p.m.)

MR. POTOK: Okay. I've got a smartphone with me that says it's 3:30, so we'll get started. At this time of the afternoon on Thursday, my smartphone is probably the smartest (indiscernible).

So I want to start by thanking you all for coming to this initial meeting, and it will be the first of three public meetings we have on a planning effort being undertaken by the Harris County Flood Control District. This planning effort is being conducted in joint sponsorship with the Texas Water Development Board and Harris County. It is being conducted under the State of Texas Federal Flood Protection Planning Grant.

With us today is Gilbert Ward, who's the head of the flood mitigation planning grant program for the state, Pam Rocchi with Precinct Four is here, Josh Stuckey, I know I saw walk in from the Harris County Permits Office, and we have a number of people from Harris County Flood Control District here as well.

My name is I'm Alan Potok. I'm the assistant director, and again, I want to thank you all for coming.

With the recent flood we had on Cypress Creek, we really weren't sure what was going to happen today. We realized it was a late afternoon opportunity, and sometimes that conflicts with people's work schedules, but we knew that a lot of people had interest because of the flooding that occurred in portions of Cypress Creek. I need to emphasize at the outset that that's not what this planning effort is to address today, but Mike Garmon, who will be giving a formal presentation prior to receiving public comments, will talk just a little bit about that flood and kind of make some distinguishing remarks about it.

I'd like to talk just a little bit about why this effort is important to not only us but probably the entire Harris County community, and I think why the Texas Water Development Board saw fit to become a financial partner in the planning itself. You know, they say necessity sometimes is the mother of invention, and I'm not sure that that's not what transpired here. The Cypress Creek watershed, just in of itself being one of the largest watersheds in Harris County, suffers some very unique hydrologic considerations. It's a natural channel for most of its length. The community prefers to keep it that way. It has a very limited flood control capacity. It's got a very large contributing watershed upstream, and actually, part of that watershed is in Waller County.

And while I mention Waller County, is anybody here from Waller County? Yancy is here from Waller County.

And so we've got a situation where you have multiple counties involved, a known concern downstream on Cypress Creek, and then we have kind of an interesting situation because of the topography that we have a very shallow watershed divide between two major watersheds, one being Cypress Creek and one being the upper Buffalo Bayou watershed. We call it the "Addicks watershed" because the upper Buffalo Bayou flows into Addicks and Barker reservoirs, which then controls flow downstream into the lower Buffalo Bayou.

While this is going on, the western part of Harris County, and Waller County too, is expected to be the next major growth area in this region. Mike will show you some figures as to how dramatic that growth is, so this is not something that you prevent; this is something you plan for. And what we wanted to do was to get a number of pertinent entities with the capability of making decisions and collaborating together that combine and develop a consensus of how we can in fact appropriately plan for development while at the same time conserving and enhancing the natural environment of roughly 400 square miles of Harris County, which is about one-sixth of the total county area. So it's a major initiative. There are a lot of factors to consider and a lot of balancing of interests that have to be addressed to reach a good consensus solution.

Our presentation today really is in three parts. I'm giving the welcome and introductions, and then I'll stand back up and moderate the public comment period. The comments -- by the way, we have a number of people. I don't know how many have signed up for comments. We probably will limit comments to three minutes each. We do have someone that is recording all of the comments and taking the transcript of the meeting. I understand she came in second in the national thumb texting contest, so I think we've got that under control.

Mike Garmon of our staff is the project manager. He will give a formal presentation that will last about 10 minutes, and then following that formal presentation, I'll get back up, and then we'll step in and let you all handle the comments. Now -- and we'll talk about the format for that after Mike's presentation. So, Mike?

MR. GARMON: I'm going to have to try real hard to make this last 20 minutes. Every time I practice this, they keep telling me to slow down, slow down.

Before I begin, I'd like to remind everyone that we have hard copies of the grant application available here. They're over on this information table, so If you're interested in the details of the application, feel free to pick up a copy.

This slide shows the topics that we're going to talk about today: What is the Cypress Creek overflow? Why are we planning? We're going to talk about a Steering Committee, critical success factors for our planning to succeed. We're going to discuss the scope of the study, the timeline, or the schedule for the study, and talk about stakeholder interaction.

The Cypress Creek and Addicks Reservoir watersheds are located in northwest Harris County, north of I-10. Cypress Creek begins over here in Waller County and flows easterly into Spring Creek, which flows into the San Jacinto River. The Addicks Reservoir drains into Buffalo Bayou and then into the Houston Ship Channel.

The reservoir was built by the Corps of Engineers back in the '40s to protect downtown Houston and the Houston Ship Channel from catastrophic floods like those that occurred in the '20s and '30s. The naturally occurring drainage divide between Cypress Creek and Addicks watershed is not well defined. When we talk about the drainage divide, that's this line that comes right along here. As Alan mentioned, it's a very shallow divide, and water overflows from Cypress Creek watershed into Addicks watershed during significant floods.

This map shows the floodplains from the Flood Insurance Rate Maps published by FEMA. The maps show the location of the 100 year floodplain, the floodway, and the 500 year floodplain. This hatched area here is labeled "Rate Zone A0" on the FEMA maps. It is the location of the overflow.

In general, the overflow from Cypress Creek flows southeasterly into Bear Creek and South Mayde Creek, which drain in the Addicks Reservoir. The flooding is broad, shallow and slow moving. The hatched area on this map is about two miles wide, and the flooding is usually less than two feet deep, flowing at less than one foot per second.

To put some additional perspective on what we're talking about, we can discuss the overflow in terms of the recent flood event that took place last month, the week of July 9th through the 13th.

Okay. I'm going to talk you guys through this map. This legend over here shows the different rainfall intensities for a 48 hour rainfall event. Most of the area is this red color that shows that the rainfall was somewhere between a 50 year and 100 year rainfall event.

There's a couple of places here and here where you can see a hundred year event. This is Cypress Creek here, and this is Little Cypress Creek. Most of the areas received somewhere between a 50 year and a hundred year rainfall event. This caused some flooding of structures along certain segments of Cypress Creek. We're still collecting the data on the flood event, but our records show most of the flooding occurred downstream of Highway 290. And this is 290 here, and the green stars are neighborhoods where the structural flooding took place. This orange dot here is the location of the Grant Road gauge, which actually indicated a record flood level for the event.

Also shown on the slide are the FEMA floodplains and the location where the overlfow is occuring. Note the relative location of the overflow where the flooding occurred back in July. I wanted to use this graphic to emphasize that the overflow and flooding that took place along Cypress Creek in July are actually two separate issues and that the focus of this planning effort is on the overflow.

We also want to point out here real quick that this is the location that drainage (indiscernible) that we were talking about. This is Sharp Road, this little -- it's kind of hard to see for probably most of y'all, this little line here. That's Sharp Road, so the divide part of the divide runs along Sharp Road. And so as I mentioned before, the dividing line on Sharp Road -- here's a picture of the flooding over Sharp Road. This is actually from the July event.

Because the overflow is a flooding issue that's primarily limited to the upper part of the watershed, we've defined the study area as the Cypress Creek watershed upstream of 290 combined with the Addicks Reservoir watershed. The drainage area of Cypress Creek above 290 is about 140 square miles, and the Addicks watershed is about 138 square miles, so the size of the study area is about 278 square miles.

While much of Addicks -- much of the Addicks watershed is urbanized, development in the overflow area is primarily rural residential, farmland and undeveloped land. So most of this area right in here is primarily undeveloped land.

However, the area is growing with respect to population. The most recent Texas Water Development Board projections show that the study area will grow by about 45 percent over the next 50 years, and with that growth comes development, and the Flood Control District is trying to be proactive and prepare for it. The primary purpose of this study is to proactively prepare for the future development of this area that is inevitable.

Due to the complex nature of the overflow problem and the limited drainage network, it's the District's concern that the development of the area could occur in a way that is haphazard and difficult to manage.

Furthermore, there's a need to balance future development and other environmental interests in the area, so in June of last year we began meeting with a Steering Committee made up of key stakeholders to discuss the problem.

The purpose of the Steering Committee is to provide direction for the study. The Steering Committee is made up of representatives of groups that meet the following criteria: They have a major investment in the property in the watershed. They're able to make regulatory policy affecting the land use in the watershed. They have developed a master plan for a major portion of the watershed. They are able to construct major public infrastructure projects in the watershed. They're willing to collaborate with other Steering Committee members to reach a consensus regarding future plans for drainage and flood control, and they can dedicate the time to complete the study on schedule.

The Steering Committee members represent the following groups: Harris County Flood Control District, the West Houston Association, the Harris County Public Infrastructure, Harris County Precincts 3 and 4, the City of Houston, Waller County, the Katy Prairie Conservancy, the Bayou Preservation Association, the U.S. Army Corps of Engineers.

After some discussion and consideration with the Steering Committee, we decided that planning was needed, and in order for that planning to be successful, we decided the planning needed to be a workable solution that allows Flood Control to fulfill its mission. It needs to define the roles and responsibilities of all the parties that support the plan both economically and from a policy perspective. It must also respond to conflicting priorities between the environment and business interests and should be completed in advance of future land development. The plan has to incorporate major planned public infrastructure projects like roadways and thoroughfares.

To help fund the planning effort, the District applied for a Flood Protection Planning Grant from the Texas Water Development Board in January of this year. We were notified by the Board in April the grant would be awarded and that we could begin work on April 19th. The contract between the District and the Water

Development Board was signed last month. According to our agreement, the final draft report must be submitted on or before the end of October of 2014. I also want to note this is a 50/50 cost share between Water Development Board and Flood Control, with Water Development Board funding $750,000 and Harris County Flood Control funding $750,000 dollars as well.

With help of the Steering Committee, we arrived at the following goals for the planning effort: We want to gain consensus on the facts relating to the flooding, flood volumes, flood peaks and flood risks. We want to gain understanding of the needs and objectives. We want to develop a consensus plan for flood risk reduction that incorporates the needs and objectives. We want to establish interim criteria while adoption of the final consensus plan is ongoing. We want to design a business plan to implement the strategies, including the roles and responsibilities, and we want to get adoption of the consensus plan and the business plan by Harris County Commissioners Court.

Again, I'd like to remind everyone that copies of the grant application are available. A detailed scope of work for the study can be found in the application, but I want to summarize the scope of the study here. The scope of work is multi-disciplinary through engineering, environmental and financial planning elements.

The engineering portion of the work involves quantifying and delineating the flood risk. What this means is that we're going to determine where, what volume, and how deep the flooding occurs.

Estimate flood mitigation requirements -- we're going to try to decide what it would take to manage, move or store the overflow, and then set basic goals for regional strategy. This means we're going to try to figure out what we think we want to do to manage the flooding problem and reduce the risk of flooding.

The environmental portion of the planning effort involves estimating the benefits of prairie restoration for flood control. What we're going to do here is we're going to collect and analyze data from prairie grasslands to identify unique runoff characteristics that may be helpful with the flooding problem.

Identify critical conservation areas -- here we're going to be looking for important tracts of land that could potentially be preserved for flood control, environmental or other reasons.

Investigate mitigation bank requirements and options -- here we're going to be looking for tracts of land that can be used for environmental mitigation for future flood control projects, and during this, we'll be considering regional and community enhancements. That means we're going to take into consideration multipurpose land use in our planning with things like recreation and green space.

The business plan portion of the planning effort involves the cost pro forma, which is, of course, eligible regional facilities, but basically this is a cost analysis for any proposed capital improvements that we come up with for the strategy.

The cash flow analysis -- we're going to estimate the cost of the strategy over time.

Roles and responsibilities -- we're going to look at who's responsible for what and who's going to pay for it.

Land acquisition -- we're going to look at what land is needed for the proposed strategy.

Guidelines for development -- we're going to develop criteria for future development of the area.

And finally, we're going to come up with an implementation plan which tells us what the nuts and bolts of making the strategy a reality are.

This is the planning effort schedule, the timeline. We're here where this red star is. This is the first public meeting, so we just started. About a year from now, we're going to have another public meeting after we've had a chance to develop some alternative strategies. A few months after that, we'll be working on the final report. We'll have another public meeting to incorporate the comments from the public.

We realize that there are individuals or other groups that may want to be involved in our planning efforts, so we're inviting you to participate as a stakeholder if you're interested. The best way for you to do that is to go to the project website, which is hscu.org/cypressoverflow. There you will find a copy of the grant application. The website is currently still under design, but eventually we plan to put summaries of the Steering Committee meetings on there as well as project deliverables. This is also the place for public comment, for your input; or you can send your comments to us by mail. This is our information. We're located at 9900 Northwest Freeway, Houston, Texas. Make sure you put it to the attention of Cypress Creek Overflow; or you can call us at 713-680-4000.

So the main thing we wanted to do today is to introduce you to our planning effort and receive your comments. So that's what we're going to do right now. Comments will be recorded, and a transcript of the comments will be put on the study website. Names will be called from the comment cards, so make sure if you want to make -- come and give your comment, write your name on a comment card. We'd like for the comments to be limited to three minutes per speaker so that everyone has a chance to talk, and we want to have the meeting concluded by 5:00 p.m.

So now I'm going to turn it over to Alan.

MR. POTOK: Okay. On the -- just as a follow up on the comments itself, it's important to understand that your comments can be received throughout the planning effort by commenting at the website itself. So those of you who have comments today, we encourage you to give them. Those comments will be posted on the website, and as we move through the planning process, we will respond to the comments as they become applicable and the answers are known.

Comments today will be treated exactly the same as comments that are written and exactly the same as comments that are provided to us by getting on our website. We will -- the website is active now, correct?

UNIDENTIFIED SPEAKER: Yes.

MR. POTOK: And it will be enhanced, as we indicated, so that you're able to view the progress of the study as it's moving forward.

So right now -- and I have my smartphone with the little clock. But if you would, those of you who have a comment, there's two ladies here. If you could provide your comments to them, we can then go ahead and take them.

UNIDENTIFIED SPEAKER: We do need them to.

MR. POTOK: Do we -- now, is this going to work, where I'm going to hand you this microphone? Is that --

UNIDENTIFIED SPEAKER: No, they need to come up there.

MR. POTOK: Okay. They're going to come up here? Okay. Great.

There's one at the very back?

All right. Mr. Mannchen?

MR. MANNCHEN: My name is Brandt Mannchen, and I'm speaking here on my own behalf. I have just a couple of preliminary comments, and then I want to go ahead and submit some written comments.

First, I'm glad to see that this study is beginning because the overflow areas have been a long issue of discussion. And in particular, I'm concerned about protecting portions of the Katy prairie because I believe the prairie actually holds water and assists in flood control naturally, so I would hope that would be part of the discussions with the Steering Committee.

In addition, I'm sad to see that this does not include the Buffalo Bayou watershed because that (indiscernible) Houston because whatever happens in Addicks and Cypress has an effect downstream on Buffalo, and I just wanted to make that comment.

I would also like to see a map of the overflow areas with how many there are and approximately what the volume is of each of the overflow areas. That would be very helpful to me, to take a look at that map in responding as far as my comments go.

And that's all I have to say at this point. Thank you.

MR. POTOK: Thank you.

Mr. Bolton?

MR. BOLTON: Sorry for the wait. First of all, I come to you as flooding -- filing two flood claims, flooding three times. I live on Horsepen Creek, which wasn't mentioned, but it's also part of the Addicks watershed. What we just saw was mainly going into Mayde and Bear Creek, but of course the water backs up into Horsepen Creek, too.

Currently we have a project just finishing up. It was 1.1 million, 3.25 miles of Horsepen Creek from Highway 6 all the way down to Addicks Reservoir, and they're finishing up there. But unfortunately there was a lot of erosion, and where they started last year, they've already got about the same amount of dirt. And one of the guys told me that they're back to where they started because of all the erosion.

But the comments or the questions I'd like answered is, number one, on the Steering Committee, I would involve national flood insurance because anybody in here that has flood insurance has to pay the federal government, and they're the ones that have to insure the houses, or the buildings or whatever, that were built on the floodplain.

And number two, in 2010, the Army Corps of Engineers did a presentation on how dangerous the Barker and Addicks dams are. In fact, they were looking for money, and I contacted my congressman, John Culberson, during his town hall meeting when he was running in 2010, and he didn't know anything about it.

But basically the Corps of Engineers -- and he also said that the Corps of Engineers have enough money, they're not getting any more. The Corps of Engineers were very concerned about Barker and Addicks. The dams and the downstream can cause tremendous amount of damage on Buffalo Bayou.

And then also what wasn't mentioned here, in April

2009, according to the Houston Chronicle, 2,300 homes flooded in the Addicks watershed, so I want that addressed, too. And I think that's about it. So...

Oh, and the overflow area, if it's only two miles wide, ten feet deep -- or less than one foot deep, that doesn't sound like much of an overflow area. It sounds like they're really the same watershed, so unless you do something to separate them, you're talking about a huge watershed. And we already have a lot of flooding in the Addicks Reservoir, especially in April of 2009. So we don't need anymore. Thank you.

MR. POTOK: Is there anybody else who would like to make a comment?

Yes, ma'am?

MS. CARTER: I'll talk loud, and I think I can make it from here. I have a question.

MR. POTOK: Can we get your name, please.

MS. CARTER: Pat Carter. I live at the corner of Lost Spring and Pine Mountain.

We had no flooding until Ike in September of '08. All right. I'm wondering what went amiss. Been there 40 years and no flooding. We've flooded ever since.

MR. POTOK: Okay. Did you copy that comment? We will make a point of responding to every comment.

Anybody else?

UNIDENTIFIED SPEAKER: There are a couple filling out cards over here.

MR. POTOK: Yes, sir?

MR. YUHNKE: Do I come up?

MR. POTOK: Uh huh.

MR. YUHNKE: My name is Jim Yuhnke. I live in Bear Creek Subdivision over here.

I wanted to follow up on this last guy's comments. I'm one of the houses that got flooded back in 2009. Whatever -- excuse me. All I want to say is this: Whatever y'all do, you need to get the Corps of Engineers involved. The -- they widened Horsepen Creek to allow for water to come down to the Addicks Reservoir, but unfortunately, once it gets to the northern part of the Addicks Reservoir, the water doesn't go down to the dam.

The Corps of Engineers refuses to clear out Langham Creek through Bear Creek Park to let the water go on down. In their mind, their mission is to keep downtown Houston from flooding, and I would say that the best way to do that is to not let any water into the Addicks Reservoir. So whatever you do, you're going to have to get the Corps of Engineers -- because if you allow a lot more water from Cypress down this direction, us poor folks that live just north of here, we're going to eat all that water. So that's my comment.

MR. POTOK: Thank you.

UNIDENTIFIED SPEAKER: Sir, excuse me.

MR. YUHNKE: Sure.

UNIDENTIFIED SPEAKER: Just fill that out for me.

MR. POTOK: Mr. Merz? Or Ms. Merz? Evelyn Merz?

MS. MERZ: My name is Evelyn Merz. I'm the conservation chair of the Houston Sierra Club. My concern is that undergoing the process, that you take into account the July 2010 revision to the operating plan for the Addicks Dam that was performed by the U.S. Army Corps of Engineers, which states that they are out to -- for the safety of the dam, that they want the maximum level behind the dam to be that of the historic 25 year storm in the watershed. (Indiscernible) the release from behind the dam downstream into Buffalo Bayou so that it does not get above that historic 25 year level, which is the point of record within the dam itself.

My other concern is that I would like to be able to find out how and -- how high and when there are overflows from Cypress Creek into the Addicks Reservoir.

It is very difficult to find out when actually we do have a rainfall event that contributes water into the Addicks watershed. I would like to know (indiscernible) a gauge to measure that point and how high it is and the extent and the approximate (indiscernible) that are going into the Addicks Dam. Thank you.

MR. POTOK: Thank you.

Troy Maxwell?

MR. MAXWELL: I don't know much, but I do know one thing. That floodplain wasn't created, you know, in the last ten years, you know. If you've owned a house for a long time or anything else, you didn't have any detention. And, you know, as a landowner out in the area, I think it's kind of interesting that we talk -- or everybody's talking about it's wrong to do anything for the benefit of the landowner. You know?

So that's all I got to say.

MR. POTOK: Thank you.

Mary Sullivan?

MS. SULLIVAN: My name is Mary Sullivan. I've lived in the Katy area for approximately 30 years, off of Fry Road when Fry Road didn't go past Clay. So I've seen a lot of growth. And my concern about this is the expansion of Highway 99. And everyone's anticipating that with -- oh, one side of the fence or the other. I'm not going to get into it, but it's going to come, and the fact that if you lived in this area and you watched the south side, I think there's a gross underestimate that we saw in these figures as to the potential population increase that would happen in that general vicinity as you build up the Grand Parkway up and around to I-45.

Having a 40 percent increase in population over 50 years I think is a gross underestimation if you look at the growth that happened on the south side of 99 going down to Sugar Land. So I would really like to see this board, this group address the true potential growth that will happen and involve some of the major landowners that have been sitting on property in that area, waiting for that monster highway, and really work with them to ensure that no houses are built in harm's way and that green spaces that can absorb flood waters are truly taken into account.

MR. POTOK: Thank you.

Pete Smullen?

MR. SMULLEN: Yes. I'm sure I can be heard from here. With the flood that happened just recently, it's a golden opportunity to collect data on the overflow. I hope that Harris County Flood Control has collected information on the overflows in terms of volume, and I request that they publish their findings, the best estimates of what those overflows were in terms of volume, before the end of the study and that they be published soon.

MR. POTOK: Okay.

Have I missed anybody? Any other comments?

Robert Grundy?

MR. GRUNDY: Actually, my comment is on the back if you just want to read it.

MR. POTOK: Okay. Mr. Grundy's comment is as follows:

"You have a map that shows the overflow area and the area subdivision, Bear Creek and others, showing which residential areas have historically flooded or may be subject to future flooding.

"Is there a monitoring system in place, and if so, are the flood measurements posted on your website? If so, where? URL address? If not, could the water/flooding levels be shown on the website in real time?"

Okay. Thank you.

Again, I would encourage anyone who has an interest in the scope of (indiscernible) there are copies over here, and it will be posted on the website so that you can understand the depth of the investigations we intend to conduct.

I was doing so well. These were easy names, Sullivan and Smith. Now I've got Julie Hejducek.

MS. HEJDUCEK: Hejducek.

MR. POTOK: I apologize.

MS. HEJDUCEK: I live on Fern Ridge in Bear Creek, and we will get one or two inches of rain, and the street will flood. We have one overflow drain at the end of the street (indiscernible). My concern is that this one drain we have -- first, we don't have enough drains. Secondly, it's probably full of grass clippings, debris, leaves, whatever from different yards, and I was wondering whose responsibility is it to clean the drain out? I really think it needs to be cleaned. It just started doing that within the last (indiscernible).

Does that fall under the responsibility of the subdivision or (indiscernible)?

MR. POTOK: Okay. I appreciate the fact that many of these are questions, and my response to you is we will respond as soon as (indiscernible) the website. But we appreciate the questions and the comments.

I saw a hand back there?

UNIDENTIFIED SPEAKER: Ask them to please come forward (indiscernible).

UNIDENTIFIED SPEAKER: I couldn't hear. Was that Stone Ridge subdivision?

UNIDENTIFIED SPEAKER: No, Bear Creek.

UNIDENTIFIED SPEAKER: Oh, Bear Creek.

MR. POTOK: Any other questions, comments?

Okay. Well, thank you all very much for your time this afternoon.

There's coffee and water if you'd like to mull around. We will be staying here for a few more minutes. Again, the website (indiscernible).

(Meeting adjourned at 4:16 p.m.)

4.1.6 Summary of Questions and Comments

Cypress Creek Overflow Management Plan

Public Comments Received by October 1, 2012

This document contains information on all comments received by the end of the formal comment period. That information includes:

1) A summary of all comments received by October 1, 2012

2) Email comments received by October 1, 2012
3) Letter comments received by October 1, 2012

Although the formal comment period has ended, comments may continue to be submitted at http://www.hcfcd.org/cypresscreekoverflow/comments.aspx.

Your comments will be considered as the study and planning process continues.

CYPRESS CREEK OVERFLOW MANAGEMENT PLAN PUBLIC MEETING
BEAR CREEK COMMUNITY CENTER, AUGUST 16, 2012

COMMENTS RECEIVED AS OF OCTOBER 1, 2012

LAST NAME	FIRST NAME	AFFILIATION	MAILCITY	SOURCE	COMMENT
Bolton	Michael	Hearthstone Flood Coalition	Houston	Meeting - Verbal	See Meeting Transcript.
Foster	Paul	Bear Creek Subdivision Resident	Houston	Meeting - Written	In addition to the Addicks and Barker reservoirs, I would like you to address the impact of the rebuilding of Clay Road between Highway 6 and Eldridge. The elevating of Clay Road in this area has created another man-made dam which restricts the water flow, north of Clay Road into the Addicks reservoir. What can be done to reduce the impact of Clay Road to improve the water flow to the south? Options may be to make Clay Road an elevated Causeway in this area or possibly a more cost effective method may be to dig under Clay Road and place more flow through drainage channels to increase water flow.
Grundy	Robert S.	Self	Houston	Meeting - Written	Do you have a map that shows the overflow area and the area subdivision (Bear Creek and others) showing which residential areas have historically flooded or may be subject to future flooding? Is there a monitoring system in place and if so, are the flood guage measurements posted on your website? If so, where (URL address)? If not, could the water/flooding levels be shown on the website in real time?
Hejducek	Julie	Bear Creek Flood Control	Houston	Meeting - Written	We have one drainage for Fern Ridge. The homes downstream get flooded after 2 inches or rain. Do these overflow drains ever get cleaned out? From trash, leaves, grass clippings? It seems after 2 inches of rain the street is flooded. I propose the drains get cleaned out from trash, grass clippings. Is this the responsibility of the subdivision or the county?
Mannchen	Brandt	Self	Houston	Meeting - Verbal	See Meeting Transcript.
Maxwell	Troy	Landowner	Houston	Meeting - Verbal	See Meeting Transcript.
Merz	Evelyn	Houston Sierra Club	Houston	Meeting - Verbal	See Meeting Transcript.
Schwartz	Gerry	Resident	Houston	Letter	See Comments Attachment A for Letter and Enclosures
Smullen	Pete	Cypress Creek Flood Control Coalition	Cypress	Meeting - Verbal	See Meeting Transcript.
Sullivan	Mary	Northwest Harris County Municipal Utility District 12	Katy	Meeting - Written	(1) What membership do you have or intend to include on the study for major land owners in the area -- re: Planned Development? (2) What inputs do you anticipate from TxDOT re Grand Parkway? (3) Given the current plans for Grand Parkway expansion -- and historical growth from South 99, isn't 40% growth in 50 years an underestimate?
Yuhnke	Jim	Resident	Houston	Meeting - Verbal	See Meeting Transcript.
Yuhnke	Jim	Resident	Houston	Email	Any additional drainage into Langham Creek will result in flooding of the Bear Creek Subdivision at Hwy 6 and Clay Road. The US Corp of Engineers will not clean out Langham Creek thereby allowing water to flow into the Addicks Reservior. All that water has to go somewhere. Additionally when Houston Metro redid Clay Road it created a dam that again impedes any water from flowing into the reservoir.

"ATTACHMENT A"

September 14, 2012

Gerry Schwartz
4410 Belle Hollow
Houston, Texas
77084

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
Ref: **Cypress Creek Overflow Management Study**

Attn: Mr. Alan J. Potok P.E.
Assistant Director
Harris County Flood Control District

Dear Mr. Potok,

I attended the Public Meeting held at Bear Creek Community Center on August 16, 2012 regarding the reference study. I am writing to you to enter the following written comments into the record for consideration and response.

I hope that Harris County Flood Control District in conjunction with the U.S. Army Corps of Engineers will adopt a comprehensive analysis of the impact of future increased drainage into Addicks Reservoir. In particular, I ask that you carefully consider the potential for ***aggravating existing flooding conditions effecting Bear Creek Subdivision and Bear Creek Park***.

Bear Creek Subdivision experiences flooding largely due to storm water sewer back-up during heavy rainfall. Concerned residents conducted their own study and analysis and presented their conclusions to Harris County Utility District #6 in 2006. A copy of the "Position Paper" is attached. The conclusion was that storm water drainage pooling in Addicks Reservoir north of Clay road was restricting the subdivision storm sewer flow.

In response to this presentation, Harris County Utility District #6 employed their Consulting Engineering Company to conduct a professional study of this flooding issue. Their analysis came to the same conclusion. A copy of the study results is sent herewith.

The focus of Harris County Flood Control has always been only to improve and increase the drainage flow ***into*** Addicks Reservoir. The focus of the Corps of Engineers has always been only to protect property ***downstream*** of the dam. Neither organization takes into consideration the impact on Bear Creek Subdivision or Bear Creek Park.

The flow of water inside Addicks Reservoir from north to south needs to be enhanced to prevent future flooding conditions in Bear Creek Subdivision and Bear Creek Park. These improvements should be part of any Master Plan for drainage involving Langham Creek and Addicks Reservoir.

Population growth and development in northwest Harris County has steadily increased the storm water flows into Langham Creek and Addicks reservoir. Absolutely nothing has been done to move this increased flow from north to south within the Reservoir and prevent repetitive flooding in Bear Creek Subdivision and Bear Creek Park.

It is time for Harris County Flood Control and the U. S Army Corps of Engineers to work jointly for the benefit of ***ALL*** effected residents/taxpayers.

Sincerely,

Gerry Schwartz

cc: Precinct 4 County Commissioner R. Jack Cagle – without attachments

Precinct 3 County Commissioner Steve Raddack – without attachments

POSITION PAPER: BEAR CREEK SUBDIVISION FLOODING CONCERNS

Background: Bear Creek Subdivsion is located at the lower end of the Langham Creek Drainage Basin and borders on Addicks Reservoir at the point where storm water drainage from the basin discharges into the reservoir.

Introduction: Following the street and home flooding that occurred on October 28, 2002, a group of Bear Creek residents convened to form an ad-hoc committee to collectively address and voice subdivision flooding concerns. The flooding event in October 2002 followed chronologically other flood events in 1994 and 1997 and a near miss from Tropical Storm Allison. We were spared from the floods from Allison due to the limited amount of rain which fell on the Langham Creek Basin.

Previous Efforts: A number of Bear Creek residents have previously expressed concern for the potential for flooding in the subdivision. These concerns were addressed to the local utility district, the Corps of Engineers who manage Addicks Reservoir, and Harris County Flood Control in 2001. Harris County Flood Control being the agency responsible for storm water management does not acknowledge that a subdivision flooding problem exists.

Source of Flood Water: Committee members have shared observations, studied topographic maps, and met with U.S. Corps of Engineers representatives. From these investigations, we have concluded that floodwaters have not entered the subdivision limits from the Addicks reservoir or directly from the Langham Creek Drainage Culvert. Instead, subdivision flooding is a result of storm water overflow from the subdivision storm sewers. This has been the pattern in previous flood events. In October 2002, an eyewitness reported seeing a storm sewer manhole cover being forced off by rising storm water.

Anecdotal Information – The storm water carrying capacity of the Langham Creek drainage culvert has been increased over the last few years to the North and West of Bear Creek Subdivision to handle additional runoff from new subdivisions and commercial development. Inside the reservoir, the creek is un-improved and becomes a meandering stream flowing south which is at places not deep enough to float a canoe.

Storm Water Drainage Inside of Addicks Reservoir North of Clay Road

From aerial photographs, observations, and discussions with U.S Corps of Engineers personnel, we understand that the Langham Creek Drainage Culvert terminates in a dam about 100 yards downstream of the Addicks Satsuma Road bridge with the old creek bed veering off to the South. On the downstream side of the dam is a semicircular holding basin which receives the overflow from the dam and also receives drainage water from Horsepen Creek. When this basin is full, storm water will sheet flow into the wooded reservoir property north of Clay Road. From that point the water will follow the natural grade to the southeast and flow under (or over) Clay Road. and into Bear Creek Park.

Bear Creek Subdivision Storm Sewer Outfall

The primary storm sewer from Bear Creek Subdivision (two 96" diameter pipes) flow into a drainage ditch (U-107 ditch) which exits the east edge of the subdivision and carries water east until the ditch intercepts the unimproved Langham Creek bed. The termination of the ditch is not far from where the holding basin overflows into the reservoir.

Residents Concerns

Topographic maps indicate that the existing surface elevation in the vicinity of the intersection of U-107 ditch and Langham Creek is around 99.5 feet above sea level. During a storm event, we believe the water spilling from the holding basin and overflowing the old creek bed will pool behind Clay road and reach an elevation of 104.6 ft which is the lowest point on the new road surface. The carrying capacity of the culverts under Clay Road have not been increased and Clay Road has a history of flooding during heavy rains. The invert elevation of the Bear Creek Subdivision outfall is approximately 93.8 feet. This means the outfall is submerged at a time when it needs to be flowing at maximum capacity.

Engineering Analysis

The attached simplified analysis indicates that the velocity and therefore the flow of stormwater from the subdivision outfall can be reduced by 59% due to the pooling of water in the reservoir north of Clay Road during a storm event. This reduction in flow results in storm water spilling out of the sewers within the subdivision and flooding low elevation areas within the subdivision.

Action Needed

We ask that the appropriate authority take action to improve the flow of storm water within Adddicks reservoir so that water does not pool and impede the discharge of Bear Creek Subdivision outfall.

Harris County Utility District No. 6
Drainage Analysis
Phase 2

Prepared for

Harris County Utility District No. 6

Prepared by

TCB INC.

STATE OF TEXAS
ANTHONY W. HOLDER
96751
LICENSED
PROFESSIONAL ENGINEER

11/14/2006

November 2006
TCB Project No. 60004276

Contents

List of Tables

List of Exhibits

List of Figures

Section 1 – Introduction

TCB is pleased to submit this drainage report to Harris County U. D. No. 6 (HCUD6). This report expands on HCUD6 Drainage Analysis Phase 1 (Phase 1) and presents the results of the most recent data collection and analysis.

1.1 Location

HCUD6 is located northeast of the intersection of SH 6 and Clay Road in northwest Houston, and includes the Bear Creek Village subdivision along with other residential, multi-family and commercial areas. HCUD6 is located entirely within the Addicks Reservoir watershed, and drains to Langham Creek (U100-00-00), one of its tributaries, U107 (U107) and to U102-20-00, which is a tributary to Bear Creek (U102-00-00). Another Bear Creek tributary, U102-17-00 is just south of HCUD6 but the storm sewer map and the overland flow paths presented in Phase 1 indicate that U102-17-00 does not provide a significant portion of the drainage for HCUD6. Exhibit 1 shows the HCUD6 vicinity, along with several stream gages that collect water surface elevation data, and a representation of elevation at 10 ft contours. The four stream gages shown here are operated by the US Army Corps of Engineers in conjunction with the USGS.

1.2 HCUD6 Drainage Analysis Phase 1

In Phase 1, TCB reviewed the existing storm sewer system, based on a map of the system. This map shows four storm sewer outfalls. One of these outfalls is on the western edge and appears to drain into City of Houston infrastructure and eventually to U102-20-00. TCB has not analyzed this system, as there has not been a discussion of flooding issues in this area. One system drains directly into Langham Creek in the northeast corner of HCUD6. This system drains a very small portion of HCUD6. The remaining two storm sewer systems are not connected, yet both outfall into U107 about 500 ft apart. The Phase 1 report states that the larger of the two has a 96" outfall, however the outfall is actually a dual 96" outfall, with each barrel draining one of the two 96" pipes that meet along Hidden Springs near Four Leaf.

The Phase 1 analysis also discussed the TSARP analysis of Langham Creek, in which it is noted that the 10-year downstream boundary condition for Langham Creek is 97.6 ft. While we do not have any surveyed slab elevations, the LiDAR indicates that the slab elevations along Mill Hollow should be around the 102 to 104 range. Given these estimated slab elevations and the downstream boundary condition, under a 10-year there should be about 4.5 to 6.5 ft of fall between the lowest slab elevation in the southern portion of HCUD6 and the water surface elevation in Langham Creek at Clay Road.

Next in the Phase 1 analysis is a discussion of the rainfall intensities used in the TSARP modeling and some recent storms in the HCUD6 area. Finally there is a discussion of overland flow, based on the Harris County LiDAR elevation data. The overland flow discussion and maps describe the patterns of flow that would occur when the subsurface system is surcharged either due to high tailwater conditions or to intense local rainfall that exceeds the capacity of the system even with low tailwater. Phase 1 also includes four maps, showing the project area, overland flow, elevations, floodplains and storm sewers.

1.3 Purpose

The purpose of the Phase 2 analysis is to more thoroughly analyze the drainage conditions, including gathering information about the operations of Addicks Reservoir and US Army Corps of Engineers

(Corps) limits to flows in Langham Creek crossing Clay Road, gathering rainfall and water surface elevations from one or more recent storm events, reviewing the LiDAR profile and cross-sections of Langham Creek south of Clay Road, reviewing LiDAR elevations of the dam and spillway, and reviewing the raw LiDAR data at the Patterson Road crossing of Langham Creek.

Section 2 – Data Collection and Analysis

2.1 TSARP Model and Storm Sewer Analysis

Building on the review of the TSARP model for Langham Creek in Phase 1, further analysis indicates that the head losses in Langham Creek upstream of Clay Road and downstream of the confluence of U107 and Langham Creek (near cross-section 18671.1 in the HEC-RAS model) may be significantly impacting the capacity of the HCUD6 storm sewer system. This confluence is about 1500 to 2000 ft downstream (along U107) from the HCUD6 outfalls. Table 1 adds information about the confluence to one of the tables from the Phase 1 analysis.

Table 1 Downstream Boundary Conditions and U107 Confluence Conditions from Langham Creek HEC-RAS/Hydraulic Model

	Downstream Boundary		U107 Confluence		Head Loss
Frequency	Flow, Q (cfs)	WSEL (ft)	Flow, Q (cfs)	WSEL (ft)	(ft)
10-yr	6,973	97.6	7,677	100.94	3.3
50-yr	12,166	99.9	13,254	102.20	2.3
100-yr	15,203	100.8	16,397	102.82	2.0
500-yr	24,506	102.4	25,681	104.27	1.9

From this table and the estimated lowest slab elevations of 102 to 104 ft, it is clear that in a 10-year storm the tailwater conditions in U107 are relatively high, limiting the effectiveness of the storm sewer system. This reduction in capacity, combined with the overland flow patterns discussed in the Phase 1 report, leads to significant ponding in the portions of HCUD6 along the east-west stretch of Pine Mountain. This area is where much of the overland flow will concentrate once the storm sewer system is surcharged.

For example, the storm sewer system along Pine Mountain from Thistlecroft to the outfall is a 96" pipe. This pipe runs approximately 3000 ft along this stretch. Assuming that the lowest slab elevation in that area is 103 ft, there are no inlet losses, and that there is no head loss along the 2000 ft of U107 between the outfall and Langham Creek, in a 10-year storm the maximum flow rate through that storm sewer is calculated and shown in Table 2. The equation for flow in a circular pipe is as follows:

$$Q = \frac{1.49}{n} A R^{2/3} \sqrt{S},$$

Where A is the area of the conduit (ft^2), R is the hydraulic radius (ft), n is the roughness coefficient, S is the friction slope (driving head divided by length of pipe, ft/ft) and Q is the flow rate (ft^3/s or cfs). Table 2 shows the capacity of the pipe for various tailwater conditions.

Table 2 Capacity of 96" Storm Sewer Under Various Tailwater Conditions

Tailwater	Headwater	Roughness	Diameter (in)	Flow, Q (cfs)	Head Drop (ft)
101.5	103	0.015	96	177	1.5
100.94	103	0.015	96	208	2.06
100.5	103	0.015	96	229	2.5
99.3	103	0.015	96	278	3.7
97.6	103	0.015	96	336	5.4

This table indicates that the capacity of the storm sewer is sensitive to changes in tailwater conditions and that during significant events, the storm sewers may not have much capacity to drain HCUD6, relative to the amount of rain that is falling over the district. Two 96" pipes and one 72" pipe would have a capacity of around 500 to 600 cfs under a moderate friction slope, which would be the design peak flow rate from a 50% (2-year) storm. From the TSARP HEC-HMS model, subarea U129F represents an area including most of HCUD6, as well as much of the undeveloped land on the west side of Langham Creek. The peak flow rates for this subarea are 1045, 1617 and 1894 cfs for the 10%, 2% and 1% recurrence probability storms, respectively. With the assumption that most of the peak flow in this subarea comes from HCUD6, it is clear that two 96" and one 72" pipe cannot carry the flows from the 10% storm.

It is important to recall that storm sewers are designed to contain relatively small storms (2-year or 3-year) and keep the water surface below gutter level, and that the 2-year capacity is present only when the tailwater conditions are low. The top of the outfall pipe elevation is the typical design tailwater. The water from larger storms is intended either to flow overland at street level or to pond in the streets temporarily, receding as the storm sewers and receiving streams recede. Because of this relatively small capacity combined with a clear overland pathway for flow, when large storms occur, water collects in the southern portion of HCUD6, along Pine Mountain and other nearby streets. This water includes the water that fell in the immediate area of these streets as well as overflow from areas upstream, including possibly some overflow from outside of HCUD6, depending on the severity of the storm. This water will either stand in the streets until it recedes through the storm sewer, or if there is enough inflow it will rise high enough to flood the lowest residences in the area. The LiDAR elevation estimates indicate that very near the lowest slab elevations there is an overland outflow path into Corps property near the Thistlecroft dead-end. This overland path, however, is not well defined and cannot carry a significant flow rate unless the water surface in HCUD6 is high enough to cause structural flooding. The ditch by the water well off of Mill Hollow provides an overland outfall for part of HCUD6 and appears to have relieved some of the frequent flooding in that area based on anecdotal evidence.

2.2 Recent Storm Event – July 26, 2006

On July 26, 2006, 5 to 6 inches of rain fell over the HCUD6 area, as measured at the three neighboring HCOEM rainfall gages (4.76" at 2120 – Langham Creek at W. Little York, 6.46" at 2160 – Bear Creek at Clay, and 4.41" at 2110 – Addicks Dam). This rainfall, combined with rainfall during surrounding days, caused high water levels inside HCUD6. Based on the 24 hour rainfall totals, the storm has around a 20% recurrence probability (5-year storm). During the most intense two hours of the storm, ending at 10am, between 3.5 and 4 inches of rain fell at two of the three gages. This intensity corresponds to about a 10% to 4% recurrence probability (10- to 25-year storm) for a two hour duration. The Phase 1 report has a summary of the TSARP rainfall totals for various recurrence probabilities and durations. After the rainfall, one of the HCUD6 residents took four photographs that have been given to TCB. One of the photographs is from 11:27 am, and one is from 3:46 pm. Both of these photographs are of U107, taken from just upstream of the two 96" outfalls and facing downstream. In these photographs, the armored section of channel across from the 72" outfall is visible, thus allowing an estimate of the water surface elevation.

From aerial photographs, the raw LiDAR and gridded LiDAR elevations, the elevation of the top of concrete on the south side in this area is about 104. ft MSL (NAVD 1988, 2001 Adjustment).

Figure 1 U107 Aerial Photograph and Raw LiDAR Elevations (72" Outfall)

Figure 2 Upstream end of U107 at 3:46 pm on 26 July 2006

The photograph in Figure 2 was taken at 3:46 pm, and shows U107 from a viewpoint standing near the two 96" outfalls. The black lines are from top of bank to top of bank in the concrete section around the 72" outfall, and from water line to water line. Estimating the lengths of the lines, the bottom line is about 80% as long as the top line. From the aerial photo, the concrete section is about 140 ft long, so 80% would be about 112 ft, so there is about 14 ft on each side. At 4:1 side slopes, the water level is about 3.5 ft below the top of the concrete. From the aerial, the top of the concrete is about 104 ft MSL, so the water level here is about 101.5 ft. 2000 ft downstream of this point at the confluence with Langham Creek, the 10-year water surface elevation is 100.89 ft. The calmness of the water surface in the photograph indicates that the flow in U107 is very slow. At the bottom of the picture, there is no indication of turbulence due to water exiting the two 96" culverts. The photograph in Figure 3 was taken at 11:46 that morning, when it was still raining, and shows no visible evidence of turbulence from the dual 96" outfalls and a similar water surface elevation to the later photograph.

Figure 3 Upstream end of U107 at 11:27 am on 26 July 2006

Stream stage and flow information was requested and received from the USGS for six gages in the area. The gage measurements are all on NGVD 1929, 1973 adjustment. Based on available elevation benchmarks from the TSARP project and a binder of elevations and adjustments from HCFCD, subsidence in the area between 1973 and 2001 has caused a datum shift of approximately 2.5 ft. Benchmarks U100 BM01, U100 BM02, W167 BM01, W167 BM02 and W167 BM03 were reviewed. The gage data summarized in Table 3 have been adjusted by this vertical shift to match the NAVD 1988, 2001 Adjustment of the LiDAR and the TSARP models. The gage data show that the water surface elevations at the Clay Road Bridge were very similar at the times of the two photographs, between 98.36 and 98.75 ft, and that the reservoir was rising during this time, yet continued to have significant capacity early in the storm. The WSELs at the Clay Road gage are higher than the 10% WSELs from the TSARP downstream boundary condition, even though the TSARP boundary conditions are upstream of the Clay Road Bridge and the gage is downstream of the bridge.

Table 3 Observed Data for Nearby USGS Gages (2001 Adj.)

Gage Number	08072800	08073000	08073000	08073500	08073500	08072730	08072730	08072700	08072760	08072760
Location	Langham @ Clay	Addicks Reservoir	Addicks Reservoir	Buffalo Bayou @ Dairy Ashford	Buffalo Bayou @ Dairy Ashford	Bear Ck @ Clay	Bear Ck @ Clay	Mayde Ck @ Groeschke	Langham @ Little York	Langham @ Little York
Measurement Date/Time	Elev (ft)	Elev (ft)	Storage (acre-ft)	Elev (ft)	Flow (cfs)	Elev (ft)	Flow (cfs)	Elev (ft)	Elev (ft)	Flow (cfs)
07/25/06 00:00	90.45	76.15	115	49.63	409	101.79	209	98.34	111.17	92
07/25/06 02:00	90.61	76.44	131	49.70	428	101.40	161	98.02	111.16	91
07/25/06 04:00	90.80	76.62	141	49.72	433	100.98	119	97.71	111.07	82
07/25/06 06:00	90.99	76.57	138	49.72	433	100.50	82	95.42	110.96	72
07/25/06 08:00	91.17	76.44	131	49.69	425	100.06	56	95.11	110.81	61
07/25/06 10:00	91.31	76.25	121	49.66	418	99.76	41	94.95	110.71	54
07/25/06 12:00	91.49	75.96	106	49.61	404	99.60	35	96.07	110.93	70
07/25/06 14:00	92.01	76.20	118	49.17	301	100.41	76	98.53	111.84	182
07/25/06 16:00	92.76	76.68	145	48.50	165	101.90	224	99.07	112.38	287
07/25/06 18:00	93.32	77.32	188	48.58	180	102.38	298	98.85	112.76	381
07/25/06 20:00	93.62	78.07	252	48.62	187	102.87	394	98.32	112.89	417
07/25/06 22:00	93.84	78.74	321	48.57	179	102.75	368	97.70	112.88	414
07/26/06 00:00	94.02	79.36	396	48.49	164	102.39	300	97.11	112.76	381
07/26/06 02:00	94.20	79.94	483	48.49	164	102.02	242	96.62	112.58	334
07/26/06 04:00	94.39	80.42	580	48.46	159	101.65	191	96.23	112.38	287
07/26/06 06:00	94.64	80.84	682	49.44	363	101.32	152	95.92	112.25	259
07/26/06 08:00	94.92	81.30	810	56.72	1897	101.43	149	96.19	112.27	263
07/26/06 10:00	96.60	82.20	1104	63.52	3483	109.11	3050	104.12	119.46	5087
07/26/06 10:15	97.05	82.27	1130	63.57	3398	109.31	3225	104.37	119.44	5062
07/26/06 10:30	97.49	82.36	1164	63.61	3348	109.27	3181	104.57	119.29	4879
07/26/06 10:45	97.76	82.45	1198	63.59	3281	109.15	3082	104.70	119.05	4594
07/26/06 11:00	98.02	82.54	1234	63.56	3215	108.96	2934	104.77	118.78	4287
07/26/06 11:15	98.19	82.64	1275	63.51	3160	108.92	2903	104.86	118.56	4046
07/26/06 11:30	98.36	82.73	1312	63.45	3107	109.06	3007	104.98	118.53	4014
07/26/06 11:45	98.49	82.82	1351	63.45	3081	109.40	3326	105.08	118.72	4221
07/26/06 12:00	98.61	82.90	1385	63.44	3054	109.81	3818	105.18	119.13	4688
07/26/06 12:15	98.68	83.00	1430	63.46	3055	109.98	4037	105.27	119.39	5000
07/26/06 12:30	98.74	83.09	1472	63.48	3034	110.03	4103	105.38	119.39	5000
07/26/06 12:45	98.77	83.20	1525	63.46	2999	109.87	3894	105.38	119.27	4855
07/26/06 13:00	98.80	83.31	1579	63.43	2975	109.60	3560	105.55	119.13	4688
07/26/06 13:15	98.83	83.39	1619	63.35	2933	109.29	3203	105.60	118.91	4433
07/26/06 13:30	98.86	83.47	1660	63.27	2895	108.99	2955	105.63	118.69	4188
07/26/06 13:45	98.87	83.56	1709	63.19	2865	108.67	2711	105.64	118.48	3961
07/26/06 14:00	98.88	83.64	1754	63.11	2832	108.37	2500	105.64	118.28	3753
07/26/06 14:15	98.87	83.76	1823	63.00	2790	108.06	2293	105.62	118.10	3571
07/26/06 14:30	98.86	83.90	1906	62.88	2766	107.78	2115	105.59	117.89	3366
07/26/06 14:45	98.84	84.09	2026	62.77	2724	107.53	1971	105.55	117.72	3206
07/26/06 15:00	98.81	84.36	2213	62.66	2683	107.29	1834	105.51	117.55	3051
07/26/06 15:15	98.80	84.69	2463	62.54	2645	107.07	1718	105.45	117.40	2917
07/26/06 15:30	98.79	85.06	2775	62.42	2611	106.86	1607	105.40	117.27	2805
07/26/06 15:45	98.76	85.47	3160	62.30	2575	106.66	1508	105.40	117.13	2687

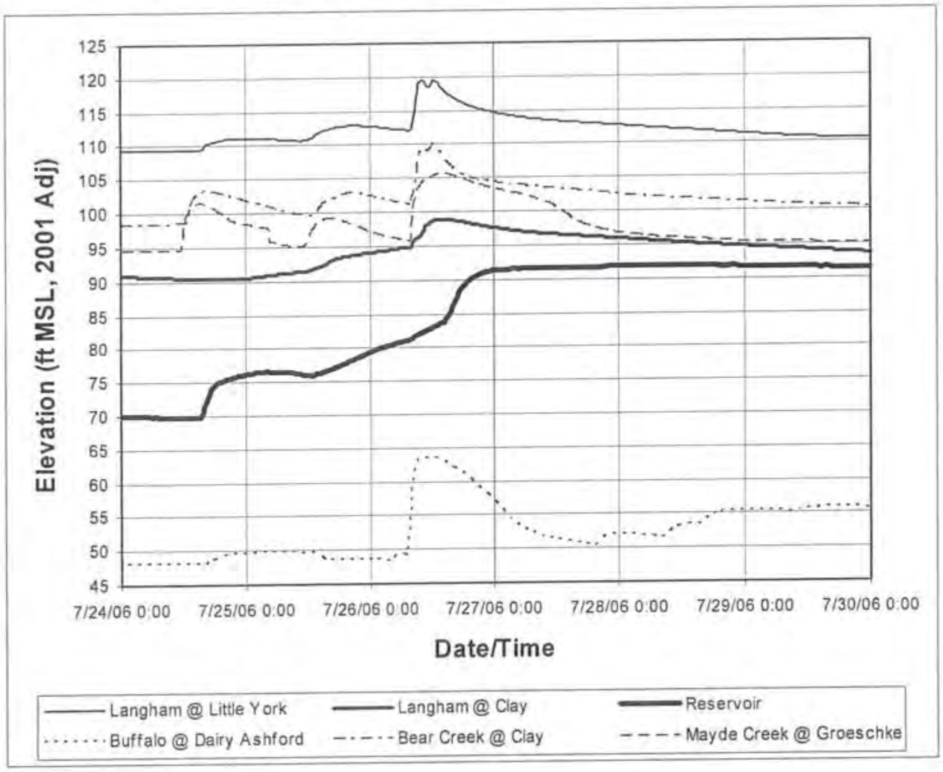
Table 3 (Continued) Observed Data for Nearby USGS Gages (2001 Adj.)

Gage Number	08072800	08073000	08073000	08073500	08073500	08072730	08072730	08072700	08072760	08072760
Location	Langham @ Clay	Addicks Reservoir	Addicks Reservoir	Buffalo Bayou @ Dairy Ashford	Buffalo Bayou @ Dairy Ashford	Bear Ck @ Clay	Bear Ck @ Clay	Mayde Ck @ Groeschke	Langham @ Little York	Langham @ Little York
Measurement Date/Time	Elev (ft)	Elev (ft)	Storage (acre-ft)	Elev (ft)	Flow (cfs)	Elev (ft)	Flow (cfs)	Elev (ft)	Elev (ft)	Flow (cfs)
07/26/06 16:00	98.73	85.93	3638	62.17	2545	106.47	1420	105.28	116.99	2572
07/26/06 18:00	98.52	88.90	8424	61.13	2274	105.42	994	104.75	116.14	1941
07/26/06 20:00	98.18	90.27	12216	59.90	2005	104.86	811	104.19	115.52	1548
07/26/06 22:00	97.89	90.97	14657	58.49	1725	104.53	712	103.74	115.06	1292
07/27/06 00:00	97.61	91.31	15946	56.98	1459	104.29	650	103.30	114.66	1092
07/27/06 02:00	97.38	91.46	16542	55.42	1212	104.09	599	103.02	114.34	947
07/27/06 04:00	97.17	91.49	16663	53.96	999	103.90	554	102.68	114.08	839
07/27/06 06:00	96.99	91.50	16704	52.88	887	103.74	517	102.29	113.87	757
07/27/06 08:00	96.83	91.50	16704	52.17	829	103.58	482	101.87	113.69	691
07/27/06 10:00	96.69	91.52	16784	51.72	796	103.44	451	101.27	113.54	639
07/27/06 12:00	96.57	91.55	16906	51.39	761	103.30	422	100.45	113.39	586
07/27/06 14:00	96.45	91.60	17109	51.07	711	103.17	397	99.42	113.26	541
07/27/06 16:00	96.35	91.64	17273	50.80	661	103.02	368	98.65	113.14	501
07/27/06 18:00	96.24	91.68	17439	50.54	608	102.86	338	97.76	113.02	460
07/27/06 20:00	96.13	91.71	17564	50.50	601	102.70	313	97.32	112.91	423
07/27/06 22:00	96.02	91.74	17690	51.87	872	102.54	287	96.96	112.80	392
07/28/06 00:00	95.91	91.76	17774	52.04	904	102.38	262	96.70	112.69	362
07/28/06 02:00	95.81	91.78	17859	51.95	886	102.24	242	96.50	112.58	334
07/28/06 04:00	95.69	91.80	17944	51.78	854	102.11	225	96.31	112.46	305
07/28/06 06:00	95.57	91.82	18029	51.65	830	101.97	208	96.15	112.34	278
07/28/06 08:00	95.46	91.83	18072	51.52	805	101.85	193	95.99	112.23	255
07/28/06 10:00	95.34	91.83	18072	52.43	981	101.76	183	95.97	112.13	235
07/28/06 12:00	95.23	91.83	18072	53.23	1143	101.67	173	95.94	112.02	214
07/28/06 14:00	95.11	91.83	18072	53.35	1167	101.58	164	95.63	111.93	197
07/28/06 16:00	95.01	91.81	17986	53.57	1213	101.51	156	95.60	111.80	175
07/28/06 18:00	94.92	91.75	17732	54.84	1494	101.42	147	95.48	111.68	156
07/28/06 20:00	94.83	91.72	17606	55.24	1580	101.33	139	95.39	111.57	140
07/28/06 22:00	94.74	91.74	17690	55.39	1614	101.24	131	95.33	111.46	126
07/29/06 00:00	94.66	91.71	17564	55.40	1610	101.16	125	95.31	111.34	112

Figure 4 shows several days of gage elevations before and after July 26, 2006. Note the relatively rapid rise and fall of WSEL for the Langham Creek @ Little York, Bear Creek @ Clay and Mayde Creek @ Groeschke gages, and the steady rise in WSEL for the Langham Creek @ Clay Road gage that precedes the rapid WSEL rise in Addicks Reservoir by several hours. The difference in behavior of these gages indicates a difference in the hydraulic behavior of the two areas. A relatively rapid rise and fall indicates that the channel fills with water from local drainage and the water then proceeds to flow to a downstream location. A steadily rising WSEL indicates that there is an obstruction to flow downstream, causing the area to act as a reservoir. The difference in water surface elevations between Langham Creek @ Clay Road and the Addicks Reservoir pool gage, and the delay in the rising limb of the reservoir gage indicates that the Langham Creek @ Clay Road area is acting more like a reservoir than like a channel where the water surface rises and falls with the rainfall events. The WSEL in the area around Clay Road that behaves like a reservoir is more or less independent of the WSEL in the main part of Addicks Reservoir. Table 1 shows the flow rates at the U107 confluence and upstream of Clay Road. The flow rate in the model is higher at the U107 confluence, indicating that the TSARP modeling also shows some reservoir-like behavior for Langham Creek between U107 and Clay Road.

Also of note is that the Bear Creek and Mayde Creek gages show larger reactions to the rainfall events on the 24th and 25th of July, indicating heavier rainfall than Langham Creek on those days, and the rise in the Addicks Reservoir WSEL prior to the 26th appears mostly due to those earlier rainfall events. Even with the relatively smaller rainfall totals coming from upstream and the availability of downstream capacity, as evidenced by the Langham Creek @ Little York gage and the Addicks Reservoir gage on the 24th and 25th, the WSEL in Langham Creek @ Clay Road continues to rise on those days, even though the water surface elevation upstream at Little York rises and falls on each of the earlier days.

Figure 4 Stream Gage Elevations Around 26 July 2006



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2.3 LiDAR Elevation Analysis at Clay Road

Figure 5 shows estimated channel inverts for Langham Creek, using the HCFCD/TSARP LiDAR elevation grid. LiDAR is an elevation measurement method that uses airplane-based lasers in combination with GPS systems to estimate elevations. It can provide reasonable estimates of elevation for large areas, but is not well suited for determining fine details in heavily wooded areas. It also cannot penetrate beneath water. As such, the following discussion of channel structure and cross-sections is not expected to be completely accurate on fine details, but to give a large-scale description of the layout of the land. A fine detail analysis for this area would require channel survey data, which is beyond the scope of this analysis.

Since Langham Creek is not well defined by the LiDAR, a neighborhood minimum estimation was performed, where each cell was given the minimum elevation observed within 300 ft, but only looking toward the south, from southwest to southeast. Using this elevation grid, a channel was defined and the channel elevations were determined. These elevations are rough estimates and the actual channel invert may be lower, however they indicate the general trends in the LiDAR data, and can be used to make some observations about the general lay of the land. For instance, between Clay Road and Brandt Road, the LiDAR indicates that there is very little, if any, fall in the channel invert, and in fact there is a rise about halfway between these points. This observation would tend to support the observation from the gage data that the area near Clay Road acts somewhat like a reservoir that is more or less independent of the WSEL in the main pool section of Addicks Reservoir during the early stages of an event, before the main pool section has started to fill significantly.

Figure 5 LiDAR Estimated Channel Invert Elevations Along Langham Creek

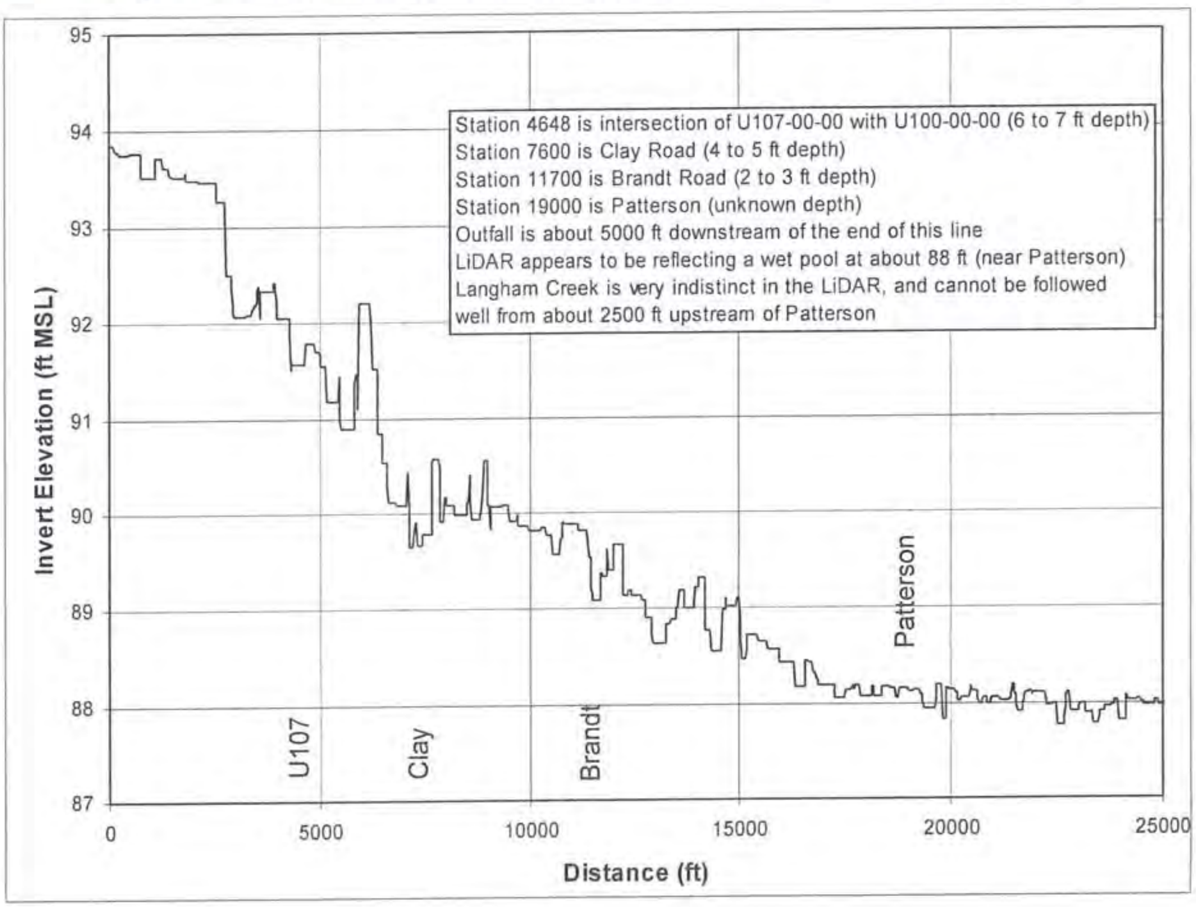


Figure 6 shows the locations of several cross-sections that were taken from the LiDAR for the area just downstream of Clay Road. Figures 7 through 15 are the elevations for the corresponding cross-sections, along Langham Creek. These cross-sections (taken looking upstream) show a very poorly defined channel, which is not surprising due to the limitations of the LiDAR data. More importantly, they show that the area of inundation, even in the July 26, 2006 storm, was very wide. The gage data at Clay Road indicated that the peak water surface elevation was almost 99 ft. This corresponds to a top width of about 6000 ft along the first of these cross-sections. At that same time, the WSEL in the reservoir was between 83 and 89 ft (rising steadily). The lowest elevation in the LiDAR cross-sections is around 89 ft, which may indicate that there was water in the reservoir when the LiDAR elevations were taken, and would indicate a limited usefulness of LiDAR to estimate channel size when the invert is below that level. There is no data to indicate how quickly the water surface elevation drops from its levels at Clay Road to the level pool elevation in the reservoir. The LiDAR cross-sections indicate that the inundation/flow area is likely to be very wide, even with relatively low water surface elevations.

Figure 6 LiDAR Cross-Section Locations

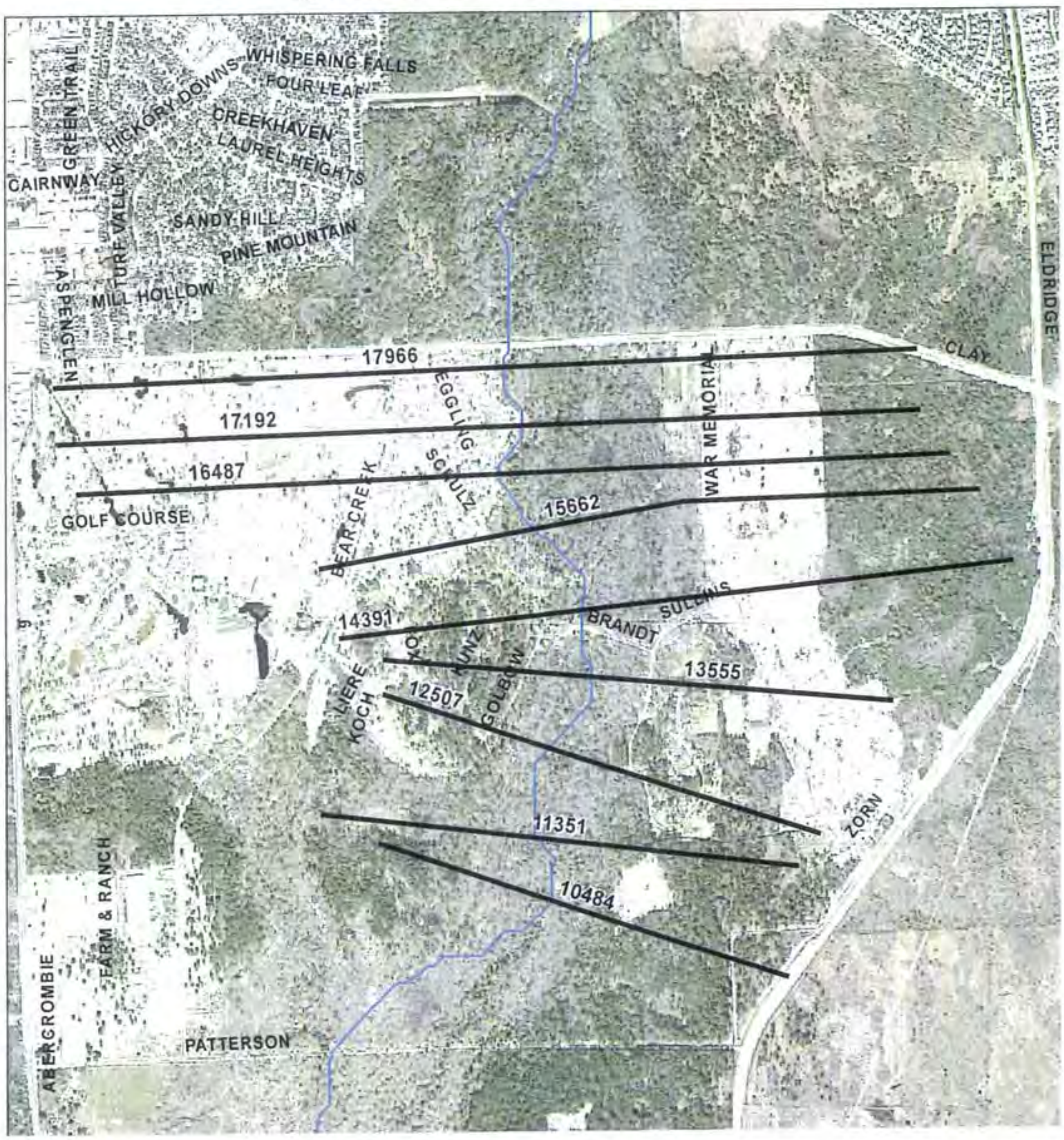


Figure 7 LiDAR Cross-Section Just Downstream of Clay Road

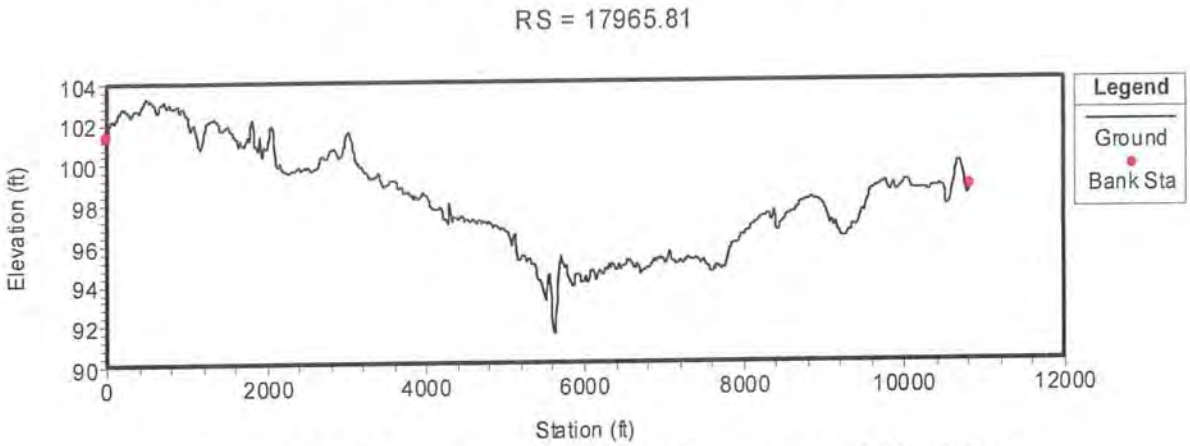


Figure 8 LiDAR Cross-Section 1000 ft Downstream of Clay Road

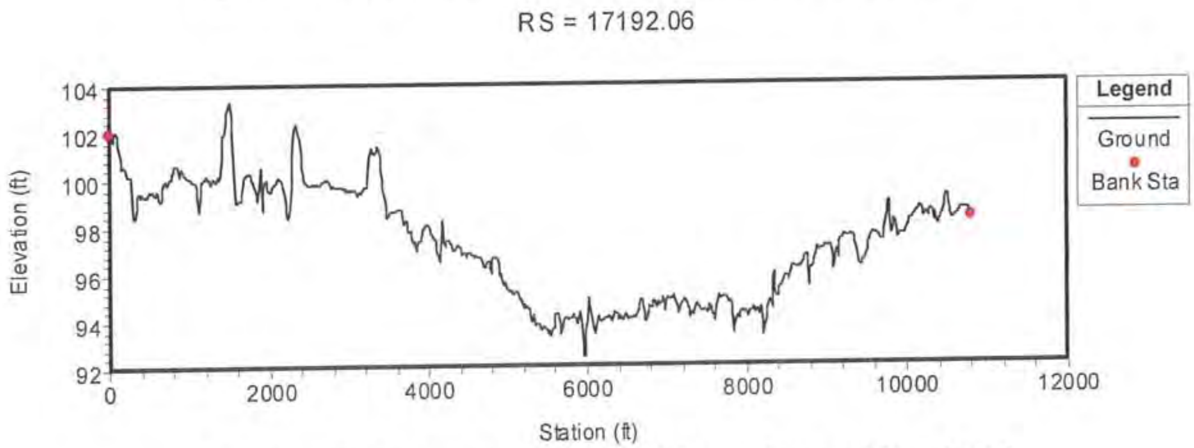


Figure 9 LiDAR Cross-Section 1500 ft Downstream of Clay Road

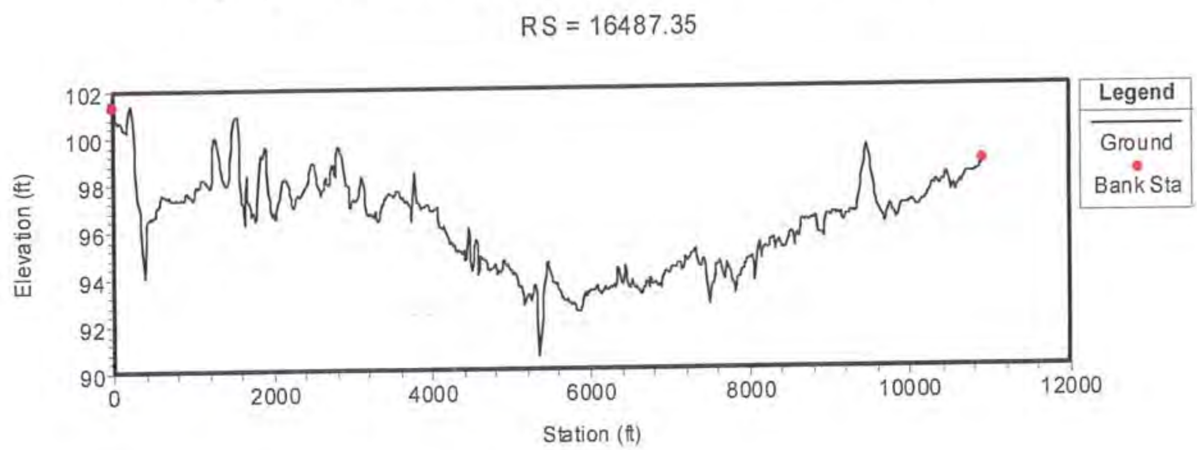


Figure 10 LiDAR Cross-Section 2500 ft Downstream of Clay Road

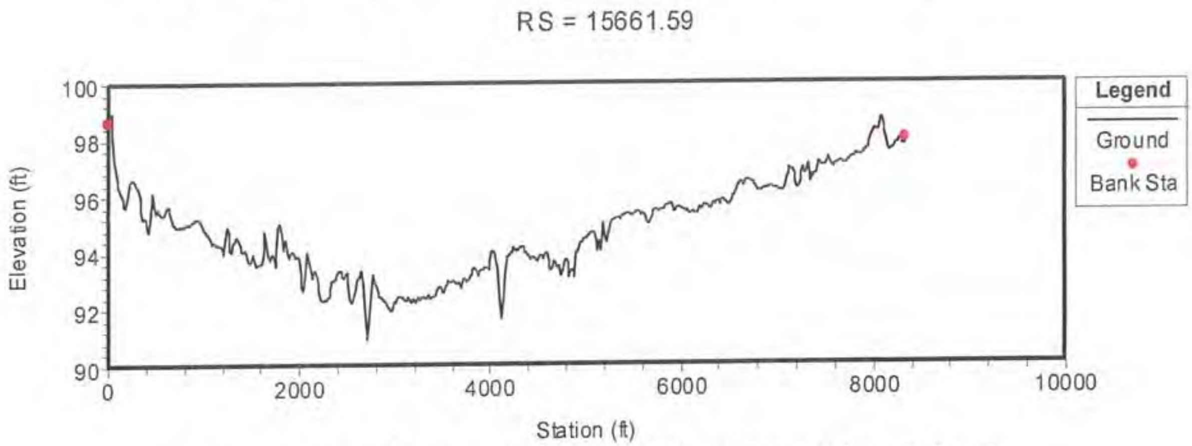


Figure 11 LiDAR Cross-Section Just Upstream of Brandt Road

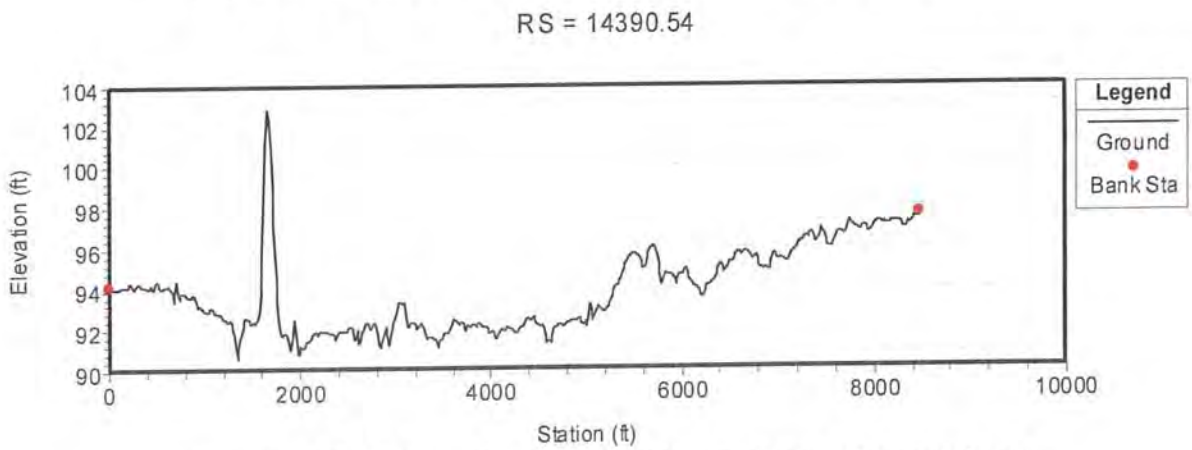


Figure 12 LiDAR Cross-Section 500 ft Downstream of Brandt Road

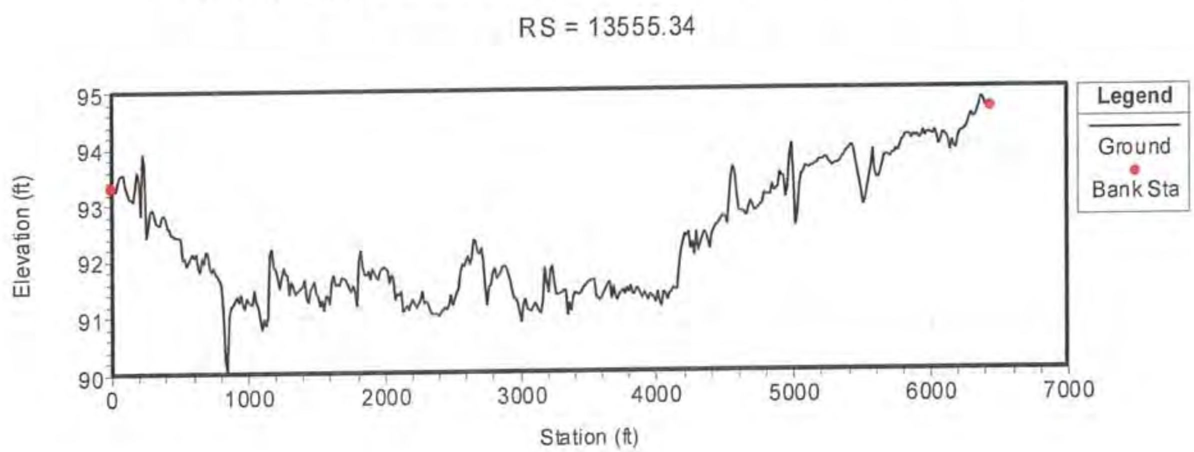


Figure 13 LiDAR Cross-Section 1500 ft Downstream of Brandt Road

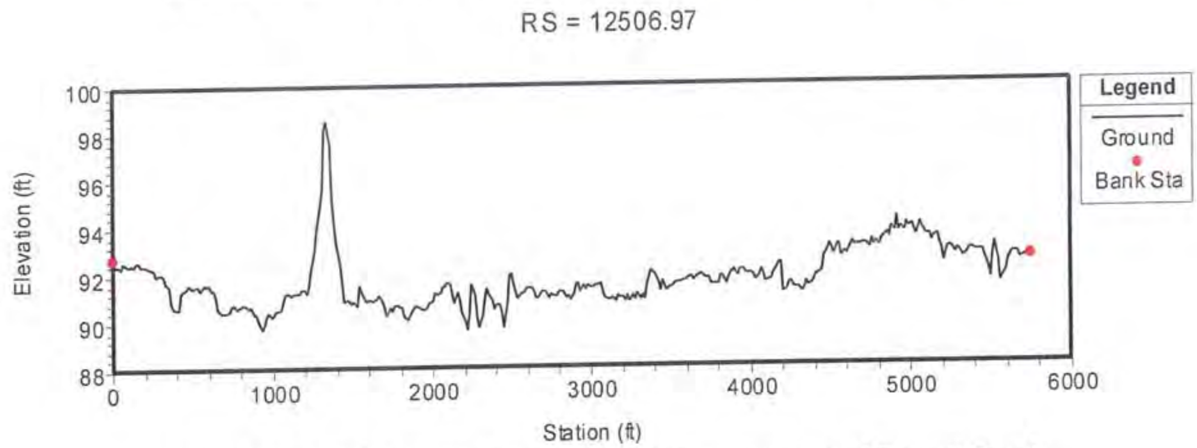


Figure 14 LiDAR Cross-Section 2700 ft Downstream of Brandt Road

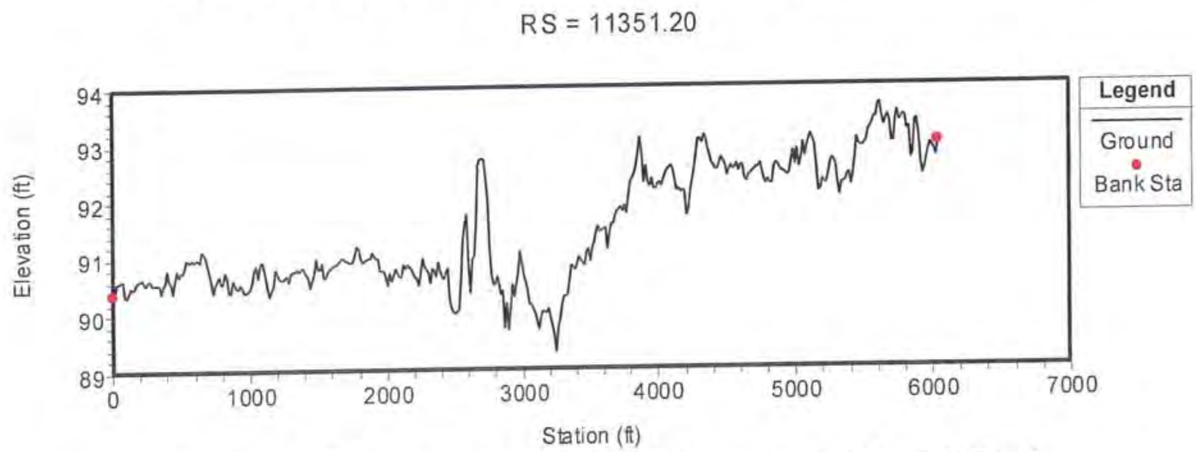
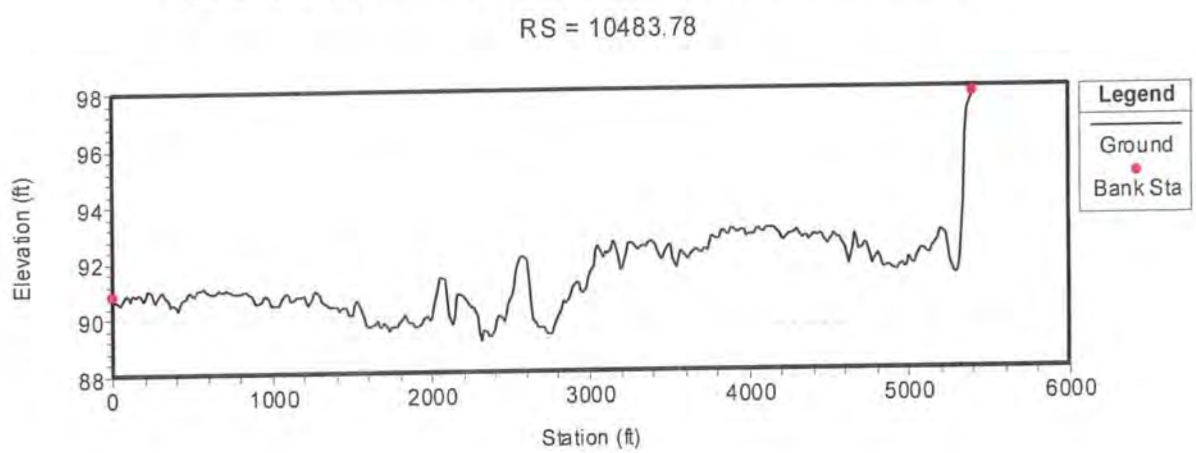


Figure 15 LiDAR Cross-Section 3500 ft Downstream of Brandt Road



2.4 LiDAR Elevation Analysis of Addicks Dam

A review of the LiDAR data along the length of Addicks Dam indicates that the lowest elevations are just north of Clay Road, where the downstream edge of the dam is concrete-lined. This area is clearly the spillway for the dam. The spillway elevations are around 107 ft MSL (2001 Adjustment). Aside from the spillway, the top of the dam ranges in elevation from 110 to 120 ft. The top elevation varies significantly from location to location, with several relatively sharp changes in elevation followed by long stretches of fairly constant elevation.

2.5 Condition of Langham Creek Crossings

TCB visited several crossings of Langham Creek to review the conditions of the channel and of the crossings, and took photographs of the conditions. Many of these photographs are included in Appendix A. The site visit and photographs show that the Clay Road crossing is a bridge, and has a reasonably large opening. Erosion has clearly affected this crossing, as can be seen from the USGS gaging station and the corrugated metal pipe (CMP) outfall.

Just downstream, at Brandt Road, there is another crossing. This is a low water crossing, with four CMP culverts. From the photographs, they appear to be around 48" culverts. Figure 16 shows the raw LiDAR points at the Brandt Road crossing. Based on the raw LiDAR, the road centerline at the crossing is at about elevation 89.5 ft. The raw LiDAR points also show gaps along the channel, where standing water would have absorbed the laser beam. From this and the photographs in Appendix A, it is clear that the channel invert is somewhere around 80 to 84 ft. The raw LiDAR analysis of the Brandt road crossing indicates that the earlier LiDAR invert elevation analysis is not accurate, and in fact misses the channel inverts by as much as 6 to 8 feet, due to standing water.

The site visit to Patterson Road at Langham Creek indicates that it is a bridge with a substantial opening, as shown in the figures in Appendix A. The Raw LiDAR for Patterson Road in Figure 17shows that the bridge deck is at about 91.5 ft above MSL, which is actually higher than the Brandt Road crossing, even though it is about 7000 ft downstream.

Figure 16 Brandt Road Raw LiDAR Elevations

Figure 17 Patterson Road Raw LiDAR Elevations

Section 3 – Possible Causes of Flooding

3.1 Riverine Flooding from Langham Creek

Some portions of HCUD6 (in the northwest corner) are inside the TSARP 1% floodplain, and will be required to purchase flood insurance when the new floodplain maps are established. These homes may become flooded directly due to high water in Langham Creek in an extreme flood event. In such an event, the local rainfall over HCUD6 would not have a significant impact on the flooding in these homes, as the high water levels will be due to regional heavy rainfalls.

Those residents who are in this area and do not currently have flood insurance are advised to purchase flood insurance before the new maps become effective, as their rates will most likely be lower than if they wait until after the new maps are effective. This 'grandfathered' rate can be maintained indefinitely with continuous coverage, and may be transferable to new owners.

In Phase 1, the 10% (10-year) floodplain was mapped from the TSARP model. This mapping indicates that there would be street flooding in the northeast corner of HCUD6 during a 10% storm, and possibly some structural flooding, but to a smaller extent than during the 1% storm.

3.2 High Tailwater in Langham Creek Affects U107

U107, the primary outfall for HCUD6, appears to have a relatively low capacity during heavy rainfall due to high tailwater in Langham Creek. The two photographs of U107, taken about 1.5 and 5.75 hours after the most intense portion of the storm (2 hours ending 10 am), both show no clear signs of flow in U107. The surface of the water appears to be very flat, with no ripples. If the flow rate in U107 is very low, the three storm sewer systems in HCUD6 that drain to U107 will not carry even their designed flow rate, leading to overland flow inside HCUD6. It is even possible, though highly unlikely, that there could be reverse flow in the pipe system, as the water surface elevation in U107 appears very near the street elevations in the southern portion of HCUD6.

3.3 Overland Flow Gathers in the Southern Parts of HCUD6

Whether due to high tailwater or simply due to large storm events (larger than the 2-year or 3-year design) locally falling on HCUD6, not all rainfall will enter the storm sewer system. When this happens, the street systems act as conduits for flow. In fact, storm sewer and street systems are often described as a Major/Minor system, with the Minor system being the storm sewers, which are designed only to carry a small portion of the flow from large events, and the Major system being the streets themselves, as well as any major overland channel systems like U107.

In HCUD6, the street system, following the natural overland gradients in the area, typically slopes from north/northwest to south/southeast. In Phase 1, these overland flow paths were documented, based on the LiDAR elevation maps. Regardless of the presence of a storm sewer system, the majority of flow in a large storm will be conveyed in the overland system unless there is a barrier to overland flow, natural or otherwise. In HCUD6, there is such a barrier, and it is the last row of homes along the south and east edges of HCUD6, along with the high natural ground elevations in the Corps of Engineers property just south of HCUD6 at the Thistlecroft dead end. As this overland flow gathers in the streets, it must either rise until finding an overland flow path or remain in the streets until there is capacity in the storm sewer system to remove the water. In HCUD6, it appears that one or more homes have elevations that are near or lower than the high natural ground elevations in the Corps of Engineers property at the dead end of Thistlecroft. Therefore, when the overland flow begins to gather in these streets, the water will enter these homes before finding an overland flow outlet. These homes and their lots, being at or below the Thistlecroft dead end elevations, are part of the current overland flow outlet.

Figure 18 shows a typical well-draining overland flow system. At each point, there is some in-street storage of water, then a Vertical Point of Intersection (VPI) is reached, either along the street or between two homes, at which point there will be flow downstream. In general, the water surface will not exceed the VPI elevations by a large amount unless there is a very small opening at that elevation and/or there is a large amount of flow coming in from upstream areas. Some areas may have very high VPIs but never experience flooding because there is no flow coming from upstream and the local drainage can remain in the streets until flowing out through the pipe system. Other areas may have relatively low VPIs, but the slab elevations are very close to (or below) the VPI and there is a large upstream area draining toward them. In these areas, there may be frequent flooding.

Figure 18 Typical Overland Flow Patterns

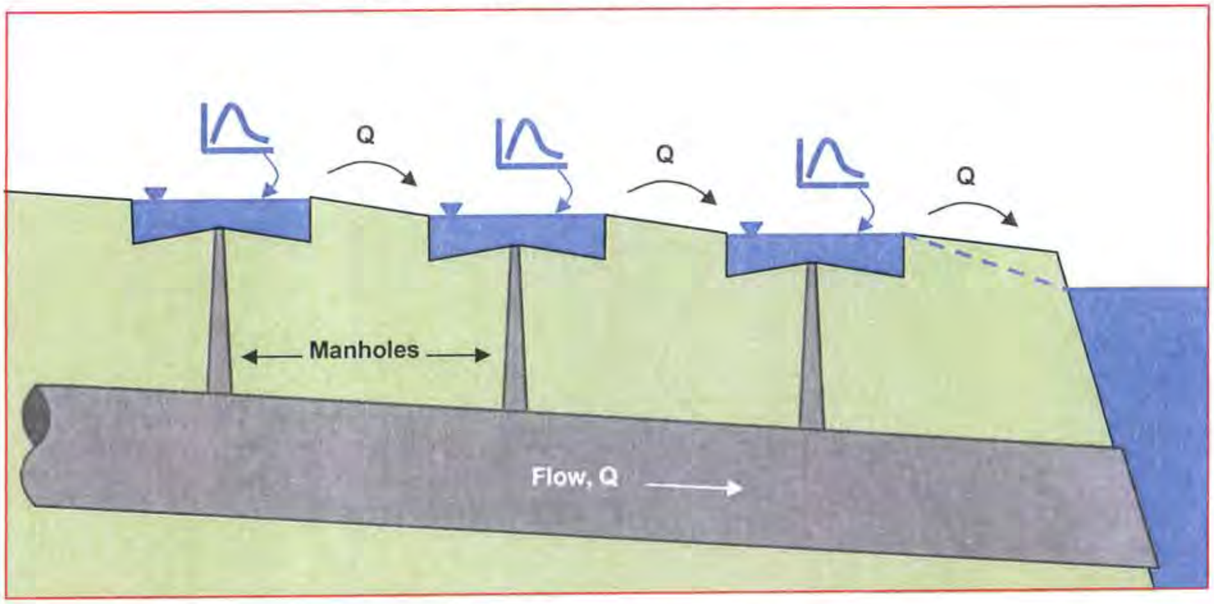


Figure 19 shows an overland flow path where the most downstream section (maybe a row of homes) is raised, limiting the overland drainage capacity by a high VPI. In this case, the overland flow from the upstream areas collects in the streets until the water surface rises enough to flow overland. If there is a house below that VPI, it will flood.

Figure 19 Overland Flow With An Obstruction

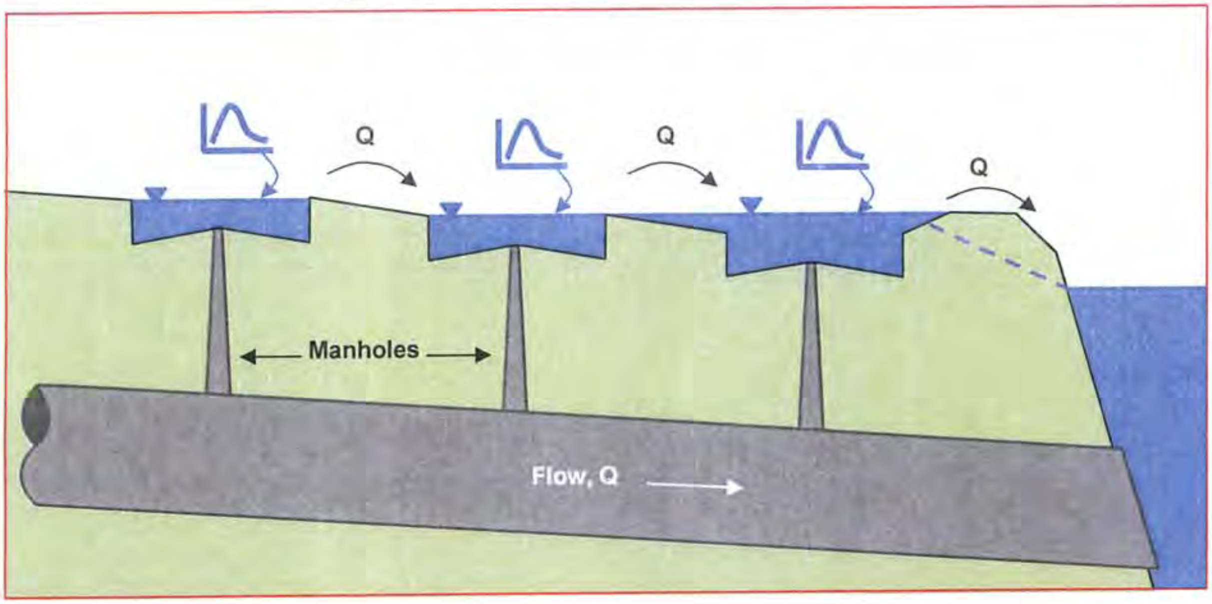


Figure 20 shows overland flow and ponding patterns for HCUD6. This figure shows several locations within HCUD6 that have high VPIs, including some to the interior. One of these areas along Seven Springs, however, has a fairly small upstream drainage area. As such, even though it is shown with relatively deep ponding depth, it may not be an area that floods frequently. Other areas that are known to have frequent high water in the streets and occasional structural flooding (e.g., along Pine Mountain) do not show nearly the depth as along Seven Springs, however the total overland drainage area is quite large.

In Figure 20, the color shading represents elevation, tending from high elevations in the northwest to lower elevations in the southeast. Yellow lines are overland drainage boundaries. Black lines are overland drainage paths, and shades of blue are likely ponding areas, with darker blue being deeper ponding. These ponding areas assume that there is no subsurface drainage and that there is enough rainfall just to reach the VPI and cause overland flow. They are not associated with any particular storm. For all the reasons mentioned above, this map does not reflect any particular probability of flooding.

Figure 20 Overland Flow Paths and Drainage Areas for HCUD6

4.2 November 2013 Public Meeting

4.2.1 Newspaper Notice, Houston Chronicle, October 4, 2013

PUBLIC MEETING NOTICE – SAVE THIS DATE

The Harris County Flood Control District is engaged in the Cypress Creek Overflow Management Plan study to develop a plan to manage flood risks in an area with unique hydrologic conditions that experiences overflows from the Cypress Creek watershed. This area encompasses upper Cypress Creek (upstream of US 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County have received a flood protection planning grant from the Texas Water Development Board to partially support this effort to gain consensus for a regional strategy to address the overflow.

Two identical Public Meetings will be held on November 7, 2013, the first from 2-4 p.m. and the second from 6:30-8:30 p.m., at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084. An update on the planning effort will be presented, followed by discussion and receipt of comments from the public. Materials for the meeting will be placed on the District's website at www.hcfcd.org/cypressoverflow as soon as they are available.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District at 713-684-4000 or online at www.hcfcd.org/cypressoverflow.

4.2.2 Letter to Invitees

PUBLIC MEETING
Cypress Creek Overflow Management Study

Date: November 7, 2013

Times: 2 – 4 p.m. and 6:30 – 8:30 p.m.

Place: Harris County Precinct 3, Bear Creek Community Center
3055 Bear Creek Drive, Houston, Texas 77084
(Directions to the Community Center are available at: www.pct3.hctx.net/cc_bearcreek.)

The Harris County Flood Control District is engaged in the Cypress Creek Overflow Management Plan study to develop a plan to manage flood risks in an area with unique hydrologic conditions that experiences overflows from the Cypress Creek watershed. This area encompasses upper Cypress Creek (upstream of US 290), the drainage area upstream of Addicks Reservoir, including Langham Creek, Bear Creek and South Mayde Creek, and that portion of the overflow area draining into Barker Reservoir that flows through Harris County. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County received a flood protection planning grant from the Texas Water Development Board to partially support this effort to gain consensus for a regional strategy to address the overflow.

You are invited to attend one of two identical Public Meetings being held on November 7, 2013, the first from 2-4 p.m. and the second from 6:30-8:30 p.m., at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084. An update on the planning effort will be presented, followed by discussion and receipt of comments from the public. Materials for the meeting will be placed on the District's website at www.hcfcd.org/cypressoverflow as soon as they are available.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District at the Project and Study Hotline, 713-684-4040, or online at www.hcfcd.org/cypressoverflow.

Cypress Creek Overflow Management Plan Public Meeting
Bear Creek Community Center, Thursday, November 7, 2013, 6:30 pm
Attendees who Signed In

LAST NAME	FIRST NAME	ORGANIZATION	CITY	STATE	ZIP
Birdwell	Wes	Halff Associates/Waller County	Austin	Tx	78759
Devine	James	MWHC MUD 12	Katy	Tx	77449
Flores	Al	DEC	Houston	Tx	77098
Hejducek	Julie	B.C. Flood Committee	Houston	Tx	77084
Hinojosa	Sam	Halff Associates	Houston	Tx	77079
Jang	Jung	R. G. Miller Engineers	Houston	Tx	77041
Koser	Larry	HC MUD 64	Katy	Tx	77493
Layton	Ron	HC Pct 4	Houston	Tx	77067
Lofts	Bonnie	HC MUD 127	Katy	Tx	77449
Mackey	Jim	WOBA	Houston	Tx	77092
Madichetti	Sirish	Baker	Houston	Tx	77086
Newman	Wesley	Katy Prairie Conservancy	Houston	Tx	77098
Rocchi	Pamela	Commissioner Cagle, HC Pct.4	Houston	Tx	77067
Sakolosky	Jack	CCFCC	Houston	Tx	77070
Shanley	Kevin	SWA	Houston	Tx	77008
Shott	Thomas	Ricewood MUD	Katy	Tx	77449
Simmons	Crystal	Cypress Creek Mirror	Houston	Tx	77070
Strange	Jon	JNC Engin.	Katy	Tx	77494
Vinklarck	Chance	Barker Cypress MUD	Houston	Tx	77084

Cypress Creek Overflow Management Plan Public Meeting
Bear Creek Community Center, Thursday, November 7, 2013, 2 pm
Attendees who Signed In

LAST NAME	FIRST NAME	ORGANIZATION	CITY	STATE	ZIP
Ahrendt	Carl	Cobb Fendley & Associates	Houston	Tx	77040
Arrajj	Shawn	Community Impact News	Houston	Tx	77064
Atkinson	Robert	EHRA	Houston	Tx	77042
Batiz	Angela	LJA Engineering	Houston	TX	77043
Berlinghoff	John	Sierra Club	Houston	Tx	77061
Bolton	Michael	Hearthstone Flood Coalition	Houston	Tx	77095
Bremer	John	Katy ISD	Katy	Tx	77494
Britt	Taylor	Houston Wilderness	Houston	TX	77007
Cannon	Delwin	Natural Resources Conserv. Service	Houston	Tx	77065
Chang	Henry	Gracias Engineering	Houston	TX	77292
Coody	Jim	Wetlands Professional Svcs.	Houston	Tx	77041
Davis	Marlon	Landowner	Katy	Tx	77449
Evans	Loretta	W. Harris County MUD #2	Katy	Tx	77449
Foster	Joan		Houston	Tx	77084
Foster	Paul	Bear Creek Subdivision Homeowner	Houston	Tx	77084
Freeman	Jackie	Ricewood Mud	Houston	Tx	77056
Garcia	Fred	MUD 239 / HCFCD Pct 4 Coordinator	Houston	Tx	77056
Gehringer	Mark	Bridgeland	Cypress	Tx	77433
Grounds	John	LJA	Houston	Tx	77042
Guerra	Kelly	Sengineering	Houston	TX	
Hirshman	Alan	Dannenbaum Eng. Corp	Houston	Tx	77098
January Bevers	Deborah	Houston Wilderness	Houston	TX	77007
Jones	Randy	Terra Visions, LLC	Houston	Tx	77055
Kalkomey	Craig	Jones & Carter	Rosenberg	Tx	77471
Kelly	James	Bayou Preservation Assn.	Houston	Tx	77027
Long	Richard	Corps of Engineers	Houston	Tx	77218
Lowe	David	Brown & Gay Engineering	Houston	TX	77070
Maaskant	Janice	HCPID	Houston	Tx	77002
Mannchen	Brandt	Houston Sierra Club	Houston	Tx	77096
McLafferty	Mark	Coldwell Banker	Tomball	TX	77377
Nestfell	Jay	JNS			
Nguyen	Long	MUD #248	Houston	Tx	77095
Orsak	Juanita	Pulte Home	Houston	Tx	77084
Ortega	Katrina	MUD 127	Katy	Tx	77449
Patel	Kirti	Richfield Investment	Houston	Tx	77042
Phillips	David	B.C. Homeowner	Houston	Tx	77084
Piacentini	Mary Anne	Katy Prairie Conservancy	Houston	TX	77098
Poppe	Russ	HCPID	Houston	Tx	77002
Potaman	Alexis	Texas A & M at Galveston	Katy	Tx	77494
Poteet	David	KPC	Houston	Tx	77084
Prudhomme	Carrie	Ricewood MUD	Katy	Tx	77449

Cypress Creek Overflow Management Plan Public Meeting

Bear Creek Community Center, Thursday, November 7, 2013, 2 pm

Attendees who Signed In

LAST NAME	FIRST NAME	ORGANIZATION	CITY	STATE	ZIP
Rayburn	Robert		Houston	Tx	77084
Reiter	Stephen	Jones & Carter	Magnolia	Tx	77357
Rienessma	Nicole	IDS Engineering Group	Houston	Tx	77092
Robertson	Jim	Cypress Creek Flood Control Coalition	Houston	Tx	77070
Rose	G. L.	Brookshire/Katy Drainage District	Brookshire	Tx	77423
Running	Todd	H-GAC	Houston	Tx	77027
Saenger	Scott	Jones & Carter			
Samanian	Houman	Ersa Grae	Houston	Tx	77042
Schmidt	Gene	City of Waller	Waller	Tx	77484
Sheldon	Steve	Dannenbaum Eng. Corp	Houston	Tx	77098
Smith	Richard D.	Cypress Creek Flood Control Coalition	Cypress	Tx	77429
Smullen	Pete	CCFCC	Cypress	Tx	77429
Spinks	Melvin	CyFair Chamber of Commerce	Cypress	Tx	77429
Tinney	David	LJA Engineering	Houston	Tx	77042
Toups	Zachary	Jones & Carter	The Woodlands	Tx	77381
Vogel	Kevin	Dodson-Walter P. Moore	Houston	Tx	77069
Ward	Gilbert	Texas Water Development Board	Austin	Tx	
Weatherspoon	Vera	W. Harris County MUD #2	Katy	Tx	77449
Wise	Anthony	HPARD	Houston	Tx	77084
Yoas	Claude	Cypress Fairbanks ISD	Houston	Tx	77064
Yung	Andy	Walter P. Moore	Houston	Tx	77010

Cypress Creek Overflow Management Plan

Public Meeting
November 7, 2013

Texas Water Development Board

Harris County Flood Control District

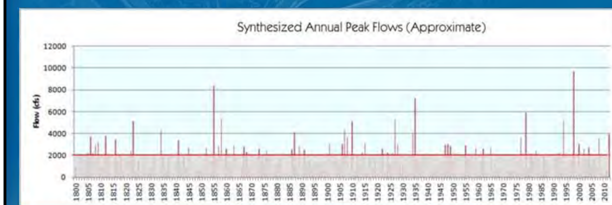
Meeting Format

- Welcome and introductions
- Presentation
  - Background
  - Management Plan Concepts
  - Next Steps Forward
- Q&A and Comments

What is the Cypress Creek Overflow?

- The water that flows out of Cypress Creek Watershed into the Addicks Reservoir Watershed.
- Historically, these flows occur about once every 10-years.

Synthesized 200-Year Overflow History

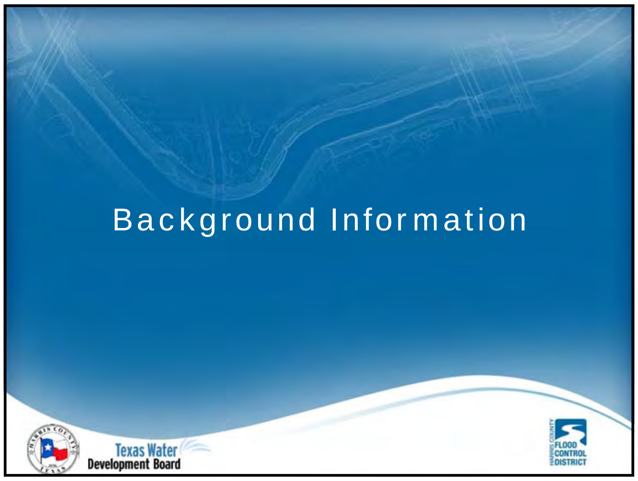


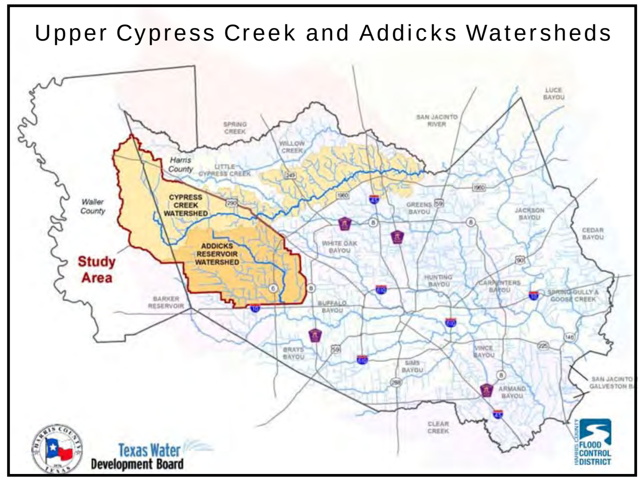
HCFCD's Mission

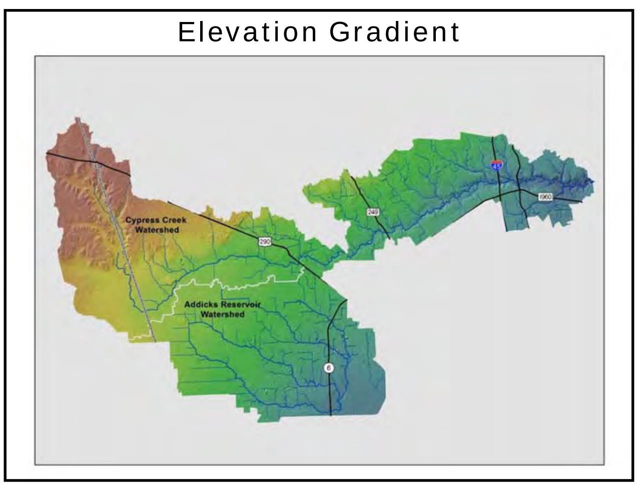
To build flood damage reduction projects that work with appropriate regard for community and natural values.

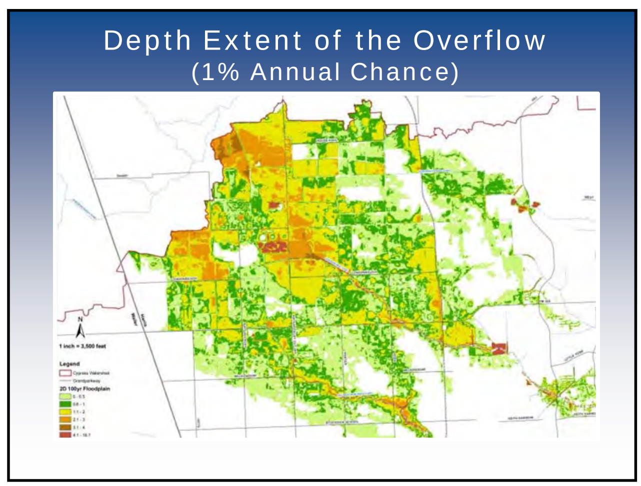
HCFCD's Interest in the Overflow

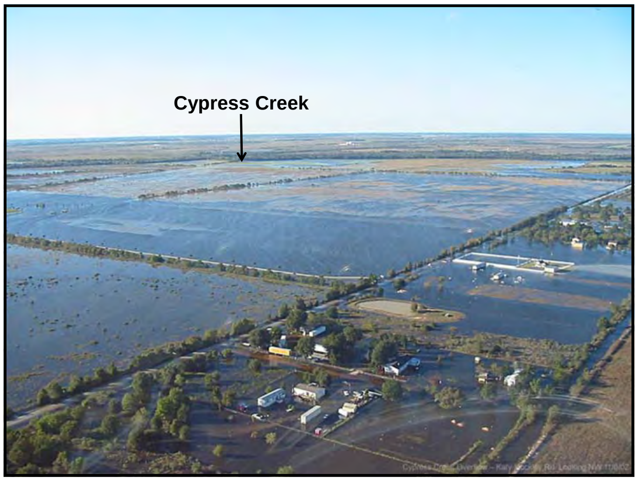
- Dramatic land use changes are predicted
- Unique hydrologic conditions in study area:
  - Existing overflow
  - Drains to reservoirs with finite capacity
    - When water is released, can affect downstream flooding
    - When water is not released, can affect upstream flooding
- Confirm current design criteria are applicable
- Preserve the flood attenuation provided by current land cover (or replace it)


Background Information
Texas Water Development Board
FLOOD CONTROL DISTRICT

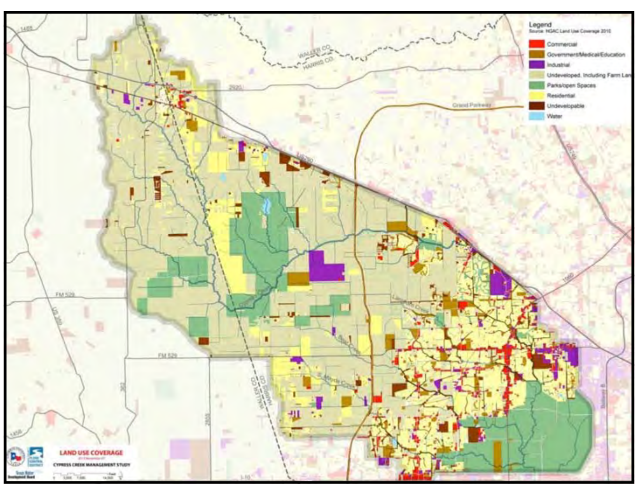

Upper Cypress Creek and Addicks Watersheds
Harris County
Waller County
CYPRESS CREEK WATERSHED
ADDICKS RESERVOIR WATERSHED
Study Area
Texas Water Development Board
FLOOD CONTROL DISTRICT

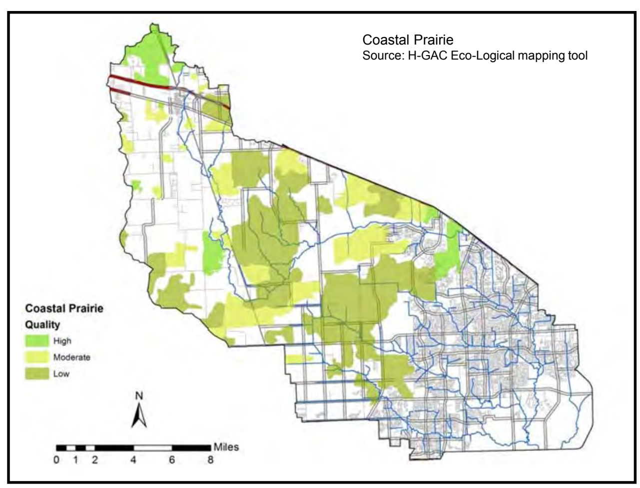

Elevation Gradient
Cypress Creek Watershed
Addicks Reservoir Watershed

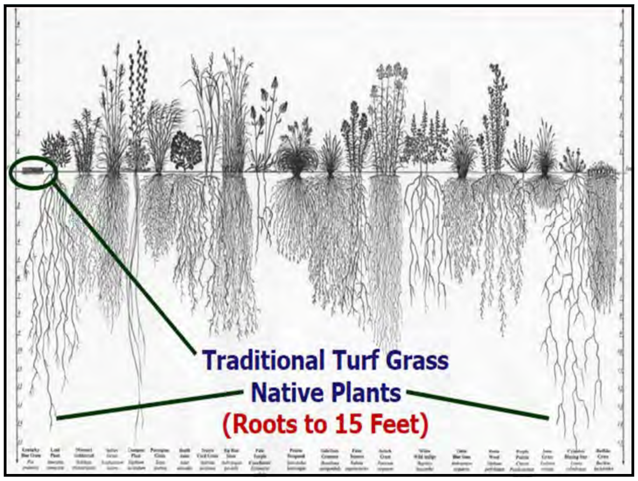

Depth Extent of the Overflow
(1% Annual Chance)


Cypress Creek


Overflow - Sharp Road


Legend
Source: HGAC Land Use Coverage 2010
Commercial
Government/Medical/Education
Industrial
Undeveloped, Including Farm Lan
Parks/open Spaces
Residential
Undevelopable
Water
LAND USE COVERAGE
CYPRESS CREEK MANAGEMENT STUDY


Coastal Prairie
Source: H-GAC Eco-Logical mapping tool
Coastal Prairie
Quality
High
Moderate
Low
N
0 1 2 4 6 8
Miles

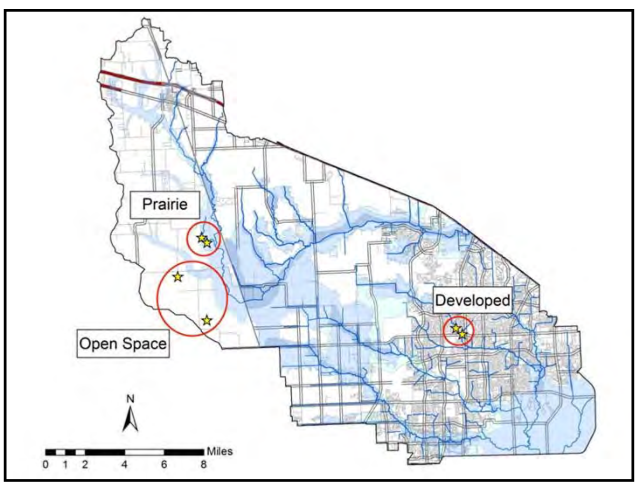


Effect of Prairie Grass on Runoff Literature Review

- Often cited – native prairie grass increases infiltration capacity of soil
- All citations point back to only two studies
  - Both studies were related to agricultural impact on soil infiltration
  - Compared to native prairie and restored prairie
- Cypress Creek Overflow Management Plan includes an activity to study infiltration rates

Texas Water Development Board

Harris County Flood Control District



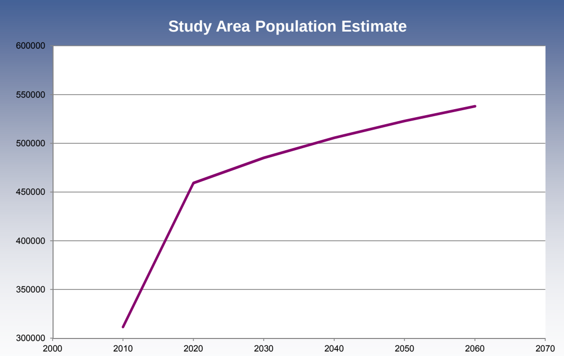
Growth Projections

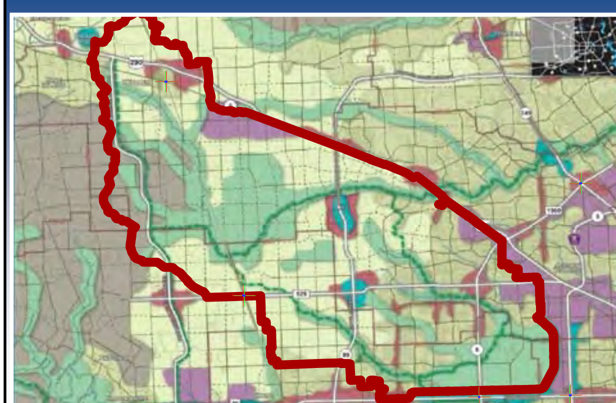
Texas Water Development Board

Harris County Flood Control District

Anticipated Growth

(Region H Water Planning Group Population Projections)

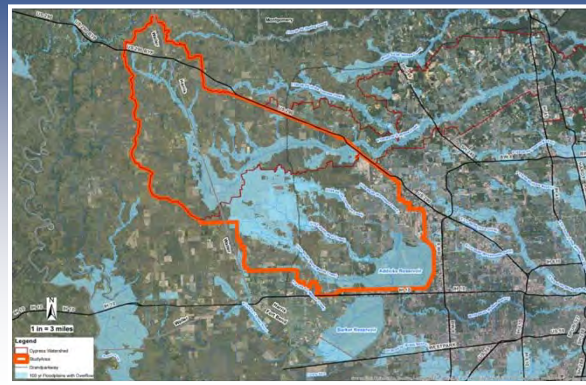




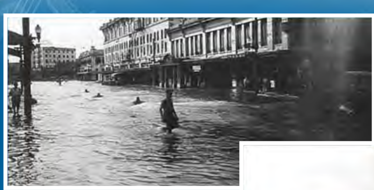
Excerpt from 2010 WHA's 2050 Land Use Scenario Map as background

Addicks and Barker Reservoirs

Addicks and Barker Reservoirs



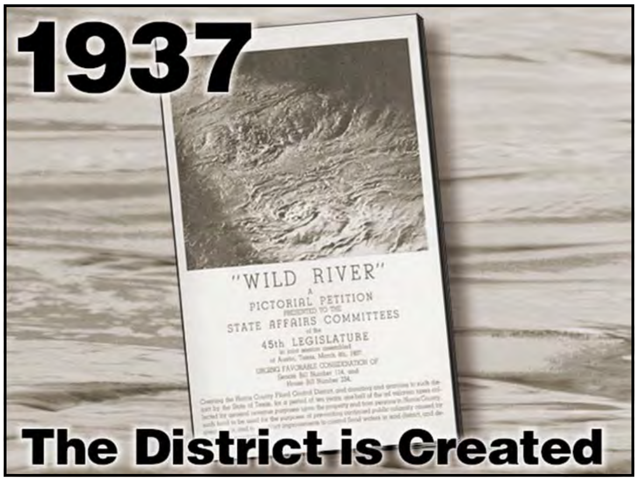
Early Houston Floods

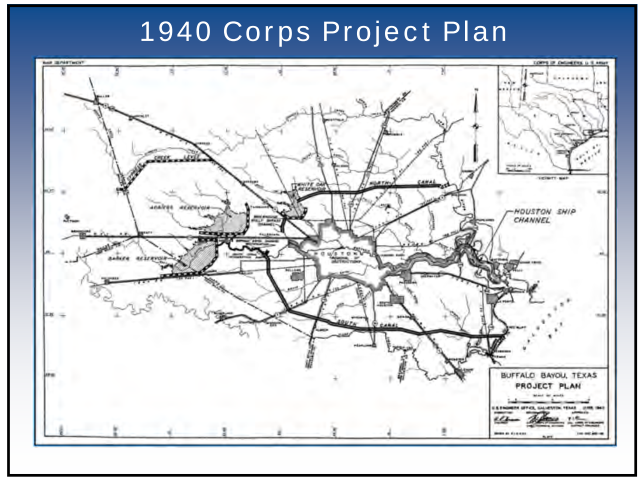


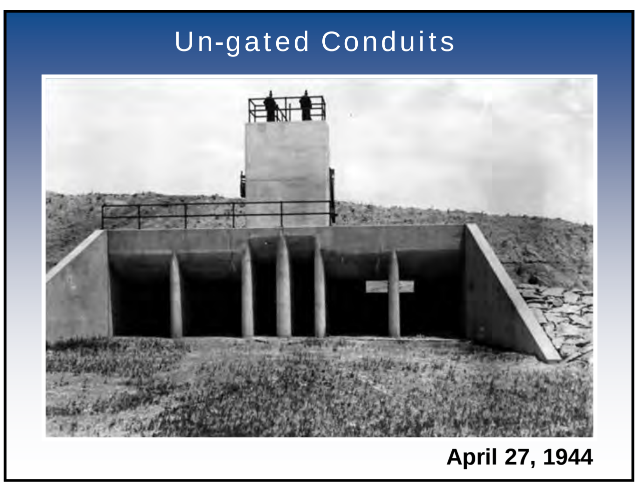
1929

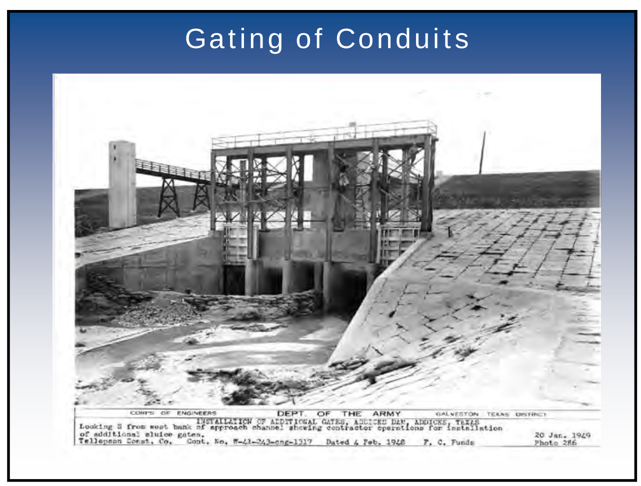
1935

Flood Control Act of 1936

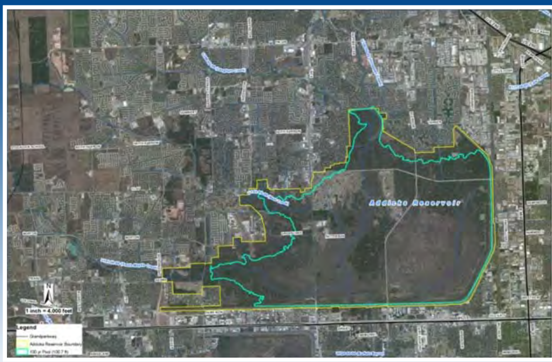

1937
"WILD RIVER"
A
PICTORIAL PETITION
STATE AFFAIRS COMMITTEES
45th LEGISLATURE
The District is Created


1940 Corps Project Plan
HOUSTON SHIP CHANNEL
BUFFALO BAYOU, TEXAS
PROJECT PLAN


Un-gated Conduits
April 27, 1944


Gating of Conduits
CORPS OF ENGINEERS DEPT. OF THE ARMY GALVESTON TEXAS DISTRICT
INSTALLATION OF ADDITIONAL GATES, ADDICKS DAM, ADDICKS, TEXAS
Looking S from west bank of approach channel showing contractor operations for installation of additional sluice gates.
20 Jan. 1949
Tellepson Const. Co. Cont. No. W-41-243-eng-1317 Dated 4 Feb. 1948 F. C. Funds
Photo 286

Current Development Around Addicks Reservoir



Why the discussion of the Reservoirs?

- Reservoirs have significant storage capacity but that capacity is finite.
- Future land use changes might alter flows into the reservoirs
- The reservoirs are owned and operated by the federal government.
- Managing the overflow requires no increase to flood risk to downstream properties as well to properties upstream of the reservoirs

Texas Water Development Board

HARRIS COUNTY FLOOD CONTROL DISTRICT

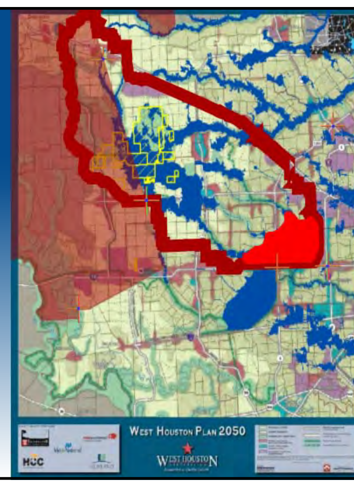
Balancing Concerns and Interests

Texas Water Development Board

HARRIS COUNTY FLOOD CONTROL DISTRICT

Multiple Interests

- Expected Growth
- Preservation Desire
- Floodplains and Overflow
  - Addicks Watershed
  - Cypress Watershed
- Waller County
- Addicks Reservoir



The Need for Planning

Texas Water Development Board

FLOOD CONTROL DISTRICT

Steering Committee Members

- Harris County Flood Control District
- West Houston Association
- Harris County PID
- Harris County Pct 3 & 4
- City of Houston
- Waller County
- Katy Prairie Conservancy
- Bayou Preservation Association
- US Army Corps of Engineers

Texas Water Development Board

FLOOD CONTROL DISTRICT

Objectives of this Planning Effort

- Identify a regional plan to manage overflow from Cypress Creek to help mitigate flood risk.
- Balance competing interests of land use preservation, business interests, reservoir operations and environmental mitigation needs during the process.
- Develop a business plan to implement regional strategies.
- Implement appropriate policies to manage the unique hydrologic conditions.

Texas Water Development Board

FLOOD CONTROL DISTRICT

Identifying an Overflow Management Strategy

Texas Water Development Board

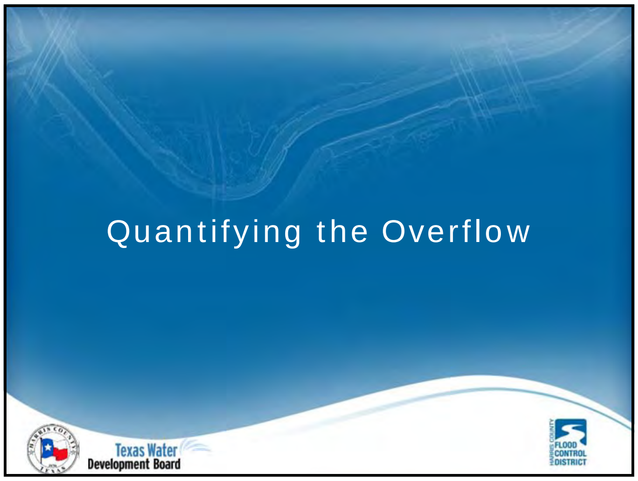
FLOOD CONTROL DISTRICT

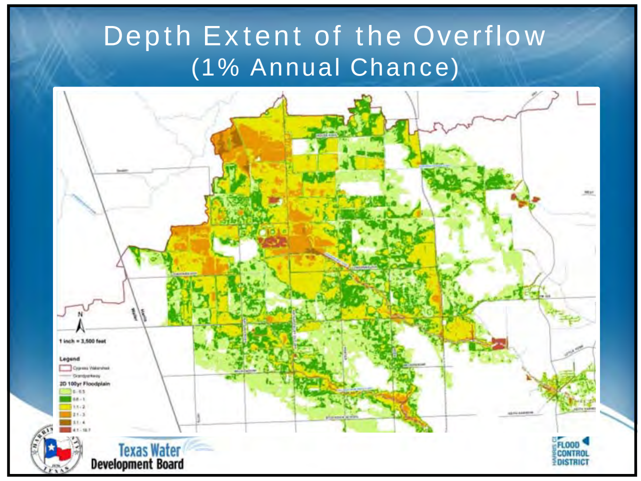
Characteristics of the Overflow

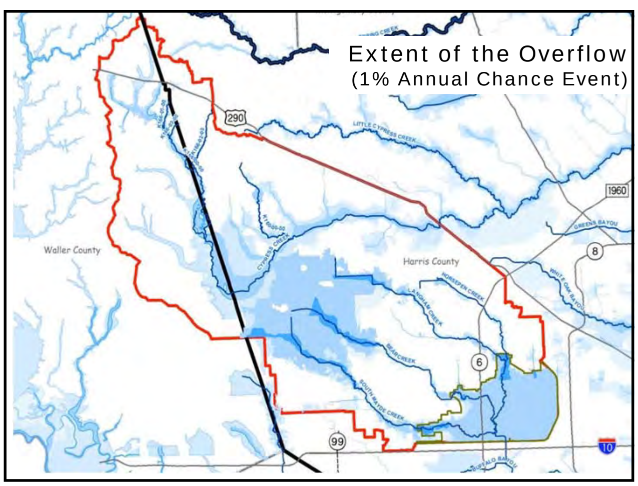
- Very Infrequent
- Covers a large area
- Shallow flooding
- Involves a lot of water
- Has a natural attenuation

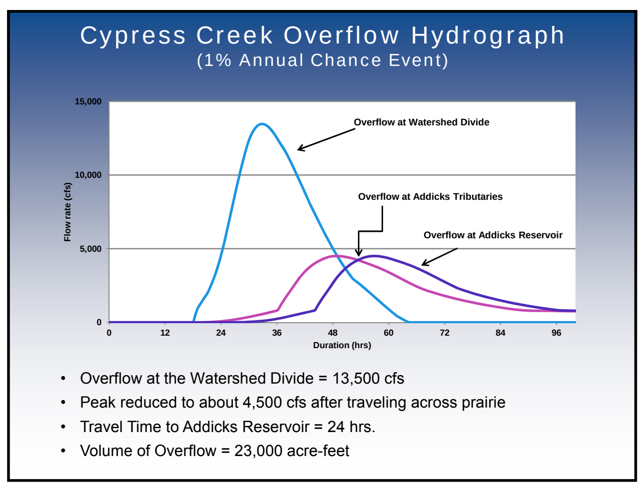
Texas Water Development Board

Harris County Flood Control District

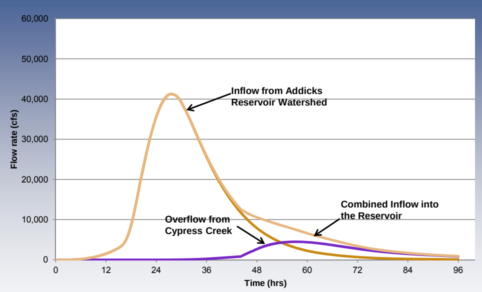

Quantifying the Overflow
Texas Water Development Board
FLOOD CONTROL DISTRICT


Depth Extent of the Overflow
(1% Annual Chance)
Texas Water Development Board
FLOOD CONTROL DISTRICT


Extent of the Overflow
(1% Annual Chance Event)
Waller County
Harris County
290
1960
8
6
99
10


Cypress Creek Overflow Hydrograph
(1% Annual Chance Event)
Overflow at Watershed Divide
Overflow at Addicks Tributaries
Overflow at Addicks Reservoir
Flow rate (cfs)
15,000
10,000
5,000
0
0
12
24
36
48
60
72
84
96
Duration (hrs)
• Overflow at the Watershed Divide = 13,500 cfs
• Peak reduced to about 4,500 cfs after traveling across prairie
• Travel Time to Addicks Reservoir = 24 hrs.
• Volume of Overflow = 23,000 acre-feet

Combined Flow at Addicks Reservoir
(1% Annual Chance Event)



- Addicks Watershed Peak Flow – about 41,000 cfs
- Local runoff about one day ahead of overflow hydrograph

Overflow Management Concepts

Texas Water Development Board

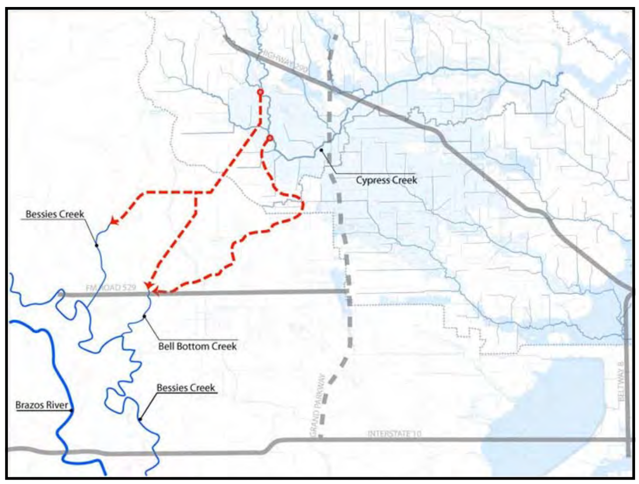
FLOOD CONTROL DISTRICT

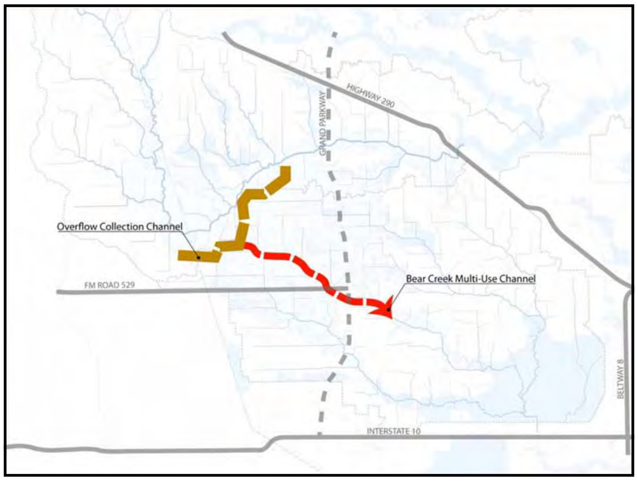
Magnitude of the Solution

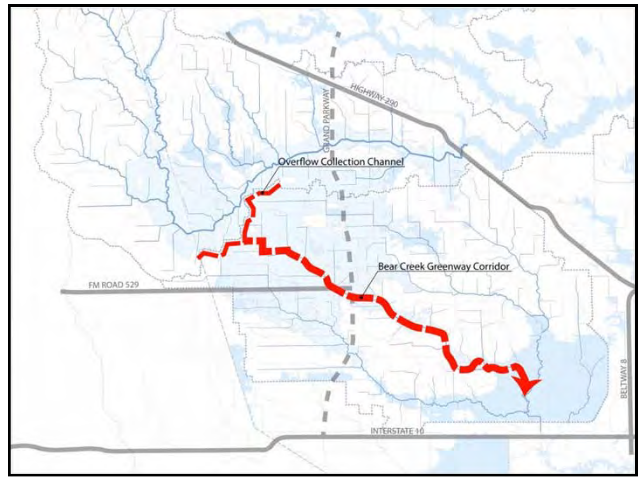
- 4,000 – 8,000 acres for flood storage
- 11,000 – 26,000 acre-feet of storage
- 250 – 600 acres of right-of-way dedicated to conveyance
- Up to 3,500 acres potential for increased open space, conservation and environmental mitigation

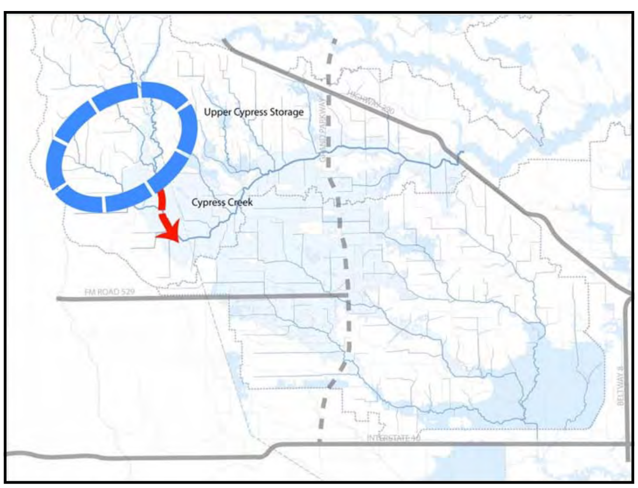
Texas Water Development Board

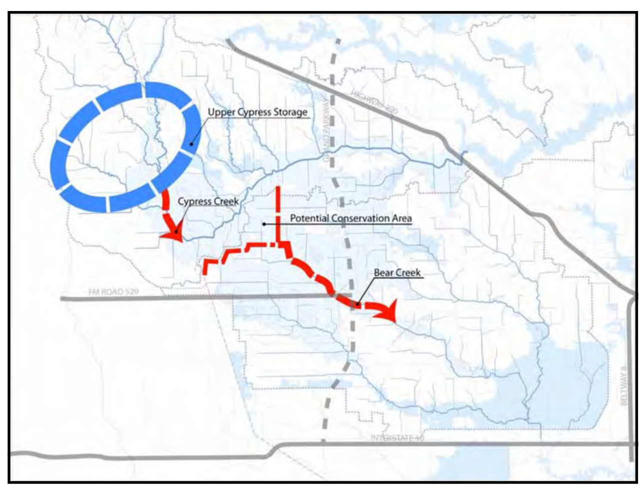
FLOOD CONTROL DISTRICT

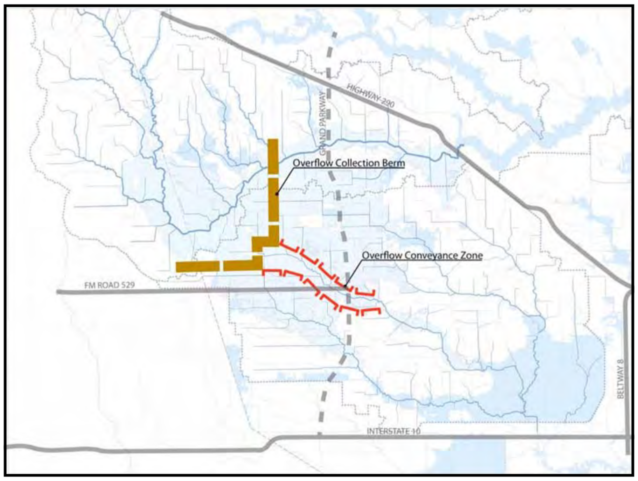


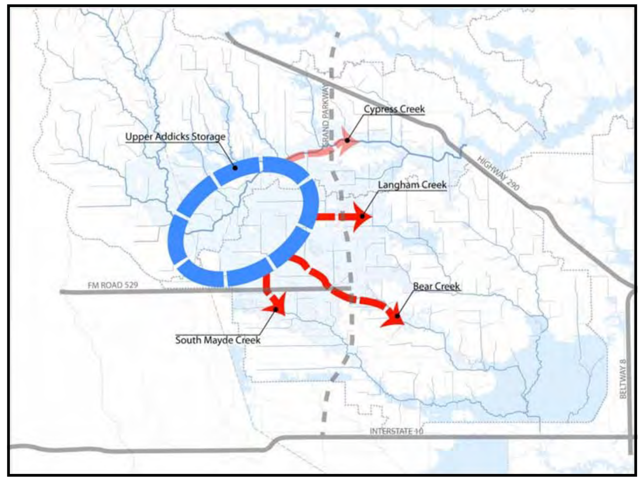

HIGHWAY 290
GRAND PARKWAY
Overflow Collection Channel
FM ROAD 529
Bear Creek Multi-Use Channel
BELTWAY 8
INTERSTATE 10

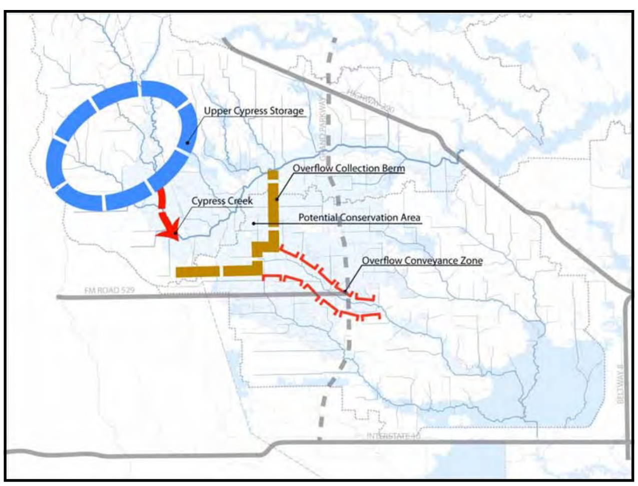

HIGHWAY 290
GRAND PARKWAY
Overflow Collection Channel
Bear Creek Greenway Corridor
FM ROAD 529
BELTWAY 8
INTERSTATE 10

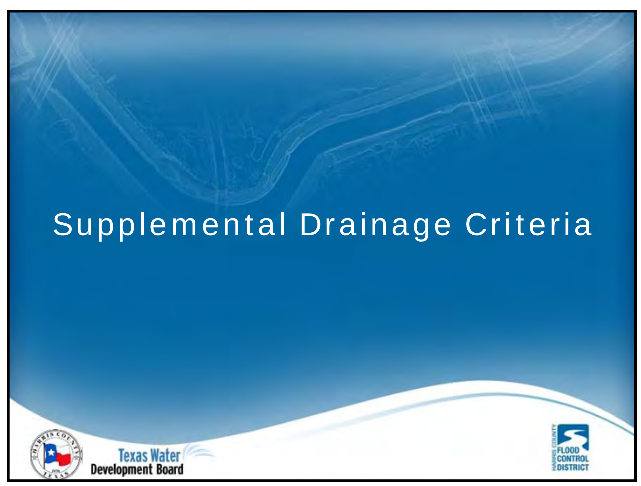

Upper Cypress Storage
Cypress Creek
FM ROAD 529


Upper Cypress Storage
Cypress Creek
Potential Conservation Area
Bear Creek
FM ROAD 529

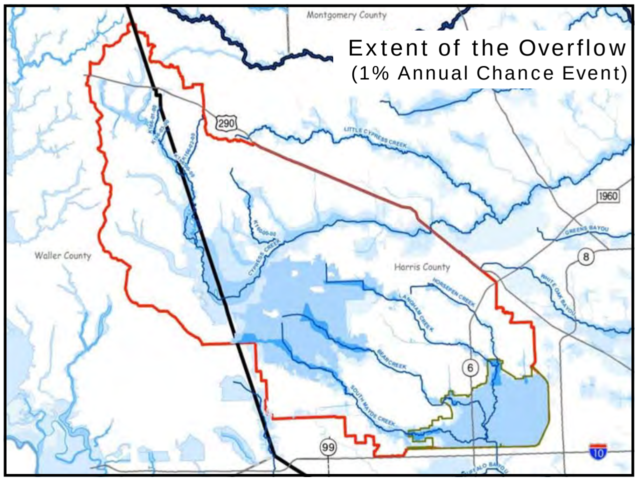

Overflow Collection Berm
Overflow Conveyance Zone
HIGHWAY 290
GRAND PARKWAY
FM ROAD 529
INTERSTATE 10
BELTWAY 8


Upper Addicks Storage
Cypress Creek
Langham Creek
Bear Creek
South Mayde Creek
HIGHWAY 290
GRAND PARKWAY
FM ROAD 529
INTERSTATE 10
BELTWAY 8

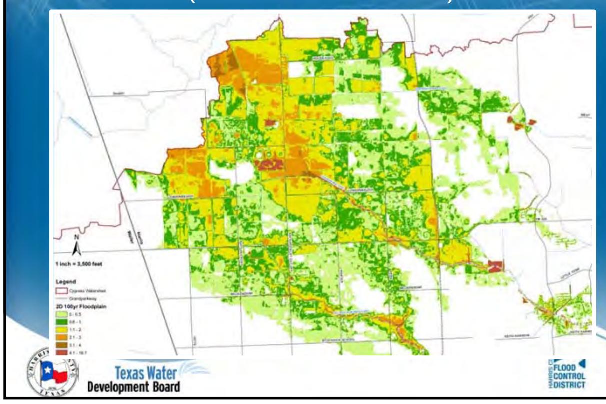

Upper Cypress Storage
Cypress Creek
Overflow Collection Berm
Potential Conservation Area
Overflow Conveyance Zone
FM ROAD 529


Supplemental Drainage Criteria
Texas Water Development Board
FLOOD CONTROL DISTRICT

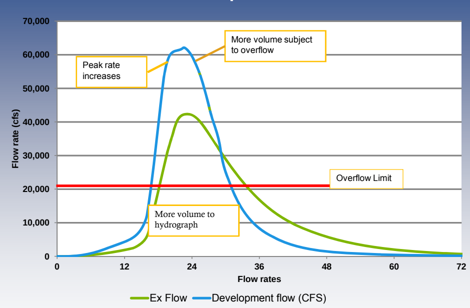
Extent of the Overflow
(1% Annual Chance Event)



Depth Extent of the Overflow
(1% Annual Chance)



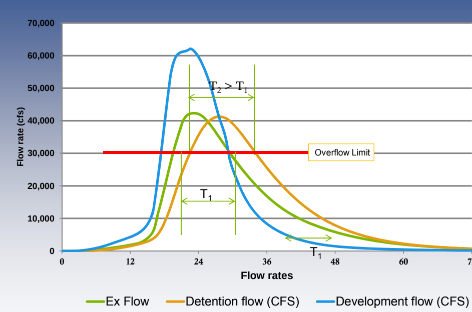
Runoff Hydrographs – Impact of Development



Impact of Developed Flow (assuming no detention policy)

- Peak flow rate increases
- Volume of runoff increases

Impact of Detention Criteria



- Detention reduced peak, but also pushes peak out
- Peak flow rate controlled
- Duration and volume of overflow increased

Preliminary Conclusions

- A major storage element is required to completely manage the overflow
- A phased approach likely will be required for financial feasibility
- Land acquisition for right-of-way and for mitigation is key to implementation
- “Do Nothing” is always a default, but with consequences

Consequences of No Regional Plan (Do Nothing)

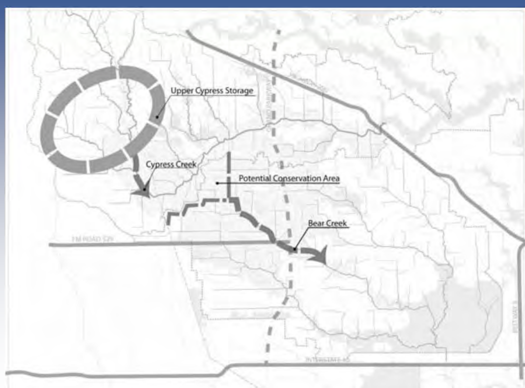
- Individual developers will move forward based on their own individual needs
- Opportunity for synergistic collective action is lost
- Opportunity for public gains in open space and environmental values is greatly reduced
- A major flood control facility is unlikely to be built.

Implementation Strategy

Implementation Strategy and Business Plan

- Must be timely
- Must be broken down into components that are financially attainable
- Must know who pays for what
- How can costs be minimized

Implementation Strategy



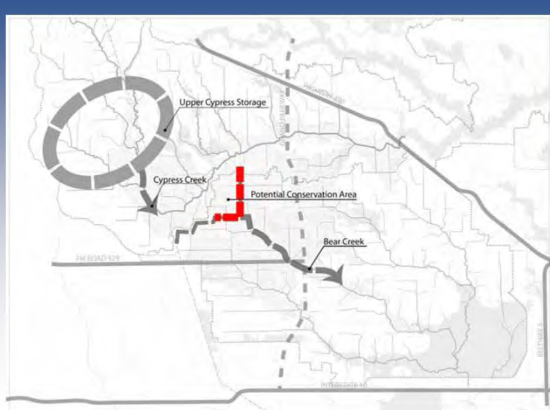
Concept – Major Costs

Land Acquisition	$150M
Construction Costs	$140M
Professional Services	$35M
Total Cost Estimate:	**$325M**

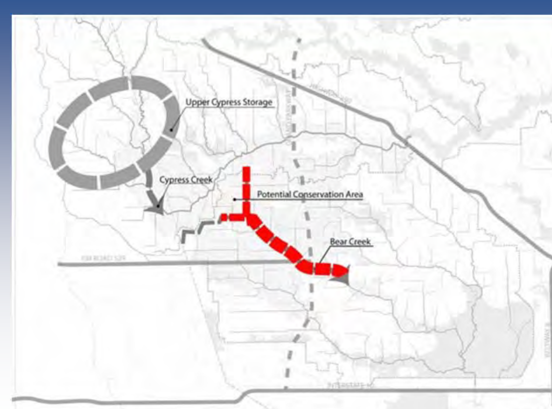
Texas Water Development Board

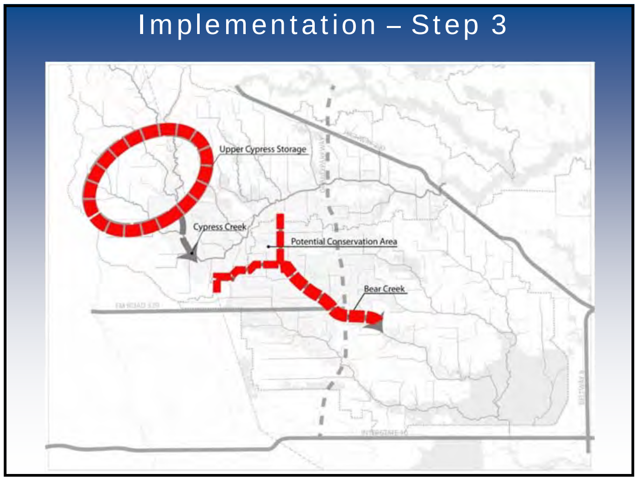
FLOOD CONTROL DISTRICT

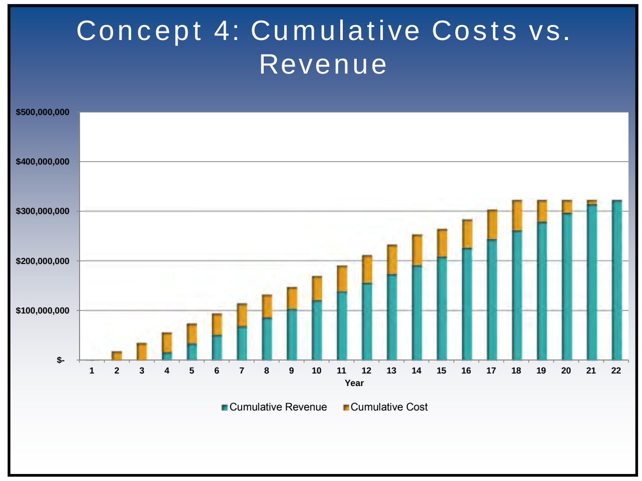
Implementation – Step 1

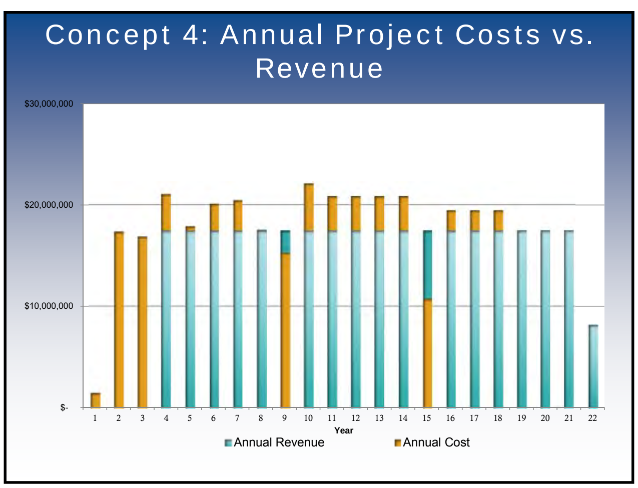


Implementation – Step 2




Implementation – Step 3
Upper Cypress Storage
Cypress Creek
Potential Conservation Area
Bear Creek


Concept 4: Cumulative Costs vs. Revenue
$500,000,000
$400,000,000
$300,000,000
$200,000,000
$100,000,000
$-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Year
Cumulative Revenue
Cumulative Cost


Concept 4: Annual Project Costs vs. Revenue
$30,000,000
$20,000,000
$10,000,000
$-
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Year
Annual Revenue
Annual Cost


Next Steps
Texas Water Development Board
Flood Control District

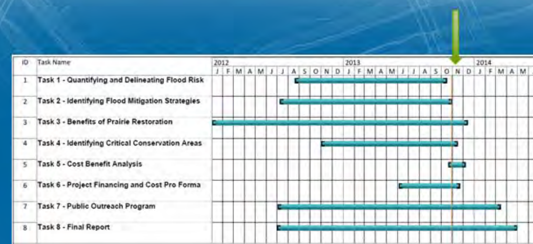
Next Steps

- Refine two concepts, including business plan
- Draft report
- Develop and submit supplemental criteria for development
- Third public meeting (Spring 2014)
- Submit draft to TWDB
- Finalize report, including CC approval
- Institute implementation plan, if plan is adopted

Texas Water Development Board

FLOOD CONTROL DISTRICT

Schedule



Texas Water Development Board

FLOOD CONTROL DISTRICT

Q&A and Comments

- Comments will be recorded; transcript will be put on study website
- Names will be called from comment cards
- Three minutes per speaker
- 2 pm meeting will conclude by 4 pm;
  6:30 pm meeting will conclude by 8:30 pm

Texas Water Development Board

FLOOD CONTROL DISTRICT

Harris County Flood Control District

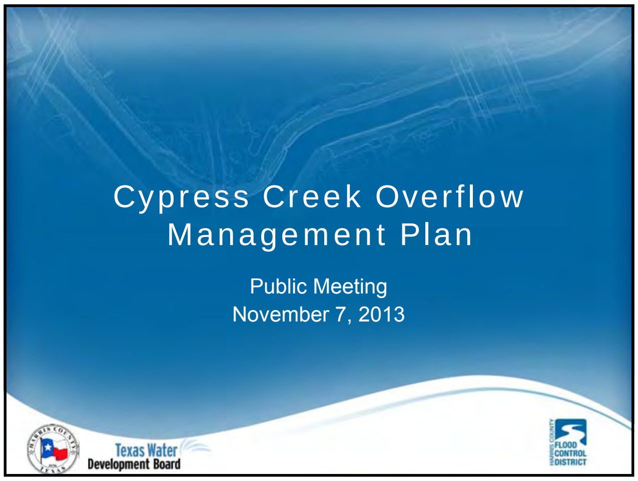
Harris County Flood Control District
9900 Northwest Freeway
Houston, TX 77092
Attn: Cypress Creek Overflow

Project Website: www.hcfcd.org/cypressoverflow

(713)684-4000

Texas Water Development Board

FLOOD CONTROL DISTRICT


Cypress Creek Overflow Management Plan
Public Meeting
November 7, 2013
Texas Water Development Board
FLOOD CONTROL DISTRICT

HARRIS COUNTY FLOOD CONTROL DISTRICT

CYPRESS CREEK OVERFLOW MANAGEMENT PLAN

PUBLIC MEETING NOVEMBER 7, 2013

HARRIS COUNTY PRECINCT 3

BEAR CREEK COMMUNITY CENTER

3055 BEAR CREEK DRIVE

HOUSTON, TEXAS

2:00 P.M.

Transcript provided by:
The Captioning Company, Inc.
565 South Mason Road, Suite 358
Katy, Texas 77450
281-684-8973 (cell)
281-347-2881 (fax)
Captioningcompany@comcast.net

P R O C E E D I N G S

MS. GREEN: It's two o'clock, and I'd like to go ahead and get the meeting started. We have a lot of information to share with you today, and we want to make sure that there's plenty of time to share that information and leave time for your questions at the end.

My name is Dena Green. I'm one of the study managers for the Harris County Flood Control District project we're about to talk about today. David Saha is with us somewhere in the crowd. He's over here. He's one of the co-study managers with me and works in the District's Watershed Management Department.

We want to thank all of you for coming out today. We have a lot of information to share about the Cypress Creek Overflow Management Plan, and it's really nice to see that there's so much interest from the community to come learn about that.

We have a few staff here from elected official offices that I'd like to recognize before we get the meeting started. We have a few folks from Precinct 4. That would include Ron Layton, Pamela Rocchi, and Janice Maaskant. I'm glad you could make it here today, back in the back row.

We also have Gilbert Ward with us from the Texas Water Development Board. He's also in the back row. They're waving if you turn around to see everyone back there. We have Richard Long with us from the Army Corps of Engineers over here. In the back, we have Mike Talbott, director of Harris County Flood Control District.

So this is our second public meeting. Many of you may have joined us last year when we had our first meeting. That was August of 2012, and at that time we had a lot of information to share with you about the general scope of the study, including the characterization of the overflow. Well, we're back with you today because we'd like to tell you what we've accomplished in the last year and to talk to you about some of the concepts that we've been coming up with.

Let's see. Our format for the meeting is going to be a few minutes for the welcome and introduction. Then we're going to go ahead and give you a presentation, and then we'll follow that with a question and answer period.

Now, we have a lot information to share, and to make sure that we have enough time to talk to you about what the overflow is, we're going to ask everybody to hold off on their questions until the end of the meeting -- excuse me -- until the end of the presentation. I want to remind everybody when you checked in you should have received a packet. On the top of that packet is a comment form.

(Technical difficulties)

In 2011, Harris County and the Flood Control District submitted a grant application for flood mitigation planning. We were awarded that funding and that's what we are using for this study. We have a 50/50 cost share with the Texas Water Development Board.

Our meeting today is focused on the upper Cypress Creek Watershed area and the Addicks Reservoir Watershed area. You can see that on the map here.

MS. CALLAWAY: Could you speak into the mike, please?

MS. GREEN: Yes. The Cypress Creek watershed is pretty long. We are looking at Cypress Creek, upstream of Highway 290, and all of the Addicks Reservoir watershed. I'd like to spend a few minutes talking about what the overflow is and how often we think it occurs and how it's of interest to the Harris County Flood Control District.

It is the water that flows out of Cypress Creek and drains south into the Addicks Reservoir Watershed. We believe this happens approximately every eight to ten years. We have a chart here. This is a chart that our team developed. I'll read out some of the information for you and move the microphone so you can hear me.

We think the overflow is probably fairly minor. It's likely to cross the watershed and dissipate into the Addicks Reservoir watershed. When we start getting into more significant flows -- that's when we think we're probably getting pretty significant water flow into the Addicks Reservoir watershed. That's when we'd expect the overflow to move across the watershed and to actually make its way into the tributary systems and ultimately make its way into the Addicks Reservoir.

So you might be wondering why the Flood Control District has begun this study. Well, Flood Control's mission is to build flood damage reduction projects that work with appropriate regard for community and natural values. And -- excuse me. So right now Cypress Creek overflow is occurring in areas that are predominantly underdeveloped or sparsely developed. They're mostly lands that are used for agriculture development or open spaces. However, we've seen a lot of information that indicates Houston and western Harris County will undergo a rapid increase in population in the near future, and if that occurs, we think there will be dramatic land use changes in western Harris County. And if that occurs, we need to be cognizant of what that means and how the overflow will impact or relate to that.

So we know that if land use changes come, that that means we need to expect changes in the hydrologic conditions that we have in the area. We have this overflow that we need to account for and it ultimately drains into the Addicks Reservoir. Now, the Addicks Reservoir is quite large and has a large capacity, and on top of that, it has a controlled discharge rate, so you have to be careful of what you're releasing. If too much is released, then you have flooding downstream on Buffalo Bayou. If you don't release enough, then you're going to impact the property upstream of Addicks Reservoir. Now, that's something that we need to be aware of and consider as we move forward with the study.

Flood Control also has an interest in what's happening in the study area because we're interested in the flood attenuation of some of the property. (Indiscernible). We believe that some of the area has certain types of grasses with root structures that actually help increase the infiltration rate of the soil. And if the land use changes, what would that change mean? We're also interested in investigating the area to have a better understanding if the current guidelines for development we have in place fit, and will be appropriate guidelines to move forward with, or if we need to look into having some supplemental guidelines to put in place to deal with land use changes that come with the future.

All right. So with that, I'd like to spend some time talking to you about background information and some of the key considerations that we've incorporated into the study. So again, I'd like to remind you of our study area. It is the upper Cypress Creek Watershed and the Addicks Reservoir. Now, the overall study area is quite large. It's about 1200 square miles, and what you can see on this map is that a large section of it is located in Waller County. About 60 square miles in Waller are located in the upper Cypress Creek watershed. We have several significant channels located in the study area, including Cypress Creek as well as South Mayde Creek, Bear Creek and Langham Creek.

On this map you can see the elevation gradient of the study area. What you can see by looking at this is really where the land drains. You can see what we have showing in the upper corner here in the reddish brown. Those are the higher elevations and the property can drop off towards the southeast, as you can see in the blue shaded areas which are lower. If you take a minute to look at this, you will notice there's a white line right through the middle of the graphic, and what that white line represents is the drainage break between the Addicks Reservoir Watershed and the Cypress Creek Watershed.

Now, what's important about that is if you look, that's pretty close to Cypress Creek, and you'll also notice that there's not a lot of change in colors to this area, so what that shows you is this is a shallow drainage break. So as the water starts building up in the Cypress Creek Watershed, it doesn't always have to get that high before it actually starts spilling over into the Addicks Watershed. There's several places along the drainage divide where we think the elevation is just a few feet higher than the Cypress Creek banks are.

This map shows you some of the depths and extents of the overflow. When we talked about the watershed divide a few minutes ago, you can see that line toward the top of the graphic. We've got a graphic, a map just to give you some bearings here, and the Grand Parkway runs right along the side of the screen there. You can take a look at this, and you will see that it covers some pretty significant areas. We estimate that it inundates about 20,000 acres, which is a lot of land -- that's a lot of coverage.

It's fairly shallow. It ranges about one to three feet deep. You can see the lighter yellow and lighter green areas shown on the map. That's about a half foot of inundation. And as the colors start getting darker -- you'll see the green, the gold, or the orange, you'll see that it starts to get deeper between one and three feet there. Now, there's a couple of areas that look like they're pretty deep, but those are just isolated areas, and that's what we see in the red. They're just localized uses -- things like irrigation ditches.

But on average, we would expect a lot of the overflow to reach about one to three feet of depth during a 100 year flood event, so that's a lot of water if you look at that as one to three feet over 20,000 acres. There's a picture of what the overflow looks like. This is one we took back in 2002. You can see Cypress Creek in the background and Katy Hockley Road in the foreground.

Here's another picture taken a couple years ago, back in 2012. This is on Sharp Road. This is Park Row, which is up near the drainage divide.

This map illustrates what the current land use looks like right now. This is some information that we obtained from the HGAC, and what you'll note from this is that -- we've got, again, the Grand Parkway that runs through here through the middle of the area and FM 529, pretty major roadways that most folks are familiar with, to get your bearings. Now, if you'll notice, there's a lot of khaki or tan color which signifies that it's farmland or undeveloped property, and there's just a little bit of area with yellow shading, and the yellow shading represents residential developments. And that public park space, or green space, is land held in conservation, so there's not a lot of development that we have in today's conditions.

We also have a significant amount of prairie grass in the study area. You can see those illustrated in the graphic. Now, there's some theory that the native prairie grasses help increase the attenuation of flood flow, that they help absorb the rainwater as it runs off the land. This illustrates part of the theory, due to the prairie grass systems -- they help create voids and help give the water somewhere to travel and drain down into the soil. But what's important about this is if they do help increase the infiltration capacity, then that means they're absorbing some of the runoff and helps reduce the runoff draining into the tributaries.

Now, we've done a little bit of literature review on it, and we have found many articles and sources that indicate that some of those exist. Prairie grasses do help with infiltration. However, most of them lead back to only two sources, and as a part of this study, we've actually set up some monitoring stations so we can look at different types of ground cover in our study areas where the infiltration is and look at the runoff that comes with it.

This maps shows you where we've got our monitoring stations set up. We have two in highly developed areas. We've got two in land that's covered by prairie, and we have two in open space sites. This is a picture of the sites. This is pretty indicative of them.

This is the picture of the monitoring equipment that we're using. We have a device you can see over here. It helps measure the amount of rainfall that we're gathering, and the pipes -- you can see out to the side of it we have those installed at the sites, and that's what we use to measure the runoff that comes from the drainage area.

Now, before I move on, I want to point out that we've been gathering this information for about a year, but we've had quite a dry year, so we don't have as much information as we'd like to have. We'll get a preliminary report in on this investigation toward the end of this year -- probably at the end of December -- and that will be included in our report to the Texas Water Development Board. But Flood Control will continue monitoring these sites for five years and we'll get more data on it.

All right. So another very important factor that we've had to consider in this study is the growth projections. Right now you've seen in many of our graphics, and we've mentioned, it's pretty rural. There's a lot of agricultural uses, but we've read a lot of information that does indicate that western Harris County will have a large growth in population in the near future. Some of the data that we were able to obtain from the Region H Water Planning Group indicates a huge jump in population just within our study area. From some of the census data that was collected in the year 2010, you can see that the population in our study area was estimated to be just over about 300,000 living there, but over the next 50 years, it's projected to jump up to almost 540,000. And if that occurs, we expect that there probably is going to be some pretty significant changes in land cover and land uses.

This map that we're showing right now shows an excerpt from a planning exercise that the West Houston Association put together. West Houston Association is a group of builders and builder interests. This is their vision plan for what 2050 would look like out on the west side of Harris County. If you take a look, we have the Grand Parkway here. That way you can get your bearings. Now, all this area shaded in yellow represents residential development. Now, that would be quite a large change in land use from now (indiscernible). We also see a lot of green space, and that is for natural preservation and parks. The red areas that you see indicated on the map represent commercial development.

We'd also like to share some information with you about Addicks and Barker Reservoirs. That's a major factor we've considered in this study.

This map shows you where we're located. So we've got our study area outlined in red. We've got the Grand Parkway going up here. Down to the south you'll see I-10. We have Addicks Reservoir, and it's located right in the southeast corner of our study area, and just south of that is Barker Reservoir, right there between I-10 and Westpark Toll Road.

Now, the two reservoirs were constructed in the early 1940s, and they were constructed in response to pretty severe flooding in downtown Houston. You can see pictures of the 1929 and 1935 floods on the screen. Both were taken downtown. The Flood Control Act of 1936, which made flood damage reduction an official function of the United States government, authorized drainage and flood control projects and a string of flood control surveys to be conducted by the Corps of Engineers, and Buffalo Bayou was included in one of those surveys. It was in 1937 that the Texas legislature created the Flood Control District, and the purpose was to act as the local sponsor for projects of the Army Corps of Engineers. Then in 1938 with the Rivers and Harbors Act, Congress authorized projects for drainage and flood control by providing improvements along Buffalo Bayou and the tributaries.

You can see from this graphic what that original plan was. We've got the Addicks and Barker Reservoirs here, but it also included a reservoir over here, two drainage canals, and it included a levee along here along Cypress Creek. Out of all those elements, it was Addicks and Barker Reservoirs that were constructed, as well as some channel modifications downstream along Buffalo Bayou. When Addicks was getting constructed, the Corps of Engineers deemed that it would be more economically feasible to increase the storage capacity in Addicks Reservoir rather than build that levee along Cypress Creek. So they decided to go ahead with capacity accommodations in Addicks Reservoir.

The original outlet for both of the reservoirs consisted of five outlet pipes or conduits, so you can see here where the five pipes were unregulated and there was a gate structure put on one of them, but they had very large discharge rates. The discharge was almost 16,000 CFS between the two of them. But over the last several decades, due to changes in land use, there have been several modifications made to the outlet structures.

What you can see from this picture is all of them were eventually gated and the release rates were cut back over the last several decades, so now instead of having the original capacity 16,000 CFS discharge rate, we have a combined discharge rate of 2,000, and that does include both reservoirs and tributaries downstream. So that's a pretty substantial change in discharge between the reservoirs.

This picture gives you a good idea of what it looks like right now for development around the reservoirs. When they were first constructed, it was pretty rural, they were out on the west side of town, about 15 miles outside of the City of Houston. This was wide open space, but you can see -- this is a pretty recent aerial photo. I think it's from 2010. There's been all this development that's occurred around the reservoir. So land use has definitely changed since they were originally constructed. You can see the outline of the government-owned land there shown in yellow. We've cited the 100 year pool elevation in green on that map. What's interesting is that they were originally designed to provide major flood control for the City of Houston, but it's actually turned into a nice dual-use facility. We have a lot of park space, and the meeting that we're at today is actually in the middle of the reservoir. If you take a look at this, that is where the Bear Creek Community Center is where we're all sitting today. Pretty nice flood control and recreational use facility.

While the reservoirs have significant storage capacity, that capacity is not finite. We also know that future land use changes might alter the pools into the reservoirs. The reservoirs are owned and operated by the federal government, and that managing of the overflow requires no increase to flood risk downstream to the properties along Buffalo Bayou or to the properties upstream of the Addicks Reservoir, but we need to be cognizant of that if we want to start developing what we think would be regional management plans for the Cypress Creek overflow.

It's also important to the study team that we balance concerns and interests in the study area (indiscernible). We know that growth is expected so there's interest in the business community in the study area. We also know that there's a lot of interest in preservation from the local conservation and environmental communities. We saw the picture earlier of the prairie grasses, and there's interest in retaining the infiltration capacity they represent. We know that there's a lot of floodplains that exist. So whatever concepts we come up with must respect that and we can't exacerbate the flooding conditions, and we also know that Waller County plays a major role in our study. Sixty square miles of drainage area is in Waller County, so it's an important partner to work with in the future with whatever context we come up with. And we also know that we need to be aware of Addicks Reservoir and that we must follow operating procedures that the Corps of Engineers has set for them, and we respect that.

So in order to balance all of these competing interests in the development of this plan, Flood Control has engaged a steering committee. It's made up of representatives from 10 organizations. It's a pretty diverse group that participates in it. You can see them listed on the slide. We have representatives from the business community, local environmental community, and we've also included several agencies, including the Corps of Engineers and Waller County as well. We meet with them pretty regularly, once or twice a month. A lot of times we talk about the study and concepts and we hear about concerns and interests and figure out how we can move forward together.

The objectives of our planning effort are to identify a regional plan to manage overflow from Cypress Creek to help mitigate the flood risk, to balance competing uses between (indiscernible), business interests, reservoir operations and environmental needs, to develop a business plan and (indiscernible), and implement appropriate policies to manage the unique hydrologic needs in our study area.

So with that background information, I'd like to introduce Alan Potok. He's our division manager for Engineering and Construction, and the project sponsor for this study, and Alan will have some information to share with you about the concepts we've been looking at.

MR. POTOK: Thank you, Dena. I'm going

to talk a little bit about the magnitude of the problem we're trying to solve, what we think it's going to take to try to solve that, and some of the broad concepts we've been looking at with our steering committee to get feedback as to whether or not there can be a consensus of all the interest groups that are involved. Dena went through that briefly.

Is that -- those are the various interest groups, and it's quite varied because if you look at it -- Flood Control District, its primary interest is to protect the existing populous from any aggravation due to increased risk of flooding, and we know that private land has a tendency to be sold and used for land development. We've spent a tremendous amount of effort over the past 25 years establishing drainage criteria that mitigate the impacts of that development so that we're doing our best to try to preserve the flooding risks that occur to the existing populous. We know it's still out there. It's not solving it. That's a separate capital initiative that Flood Control has, but we at least establish policies to try to make it work so we don't aggravate the problem.

But as Dena said, there's a lot of other interests in the watershed. One thing I wanted to point out about the open spaces, the prairie grasslands, and that is that Flood Control's interest in that is that we believe they attenuate the existing flood flows. And so if you do away with those, is our current criteria still applicable? And if it's not, what changes do we need to make?

We've got Harris County PID. What do they do? They build a lot of thoroughfares in the watershed, and as Dena indicated, that overflow area is bisected by those thoroughfares. And so the drainage criteria has to respect what that overflow is, and we want them at the table so that they understand what the issues are. And they can work with us on developing a consensus on the solution and buy into the answer we come up with. City of Houston is out there. Obviously this is all in their drainage area. They're interested in what we have to say because at the end of the day they may want to have a significant influence on the decision making.

Waller County, Dena indicated, is a political entity over which we do not have jurisdiction, but they have worked really closely with us. Anybody from Waller County here?

They have worked really closely with us in helping to mimic our drainage criteria so that they don't aggravate the drainage problems along Cypress Creek.

Katy Prairie Conservancy is a main conservancy group. Bayou Preservation Association is interested in the green space for this entire watershed that's so significant. The U.S. Army Corps of Engineers is interested because if we adopt policies that in any way alter either the rate or volume of flow entering the reservoir, it has the potential to impact their operating policies. Those operating policies protect, as Dena said, properties both upstream and downstream of the reservoirs themselves. So we are very cognizant that any changes that occur in the watershed itself, we are not interested in taking -- doing anything that in any way increases the risk to those existing properties.

So I'm going to talk a little bit, like I said, about the magnitude of the problem, some concepts we have, show you some of the ideas on business plans so you can understand how things might be implemented. But before I do, I know Dena said we'd answer questions at the end. It's kind of a good stopping point here since Dena did such a great job with the background.

Does anybody have a question on the background issues before we move forward?

Okay. Great.

So what do we know about the overflow? First of all, it's relatively infrequent. This is not like every time it rains it runs off into the storm drains, runs off into the channel, flows down the channel, out into the ship channel or the Galveston Bay. It happens on a very infrequent basis, so what that means is that for most part, any lands that are affected by the overflow can continue to function in the manner that it currently functions. It starts to be a problem if someone tries to develop in that area, but in point of fact, the criteria are in place that would allow land development to occur within the overflow.

Dena also mentioned it covers a really large area. It covers about 20,000 acres. Dena showed you a population graph that says there's going to be growth in the watershed of about 250,000 people. If you assume 10 people per acre, which is not a bad assumption to make, that's 25,000 acres. So that entire area that you saw that is influenced by the overflow zone could well be influenced by land development in the future.

We also note that it's very shallow flooding. It's not a life threatening, rapid flows, deep water situation, but it's a lot of water. I'm going to show you some slides as to how much water that is, but it's well in excess of 20,000 feet.

But the other thing that's kind of interesting about it is there is a natural attenuation to the water as it flows over that broad floodplain that has slowed down and infiltrated into the ground until it eventually migrates into one of the streams and empties into the managed reservoir system so that some of the events that occur, we don't think they'll reach the reservoir systems themselves. They dissipate in the land. As we get more moderate rainfalls, they will in fact accumulate in the reservoirs downstream.

So this is an example of a reservoir and what it would look like about 1500 days out of 1530. Okay? It would be dry. It could be used for whatever current open space use the property owner wanted to use it for. There would be difficulty if there was a house in the middle of it, but for most of the time it would function as it functions today.

Occasionally, if there was a reservoir, or as this overflow occurs, there's a natural reservoir that's there and it becomes inundated. You're going to see, when I show the numbers, that this is a lot of flow, and so we need a very wide conveyance system to make this work. If we tried to channelize it, to move it from Cypress Creek into Addicks Watershed, we need something very wide to be able to make that happen. And so the question is, what kind of green space opportunities exist associated with any form of conveyance system that you might put into play?

Now, quantifying the overflow -- how big is it? So this is the graphic that Dena described earlier. The shallow areas are the light green. As you move towards yellow, it gets deeper and deeper. And what I'd point out is the deeper areas, this is one continuous -- this is the watershed divide. You can see it's rather continuous from an -- this is Katy Hockley right here. It's rather continuous along that entire region, so when it overflows it affects all the channels downstream, and there's four major channels: Langham, Horsepen, Bear Creek and South Mayde. And they're all affected by one of these systems.

Now, these channel systems -- of these channel systems that we have here, this has a very limited capacity. Dena showed you the downstream development, which is really pretty interesting. You see how there's a floodplain here and not much here? That's because a lot of this got channelized as the existing development occurred, but there's three points of interest to us when we're talking about the overflow. One is what's happening at the watershed divide? The next is what's happening as it begins to enter into these channels as it communicates upstream here and collects into one of these various channel systems and then is rapidly conveyed down the reservoir? And then what happens in the reservoir itself because there is this natural attenuation that takes place in the wide valley floodplain.

So here is a graphic of what we feel is the overflow volume that occurs during a 100 year, one percent, storm on the Cypress Creek Watershed. Now, these numbers are irrespective as to whether or not it's raining in the Addicks Watershed. If it's dry and there is no -- in fact, we almost had that situation in 2012, but this is just what will happen if it rains in the Cypress Creek Watershed and at the watershed divide -- that's that line right here. Right here we'll have a hydrograph that looks like this.

Now, engineers know what hydrographs are. If you were standing on the bank of the stream, and if you were going to watch the water rise as it went by and fall as it passes, that's what this is. Imagine yourself standing on the side of the bank, the water rising and falling as it goes by. And what's underneath this hydrograph is the volume of water that you saw, and the line itself of the hydrograph represents what the flow is at any time. So at this point, at the overflow divide, we feel that the flow is about 13,500 cubic feet per second. It's a very rapid, collectively, rate of water, but it's spread out over the big, wide area.

Now, I mentioned the attenuation. "Attenuation" means it lags out, spreads out, smooths itself out, delays itself. That occurs in that big, wide flooded area. And so by the time it goes into those three -- by the time it hits these points right here in this watershed, which is where the channelization occurred, it's attenuated down so that the peak flow is only about 4800 cubic feet per second. So you get this nice, delayed action, if you will, and it's much more smoothed out. And the value here is still the value here. Okay?

But then as it enters the reservoir, there is a time for it to get there from that point in the watershed until it gets into the reservoir. There's an additional lag in time but probably not too much more attenuation because we've collected it in very nice, efficient channels, and it moves downstream, and it gets there, and we're done. That's what's entering the reservoir system itself. But as we're looking for a solution to the problem, we need to be aware of all three points because the conditions we're dealing with are different at all three points in the watershed.

So if I looked at what was happening, assuming it rained in the Addicks Watershed at the same time it was raining in the Cypress Creek Watershed, the overflow is happening right here and comes roaring down. Here's what's happening at the watershed divide. Here's what happens when it enters the tributaries. Here's what's happening when it enters the reservoir. But the local runoff from the watershed, which is about 130 square miles, is now this yellow hydrograph.

Now, this is in and of itself is draining into the reservoir. Okay? Well, this blue line was that blue line from the prior chart, and that's the hydrograph now from the overflow. That's also entering the reservoir, so you get a bit of an increase in that hydrograph volume right here in the shaded, but you really don't affect the peak rate of runoff. The peak rate of runoff is affected by the local watershed because it gets to the streams faster. Not only that, but the significant thing is, this happens every time it rains within the watershed at a one percent level. You get a 12 inch rain, a 13 inch rain, that's what you'll see. This only happens when there's an overflow. Otherwise, it never happens, yet some form of this hydrograph will always happen.

Okay. So what we wanted to do was look at various concepts, and just to give you the scale of what it is we'd be talking about to try to manage this. And the management of it -- you could start and say, well, it's managed just fine right now, isn't it? And I guess there's a theory that could say that's true, but, again, this is all land that is held in private hands. They have a right to do what they want to do with that land, and they typically will sell that land and someone will develop that land. That's how Houston has grown successfully over the past 100 years.

We've got to figure out if we're going to solve this problem in a singular management system, what are we talking about? And so this is the scope of what we think is necessary. We think somewhere between 4 and 8,000 acres of land are going to have to be held somewhere to be able to hold the water. We think it's virtually impossible to do this without some kind of storage capacity somewhere. We're going to need to store somewhere between 11,000 and 26,000 acre feet of water. And the size difference is a function of how much you want to release and how fast into the Addicks Watershed, if you want to continue to let it release into the Addicks Reservoir.

We're going to need somewhere between 250 and 600 acres of land to convey it. And then in doing so, we think we'll end up creating about 3500 acres of land for new conservation and environmental purposes. So that's the magnitude of it. Now, whether or not this gets done as a single management plan or whether or not this is done individually as land development occurs and design criteria are put into place to manage that land development and it's built in pieces -- in either case, this is probably the magnitude that's going to end up being reserved in some fashion.

So we wanted to get a little out of the box with our thinking and just look in terms of broad concepts. So one of the first things that we thought of is, well, why don't we just get rid of the water? Let's not let it get into the Addicks Reservoir. What's the advantage to that? Well, the advantage to that is that if it doesn't go into the Addicks Reservoir, they're releasing a lot less water downstream. There's certainly more capacity in that reservoir.

We could allow the Addicks Watershed to develop without too much concern because that overflow would not be occurring, and so we looked at the possibility of diverting the Cypress Creek Watershed into the Brazos River. There's some underlying problems with that. The least -- not the least of which is we're asking Waller County to create a south of the river and north of the river identity, but we also have a situation with water rights and interbasin transfer and things of that nature. So we did not really pursue this alternative with a lot of vigor just because of the political and the legal challenges we thought we'd be faced with trying to divert all that water.

We then looked and said, well, why don't we collect the water? This is the watershed divide. This is Cypress Creek here. Okay? Grand Parkway, I-10. What if -- you know that overflow is going to happen. Let's just collect it and build a channel, and we'll build that channel down to where there's an existing channel. What happens? Well, what happens when you take this answer -- if you remember the three hydrographs where I had a big hydrograph of 13,500 and a littler hydrograph of 4,800 CFS. Well, if all I do is collect it in a nice, efficient channel system, I lose all of that attenuation, so I have to plan for a system that can collect and convey 13,500 cubic feet per second of water. And when I do that, then this channel system doesn't work.

Now I've overloaded that channel system. So then we say, well, let's extend that channel system. What are the impacts if we extend that channel system downstream? Well, there start to be some rather significant impacts to that channel -- to the existing development adjacent to that channel.

Now, what is that channel? Let me back up. That is Bear Creek. Why Bear Creek? Why not South Mayde Creek down here? Well, of the three channels we've got, Bear Creek is the one that has a reasonable amount of existing capacity in it. So most of our answers have focused on the idea that we can somehow collect, hold, and slowly release water down into Bear Creek to make it all work. Okay?

Another alternative we said was, well -- Dena showed you some of the topographic relief in Waller County -- and because of that topographic relief, it's actually possible to build another large reservoir. We would have to build it in Waller County. The county line is right here, so we would build a lot of it in Waller County. The problem with this solution is that in and of itself we can't build it big enough. You can't hold all the water upstream of that and avoid having the overflow. We still get an overflow. So this in and of itself doesn't answer the question.

Then we said let's combine the two. Let's put some kind of conveyance and some kind of holding basin upstream in Waller County. Let's collect and convey the rest of it in Bear Creek. That became a concept that said, yes, that's a workable answer.

Another concept we had was to say, well, what if we don't store it in Waller County? What if we let the overflow occur but we held it at Cypress Creek downstream and we built a berm and collection system down here and then conveyed it through a large parkway system down into Bear Creek? And the parameters of this are such that the height of that levee, or the height of the water behind that berm system would be probably six to seven feet at its highest. The berms might be ten feet high. You'd have a large conservation area in back here that could be used for mitigation purposes, but the conveyance system itself ends up being rather wide. It ends up being somewhere between a thousand and 1500 feet wide.

We looked at that and said, well, what if we build a storage system after it overflows? Let's build it. Let it overflow into the Addicks Watershed, and then we'll figure out how to release it. We'll come up with multiple release points in South Mayde, Bear Creek, Langham Creek and Cypress Creek, depending on which channel has available capacity. So that became one of our other answers.

Now, interesting thing about these, from the various steering committees' perspective, if we can do this, the Corps of Engineers is very happy. We've eliminated part of the overflow and they have more capacity in their reservoir system. If we do this, the same thing still occurs. We've held back a lot of water. If we do this, we're not holding back any of the water. We're letting it overflow and the Corps of Engineers is going to receive it, but we need to release it at a rate that accommodates their ability to receive it. So we have varied interests there -- or varied responses to the solution of the limited capacity within the reservoir itself. I say that -- it's a finite capacity. A lot of capacity there. We're not worried about the capacity itself. We just don't want to use it any more than it's been used where land development occurs.

And this one here would be advantageous because we might actually be able to release it back into Cypress Creek if the Cypress Creek Watershed could accommodate it, or we would take all the waters and release them into the Addicks Watershed. One of the ideas behind this solution is that we might actually use it to reduce all overflows into Cypress Creek if that was necessary, or we could take more water to Addicks, depending on the conditions existing in the Addicks Watershed.

So this ended up being kind of like a combination of the plans that we came up with. It's one of several that we're still investigating. And it includes a collection system here, letting the overflow occur, building a conveyance system, and then ultimately building a storage reservoir in the Waller Creek. Doing this reduces the flows in Cypress, reduces the amount of overflow that's actually occurring and controls the flow rate into the reservoir. So this is a plan -- this is one of a couple plans that we're looking at that at least answers a question for each of the parties on the steering committee.

Now, one of the questions that we have is, does it -- would our criteria still apply? Do what we have in place still work for the conditions we have or anticipate in the watershed? We've got some pretty good evidence that says that the criteria we have in place is doing a good job of controlling peak flows in the receiving streams. There's a difference, however, because our design criteria is structured so that we release water into a receiving stream that conveys that water into a bigger bayou that goes out into either the Houston Ship Channel or into Galveston Bay. Here, it's going into a reservoir. The reservoir isn't releasing the water; the reservoir is holding the water. There's a bit of a twist to it.

So we know that our criteria can control peak rate of runoff. What we don't know is whether or not that's enough when what we're suddenly dealing with is a situation where we're holding water in a downstream reservoir for a long period of time. So this is, again, the watershed just showing you again the relationship of the reservoir itself, that it is the ultimate holding pond. It is the ultimate detention basin for this watershed today and will continue to be in the future. Just, again, the fact that this overflow is affecting all of those channels that you see right there. Okay?

Now, here might be an example case that we've tried to put together some slides to describe the situation to you. If this is the existing runoff hydrograph in the Addicks watershed, and it developed and we have no controls at all -- we didn't have any detention, we didn't have anything, which many of you in the room are familiar with our criteria where we require detention and mitigate for increase in runoff rates. Now, that's how fast the water goes. But if we didn't have any of that, then that runoff hydrograph would look something like this. And if we drew a horizontal line and said, well, that's the overflow limit, anything above that is overflow. So you can see that it's real obvious that if you allow detention -- if you allow that development to occur without any form of mitigation at all, you'd have a lot more volume to contend with, and that volume now goes into the reservoir systems.

But we do have criteria in place, and that criteria effectively controls the peak rate. So the question is, is that enough? So here are the same two hydrographs. That's the existing hydrograph. This is the future hydrograph. But in reality we would require them to detain water so that it follows that gold hydrograph. That peak rate is the same as the green, theoretically. But what becomes different, if this is the overflow limit, the green hydrograph has a certain period of time where this volume is over the overflow limit. But with our detention criteria, even though we've controlled the rate, the time over which this part of the hydrograph is occurring is longer than the time for the green, which means there will be more volume of runoff occurring when there's land development than when there's not, under current agricultural conditions.

So for that reason, we are looking at whether or not we need to incorporate a volumetric limit on land development activities and ask them to actually not detain water but to retain water and not release it into the reservoirs, or if you're going to release it, release it very slowly over a long period of time. And it's that design change that we're considering.

Now, whatever we do to respond to this criteria -- or this concern, I should say -- whatever we do has to almost be independent as to whether or not a management plan comes into play or not. It really needs to be a stand-alone activity, but it will be incorporated into the management plan if a management plan can actually be implemented.

So the preliminary conclusions we have from our work is that somewhere a major storage facility will have to remain. We will have to replicate what's out there today, perhaps in a smaller footprint. In order to make this work, we are going to have to phase its implementation. But for it to be successful, we have to do this in a very timely manner because as most of us read the newspaper, there's a housing shortage in Houston right now. There's a demand for building. Building is going to happen, and if we're going to take advantage of the opportunity, we have to do something in a very timely manner or the opportunity will pass us by.

And it does require a lot of acreage and a lot of cooperation on people's parts, so somehow either acquiring the land or getting the land in some form of relationship that it can be used for inundation during these very infrequent flooding occurrences has to be happening -- or has to occur.

Do nothing. Do nothing. By that I mean there does not have to be a management plan. We can put policies in place, and that was the purpose of the prior discussion -- we can put priorities and policies in place that allow land development activities to continue. We still think the same magnitude of acreage and conveyance areas are going to be necessary, but in point of fact, we can -- or development could occur without a form of regional management plan put in place.

If we do it, here's some of our thinking behind that. And one of the reasons to have all the members at the steering -- of the steering committee at the table is to recognize that there is actually a benefit to everyone if we can get a consensus on actually implementing a plan. But the key to that plan has got to be some form of implementation strategy, and it has to be -- you have to show that you can build a management system, that you can get the financial commitments in place to make it work, and that nobody's initiatives have to slow down.

So here's some of the ideas and key points behind a business plan that we need. It has to be very timely. We have to break it into manageable components that can be economically feasible. We have to decide who would pay for what, what would be dedicated, who would convey, who would build, and then how can we minimize the costs.

So let's take a look at this last concept, and this is just -- this is just figurative that we're using right now. But if that was the plan that we're going to build -- we're going to build a storage system here, a conveyance system here, and then a storage system up here. This is actually a storage and collection system and build a conservation area in back of it. So we might build it. The total cost of that system is going to be about $325 million dollars. Point of reference, the Flood Control District's capital program right now is estimated to be about $60 million a year. So our ability to build this ourselves would require us to dedicate virtually all of our resources for a long period of time, so I don't think we're going to be able to do that ourselves. But you never know. But that's just a point of reference.

So that would be -- the first phase might be, well, let's build the berm system and hold a portion of the water. That would eliminate a portion of that overflow. It might allow some land development to occur, and one of the strategies that Flood Control has had in place since the early '80s has been a thing called "impact fees," where you pay for the privilege to develop in the watershed, and developers typically are financing the improvements. Now, the general concept behind this was you pay us a fee, you pay Harris County Flood Control District a fee and you can release your water and put it into a regional facility. The problem was that we never could get the regional facilities in place fast enough so we had a backstop that if the facilities aren't placed fast enough you can build your own detention system and go about life.

But in this case the strategy might apply again. We might say let's consider development fees in this watershed. And we would build the first phase with the partial berm which would free up some land, relieve some of the overflow area. Then we would figure out how to get that overflow conveyed downstream to the existing channel where it has capacity and then the third phase would be to build the big storage facility. Each phase requires different levels of property acquisition, different levels of construction, and in return you get different levels of land removed from the overflow area.

And so then we looked at, well, how could we actually do this? This plan -- this is typical of one of the plan strategies that we have that look at the cumulative cost of implementing one of these plans versus the revenues that you might get by asking for developer fees. And so the total cost of the project is right here at about $325 million. We would stagger this to be about $20 million a year, and the first couple of years you can see it's all a cost. There's no revenues coming in. The blue is revenue; the yellow is cost. Every time you see a yellow line that's higher than a blue line, it means there's more cost than there is revenues, so someone has to pick up that difference in cost.

First couple of years, there's no revenues. Someone has to pick up that tab, and even as you go there's always a shortage up until out here where suddenly it's all revenues and no more costs because once the plan is built, it's built. We don't have any more costs associated with it.

This is just another graphic that depicts how that might happen on a year-by-year basis, and again, you can see this front end, the first three years would be total costs with no revenues. This is one of the sticking points to trying to implement a regional plan, is someone has to come up with about $38 million to make the plan work in a timely fashion. If it's done on a developer-by-developer basis, alternatively, then that cost is avoided. Okay? And that is one of the obstacles that has to be overcome in order for us to implement -- develop any sound implementation strategy.

So our next steps. We're going to look at two concepts. Those two concepts will be followed through with a detailed business plan, working out with the steering committee and how we think it could work, what each of them thinks would be a reasonable responsibility on their part to help make it happen. We'll develop a draft report. That draft report is still scheduled for early spring, about February. We do anticipate having supplemental criteria to address the volume control associated with land development. That activity would have to be approved by Harris County Commissioners Court in order for it to be effective.

We are anticipating a third public meeting after we've completed the draft report but before we finalize the report. We'll submit that draft report to the Texas Water Development Board, and then when the final report is completed, we will ask for adoption by commissioners court. And then if a plan can be adopted, the implementation strategy would be a document that we'd ask commissioners court to also adopt.

This is our project schedule. The yellow arrow at the top shows where we are today. There were eight major tasks. Task one was quantifying and delineating flood risk. Two was identifying mitigation strategies. Three was looking at the benefits of prairie restoration. As Dena pointed out, we're going to do a five year monitoring program of that. That task is going to continue regardless.

Four was identifying critical conservation areas. Five was a cost/benefit analysis. Six was project financing and cost pro forma. Seven was public outreach, and eight is the final report. We're scheduled to complete the study in about April of next year. We still anticipate we'll be able to complete the study on time.

With that, I'm going to turn it back to Dena who is going to moderate any Q and A's we might have. Dena?

MS. GREEN: Okay. I just found out we've got some already for the record.

Everybody should have gotten a couple of forms when you walked in. We pointed one out earlier, the comment card you could make notes on during the presentation. So if you could take some time to fill that out if you have comments, we'll have folks walking around the room that can collect those from you, and then they'll bring them up to the front, and I can read those out. We have received a few right now -- or a couple.

Let's see. I have one here. It's a written comment by Dick Smith that was already submitted. So I can go ahead and read that out.

Would you like to start this right now or wait a few minutes and give everybody a chance to fill out?

MS. CALLAWAY: John Singleton has said he would like to speak. He'd probably like to come to the front and speak. And this -- he said he would like to speak.

MS. GREEN: Mr. Singleton, if you want to come forward. We can pass the microphone over to you.

Okay. We've got our study team with us today so they should be able to help answer your question.

MR. SINGLETON: All right. This is more of a comment than a question.

My name is John Singleton. I'm one of the directors of Harris County MUD 136. And we are a member of the West Harris County Regional Water Authority, which is the water supply authority between actually Highway 290 and I-10. And I just noticed that in the group on the steering committee the regional water authority wasn't included, and I think they should be put in the loop for a couple of reasons.

For one thing, while originally MUDs were designed around providing fresh water, over the years they've morphed into other things, one of which is developing parks which would fit very well into this detention of water and design.

Secondly, if we are going to get into retention of water in recreational areas, the MUDs in the future are going to be more and more involved in use of non-potable water in other areas of the development.

And then third, we've recently been notified by Harris County that the MUDs will be taking over the maintenance of storm sewers. So the MUDs are getting more and more involved, and so my recommendation is that the regional water authorities, both the west and the north, be included in the conversations.

MS. GREEN: Okay. All right. Thank you.

Okay. I also have a request here from Michael Bolton, who would like to speak today.

MR. BOLTON: Hello. My name is Michael Bolton. I'm with Hearthstone Flood Coalition. I have a couple of things to show for show and tell.

First of all, thank you very much for having the meeting. This has been very informative, and you've done a good job.

There was an article in the Chronicle about flood insurance getting too costly, and what they said was because of the Biggert Waters Flood Insurance Reform

Act last year of 2012, two counties in our area -- they're increasing the flood insurance because the flood insurance is $25 billion in debt after super storms Sandy and Katrina.

So one of the aspects we really didn't touch on are flood insurance rates. (Indiscernible) this guy went from 1700 a year to 25,000 for flood insurance. So that's a big difference, big deal.

Second of all -- here's my notebook. And I've flooded three times, and the whole front part of this notebook are my inventory for all the stuff that was ruined in flooding. So those are three -- I filed two flood claims.

Then our MUD district, we petitioned them to do a flood study, so we did the Hearthstone subdivision flooding and draining analysis. This came out in December 2010, which is about three years ago. It costs us, our neighborhood, about $40,000 to do it. It ended up costing 60,000 because the data from Harris County Flood Control wasn't available because it failed -- the storms came, didn't have power, so all the data collection sites failed. So we actually had to (indiscernible) our data and that jacked up the price about $6,000.

And then here's the project manual for

Horsepen Creek, and this is dated April 2011. This was about 1.4 million and about 3.25 miles, and you saw Horsepen Creek up on the slides. It's at the top of the Addicks Watershed. And I begged Harris County Flood Control to tell me how much dirt they removed, but they will not tell me. The bulldozer guy said it was about 90,000 cubic yards came out of that creek, but the official report was more like 20 to 30,000 cubic yards. So anyway, that's a huge amount of dirt out of the creeks, so we've got to maintain what we have to do that.

So I won't take any more time. Probably only have three minutes.

One thing in the presentation we didn't talk about is sheet flow. Sheet flow is huge. That water running down, we didn't talk about -- according to the Cyfair Chamber of Commerce, 40 per cent of that area is undeveloped, so that's a lot of land to develop.

Let's see. What else?

Oh, on the statistical analysis, we're assuming the weather is the same, but according to some of the atmospheric scientists we have 4 percent more moisture in the atmosphere, so if you look at what happened to Colorado this summer and how much rain they got, we can't necessarily assume that we're going to have the same one out of ten years of flooding the way the rain is dumping.

So finally, to conclude, one of the things you showed was that there was actually a levee in 1940. They said, hey, let's build a levee. There was no word about the levee at all. So where's the levee?

And let's see -- oh, so my solution may be kind of silly -- is why don't we just say you have to build a golf course before you build a subdivision, and you dig up all the dirt, you dig the dirt up, you put the houses on top of the dirt. And then you have Houston Republican Golf Course -- perfect. That would be my simple, silly solution.

MS. GREEN: Thank you. Thank you for your comments, and I can give you a little information about the levee if you want.

I may have combed through that pretty quickly. While it was included in the original design, they actually altered it and thought that it would be more cost effective to increase capacity in the Addicks Reservoir and leave room for the overflow instead of construct that levee. It was an adjustment in the overall design of the projects. It wasn't (indiscernible).

Okay. All right. Well, our next comment card comes from Dick Smith. And he has written his down so we can read them back to everybody. His first comment is a question.

"Will comments and questions submitted at both of today's two sessions be published on the Flood Control website, and if so, approximately when?"

Yes, we are going to publish information from the meeting on our website. We'll include the PowerPoint slides as well as the comments we received today. I think that should be a pretty short period of time to get that up on the website. I know today we were already making provisions to get the slides up, but I do know we'll need a little bit of time to get the comments written down and back from our court reporter before we can put those up, but I think in the next week or two you'll be able to find those on our website as well.

And then the second question we have from Dick Smith is: "At the time of the first public meeting, August 16th, 2012, one of the objectives among several of this overflow plan study was reported to be to establish a set of policies, technical criteria and dot dot dot, that will allow Flood Control District to implement programs that reduce flood risks that reflect the unique hydrologic conditions in upper Cypress Creek and the drainage areas upstream of Addicks and Barker Reservoirs.

"This technical criteria, which is so critical to success of the project, requires utilization of the updated FEMA hydrology and hydraulic computer models for the Addicks Watershed, which the project team said the expected completion date was for end of December 2012. This was per the December 2010 kickoff meeting for this model and map update project. However these models are still undergoing FEMA evaluation.

"So with this schedule slippage now going on a year, A, when do you think these current condition models and maps will be available for public review, comment and appeal?"

Alan is stepping up. I think he has a comment to add.

MR. POTOK: I can respond to that question a little bit. The hydrologic models that we used for this -- where's Dick -- anyway, are very consistent with the data that was submitted to FEMA. What we're doing the -- the information we're dealing with right now is consistent with that information. We've got that incorporated and I think I pointed out some of the policy things we were talking about changing. Hopefully that answered your question.

MR. SMITH: FEMA is still reviewing the (indiscernible).

MR. POTOK: Yeah. FEMA is still reviewing the information submitted to them, and we probably are not going to hear anything from them for another six months.

MS. GREEN: Okay. And I have a request to speak from Paul Foster.

MR. FOSTER: Thank you. My name is Paul Foster. I'm a resident of Bear Creek just north of here. Certainly appreciate all the information you've given to us today. However, when I noticed that you had the Addicks and Barker Reservoirs on your list, I think there's a second one that hasn't been taken into account, and that's what I call the "Clay Road Reservoir," which really exists between Bear Creek Drive and War Memorial.

Ever since they've built that up, we've had significant flooding within the Bear Creek subdivision. I think although with an analysis back in 2006, I think by the Harris County Utility District, water flow analysis, they considered the Langham Creek Reservoir that's coming down through that area and crosses Clay Road to be an adequate size flow area.

What you've done by elevating Clay Road

between the two roadways is essentially eliminate about 2500 feet of drainage to make that a channel such that you've really caused a detention area, such that any land that exists south of Clay Road that's below the 100 foot elevation, which is probably the lower elevation of Bear Creek, is no longer available to collect water to prevent water from flooding in the Bear Creek subdivision.

(Indiscernible) I'm talking about a very small part of this area, study area that -- that you will take that into account.

MS. GREEN: Thank you. All right. I have another comment card here from Pete Smullen. Pete, did you want to speak?

MR. SMULLEN: I just had a quick question. Given the (indiscernible) discussed a minute ago, will you be doing a modeling for Cypress Creek given your final proposed solution for your draft proposed solution that would model the respective area of the watershed under fully developed conditions?

MR. POTOK: I'm not sure if everybody heard the question.

The question was, at some point in this study, will we look at the impacts of full development of the Cypress Creek Watershed and what that might do to the flooding conditions downstream in Cypress Creek, in essence?

And the answer is, yes, we've already started to look at -- and one of the reasons this volumetric criteria came about is that we began to realize that we had the tools that can require land developers to consider the change from whatever the existing land use is to a future land use. We have that. Even if it was concrete out there today and they wanted to make new concrete, they have -- we have one set of criteria. If they're dealing with a marsh and want to convert it to concrete, we've got a different set of criteria. It's different. Eventually they'll be required to do more.

Even though we've controlled the peak rate, what we began to notice was that we have to consider -- because of the sensitivity of that overflow situation, we have to consider something else. So we've looked at what the development hydrograph would be. We've looked at what we need to do to make sure that not only is the peak rate not affected but the volume is not affected also. So that in and of itself is going to benefit Cypress Creek.

If the solution -- if the management plan includes -- one of the options that we have showed on the board was something -- a berm that would cross

Cypress Creek. And if that is the plan that we decide is the most feasible plan, there will be a better management structure about stream flows that I think will also benefit Cypress. So anything that we do, we're looking at release rates on Cypress versus historic flood controls on Cypress to make sure whatever we do would affect it.

MS. GREEN: Okay. I have written comments from Fred -- looks like -- Gracia. Oh, Garcia. You're like a doctor.

"Have you thought about creating a separate taxing authority with boundaries covering Addicks and Cypress Watersheds to finance the project?"

MR. GARCIA: I don't have a lot of confidence in the impact fees of the program given the failures in the past.

MR. POTOK: Yeah. One of the things we discovered was that, hey, these impact fees look good on paper, but there's always a shortfall upfront. There's no ability to collect those monies, so the question is, is there an alternative entity that can be put into place that might cover that upfront cost and be there so that the people benefiting from the solution are paying right upfront? And we are looking at -- we're looking at a TIRZ potentially and regional WCID concept or --

MR. GARCIA: So you're looking at that?

MR. POTOK: Yeah.

MR. GARCIA: I believe the beneficiaries could be -- the entire Cypress Creek Watershed, the Addicks Watershed, and possibly even Buffalo Bayou can give you a tax base that's spread out over that population that you would be able to fund -- 325 million is a lot of money, but it's not an insurmountable amount for this.

MR. POTOK: We've had that conversation. Who benefits? We line them up on the board. The question includes, well, how much of that is represented by Flood Control District, and how do we decide whether that's some other entity or whatever. All of that is on the table. Thank you.

MS. GREEN: And I have one more written comment form, and this one is from Steve Sheldon and the question is: "What is the flood control project occurring between Katy Hockley Road and Cypress Creek north of Paul Rushing Park? What impact will the project have, if anything, on this issue?"

You know, I'm not sure.

UNIDENTIFIED SPEAKER: That's the Hornberger Tract, and the Flood Control District is creating about a hundred acres of prairie habitat, wetlands and preservation on that to offset some of the disturbed wetlands on other projects. And it doesn't have a direct correlation to this particular study.

MS. GREEN: Okay. That was my last comment card.

Are there -- one more over there. I think I can probably walk over there with this cord.

Okay. So our next one, written comment from Jim Robertson, and he asks: "With the current proposed solution, storage and flow defector and conveyance channel, how much acreage is required for each part of this -- storage, possible conservation area between flow deflectors and conveyance channel?"

Well, we had a slide that estimated that. Did you have a question?

MR. ROBERTSON: I was confused. I guess there were ranges on that. They were saying this is what we need, and then you went through the solutions. And the one (indiscernible) that those figures were for the solutions.

MS. GREEN: We've gone through a pretty broad range because we've looked at so many. (Indiscernible) we've created a lot of different concepts today, and it depended on which elements we looked at.

MR. ROBERTSON: You got down to the final one and said we have a storage area plus.

MS. GREEN: Because the one we showed today is just one of several concepts on the table, so that's why we gave a whole range of different acreages for storage or for conveyance because we're still looking at several concepts and we haven't narrowed it down yet. It's still a pretty broad range.

Would you like to take a look at those again?

MR. ROBERTSON: I wrote down the figures. It wasn't clear to me how you went from the broad ranges of everything, and then you had it narrowed down to the one solution, and I was trying to get a better sense of which of those figures applied to that solution.

MS. GREEN: Okay. To get a better idea for that. I think Alan has got some more information.

MR. POTOK: I was trying to see if we could get close to that. Did you want to know how much was for storage and how much was for conveyance on the slides?

MR. ROBERTSON: Yeah, there were kind of three pieces.

MR. POTOK: Yeah. Okay. So for storage on that particular concept, we're talking a total after 6700 acres, and for the collection channel, we're talking 544. Excuse me. That is not correct. We're talking 3500 acres for storage and 550 for conveyance.

MR. ROBERTSON: Okay. Thank you.

MS. GREEN: I think we had one more.

MR. MANNCHEN: I wanted to make a comment. I can read my questions if you want.

MS. GREEN: Okay. Come on up.

MR. MANNCHEN: Thank you. My name is Brandt Mannchen. I'm representing the Houston Sierra Club.

I had a couple of questions, and also we wanted to probably submit something after this meeting in writing, so just wanted to let you know that.

First of all, what are the maintenance costs of the -- if the project is built? What are the yearly maintenance costs?

Secondly, there was a reference to a conservation area behind the berm, and a lot of that property currently is owned by the Katy Prairie Conservancy or could be owned by the Katy Prairie Conservancy. So we're kind of interested in what are the impacts or effects on that property as it's currently managed when you hold water for a long period of time.

Also, it's not evident how Waller County benefits from this, so I guess the question is, how does Waller County really benefit from this? We're going to build a reservoir in their county, and the drainage isn't really their problem, at least at this time. So I'm curious how they're benefiting.

And the last one, with the present design criteria, future modified design criteria, with 25,000 acres developed, it wasn't clear how much more water is going to be flowing into Addicks Reservoir with all that additional -- full build-out of the watershed. So it wasn't clear how much water is going to be in there and how that's going to affect that -- the operation of that particular reservoir.

Can I finish writing this, and then hand it in?

MS. GREEN: Okay. That sounds good. It looked like you were raising your hand.

MR. POTOK: I can respond to some of that.

MS. GREEN: Okay. Okay.

MR. POTOK: When implemented, a pretty good rule of thumb for maintenance -- you know, if the total cost is $325 million, pretty good rule of thumb would be somewhere between 1 and 2 percent would be the annual maintenance cost associated with a project.

The conservation area you're talking about, actually that is not land that -- land that we're talking about is not land owned by or managed by the Katy Prairie Conservancy. And one of the -- the KPC is a very valued member of our steering committee because the lands they hold offer potential to help us, but there are covenants on those lands that may be difficult to overcome. We have to get with them and work that out. But one of the -- one of the incentives behind a regional plan would be that we would create additional conservation lands. The lands I was referring to were additional lands beyond what KPC had.

Phone works great until you shut it off. (Indiscernible) operating system.

Waller County benefits -- there are actually some benefits if we were to -- if we were to build a facility in Waller County -- and that's a "if" because we haven't decided -- that was just one strategy that we showed. It's not necessarily a strategy that will work its way through. They actually have an overflow that flows into South Mayde Creek, so by managing that overflow inside a confinement, some form of reservoir, that overflow would be eliminated so they would benefit in that regard.

They also have some drainage problems in

Waller County that may be able to be resolved as part of this regional plan also.

And how much more water into Addicks? We've done -- as part of the study effort, we've looked into some of the history of flows into the Addicks Watershed, and as you might suppose, the effects of prairie grasslands during small and moderate rainfall events are very effective. The question is, are they effective during severe storm events or is that soil so saturated that the runoff occurs? There was, for example, a 90 day period that occurred in 1998, was it? I can't remember the date.

UNIDENTIFIED SPEAKER: '92.

MR. POTOK: Okay. '92. And what was interesting is almost 76 percent of the rainfall that occurred in that period ended up in the reservoir, so that would kind of say when the soil is saturated maybe the prairie grasslands aren't working the way you'd like them to work, and yet during that 90 day period there wasn't a (indiscernible). It was moderate rainfall, but it was very saturated.

So the impact of development, we think, is about two inches or 7,000 acre feet of additional water, and it is that two inches that we're currently looking at using as a volume for retained flow.

There was one other question you had. I missed it.

MR. MANNCHEN: Those were the four.

MR. POTOK: Those were them?

MR. MANNCHEN: Yeah. Well, also the impacts on operating the reservoir with (indiscernible).

MR. POTOK: Addicks? Well, what we're saying is by -- we -- our current criteria -- our current criteria, we feel, are very effective in managing rates of flow. If we supplement that with a volumetric criteria, we think we're minimizing any impact to the reservoirs themselves.

MR. MANNCHEN: Would that also be development in Waller County?

MR. POTOK: Yes. Yes.

UNIDENTIFIED SPEAKER: Alan, go back to your comment.

MR. POTOK: (Indiscernible) answer the question.

UNIDENTIFIED SPEAKER: The comment a minute ago about the development would increase the overflow by how many gallons?

MR. POTOK: About -- we think about 7,000 for the entire watershed.

UNIDENTIFIED SPEAKER: Thank you.

MR. POTOK: That's during a (indiscernible).

And, Dick, that's the Addicks Watershed. That's the Addicks Watershed --

UNIDENTIFIED SPEAKER: Development of the --

MR. POTOK: -- not upper Cypress. I don't have that answer for you.

MS. GREEN: Okay. Thank you.

Anymore questions or comments? Looks like not.

MR. RAYBURN: I've got one question.

MS. GREEN: You've got one? Okay.

MR. RAYBURN: Real quickly. Now, first they said before -- and I won't quote where I heard it from, but it was another meeting similar to this one and it was -- first comment was all the easy solutions are off the table. I think (indiscernible) on that. As we move forward, this is pretty civil engineering approach to solving an engineering.

MS. GREEN: (Indiscernible).

MR. RAYBURN: First time I've ever been (indiscernible). I understand that this is a -- what we're seeing is an engineering solution to a problem that has multiple issues related to it, and if it was a very simple engineering solution, I think we would probably not be having this meeting today.

But in the finished product, is there going to be a -- some policy changes implemented in terms of perhaps low impact development for both our public roadways and our public developments? And are there going to be possibly some incentives for private land developers that we don't have control of what you can do within the boundaries of the property that you have, but there may be some incentives to provide the private land developers to make them part of this? And that is, reduce the amount of impact to their project that if they do do low impact and reduce their impact to a public utility, our drainage way, maybe that also begins to reduce your models to what you believe to be (indiscernible). Can you reply to that?

MR. POTOK: Let me -- when someone says, "Can you reply to that," I'm going to have to learn to say no.

But, Robert, to answer that question, the way we're phrasing this is to say, look, you have to retain the water. Now, you can pick your poison, and we're saying examples include low impact development like number one on the list. The idea that they might also prefer to restore a prairie grassland as opposed to building another detention basin -- that would work because what we want them to do, we want to leave the creativity to the solution to the applicant, the developer themselves, but those kinds of activities -- it's not merely just build us another basin to store water. It's come up with different ways to do it, and these are examples of the types of things (indiscernible). But low impact development is certainly one that we're suggesting to them.

MR. RAYBURN: But even further, what about public policy for public development?

MR. POTOK: We --

MR. RAYBURN: I know. It's a tar baby.

MR. POTOK: No. Well, it was interesting. We halfway thought about specifically pointing out public infrastructure. But the fact is, the way this is worded, I think it gets incorporated into that by default because PID has an initiative to try to implement low impact development in their roadways, systems that are applicable also. But the criteria would apply to everything, the way we're thinking of it. One of the real issues that I see moving forward, if a management plan is not put in place, is every one of those roadways is crossing that huge overflow area and the complexity of solving that problem is going to be difficult.

MS. GREEN: All right. Any more comments or questions?

MR. MANNCHEN: When will -- will the presentation be on the website?

MS. GREEN: Our slides, yes, they will be on the website.

MR. MANNCHEN: Do you know when that will be?

MS. CALLAWAY: It should be days. We started working on it this morning. Believe it or not, this presentation was completed this morning, so as soon as it was completed, we started asking them to prepare it for the website. It will take a couple of days.

MR. MANNCHEN: Probably next week?

MS. CALLAWAY: Yes. The comments will take a little longer because we have to get them transcribed.

MS. GREEN: Anything else?

Okay. Well, we do have our website listed up on the screen, and you can go there and look for comments and copies of the presentation.

And before we break today, I actually would like to thank our consultant team: Michael Baker Associates and SWA Group. They've done a lot of hard work for us on this study. And from the Flood Control District staff that helped facilitate our meeting today. They've been great to work with today.

Thanks to everybody who showed up today to learn more about our study. We really appreciate that as well. Thank you.

(Meeting adjourned)

HARRIS COUNTY FLOOD CONTROL DISTRICT

CYPRESS CREEK OVERFLOW MANAGEMENT PLAN

PUBLIC MEETING NOVEMBER 7, 2013

HARRIS COUNTY PRECINCT 3

BEAR CREEK COMMUNITY CENTER

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6:30 P.M.

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P R O C E E D I N G S

MS. GREEN: Hi, everybody. Welcome to our meeting this evening. If you could please take your seats, we'll begin the meeting now.

Okay. Welcome to our meeting this evening. This is actually our second meeting today. We had one earlier today at 2:00, and we wanted to offer the second session so that those who couldn't make it in the afternoon could attend and hear the information we have to share tonight.

My name is Dena Green. I am one of the study managers at Harris County Flood Control District, which is the entity that is conducting the study. David Saha is my co-manager, but he was unable to make it here tonight.

During our meeting this evening we have a lot of information to share with you. We're going to ask that everybody hold off on their questions and comments until after we end the meeting, but when you checked in, you should have received a packet that looks something like this. If you notice, there's a comment card on the front, and you can take notes on that as we do the presentation, and that way you can talk to us at the end.

I'd like to recognize the Texas Water Development Board. The Harris County Flood Control District applied for a grant in partnership with Harris County and the Texas Water Development Board. We were awarded grant funding, and that's what we're using to fund this project. We have a 50/50 cost share with the Water Development Board.

I'd like to start off and talk a little about the study area. It does involve Cypress Creek as well as Addicks Reservoir Watershed. As you can see, in the photo we're actually talking about the upper portion of Cypress Creek, which is upstream of 290. So if you saw fliers and you saw that is Cypress Creek Watershed, it was partly right. It is Cypress Creek, but it's Cypress Creek upstream of 290. And I'd like to spend a couple of minutes talking to you about what the overflow is so that you understand a little bit more about that before we start giving you background information and to share some information with you about why the Flood Control District is interested in overflow and why we're doing this study.

To put it simply, the overflow is water that flows out of Cypress Creek Watershed and drains outward into the Addicks Reservoir Watershed. We believe that this happens about once every eight to ten years. We've come up with a chart that the team put together.

You can see this estimates annual peak flow rates along Cypress Creek, and we've got quite a bit of information, all the way back to 1800 to 2010, so we've got just over 200 years of information. You can see the peak flow rate varies quite a bit, but it's around this level that we think the overflow kicks in and occurs. When flows in Cypress Creek get close to that range, probably a pretty minor overflow. It probably crosses into the Addicks Reservoir Watershed and dissipates pretty quickly into the upper end of the watershed. But when we start having a higher flow of rainfall, we estimate that's probably a pretty significant overflow, and we start getting that type of water coming over into the Addicks Watershed from Cypress Creek. That's when we estimate it's going to affect the channel systems and ultimately drain into the Addicks Reservoir.

Harris Country Flood Control District's mission is to build flood damage reduction projects with appropriate regard for community and natural value. Now, with that, we do have (indiscernible).

Right now the land where the overflow currently occurs is primarily undeveloped or used for agricultural purposes. However, we've seen a lot of indication that growth projections are projected to be quite large in the area. With that, we think there's dramatic changes in the land views as well. So if there are changes in land use, we know that we need to be proactive. We need to think about how hydrologic conditions will be addressed in the future.

We know that the overflow occurs. We also know the Addicks Reservoir is the outlet for the overflow. Now, while Addicks Reservoir has quite a large storage capacity, it is finite. Furthermore, the release rates from the reservoir are also controlled. If they release too much water downstream, you'll have flooding conditions along Buffalo Bayou. And if you don't release enough water downstream, you'll start impacting the properties upstream of Addicks Reservoir. So those are things to keep in mind as we start to think of solutions.

We also are interested in looking at the additional ground cover with considering some of the runoff attenuation. We also think that there may be some infiltration properties that prairie lands can help contribute to and that's what we mentioned here when we talk about the flood attenuation. We're interested in learning more about that and how it behaves. We'd also like to investigate whether our current development criteria is suitable for the study area or if we need additional supplemental flooding criteria to use in our study area.

I'd like to share some background information with you now and talk to you about some of the key concepts as we move forward in identifying the strategies for a regional management plan. I wanted to start back and talk to you a little bit more about the study area again. We pointed out earlier that it's upper Cypress Creek and the Addicks Reservoir Watershed. And as you can see, it's a pretty large area. It's about 400 square miles in total, but about 60 miles are in Waller County. We have several streams in the study area. We have Cypress Creek. It also includes Bear Creek, South Mayde Creek, Langham Creek and Horsepen Creek.

This picture shows you information about the elevation gradient in the study area. This gives you indication about how the water drains. We've got the higher elevations up here shown in reddish brown, and it tends to drain down toward the south and east. Now, if you take a look, we've got Cypress Creek.

My clicker is acting up on me here.

We've got Cypress Creek that runs right through this area, and south of that, in here, you see this white line. And that white line is what we refer to as the drainage break or the divide between the watersheds.

If you take a look at that, it's awfully close to Cypress Creek, and there's not a lot of elevation gradient there, and what that indicates is there's a fairly shallow break between the two watersheds, and there's some areas along the white line where it's just a few feet higher than the banks of Cypress Creek. So if you can imagine Cypress Creek filling up with water, elevation starts to rise, it doesn't have to get that high before it actually does start spilling over into the Addicks Reservoir Watershed.

This picture gives you an idea of the extent of the overflow. I'll give you some landmarks to work with. We've got Stockdick School Road. Here is the Grand Parkway. FM 529 runs through the middle of it. It's quite a large, wide, shallow overflow area. It's about 20,000 acres in total that we think become inundated in a storm event. It does range in depth from one to three feet on average. The lighter colors, it's about a half a foot to a foot in depth. But then all the areas you see here in darker orange get up to three feet, so it's a lot of volume of water coming over and it covers a very wide area.

Here's a picture of what that looks like. We took this picture back in 2002. You can see Cypress Creek in the background, and we have Katy Hockley Road. You can see the water comes over and it spreads out.

Here's another picture. This was taken in 2012, and that's Sharp Road, which is right by the watershed divide.

This is a graphic that indicates the current land use right now, so we've got FM 529 that runs through here. Here's the Grand Parkway. Here's Cypress Creek. The overflow area we were talking about is right in this area, but if you take a look at the overall study area, you'll see there's a lot of tan. And what that indicates is land that's primarily used as farmland or agricultural purposes or land that's undeveloped. There's a little developed in the yellow patches -- not too much -- and then a lot of green space up through here. That indicates parks, reserve land and open space.

We also have a lot of coastal prairie grasses right here in this area. You can see that on the graphic. One of our interests in the study is actually learning more about those prairie grasses. There's some theory that it helps increase the infiltration capacity of the soil. What that means is we think that the long root systems help create voids and openings that help make the soil absorb more, so as the rainfall occurs and runoff goes over the land, the soils are actually able to soak up more of that water. And that becomes important because the more water that the soil can absorb, the less runoff of water that reaches the tributaries and channel systems in the drainage area.

So we've done an initial literature review, and the information that we found indicates that some of the native prairie grasses actually do help increase the infiltration property. However, the data we found seems to lead back to two sources. As part of our overall study, we have set up a few monitoring sites so that we can go ahead and start gathering more information and learning more about the infiltration and runoff that occurs in different ground cover in the study area.

I have a map. We have two in pretty heavily developed areas. Two in areas developed by the prairie grasses and another two in open spaces. That's a picture. That gives you an idea of what the sites look like that we're monitoring.

Here's a picture of the equipment that we're using. We've got this machine you can see in the middle. That helps gather how much rainfall has occurred. That helps measure the rainfall, and we have a pipe at each of the sites, and we have more equipment set up in the pipes, and it helps measure how much runoff comes from each of the measurement sites. They range in size probably from about 20 to 40 acres, so they're pretty big sites. They create a pretty good amount of runoff. We get great data from it except we need rainfall in order to get that. We've had a few good storm events over the last year but not as many as we'd like.

We do have initial results that will come in from the study. We're expecting those at the end of December. We've been monitoring for about a year, but Flood Control will continue monitoring the sites for another five years. And hopefully after that period of time we'll have some good data to work with and some good information about the types of runoff and infiltration we get from different ground covers.

Growth projections for western Harris County -- that's been a factor that we've considered in the study. We've read a lot of information and received a lot of data about growth projections indicating they're going to be pretty large. Some of the information that we were able to obtain from Region H Water Planning Group, you can see charted here. It estimates from the 2010 census data that the population in our study area is around 300,000 -- just over that.

So we're estimating over the next 50 years you can see it's going to rise substantially. And by the year 2060, we're estimating that population to be almost 540,000 in our study area. And if we get population growth like that, you can imagine that we'll get some pretty big changes in land use from what we have now.

This graph you can see is a vision planning effort from the West Houston Association. What this shows is their vision for development over the next 50 years. It is concentrated on west Harris County. We've got our study areas shown by the (indiscernible). We've got FM 529. This is the Grand Parkway that comes up through the middle. You can see a lot of areas where the overflow occurs showed in yellow on the graphic. What the yellow represents is single family development. That would be quite a large change in land use if we go from agricultural use that we've got today to a lot of residential development in the area. You can see, too, that they've got planning involved here for a lot of green open spaces and parklands as well, but it's still a pretty dramatic change in land use.

I'd also like to speak about the Addicks Reservoir and talk about why they're relevant to our study. This shows where our study area is. We've got Addicks Reservoir down here, north of I-10, west of

Beltway 8. Then we've got Barker Reservoir just south of that which in between I-10 and the West Park Toll Road. Now, both of those reservoirs were constructed in response to devastating flooding that occurred in Houston in the early 1900s. You can see we've got some pictures on the screen taken downtown from some of the flooding in 1929 and 1935. It was very devastating, caused a lot of damage. After that, the Flood Control Act of 1936, which made flood damage reduction an official function of the United States government, authorized a stream of flood control projects and another stream of flood control surveys all to be conducted by the Army Corps of Engineers. And Buffalo Bayou was one of the channels listed on the survey.

In 1937 the Texas state legislature created the Flood Control District. The purpose of creating the district was so we would have a local sponsor to work with the U.S. Army Corps of Engineers. It was the 1938 Rivers and Harbor Act that included provisions to protect the City of Houston from further flooding by providing improvements along Buffalo Bayou and the tributaries. The map we're showing you on the screen gives you an idea of what that looks like. You can see Addicks Reservoir right up in here, down below the Barker's Reservoir. It also included White Oak Bayou as well as two significant drainage channels and a levy that was to go along Cypress Creek. And the purpose of the levy was to keep that overflow from occurring.

Now, the Addicks Reservoir and the Barker Reservoirs were the first two elements to be constructed. It turned out they were the only elements to be constructed in addition to a (indiscernible) along Buffalo Bayou as well. And it was while the construction of the Addicks Reservoir was underway that the Corps determined it was more cost effective to actually increase the volume of Addicks Reservoir to account for the overflow and accommodate it rather than to build the levy along Cypress Creek to prevent the overflow from occurring.

This is a picture of what the outlet structure looks like on the reservoirs -- what it looked like in 1944, I should say. You can see we've got four open conduits in it. One in the middle is gated here. The original design called for the five to be uncontrolled and to drain as the reservoir filled up. But after several changes over a series of decades, the gates were altered -- or the outlets were altered, so you can see gates were put on all five of the discharge pipes.

So the pipes were restricted from what was once almost (indiscernible) to what we have in store now that is an operation procedure that calls for a combined discharge rate of about 2,000 CFS. And I should mention that the combination of -- excuse me -- the combination overflow of 2,000 CFS does include both reservoirs as well as a few of the tributaries that are just downstream of Addicks and Barker Reservoir. So pretty significant reduction, but over time there was a lot of development that occurred along Buffalo Bayou so just reacting to the times and changing to what needed to be done to prevent further (indiscernible).

This is interesting, too. This is Addicks Reservoir. As you can see right here, the surrounding land use is from an aerial photograph that was taken in 2010. When this was originally constructed, they were 15 miles west of town out in a rural area, so not much out there. You can see a lot of land and open space. Now you can see all the development that's occurred. Houston has definitely grown a lot since the reservoirs were first constructed.

There's a lot of dense development. Most of it is residential. You can see the (indiscernible) and inside you can see the green lines. That's the hundred year pool elevation within the reservoir. Not only do they provide a lot of flood risk protection for Buffalo Bayou and downtown, but they're also a nice green space and park facility for the greater community. In fact, the place we're meeting tonight, the Bear Creek Park Community Center, is right there, right in the middle of the Addicks Reservoir. I'm not sure if you knew that or not. We're lucky it didn't rain quite a bit over the past couple days or you would have had a pretty wet drive in.

You might be wondering why we are discussing so much about the reservoirs. Well, they do play a pretty significant role in some of the ideas that we've been considering and some of the concepts that we've been looking into (indiscernible). Now, the reservoirs do have significant storage capacity, but the capacity is limited. Future plans (indiscernible). The reservoirs are owned and operated by the federal government. And managing the overflow requires no increase in flood risk to the properties downstream across Buffalo Bayou. We have to make sure there's no -- we have to make sure that there's no increased flooding risk upstream of the reservoirs as well.

We also know that there are a lot of different interests and concerns in the study area, and it's important to balance those concerns from the different entities and individuals. If there are indeed the population growth that's expected, we know that there will be significant land changes and interests from the business community. So we need to -- we need to be aware of that. We also know that there's a large desire to preserve some of the existing prairie lands that are in place right now, the environmental and conservation community. The (indiscernible) is interested in that. We also know that there's a very significant floodplain along several of the channel systems (indiscernible).

Watersheds -- we know that we need to come up with a management plan that's not going to exacerbate any of the flood conditions. We also know that Waller County is going to be an important partner in whatever plan that we come up with. We mentioned before 60 square miles of the drainage area is located in Waller County, so they're definitely going to be a partner in the future for an overflow management plan. We also have Addicks Reservoir to worry about and keep in mind. We need to come up with a solution that's going to work with their operational procedures.

So to balance all of these competing interests and keep in mind the community's interest and desires, the Flood Control District has engaged a committee that we've been working with. You can see the list of our steering committee members here. We have ten organizations that are participating. They're pretty diverse. We have some very big discussions in our meetings. We meet pretty regularly, about twice a month on average, to discuss different concepts and try to come up with consensus of how to move forward and talk about management plans that we think could be a good solution for the study area.

It's made up of business community interests as well as environmental interests. You can see here the West Houston Association, the Katy Prairie Conservancy, as well as the Bayou Preservation Association participate. And we also have several other agencies that participate as well, such as the Corps of Engineers, as well as (indiscernible) representation from Harris County Precincts 3 and 4.

The objectives of our planning effort are to identify a regional plan from overflow from Cypress Creek to help mitigate flood risk, to balance the competing interests of land use preservation, business interests, reservoir operations, and environmental mitigation needs during the process, to develop a business plan to implement regional strategies, and to implement appropriate policies to (indiscernible).

With that, I'd like to turn over the presentation to Alan Potok. He's our division director of the engineering and construction division and the director of our project.

MR. POTOK: Thank you, Dena. Just like to start by echoing Dena's welcome and thank you for attending the meeting tonight. It's our second meeting. We weren't sure that -- we held a meeting on this project last August, and it was an overflow meeting. We had filled the room, and so we wanted to make sure we had enough room to accommodate everyone who held an interest. The time -- with Houston traffic, you don't know if that will be 5:30 or 9:30 at night. We picked 6:30, and we appreciate everybody's effort to get here tonight.

I want to talk a little bit about the magnitude of the problem we're facing and the quantity of water we're talking about, what the impacts of development might mean to that and, you know, talk to you about some of the concepts that we're looking at to try to manage this whole situation in the event a regional plan actually was to become reality and what it would actually take to try to get something done.

Before I do that, Dena indicated we'd have questions at the end, but does anybody have a question about anything Dena said? We could take that right now, or else I'll just proceed.

Okay. Great.

Let me start by just mentioning -- go back to the slide on the steering committee. Dena touched based on the fact that we have all these complementary interests in the watershed that are -- have an investment in what's going on. Flood Control District is very concerned about protecting the interests of the existing populous and avoiding any increase that may be associated with developing properties. So we represent the people downstream on Buffalo Bayou, downstream on Cypress Creek, and upstream of the reservoir in the already developed properties.

The West Houston Association represents the business community. They represent the land developers, the people who are going to somehow figure out how to house the additional 300,000 people that are going to reside in this area. And that 300,000 people -- if you assume about 10 people per gross acre of land, that's about 30,000 acres of land that are going to be occupied sometime in the next 60 years with some form of development. Since most of the land (indiscernible) development occurs.

Harris County PID and Harris County Precinct 4, they build roads, they build the main roads and streets. So their interest in this project is how are they going to be able to build the roads with the massive area of overflow that Dena depicted on that map? It affects almost all of the area, and somehow we need to develop a system by which they can go about doing their business without adversely affecting the interest of the Harris County Flood Control.

Waller County has an interest because the overflow affects them. They have drainage problems in Waller County. If there's a way to incorporate them as a partner -- we need them as a partner because what they do in their county affects the waterflow downstream, so we have a very interest -- strong interest in a partnership with them.

The Katy Prairie Conservancy has an interest in restoration of much of the grasslands, but we also have an interest in much of the grasslands because we really believe that through -- for low and moderate storm events, it functions as a flood retardation function that we don't want to lose. If we're going to lose it, we want to figure out how to replace it.

The Corps of Engineers has an interest because they are always receiving the water from this watershed and the overflow from Cypress Creek, so they have an interest in making sure whatever policies and practices we put in place do not somehow adversely affect their operations of their reservoirs. And if it's possible, to somewhat try to benefit the operations of that (indiscernible).

So what do we know about this overflow? Well, first of all, the graphic that Dena depicted that showed you that it only occurs once every eight or ten years, that means it's very infrequent. So about out of 2400 days you're going to have it wet one day. Okay? But when it gets wet, there's a lot of it that's going to get wet, and we need to recognize that fact. It covers a very large area. It's not deep flooding; it's very shallow flooding. So it's not a life threatening function. It is from the perspective that there's no access around, but it's shallow flooding. But nevertheless, the combination of the wide area with the shallow flooding still means there's a lot of water involved in the solution.

One of the other things that I mentioned again about the prairie grasslands and the current land uses, there's a natural attenuation that occurs from the time that the water leaves the Cypress Creek Watershed, enters the Addicks watershed and the time that it hits Addicks Reservoir itself. And the reason for that is it's very shallow over this big, broad floodplain, and the water slows itself down and either gets absorbed into the ground or slowly meanders back into one of the receiving streams and flows into the reservoir.

So most of the time whatever management plan solution we come up with, the solution could look very much like this. It could be land in its current, natural state. Could remain that way. And most of the time, so long as it's preserved as an open space type of function, it will work just fine. Then on very rare occasions, it will fill with water. This is a little bit of a misrepresentation because the water looks very deep, and actually the depth of the reservoirs will be comparatively shallow for the most part.

If we try to move that water, if we try to collect that water at the Cypress Creek divide and convey it down to Addicks Reservoir, it's going to require a large swath of land to be able to do that, so the question is, if you're going to do that, what kind of environmental features or what kind of land restoration activities might you incorporate into a very large channel? So you might see a meandering channel like this here that is all floodplain but is actually used to move that large amount of water on a very rare occasion.

So let's talk about how much flow we're talking about. Again, this is that map that Dena described, roughly 20,000 acres of land. The light green areas are half a foot deep. The yellow and gold areas are two to three feet deep, but nevertheless, covers virtually all the area. This line here is the watershed divide. This line is Cypress Creek, South Mayde Creek, Bear Creek, Langham Creek, and the thing to note is that there is a rather continuous overflow along this entire watershed line, so all three of these channels are affected by the overflow. All three of the watersheds are affected.

Here's another graphic of that watershed of our study area. Here's Cypress Creek again. Here's a depiction of the overflow. Here's the (indiscernible). There's three points I want to point out to you. The first is the watershed divide where the overflow begins, and then you have this wide, big area that's the floodplain that's the overflow area that we just looked at. But then it all collects in these channels, and at that point in time, it's conveyed very quickly into the reservoir. So there's three points of interest to us when we're devising any form of strategy to solve this. Problem one is as it's occurring, one is as it's collected, and the third is as it's received into the reservoir itself.

Now, this is what engineers call "hydrographs." And what it is is it's a measure of the water that is passing you by. So imagine you're standing on the banks of a stream, and you're watching the water level rise and then fall again. That's what is depicted by this blue line here. It rises and it falls. And you're standing, watching it go by. And this is the time it takes for that to happen. So you can see it is not only large in magnitude, but it takes a long period of time to occur. And at the overflow divide, which is what this blue line is, the peak rate is about 13,500 cubic feet per second. That's a lot of fast moving water. The total -- the area under the blue line represents the total volume of water that you just watched go by, and that is also a very large number. It's about 23,000 acre feet of water.

Now, that large floodplain -- whoop -- that is shown right here, and I mentioned the attenuation factor, how it all slows it down. Well, by the time it recedes -- by the time it reaches this point here in those channels, the attenuation caused that peak to shrink from 13,500 to about 4800 cubic feet per second. So it has shrunk the speed by a factor of two and a half. Once it's collected in the channels, the channels are very efficient. They pull the water into the reservoir, and so (indiscernible) hydrograph occurs in the reservoir. It's just that all this takes time. So here it is that the overflow divide is -- the peak is appearing at 36 hours. Another day later it's being collected by the tributaries, and about a day and a half later it's going into the reservoirs.

Now, the last slide was just the rainfall, the result of rainfall occurring in the Cypress Creek Watershed and what was happening as it overflowed. This set of hydrographs shows you the impact to Addicks Watershed as a result of it raining -- the Addicks Watershed itself. In other words, every time it rains, it's now going to run off into the watershed and this is a one percent, 100 year rainfall event, and the runoff that is occurring from that, and what it is saying is that the runoff from the watershed would be about 40 -- a little over 40,000 cubic feet per second.

The prior graph showed this lag that was occurring in the hydrograph, this dark blue line, being the hydrograph of that overflow as it comes into the Addicks Reservoir, and it's on a different time scale. So here's that same blue line again that's shaped differently because of the scale of this (indiscernible). But you can see that it actually does affect -- if this golden line here is the runoff from the Addicks Watershed, when the overflow hydrograph coincidences with that hydrograph, you get a slight change in the hydrograph's shape entering the reservoir itself, but it doesn't affect the peak (indiscernible). It affects the volume, but the peak of the watershed itself would remain about the same.

So what we're trying to solve is how to manage this and how to manage this increase in flow right here into the reservoir itself. So some of the concepts we've come up with -- just so that you understand -- we tried to give people a perspective of what we think it's going to take to solve this problem. Now, this -- if we developed a single regional management strategy, we think it would take on the order of this magnitude of facilities. Now, even if a regional management plan is not put in place, if -- as land development comes in, they solve the problem in individual pieces, we think they're still going to spend about this order of magnitude of resources, of natural resources. So we would need somewhere between 4 and 8,000 acres of land just to store that floodwater, as opposed to letting it run all over the place. We would still need an area about that big. We'd have to store in that 4,000 to 8,000 acres -- we would need to store somewhere between 11,000 and 26,000 acre feet of water. We would have to figure out ultimately how to take that stored water and push it into the reservoir, and that's going to require somewhere between 250 and 600 additional acres of land. And in the course of doing this, if I go back to the slide of all the complimentary interests and what those various parties are interested in, part of the solution would actually create about 3500 acres of new land that could be preserved for natural conservation purposes and restoration purposes.

So we wanted to kind of look at all types of concepts that we could think of. One of the first ones, getting out of the box a little bit, was the idea that we would take -- here's Cypress Creek right here. Here's the watershed divide. And then this is Bear Creek and South Mayde Creek here. We said, well, what would happen if we just got rid of the water, we didn't let it overflow here, we just got rid of it? So we took it, and we diverted it over to the Brazos River, which has plenty of capacity. Couple of major issues with that. One of them is we would basically be creating a South Waller County and North Waller County, and then there's also some issues with water (indiscernible) and (indiscernible) transfer issues, so we weren't real comfortable that that solution had a real practical, real feasible opportunity.

I want to touch base -- I don't have a slide that shows this because you don't see it because we discounted it immediately. The Corps' original plan was to build a levy here. So you might say why don't we just build the levy here? Well, if you build the levy here along the watershed divide and you prevent the runoff that's generated up here from draining this way, it will now drain back down Cypress Creek, and Cypress Creek has a lot of problems right now. And all that would do is aggravate that problem. So we would have to build more mitigation up here to create the solution we'd have to look at anyway, so the levies at this point do not appear to be a practical answer to us. Okay?

So then we said, well, what would happen if we just collected it and conveyed it? So this is Cypress Creek, and this gold line here is right along the watershed divide. We said let's let the overflow occur. We'll catch it all in a channel, make it nice and efficient, and then very quickly move that water down into Bear Creek. Well, the problem with this answer is that this channel down here only has capacity of about 4500 to 5,000 cubic feet per second. Now, if you remember -- I had this long discussion with the hydrograph up here that had a flow of about 13,500 cubic feet per second, but it attenuated, and by the time it got down here to this channel it would be about 4500. If I put it in these nice, efficient collection systems, I don't get that attenuation anymore. So I have to assume that I've got 13,500 cubic feet per second of water flowing down, so not only do I lose all that attenuation, but I am now flooding all this down here. So we didn't view that as a very practical answer in and of itself either.

We looked at -- well, okay. Well, then let's look at -- just taking that same approach as the watershed divide, we'll build the channel, go all the way through the subdivisions down here, all the way into the reservoir and try to solve the problem that way. And the problem with that is the restrictions in the right of way, number of people that would have to be displaced, and the difficulty associated with trying to build something in the reservoir itself.

So then we said, well, rather than diverting the water over to the Brazos River, let's just catch the water up here and hold it in the upper Cypress Creek Watershed and release it more slowly. If we release it more slowly, maybe we won't have an overflow. Again, this is Cypress Creek. This dotted line is the watershed divide. But what we found was even though we can build this and it works kind of sort of, we can't capture enough water, and that overflow will still occur, and it will still flow into the Addicks

Watershed. So this area will remain inundated as an overflow zone.

So then we looked at combining two of the strategies. We said, okay, let's build this reservoir up here, and whatever we can't find -- or whatever we can't control, we'll catch after -- this is the divide. We'll catch the rest of it after it's come over the divide, and we'll build a channel, just like we had. Now, this solution actually works. We figured out how to actually build this big enough, collect this, and convey it without harming the downstream interests here. This answer actually would work. This is one of the answers that actually works. We'll come back to it. We'll come back to an alternative of it. But this strategy will cost about $325 million to build.

We then looked at another strategy and we said, well, rather than build a storage facility up here, what if we built a storage facility further downstream and we actually crossed Cypress Creek downstream near Katy Hockley and add this collection system here? And in doing so we could regulate the flows at this point going downstream into Cypress Creek, or we could actually move more water into Cypress Creek if it was capable. Nevertheless, we still had to build some kind of conveyance zone to take the collected water and move it downstream into Bear Creek. This answer also works. It collects all the water. Delays it long enough -- stores it long enough so we can actually collect and convey the water without adversely affecting anything downstream on Cypress Creek or anything downstream on Bear Creek. The advantage to this strategy as well as the other strategy is more water is held into -- in the Cypress Creek Watershed, so the volume of water that would flow down Cypress Creek would be increased, but the peak rate of flow would not be increased. So the floodplains -- the flood risk would not be increased.

We also looked at a strategy that said, well, let's let all of the overflow come over the divide. Here's the divide. The dashed line is the divide. Here's Cypress Creek here. Once it crosses over here it's now in the Addicks Watershed. We said let's build a watershed down here and build multiple outlets to Cypress, Langham, Bear Creek and South Mayde, so that would give us the option of deciding where to best release the water based on what the downstream conditions actually were. So that was another strategy that we had come up with to try to solve the problem.

And then this turned out to be a modification of the other one that I said that worked, and we said, well, let's take this crossing of Cypress Creek option that we had that I said worked. Let's also consider building this reservoir up here. Let's build a conservation area and leave ourselves some room to build a third dam right here. (Indiscernible) anything on this side is the Addicks Watershed and has overflowed into the (indiscernible). So this is another strategy we came up with that we said also solves the problem.

So one of the things we wanted to look at when we did this was what are the impacts -- or do our current design criteria properly account for the hydrologic conditions that we're going to be looking at in this watershed? And the reason that it's different, we -- our current criteria, we feel rather confident can control peak rate of runoff. It's designed to do that, regardless of what the starting point is on the land use. It could be a marshland. It could be a preexisting contract. And we've got the mechanisms in place that tell land developers what they have to do in order to mitigate for any rise in peak flow rate as a result of their actions. But our current criteria is based on the fact that flow ultimately gets into a receiving stream, and that receiving stream goes into a larger bayou, and that bayou then drains either into the Houston Ship Channel or Galveston Bay, one of the two.

It all works well and good because it keeps moving down. The difference here is that we can get the water into one of the main creeks, but those creeks then flow into a reservoir with a finite capacity, and that water is held in that reservoir for a long time. So we now have to be concerned not only with the peak rate of flow, but we also need to consider what happens to the volume of flow. Is land development actually increasing the volume of runoff that would enter into the reservoir that's now being held for a long period of time, and a second rainfall occurs, and now the water is still in the big reservoir. Where does the new water go? So we wanted to look at whether or not supplemental criteria is necessary. And here's that watershed graphic again that shows the water -- Cypress Creek, the overflow zone collecting into the creeks and then the downstream reservoir.

And again, the aerial extent of the overflow zone itself. So both conditions apply. If this is the watershed divide, not only are we concerned that this rate and volume of overflow from this watershed -- into this watershed not be increased, but we are also concerned that the runoff that is generated as a result of a rainfall just in this watershed does not increase as it goes into Addicks Reservoir. So we really have two conditions. We have every time it rains runoff occurs and goes into the reservoir. We don't want that to increase. We have this condition in the Cypress Creek Watershed that says every time it rains, runoff goes this way, but every now and then it also comes this way. And we don't want that to increase either.

So what we did was we looked at a logic that said what is the impact of land development of the (indiscernible). And this represents the existing hydrograph in the Addicks Watershed. So every time it rains, water runs off and goes into Addicks Reservoir. If we had no drainage criteria at all -- which we do have drainage criteria. But we have drainage criteria that says if you develop you can't increase that point right there. You can't increase the peak. But if we didn't have that criteria, that hydrograph would look like this. It would be much higher, and there would be more volume associated with it.

Well, if you add this -- if this red line represented the overflow, then it -- looking at the green versus the blue, you can see that obviously more overflow would occur because there's more water above the horizontal red line. The green volume is less than the blue volume. But we do have criteria in place.

And that criteria is represented by this orange hydrograph. So the green represents the existing runoff hydrograph. The blue represents if we didn't have any criteria at all. But the orange says but you do have criteria, and that criteria says the peak rate of runoff is no more than the existing rate of runoff. But go back to the logic and look at the green hydrograph here, and whatever you see in green above the red line, that represents the overflow. Because we took this larger volume and spread it out over a much longer time, even though the peak rate right here is the same as the green, there's a longer time period over which this orange line is above the red line than there is the green line above the red line. So that's telling us that we need to be concerned about the additional volume that is occurring. We don't want that to just be allowed to run off into the Addicks Watershed. So what we're doing is suggesting supplemental criteria that land development would have to not detain but retain an additional two inches of runoff. By "retain," that means you store it and dispose of it in some manner other than letting it run off, or you allow a very slow release for that runoff to make sure that it does not affect the operation's advantage -- one of the two.

So our preliminary conclusions based on the concepts that we put together is that a very major storage element is going to be required. We don't see any way to just collect and convey the runoff. We're going to have to phase the project if a regional plan is developed. The economics are such that we don't think we can do this all in one piece. Land acquisition and obtaining the appropriate right of way is going to be key to this, and developing the mechanisms by which we can get control of that land as quickly as possible is going to be important.

And I mentioned the fact that a regional management plan is not necessary. I mean, something could be done without there being a regional plan in place. The supplemental criteria that we put in place have to stand alone. They have to come into fruition, or come into place, regardless as to whether or not a regional plan is put in place or not because individual developers can in fact develop their land with the supplemental criteria put in place, and we feel confident that the (indiscernible) is protected and we feel confident that the criteria protects the existing populous. But we think we'll lose a lot if that occurs, and some of the things that we'll lose, we think, are the opportunity for a collective solution that meets the needs, the consensus needs of all the parties in the steering committee that we're talking to. The public loses the opportunity to gain a lot of open space, and some of the environmental values get lost as a result of each development project responding to its own individual mitigation requirements.

And if it's done this way, it's unlikely any form or major regional (indiscernible) would be built. So you would see a lot of small facilities, which would likely end up with more maintenance problems and more management problems in the long run.

So implementation strategy -- one thing is for certain, land development is coming. The population growth is coming. We can't stop it. We don't want to stop it. It's an economic benefit to Harris County that it occur in a managed manner, but our solution has to be timely so they can take advantage of it. And we've got to break it down into chunks that are truly financially feasible so that the public can play its part and the private sector can play its part. But we've got to know who will pay for what piece of the puzzle and how those costs can be minimized. So one strategy I showed you -- this strategy right here. You know, we have a storage system up here. We have a collection system here. We've got a conservation area back here of about 2200 acres and a conveyance system down here. I said this is one of the solutions that works. This is not our preferred solution. This is just one of the solutions that works. Okay?

We can talk about how to phase this. So the total cost of that solution that I just depicted to you would be about $325 million. Of that, land acquisition is about 150 million of it, and construction cost is about 140 million. So what we might do is we might first build one piece of this collection system here, and if we did that, it would eliminate a portion of the overflow system that is downstream that we'd be able to collect it and move it into Bear Creek. So that would free up a portion of the area for development.

We would then improve Bear Creek itself into a wider corridor which would also help -- we'd also extend this collection system out here, which would then free up even more of the overflow area. And then a third step might be to extend this collection system further, build a storage reservoir and complete the whole picture. This is just kind of -- this is a sample case. We've done a lot more detail on some of these. So you can say, well, there's a three-phased approach to try to get this done. And at the end of the three phases, we've eliminated all of the overflow. We've protected the existing populous, and we have a system that we can actually manage.

And I think we're frozen. Sorry.

So if we look at that, we have to look at how we could practically phase this, and along the horizontal axis is how many years it would take. The vertical axis is the cumulative cost of the investment. So it would take 18 years to build this entire system, and it would take $325 million.

Now, Harris County Flood Control District has several watersheds where it imposes something called an "impact fee," which is a privilege to develop in the watershed. And developers pay a fee, and that fee is used to help us build regional facilities within the watershed. We said what if we -- we said what if we took a similar approach here? But there are -- this is only one approach. I'd like to talk about the total people who actually benefit from this. But we said, okay, if we have the growth curve and as land development is occurring we get revenues back on the project -- but someone's got to front end the cost, someone has to make it all happen.

So the tops of the yellow bar represent the cumulative investment. The blue lines represent the cumulative revenues that can be received from land development. And 22 years out, land development would have picked up the entire cost. But for these years, someone else has to pick up the cost, and that someone else might be someone in the public sector, might be a new political entity, could be any -- but the point is there's a shortage of cost while the project is being built.

Here's just another depiction of that same example showing when revenues could actually occur, and the idea would be to try to control the costs to about $20 million per year for 18 years. At that point in time, it all gets paid, and the blue lines represent land development occurring, revenues being paid to help finance the project. The yellow lines represent someone else picking up the cost to make that occur. So you can see at the very front end of this project there are no blue lines, which means someone has to front end that cost, and that cost is about $38 million, something of that nature.

So what these strategies, these financing strategies have shown us is if this type of technique was to be used, there has to be a partnership between the private sector providing these revenues and some form of public entity, taxing authority -- something picking up the yellow lines to fill in the blanks to make that work.

So where do we go from here? We are working with our steering committee to refine two of the concepts, work out all of the details, work out a business plan strategy, and when that is done, we will complete a draft report in about February of 2014. Simultaneous to that, we will be trying to go to Commissioners Court to adopt the supplemental criteria for volumetric control of runoff, to supplement our current control peak rate (indiscernible).

When the draft report is completed, we'll have a third meeting with the public, sometime in the spring of 2014. And when we have collected all of the comments from the public, we'll incorporate those comments and submit the draft report to the Texas Water Development Board. And then once we've gotten their comments, finalize the report and send it to Commissioners Court for approval.

If the steering committee, which represents the major interests -- we can get a consensus approval on how to move forward with a plan -- if something can be done where we get that consensus, we would also institute an implementation plan and present that to Commissioners Court for adoption also. That's the approach we intend to take. We are on schedule with the study. The steering committee is working really well together, for having such diverse interests. And so we feel really good about being able to complete the study on time.

Here's where we are on that study process. The yellow line represents where we are today. There are eight primary tasks. Top task is quantifying and delineating flood risk. Task two is identifying mitigation strategies. Task 3 is benefits of prairie restoration. Task 4 is identifying critical conservation areas. Task 5 is a cost/benefit analysis. Task 6 is project financing and cost pro forma. Task 7 is a public outreach program. Task 8 is the final report. So we do intend to complete the project on schedule.

With that, I'm going to turn it back to Dena to moderate the questions that you might have. Dena?

MS. GREEN: Thank you.

Okay. We passed out question and comment forms earlier. We'd like to ask everybody to fill those out and write your name down on them if you have comments, and Glenda is here. She can walk through and collect the cards, and we can have some discussion.

Does anybody have a comment form they'd like to turn in?

UNIDENTIFIED SPEAKER: Comment cards?

MS. GREEN: Thank you.

Okay. This is a comment that we have from Jung Jang, and he asks, "Was the historical rainfall events analyzed for the event today, and was (indiscernible) considered since the impact on the reservoirs for the 24 hour storm duration would not capture true impact upon the watershed?"

MR. POTOK: The easy answer to the question is, yes, they were. The two highest levels in Addicks Reservoir occurred in 1992 and 2009. 2009 was a single, one-day event that had about ten inches of rain. In 2002 there was about 21 inches of rain that occurred over a 90-day period, and the largest rainfall was about six inches or five inches maximum. What we looked at in coming up with our retention -- volume retention criteria was what would have been the cumulative impact over that 90-day period had development occurred and we had seen an increase not only of that but we had seen an overflow? And so we looked at what was actually happening in the reservoir, what their release rates were, historic release rates were, and looked at a long duration. Yes.

MS. GREEN: Thank you. Are there any other comments or questions?

Anybody that wants to make one without the official form?

UNIDENTIFIED SPEAKER: I had a question on (indiscernible). (Indiscernible) so far because of the lack of rain there was little conclusion. Where do you expect that study to go and how might it impact (indiscernible)?

MS. GREEN: Sure. We have some more information to share with you on that, but we have been collecting data for the last year. We had several storm events. We wish we had more, but we'll get that initial report in at the end of the year. So we'll have some draft data to share with that. We'll share that information in the report where (indiscernible) for the Water Board. Flood Control is going to continue monitoring for an additional five years, and that way we'll have some more additional data to share.

Stephen, when we talked about it, it sounded like we had mixed results when we were waiting for the report to come in in December.

UNIDENTIFIED SPEAKER: That's correct. Just preliminary data so far.

MR. POTOK: Yeah. The data we've gotten has been for some pretty small storm events, and what we need to understand when it comes to prairie grass is are they effective not only during small rainfall events but also major rainfall events. So we wanted to keep the monitoring programming going for a longer period of time in hopes we would catch one or two major events to see if we actually had large absorption rates associated with the prairie grasses.

If we do, there's always a possibility that we may make a decision to say we need to change the supplemental material, but for right now, based on the rate long duration study that we came up with, over that 90-day period, the runoff rate was about 73 percent, something like that. 73 percent of the runoff in the Addicks Watershed reached the reservoir, which is a pretty high percentage. So we're wondering just how effective the prairie grasses are because a lot of the agricultural area is not prairie grass; it's just open space. And we really want to try to understand the prairie grass itself because if they are, one of the strategies for retention that we're offering to the developers is to say, if you want to, you can go restore an acre of prairie grassland, and that can be the form of mitigation. We don't have to build a space to hold the water. If you want to go out -- go into a conservation area and build a prairie grassland, we may be on board with that if it works. That's why we need to see how (indiscernible).

MS. GREEN: Any more questions? Yeah?

UNIDENTIFIED SPEAKER: You had said something about impact fees.

Isn't the whole purpose of having a detention pond that there is no impact? How would you assess your impact?

MR. POTOK: The question is -- you mentioned impact fees. If we're building a regional basin to handle the impact, why would we have impact fees, right?

Well, the idea of the impact fees is that if development wasn't occurring, we wouldn't be building a regional basin, so we're not in the business of subsidizing new development. We're in the business of protecting the existing infrastructure and protecting the existing (indiscernible). If we build a space center -- if someone builds a space center for mitigation of land development, we expect them to pay us back for the fact we built it. That's how (indiscernible).

UNIDENTIFIED SPEAKER: (Indiscernible).

MS. GREEN: We're keeping track of the comments tonight. Would you mind telling us your name?

MR. VINKLARCK: Chance Vinklarck.

MS. GREEN: Thank you. And your name?

MR. SAKOLOSKY: S-a-k-o-l-o-s-k-y. First name, Jack.

UNIDENTIFIED SPEAKER: Was that study -- was that included in the study? Have the reservoir and it would be diverted down the channel but the upper where Langham Creek also falls.

MR. POTOK: Yes, it was. We just -- we just didn't include Langham Creek.

MS. GREEN: What was your name?

MS. HYDUCEK: Julie Hyducek.

MS. GREEN: The question was about building (indiscernible).

MS. HYDUCEK: Down Langham (indiscernible)

MR. POTOK: We are looking at Langham.

MS. HYDUCEK: The Bear Creek channel would include pumps -- sort of like New Orleans have pumps?

MR. POTOK: No, we are not -- well, we're not currently looking at pumps. (Indiscernible). We may -- one of the strategies where we would actually cross Cypress Creek in order to equalize -- in order to make a decision as to which is the best way to get rid of the water. The idea of a pump station may result, but it's not currently (indiscernible).

MS. GREEN: Can I have you speak into the microphone so everybody can hear? Kind of limited here. Let me try to bring it down.

MS. LOFTS: My name is Bonnie Lofts. I just (indiscernible). Who is the most likely taxing entity for the portion of the funds or the initial funding?

MS. GREEN: Who's the most likely taxing entity? Well, that's something we're discussing right now in the steering committee. We've talked about different tax (indiscernible) might come into play. We've talked about it at the Flood Control District. But right now we have a operational budget of about $6 million a year. So if we were to (indiscernible) something like this, that would use most of our funding for several years.

We've talked about a new taxing entity, creating a tax increment reinvestment zone. (Indiscernible). It's something we've just started the discussion on, and so we will be working on that and try to identify ways we think it would be viable to fund the plan. And that's something we hope to bring back to you later next spring when we come, but right now I don't have a suggestion on that.

Do you have something you'd like to add? No?

Any more questions or comment forms if you want to turn those in?

Over here? No?

Well, I'd like to let you know that we are going to be posting our comments and a copy of our program slides tonight on our website, which you can see listed up here, www.hcfcd.org/cypresscreekoverflow, if you want to note that down. If you forget that, if you go to the Flood Control District website and click on the tab for the major projects, you should be able to navigate to the site pretty easily.

And I would like to thank all of you for coming out tonight. I know it's just after work. We just had the time change. It's really dark. It's pretty cold out. It would be a nice evening to be inside and warm, so thank you for spending your time here to be with us tonight so we could get feedback from you and then tell you more about the study that we're conducting. We have gathered a lot of information and are working on a lot of analyses that we'll share with you this spring, but we do appreciate your input and the time with us this evening, so thank you very much for coming.

And I'd also like to thank the Flood Control District staff that helped facilitate the meeting today. You did a great job. Thank you very much.

And a big thanks to our consultants as well. (Indiscernible).

If any of you have questions, we'll be here for a little bit longer. We can show you some more of the slides again or talk about some of the graphics that we've got around the room.

We also have some cookies and some coffee in the back, too. Please help yourself to that.

Thank you.

(Meeting adjourned)

CYPRESS CREEK OVERFLOW MANAGEMENT PLAN PUBLIC MEETINGS
BEAR CREEK COMMUNITY CENTER, NOVEMBER 7, 2013, 2:00 P.M. AND 6:30 P.M.

COMMENTS RECEIVED AS OF DECEMBER 31, 2013

LAST NAME	FIRST NAME	AFFILIATION	MAILCITY	SOURCE	COMMENT
Bolton	Michael	Hearthstone Flood Coalition	Houston	Meeting - Verbal	See Meeting Transcript, 2 pm.
Foster	Paul	Bear Creek Subdivision Resident	Houston	Meeting - Written and Verbal	Since at least 2006, Clay Road between Bear Creek Drive and War Memorial has ben identified as "acting like a reservoir, then a channel, independent of the Addicks Reservoir" (HCUD #6 Drainage Analysis). I would like to know what is being done or planned to improve the flow in this area and eliminate what I perceive to be a cause of flooding in the Bear Creek Subdivision. See also Meeting Transcript, 2pm.
Garcia	Fred	MUD 239	Houston	Meeting - Written	Have you thought about creating a separate taxing authority with bounderies covering Addicks and Cypress Watersheds to finance the project?
Hejducek	Julie	Bear Creek Flood Committee	Houston	Meeting - Verbal	See Meeting Transcript, 6:30 pm.
Jang	Jung	Homeowner Eldridge Park	Houston	Meeting - Written	(1) Were historical rainfall events analyzed for the alternatives presented today? (2) Were longer duration storms considered since the impacts on the reservoirs for 24-hour storm duration would not capture true impact on the watershed?
Lofts	Bonnie	HC MUD 127	Houston	Meeting - Verbal	See Meeting Transcript, 6:30 pm.
Mannchen	Brandt	Self	Houston	Meeting - Written and Verbal; Letter	(1) What are maintenance costs? (2) What are impacts on conservation area when water is held for longer period of time? (3) H:ow does Waller County benefit from this? With present design criteria or future modified criteria, with 25,000 acres developed, how much more water will go into Addicks, and how will the resevoir be affected at full watershed build-out? See also Meeting Transcript, 2 pm.; See Comments Attachment A, Letter.
Rayburn	Robert	Self	Houston	Meeting - Verbal	See Meeting Transcript, 2 pm.
Robertson	Jim	Cypress Creek Flood Control Coalition	Houston	Meeting - Written and Verbal	With the current proposed solution (storage + flow deflector + conveyance channel) how much acreage is required for each part of this: 1) storage, 2) possible conservation area behind flow deflectors; 3) conveyance channel? See Meeting Transcript, 2 pm.
Sheldon	Steve	Dannenbaum Engineering	Houston	Meeting - Written	What is the HCFCD project occurring between Katy-Hockley Road and Cypress Creek, north of Paul Rushing Park? What effect will the project have, if anything, on this issue?
Singleton	John	HC MUD 136	Houston	Meeting - Verbal	See Meeting Transcript, 6:30 pm.
Smith	Dick	Cypress Creek Flood Control Coalition	Houston	Meeting - Verbal and Written	See Meeting Transcript, 2 pm; (1) Will comments/questions submitted at both of today's 2 sessions be published on the HCFCD website? If so, approximately when? This would be helpful and appreciated. (2) At the time of the 1st Public Meeting, August 16, 2012, one of the objectives among several for this Overflow Plan study was reported to be "to establish a set of policies, technical criteria and...that will allow the Flood Control District to...implement programs that reduce flood risks that reflect the unique hydrologic conditions in upper Cypress Creek ...and the drainage areas upstream of Addicks and Barker Reservoirs..." This technical criteria which is so critical to success of the proejct, requires utilization of the updated FEMA hydrology and hydraulic computer models for the Addicks Watershed which the project team said the expected completion date was the end of December 2012. (This was per the December 2010 "Kick-off Meeting" for the "Model and Map Update project.) However, these models are still undergoing FEMA evaluation. So with this schedule slippage -- now pushing on 1-year, When do you think these "current conditions" models and maps will be available for public review/comment/appeal?
Smullen	Pete	Cypress Creek Flood Control Coalition	Cypress	Meeting - Verbal and Written	See Meeting Transcript, 2 pm; Will you do modelling of Cypress Creek Overflow under fully developed conditions including your solution?
Sokolosky	Jack	Cypress Creek Flood Control Coalition	Houston	Meeting - Verbal	See Meeting Transcript, 2 pm.
Strange	Jon	HC MUD 405	Katy	Meeting - Written	Is there a possibility of having some of the water impounded for potable water use? Could this project utilize the recently passed Proposition No. 6 for use of the 2 billion dollars for reservoir development? Can Katy Prairie Conservancy be assisted or helped by this project?
Vinklarck	Chance	Barker Cypress MUD	Houston	Meeting - Verbal	See Meeting Transcript, 6:30 pm.

November 18, 2013

Mr. Mike Talbott, P.E.
Director
Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092

Dear Mike,

Enclosed are my personal comments regarding the Harris County Flood Control District's (HCFCD) November 7, 2013 Cypress Creek Overflow Management Plan (CCOMP) public meeting.

1) HCFCD should model and make easily available to the public the complete build-out of the Cypress Creek and Addicks' Reservoir Watersheds and the effects this will have on flows and timing of flows into Addicks Reservoir. It is important for HCFCD to model this complete build-out with the present water holding limit that Addicks Dam has and any future changes to this limit.

Next year the Corps of Engineers will have public meetings to address long-term management changes to Addicks Reservoir. HCFCD should model these proposed changes over time and the degradation of existing or future Corps Addicks Reservoir management changes as both the Addicks and Cypress Creek Watersheds are built-out.

HCFCD must present a worst-case analysis so that the public can understand the seriousness of doing little or nothing about this problem and what it means for those who live near or around the perimeter of Addicks Dam, those who live downstream along Buffalo Bayou, and those who live in Downtown Houston.

2) HCFCD is right to pursue protection of lands in their natural or near natural state. This will ensure that water flows and timing of flows are reduced or slowed down to allow evaporation and infiltration to work maximally. I urge HCFCD to pursue the protection of lands in their natural or near natural state to the maximum extent possible, perhaps doubling (7,000 acres), tripling (10,500 acres), quadrupling (14,000 acres) or more the acres that will not be developed. I believe that the magnitude of the development that will occur in the Addicks and Cypress Creek Watersheds will be underestimated, the water flows due to this development will be underestimated, how quick these flows enter Addicks Reservoir will be underestimated, and the effect this will have on the operation and flooding in, around, and downstream of Addicks Dam. Existing native prairie must be protected and preserved and grasslands or shrub-lands that used to be native prairie must be restored and preserved.

Org: Potok
cc: Green
Saha

M333574

3) I am very concerned that the proposals presented require that the natural channel of Bear Creek and other creeks be destroyed by widening and deepening. If this is done the natural riparian vegetation will no longer exist. Planting trees afterwards does not recreate a natural riparian forest. While Meyer Park is an improvement on past HCFCD practices it none-the-less embodies the tactic of destruction of natural riparian forests and then the recreation of a replacement that is in not equal to a natural riparian forest. See in particular the artificiality embodied on the slide labeled "Large areas for conveyance" in the meeting presentation. The diversity of aquatic habitats are reduced or eliminated for human created ones.

4) With regard to the alternatives I do not support:

a. **Bessies Creek/Bell Bottom Creek** alternative because of the damage done to natural creeks and the interbasin transfer of water.

b. **Overflow Collection Channel/Bear Creek Multi-Use Channel** alternative goes through Katy Prairie Conservancy (KPC) properties and will alter water flows and may alter natural water regimes (flooding and drying). The Bear Creek Multi-Use Channel will destroy native riparian habitat in Bear Creek.

c. **Overflow Collection Channel/Bear Creek Greenway Corridor** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). The Bear Creek Multi-Use Channel will destroy native riparian habitat in Bear Creek.

d. **Upper Cypress Storage/Cypress Creek** alternative places much of the burden on Waller County for Harris County flood problems. This is not fair politically, environmentally, and socially. This proposal also destroys native riparian habitats in Cypress Creek.

e. **Upper Cypress Creek/Cypress Creek/Potential Conservation Area/Bear Creek** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). Bear Creek and Cypress Creek will have native riparian habitat destroyed. This alternative does provide a conservation area which would be good. However, the conservation area is too small. This alternative places much of the burden on Waller County for Harris County flood problems. This is not fair politically, environmentally, and socially.

f. **Overflow Collection Berm/Overflow Conveyance Zone** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). Bear Creek will have native riparian habitat destroyed.

g. **Upper Addicks Storage/Cypress Creek/Langham Creek/Bear Creek/South Mayde Creek** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). Bear Creek, Cypress Creek, Langham Creek, and South Mayde Creek will have native riparian habitat destroyed. This alternative places much of the burden on Waller County for Harris County flood problems. This is not fair politically, environmentally, and socially.

h. **Upper Cypress Storage/Cypress Creek/Potential Conservation Area/Overflow Conveyance Zone** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). Bear Creek and Cypress Creek will have native riparian habitat destroyed. This alternative will provide a conservation area which would be good. However, the conservation area is too small. This alternative places much of the burden on Waller County for Harris County flood problems. This is not fair politically, environmentally, and socially.

j. **Upper Cypress Storage/Cypress Creek/Potential Conservation Area/Bear Creek** alternative goes through KPC properties and will alter water flows and may alter natural water regimes (flooding and drying). Bear Creek and Cypress Creek will have native riparian habitat destroyed. This alternative will provide a conservation area which would be good. However, the conservation area is too small. This alternative places much of the burden on Waller County for Harris County flood problems. This is not fair politically, environmentally, and socially.

5) The proposal I support would require onsite detention for all developments and a 20,000 acre undeveloped parcel in the Cypress Creek and Addicks Reservoir Watersheds connected to KPC properties. This will provide flood control, recreation, wildlife habitat, and green space for solitude, quiet, and natural sound enjoyment.

I support acquisition and maintenance for flood easements, low-impact recreation, and wildlife and ecosystem restoration and preservation a large portion of the remaining Katy Prairie to the Brazos River, and Cypress Creek. Only by use of the characteristics and tendencies of the natural landscape to retain, detain, slow down, and evaporate water can HCFCD reduce impacts on Addicks Dam, ensure it is safe, and slow down the scouring erosion caused by excess water flushed down Buffalo Bayou.

I support the permanent preservation, protection, and restoration of the Katy Prairie and Cypress Creek and their natural beauty, ecological integrity, use for compatible recreation, and quiet and solitude. This study has the potential for permanent protection of a substantial portion of the Katy Prairie and Cypress Creek.

Most naturally vegetated landscapes left on the Katy Prairie and Cypress Creek should be protected. We have already lost most of the native prairie, bottomland hardwood forested wetland, and riparian woodland forests on or in the Katy

Prairie and Cypress Creek and other streams in the Addicks Reservoir Watershed that naturally attenuate and reduce floods. We need to restore these areas and natural flood control characteristics.

6) HCFCD must require that all documents connected with this study be made easily available to the public. There must be a comprehensive public outreach, education, participation, and input program.

7) Methods of flood control reduction must focus on non-structural means including buyout and use of the landscape of the Katy Prairie as natural flood easement areas; additional voluntary buyouts of flood-prone properties in appropriate places; extensive onsite rainwater collection and detention for residential and all other properties; green vegetated erosion control measures (Black Willow plantings); low-impact detention ponds which are designed to blend into the natural landscape and not replace it; and other undeveloped watershed land acquisition and protection integrated with compatible recreation, park use, and wildlife habitat protection areas.

I appreciate this opportunity to comment. Thank you.

Sincerely, Brandt Mannchen

Brandt Mannchen
5431 Carew
Houston, Texas 77096
713-664-5962
brandtshnfbt@juno.com

4.3 September 2014 Public Meeting

4.3.1 Newspaper Notice, Houston Chronicle, September 3, 2014

PUBLIC MEETING NOTICE – SAVE THIS DATE

The Harris County Flood Control District is completing the Cypress Creek Overflow Management Plan study to develop a plan to manage flood risks in an area with unique hydrologic conditions that experiences overflows from the Cypress Creek watershed. This area encompasses upper Cypress Creek (upstream of US 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County have received a flood protection planning grant from the Texas Water Development Board to partially support this effort to gain consensus for a regional strategy to address the overflow.

A Public Meeting will be held on September 25, 2014, from 6 - 8 p.m., at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084. A draft final report of the planning effort will be presented, followed by discussion and receipt of comments from the public. Materials for the meeting will be placed on the District's website at www.hcfcd.org/cypressoverflow as soon as they are available. Written comments will be accepted through October 25, 2014.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District at 713-684-4000 or online at www.hcfcd.org/cypressoverflow.

4.3.2 Media Release

FOR IMMEDIATE RELEASE
September 19, 2014

FOR MORE INFORMATION CONTACT:
Kim Jackson, Harris County Flood Control District Communications
713-582-5124
kimberlye.jackson@hcfcd.org

Harris County Flood Control District's Cypress Creek Overflow Management Plan Public Meeting is Sept. 25
Meeting will focus on results of two-year study and draft report

The Harris County Flood Control District invites the public to a meeting on Sept. 25 from 6-8 p.m. at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084.

At the meeting the Flood Control District team will share details of the Cypress Creek Overflow Management Plan study, as well as the draft report that features those study findings. The presentation will be followed by a question-and-answer period and study team members will receive comments from the public.

In 2012, the Texas Water Development Board (TWDB) awarded a flood protection planning grant to Harris County and the Flood Control District to support development of the Cypress Creek Overflow Management Plan, which has focused on proposed ways to manage the occasional overflow of stormwater from Cypress Creek into the Addicks Reservoir watershed that can lead to widespread flooding in western Harris County. The 277-square-mile study area encompasses the upper Cypress Creek watershed (upstream of US 290); the drainage area upstream of Addicks Reservoir, including Langham Creek, Bear Creek and South Mayde Creek; and that portion of the overflow area draining into Barker Reservoir. A 63-square-mile portion of the upper Cypress Creek watershed is located in Waller County and drains into Harris County.

All public comments on the draft report are due by Oct. 25, 2014, and the Flood Control District will submit the Cypress Creek Overflow Management Plan report to the TWBD at the end of October. The report will be posted on the Flood Control District's website at www.hcfcd.org/cypressoverflow in advance of the public meeting date.

Written comments on the draft report can be submitted by e-mail through the study website, www.hcfcd.org/cypressoverflow or by mail to:

Harris County Flood Control District
9900 Northwest Freeway
Houston, TX 77092
ATTN: Dena Green, Study Manager

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District's at the Project and Study Hotline, 713-684-4040, or online at www.hcfcd.org/cypressoverflow.

For your calendar:
Cypress Creek Overflow Management Plan Public Meeting
Who: The public is invited
What: An overview of the Cypress Creek Overflow Management Plan study and draft report
When: Sept. 25, 2014, 6-8 p.m.
Where: Harris County Precinct 3, Bear Creek Community Center
3055 Bear Creek Drive, Houston, Texas 77084
Directions are available at www.pct3.hctx.net/cc_bearcreek

ABOUT THE HARRIS COUNTY FLOOD CONTROL DISTRICT

The Harris County Flood Control District provides flood damage reduction projects that work, with appropriate regard for community and natural values. With more than 1,500 bayous and creeks totaling approximately 2,500 miles in length, the Flood Control District accomplishes its mission by devising flood damage reduction plans, implementing the plans and maintaining the infrastructure. To learn more about the Flood Control District, visit www.hcfcd.org.

# # #

When posting this information on your social media site, remember to use the hashtag #HCFCDnews.

PUBLIC MEETING
Cypress Creek Overflow Management Plan

Date: **September 25, 2014**

Time: **6:00 – 8:00 p.m.**

Place: **Harris County Precinct 3, Bear Creek Community Center**
3055 Bear Creek Drive, Houston, Texas 77084
Directions are available at www.pct3.hctx.net/cc_bearcreek

The Harris County Flood Control District is nearing completion of a study effort aimed at developing a plan to manage the overflow of stormwater from Cypress Creek into the Addicks Reservoir watershed in western Harris County. In 2012, the Texas Water Development Board (TWDB) awarded a flood protection planning grant to Harris County and the Flood Control District to support development of the plan, formally known as the "Cypress Creek Overflow Management Plan." The 277-square-mile study area encompasses upper Cypress Creek (upstream of US 290); the drainage area upstream of Addicks Reservoir, including Langham Creek, Bear Creek and South Mayde Creek; and that portion of the overflow area draining into Barker Reservoir. A 63-square-mile portion of the upper Cypress Creek watershed is located in Waller County and drains into Harris County.

You are invited to attend the Cypress Creek Overflow Management Plan Public Meeting on Sept. 25, 2014 from 6:00-8:00 p.m., at the Harris County Precinct 3 Bear Creek Community Center, 3055 Bear Creek Drive, Houston, Texas 77084. Study team members will present study findings and the draft Cypress Creek Overflow Management Plan report, which will be submitted to the TWBD at the end of October. The presentation will be followed by a question-and-answer period and study team members will receive comments from the public. Written comments on the draft report can be submitted by e-mail through the study website, www.hcfcd.org/cypressoverflow or by mail to:

Harris County Flood Control District
9900 Northwest Freeway
Houston, TX 77092
ATTN: Dena Green, Study Manager

All public comments on the draft report are due by **Oct. 25, 2014**. Meeting materials will be posted on the Flood Control District's website at www.hcfcd.org/cypressoverflow as soon as they are available.

For more information on this event, or to request accommodations for a disability, please contact the Harris County Flood Control District's at the Project and Study Hotline, 713-684-4040, or online at www.hcfcd.org/cypressoverflow.

Cypress Creek Overflow Management Plan Public Meeting

Bear Creek Community Center, Thursday, September 25, 2014, 6 pm

4.3.4 Attendees Who Signed In

LAST NAME	FIRST NAME	ORGANIZATION	CITY	STATE	ZIP
Chang	Henry	Gracious Engineering	Houston	TX	77292
D'Armond	Perry	West Houston Association	Houston	TX	77024
De la Pena	Jose	5engineering	Houston	TX	77042
Denny	K		Houston	TX	77060
Driver	Joan	Harris County MUD 64	Katy	TX	77493
Falknor	Chuck	Jackrabbit Road PUD	Houston	TX	77084
Fitzgerald	Mike	Brown & Gay Engineering	Houston	TX	77042
Flores	Al	Dannenbaum Engineering	Houston	TX	77098
Forrest	Chris	Charter Development	Houston	TX	77056
Gagne	John	Harris County MUD 127	Katy	TX	77449
Gallegos	Rick	Costello Engineering	Houston	TX	77042
Guerra	Kelly	5engineering	Houston	TX	77084
Hinojosa	Sam	HALFF Associates Inc.	Houston	TX	77079
Jones	Randy	Harris County resident	Houston	TX	77055
Jung	Jang	RHME	Houston	TX	77061
Kirk	Bryan	Houston Chronicle (reporter)	Houston	TX	77002
Koser	Larry	Harris County MUD 64	Katy	TX	77493
Lanafin	William	Brewer & Escalante	Houston	TX	77074
London	JoAnn	City of Waller (city secretary)	Waller	TX	77484
Lutringer	Elaine	City of Katy	Katy	TX	77493
Maaskant	Janice	Harris County PID	Houston	TX	77002
Madichetti	Sirish	Michael Baker International	Houston	TX	77042
Marks	Malcolm	Barker Cypress MUD	Houston	TX	77084
McCavitt	Bob	Harris County MUD 208	Houston	TX	77095
McGovern	Mike	Brown & Gay Engineering	Houston	TX	77057
Montes	Marco	Harris County Precinct 4	Houston	TX	77067
Moore	Frank	Harris County resident	Houston	TX	77084
Ortega	Katrina	Harris County MUD 127	Katy	TX	77449
Palermo	Andy	EHRA Engineering	Houston	TX	77042
Pearson	David	City of Katy	Katy	TX	77492
Piacentini	Mary Anne	Katy Prairie Conservancy	Houston	TX	77098
Rayburn	Robert	Energy Corridor Management District	Houston	TX	77084
Robertson	Jim	Cypress Creek Flood Control Coalition	Houston	TX	77070
Saenger	Scott	Jones & Carter	Houston	TX	77081
Shott	Tom	Ricewood Mud	Katy	TX	77449
Singleton	John	Harris County MUD 136	Houston	TX	77084
Smith	Richard D.	Cypress Creek Flood Control Coalition	Cypress	TX	77429
Smullen	Pete	Cypress Creek Flood Control Coalition	Cypress	TX	77429
Sosa	Joseph	LJA Engineering	Houston	TX	77042
Szinyei	Jay	Chimney Hill MUD	Houston	TX	77041
Thompson	Chuck	Jackrabbit Road PUD	Houston	TX	77084
Turner	Carl	Harris County resident	Houston	TX	77084
Turner	Lois	Harris County resident	Houston	TX	77084
Tyler	Bonnie	Harris County MUD 127	Katy	TX	77449
Walker	Scott	Katy Independent School District	Houston	TX	77292
Ward	Gilbert	Texas Water Development Board	Austin	TX	78701
Wilcox	Stephen	Costello Engineering	Houston	TX	77042
Wilcoxson	Charlanne	Harris County resident	Houston	TX	77084
Winoske	Lorna	Morton Road MUD	Houston	TX	77084

HARRIS COUNTY FLOOD CONTROL DISTRICT

Cypress Creek Overflow Management Plan Public Meeting

Bear Creek Community Center, Thursday, September 25, 2014, 6 pm

4.3.4 Attendees Who Signed In

LAST NAME	FIRST NAME	ORGANIZATION	CITY	STATE	ZIP
Wise	Anthony	City of Houston Parks and Recreation Depa	Houston	TX	77084
Woltz	Tom	Chimney Hill MUD	Houston	TX	77041
Yelverton	Andy	Harris County MUD 64	Katy	TX	77493
Yelverton	Loretta	Harris County MUD 64	Katy	TX	77493
Zurawski	Karen	Houston Chronicle (editor)	Katy	TX	77493

4.3.5 Presentation

Agenda

- Welcome and Introductions
- Presentation Topics
  - Background Information
  - Identification of Critical Conservation Areas
  - Investigation of Prairie Restoration for Flood Control
  - Supplemental Development Guidelines & Criteria
  - Preferred Overflow Management Plans
  - Next Steps Forward
- Q&A and Comments

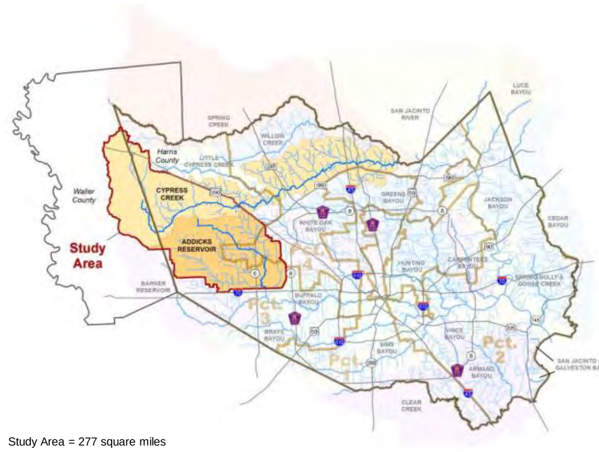
Texas Water Development Board Grant

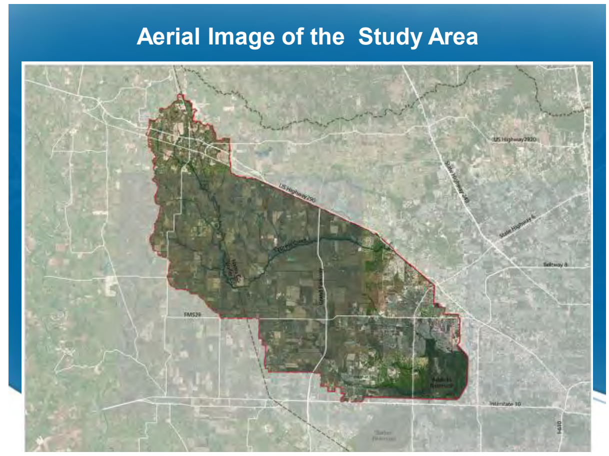
- Grant to Harris County and Harris County Flood Control District
- Contract initiation date : April 19, 2012
- Executed contract: July 2, 2012
- Contract completion date: October 31, 2014
- 50-50 Cost-share: TWDB $750k | HCFCD $750k

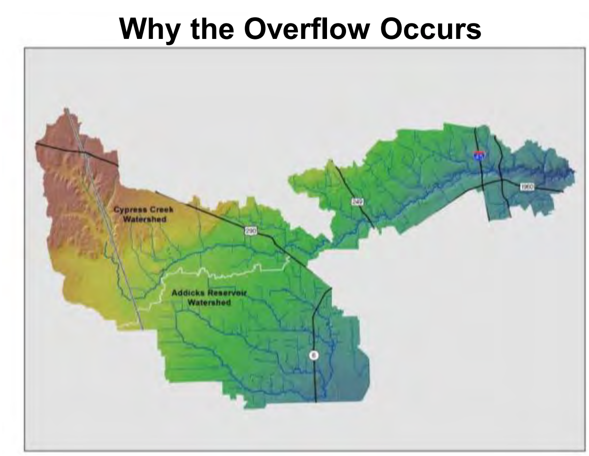
Presentation Topics

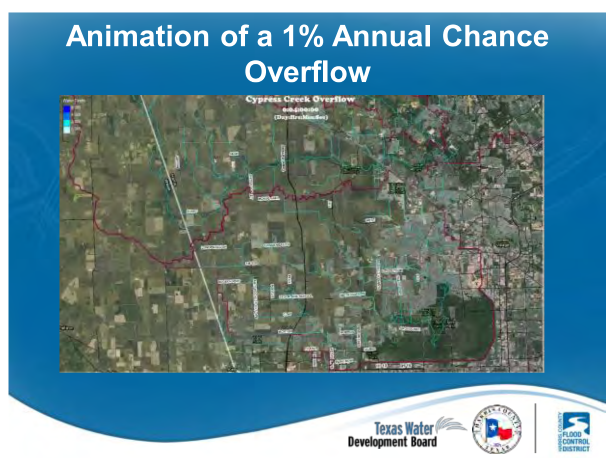
- **Background & Study Process**
- Identification of Critical Conservation Areas
- Investigation of Prairie Restoration for Flood Control
- Supplemental Development Guidelines & Criteria
- Preferred Overflow Management Plans
- Next Steps Forward

4.3.5 Presentation

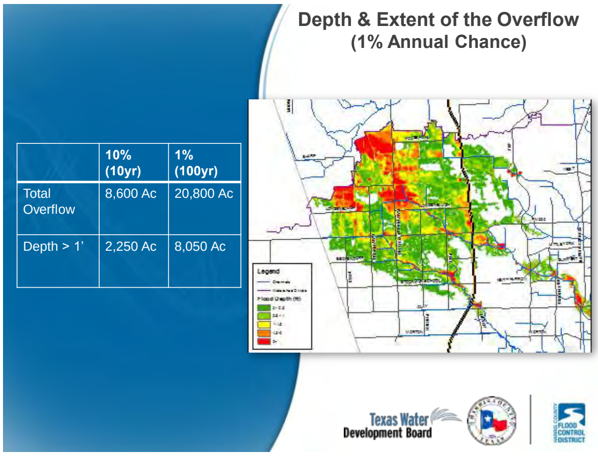




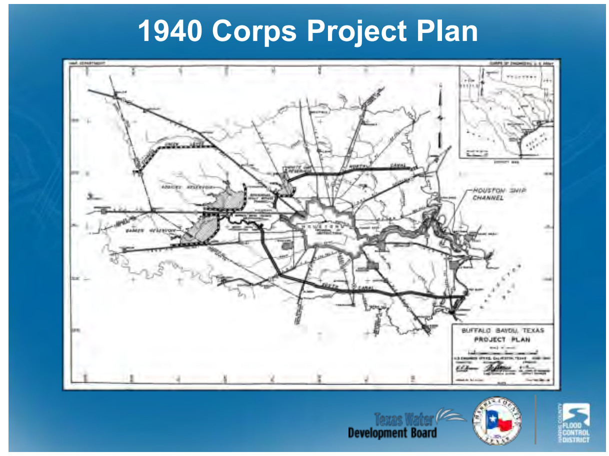


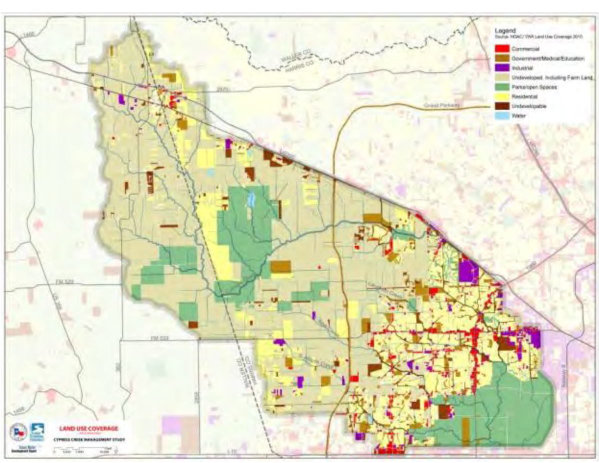


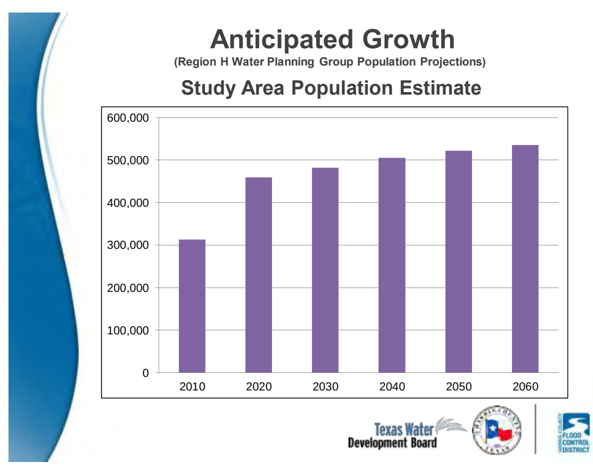
4.3.5 Presentation



	10% (10yr)	1% (100yr)
Total Overflow	8,600 Ac	20,800 Ac
Depth > 1'	2,250 Ac	8,050 Ac







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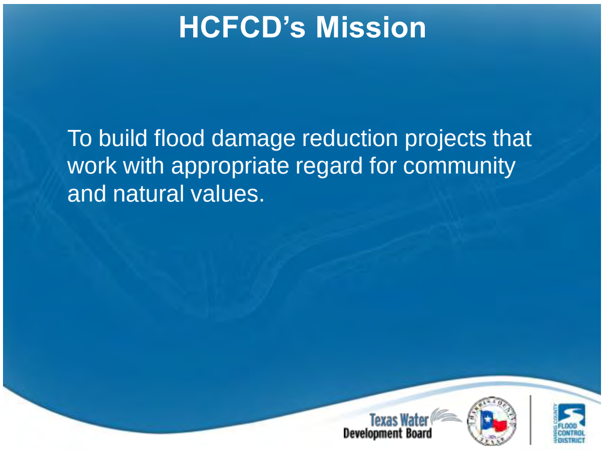
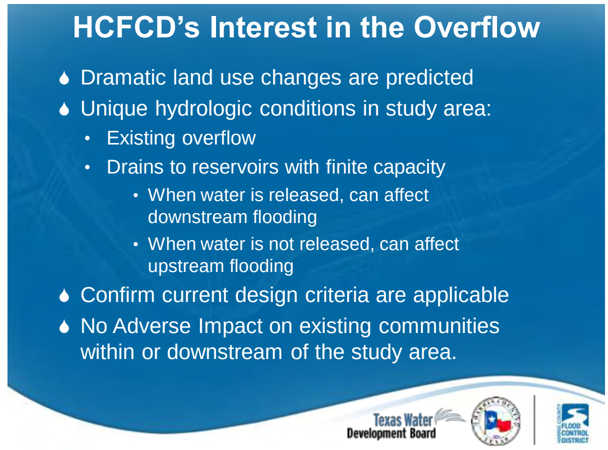




4.3.5 Presentation

Presentation Topics

- Background & Study Process
- **Identification of Critical Conservation Areas**
- Investigation of Prairie Restoration for Flood Control
- Supplemental Development Guidelines & Criteria
- Preferred Overflow Management Plans
- Next Steps Forward

Texas Water Development Board

Identifying Critical Conservation Areas

- Critical Conservation Areas
  - Identified land within the Cypress Creek Overflow Management Area potentially suited for conservation purposes
- Possibilities for Land Management
  - Ecological Preservation
  - Sociological & Recreational Purposes
  - Wetland Mitigation Banking
  - Floodplain Preservation

Texas Water Development Board

Identifying Critical Conservation Areas

Conservation Criteria

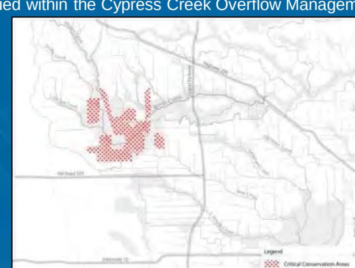
- Land Connectivity - adjacent to current conservation land
- Ecological Type and Quality - current habitat and condition
- Potential for Prairie Restoration - ability to support native prairie habitat
- Potential for Passive Recreation - ability to support hiking, fishing, etc.
- Potential for Wetland Mitigation Bank - ability to support wetlands for mitigation purposes
- Aesthetic Quality – current quality of the land
- Absence of Current Development – no previous residential or commercial property

Texas Water Development Board

Identifying Critical Conservation Areas

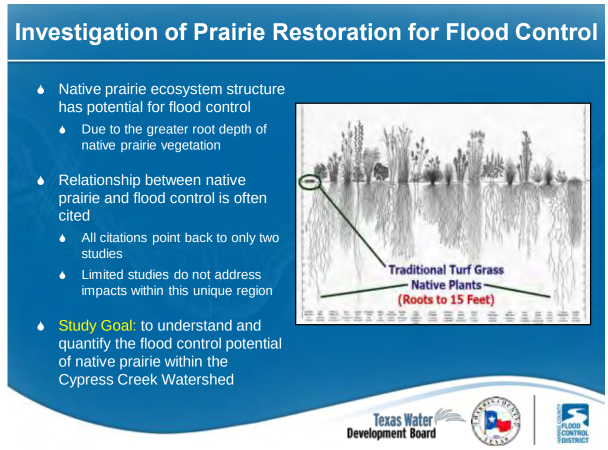
7,800 acres of Critical Conservation Areas

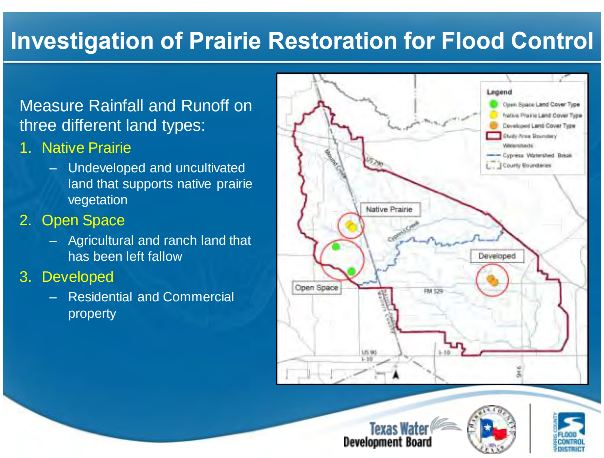
identified within the Cypress Creek Overflow Management Area



Texas Water Development Board

4.3.5 Presentation





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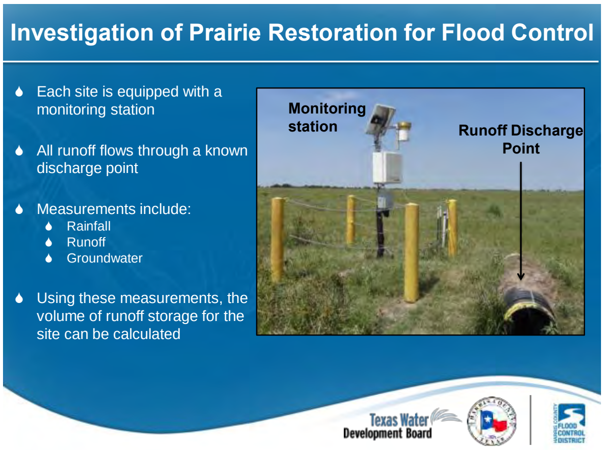

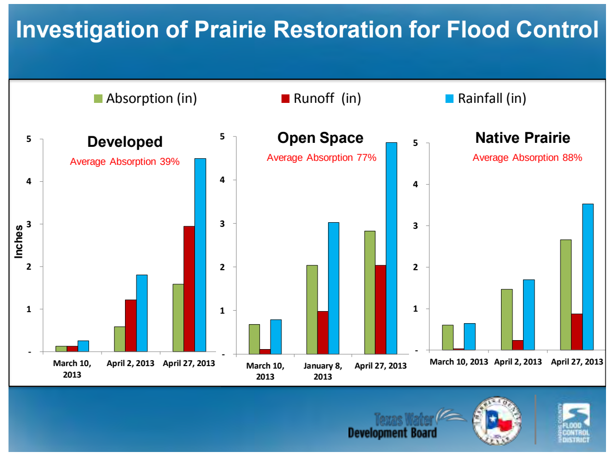

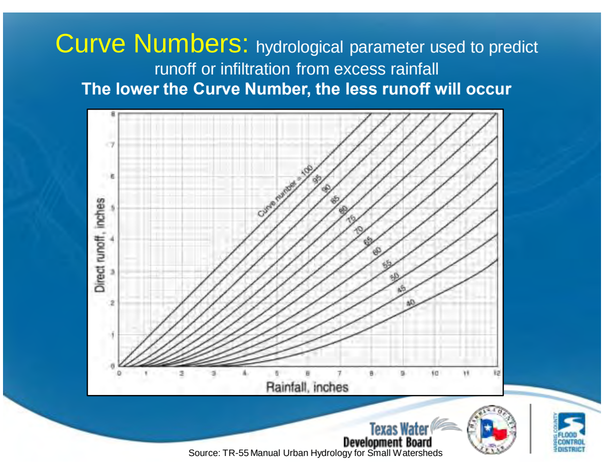

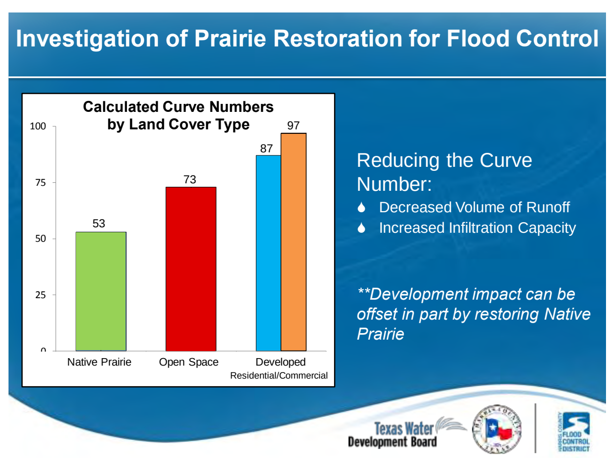

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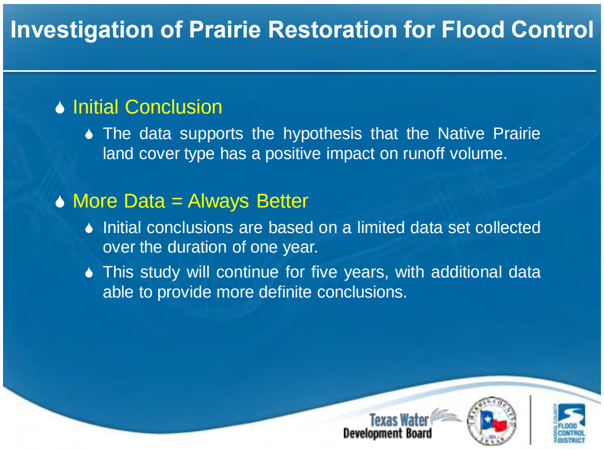

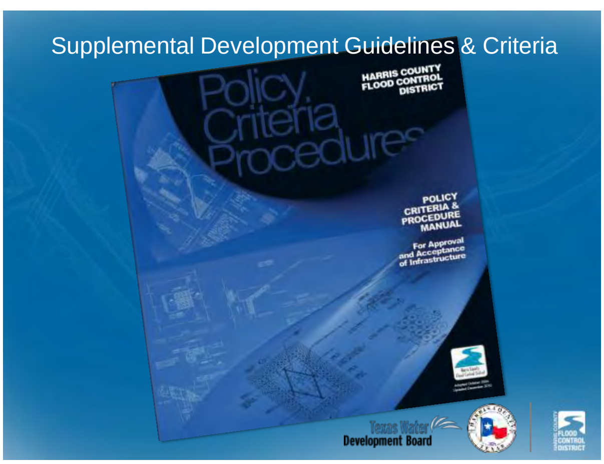

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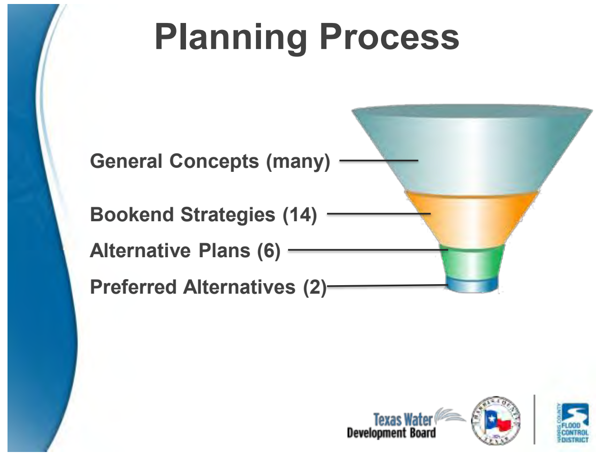

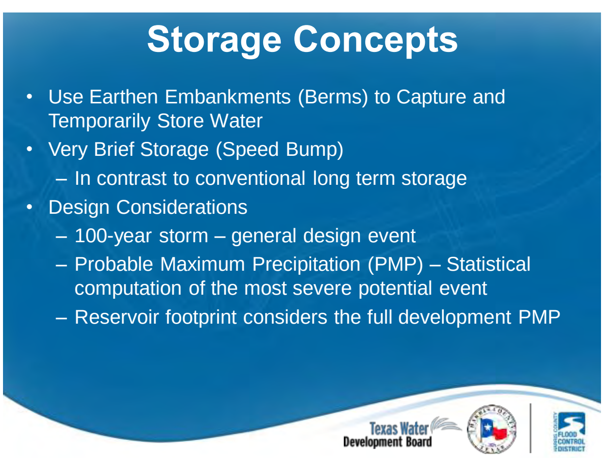

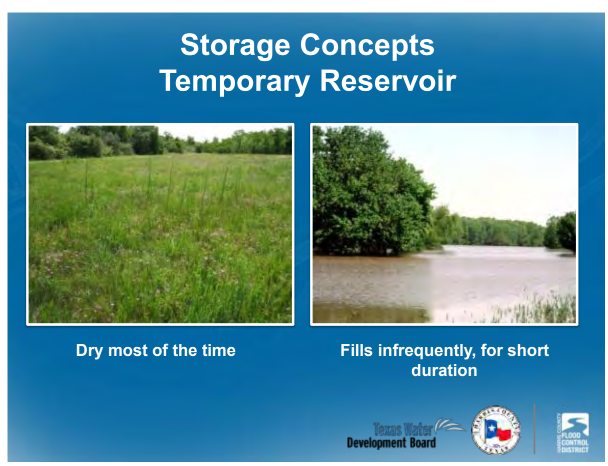

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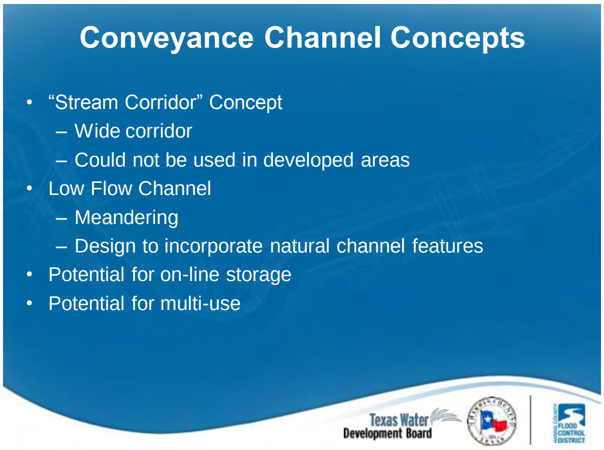

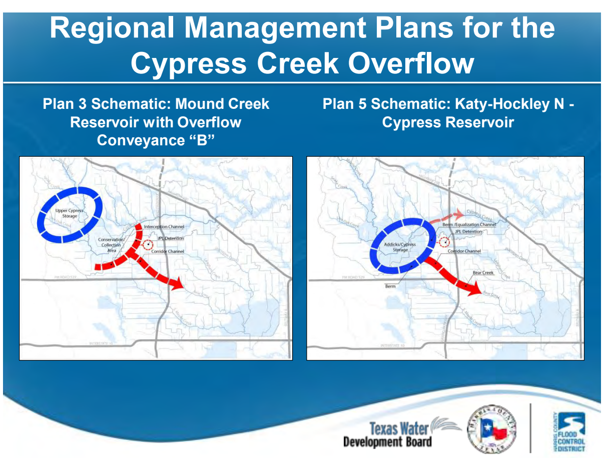

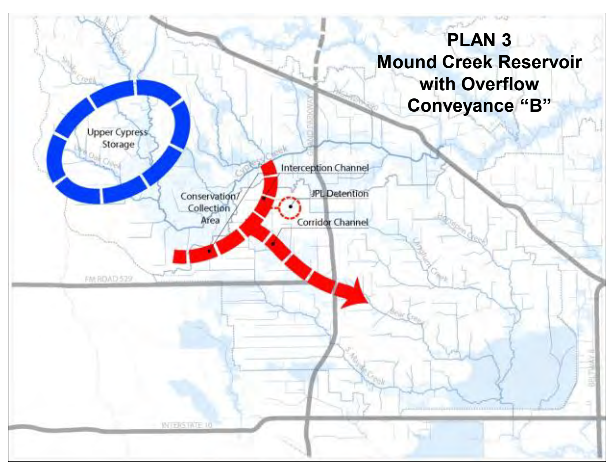

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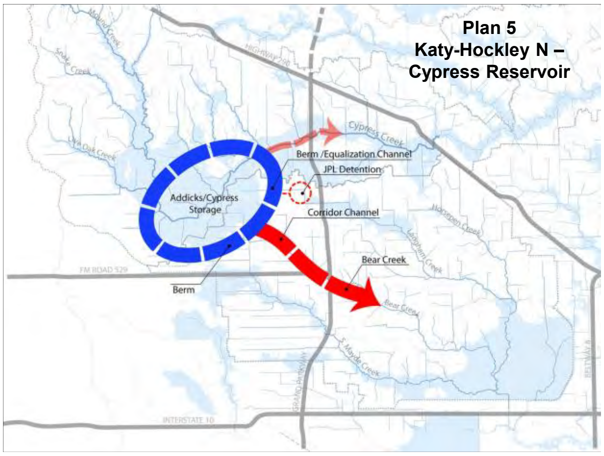
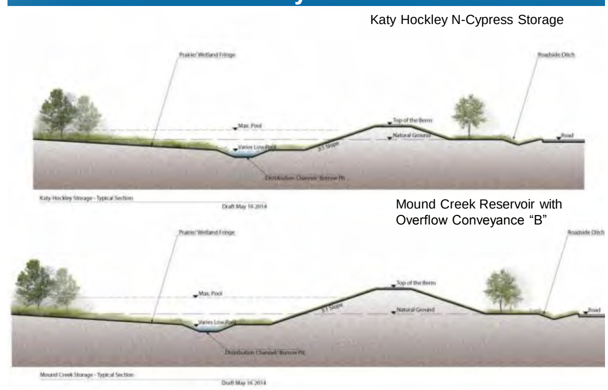


Typical Sections of the Storage Facility Berms



Plan Comparisons

	Plan 3	Plan 5
Land Area	5,400 ac	11,300 ac
Managed Storage Volume (Addicks Reservoir Manages 200,800 ac-ft over 16,400 ac)	15,700 ac-ft	26,500 ac-ft
100-yr Event		
Inundation Depth	13' Max	8' Max
Drain Time	3 days	7 days
Land Protected From Overflow	18,500 ac	18,000 ac
Potential to Increase Conservation Footprint	3,100 ac	5,000 ac

Plan Costs

Item	Full Cost	With Partner	
		Partner Contribution	Project Contribution
Plan 3			
Land	$117 M	$38 M	$79 M
Construction	$126 M	$47 M	$79 M
Professional	$28 M	$8 M	$20 M
TOTAL	**$271 M**	**$93 M**	**$178 M**
Plan 5			
Land	$206 M	$82 M	$124 M
Construction	$134 M	$36 M	$98 M
Professional	$29 M	$8 M	$21 M
TOTAL	**$369 M**	**$126 M**	**$243 M**

4.3.5 Presentation

Benefit-Cost (B/C) Ratio

- Annualized Benefits / Annualized Costs
- Indicator of "Return on Investment"
- Higher B/C is Good – Desire greater than 1.0
- Quantified Benefits and Non-Quantified Benefits
- Quantified Benefits – those we can assign a dollar value to
  - Reduction in Flood Damages
  - Impact to Land

Texas Water Development Board

FLOOD CONTROL DISTRICT

Benefit-Cost (B/C) Ratio (con't)

- Non-Quantified Benefits – difficult to assign a dollar value to
  - Value of conservation
  - Certainty / Predictability
  - Future flood emergency and management costs
  - Impact to Addicks and Barker Reservoirs, Buffalo Bayou, and Lower Cypress Creek
  - Benefit to roads, parks, and infrastructure in the overflow
  - Recreation and quality of life
  - Carbon offsetts

Texas Water Development Board

FLOOD CONTROL DISTRICT

Benefit-Cost (B/C) Ratio

- Actual Benefit = Quantified Benefit + Non-Quantified Benefit
- Computed B/C Ratios from Quantified Benefits
  - Mound Creek Reservoir (Plan 3): B/C Ratio = 1.14
  - Katy Hockley – North Reservoir (Plan 5): B/C Ratio = 0.89
  - Non-Quantified Benefits are considerable
  - Actual B/C Ratios are greater than 1.0

Texas Water Development Board

FLOOD CONTROL DISTRICT

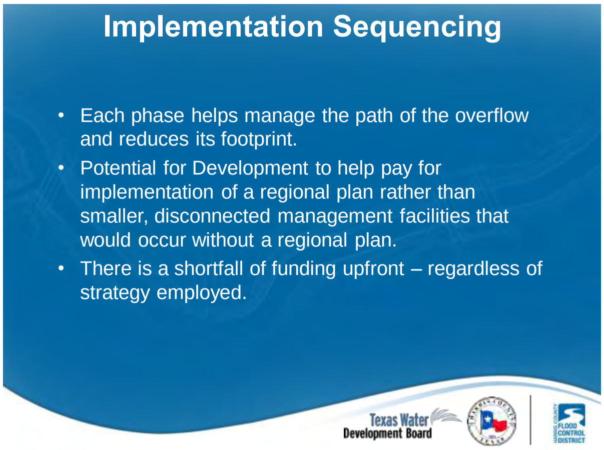
Funding

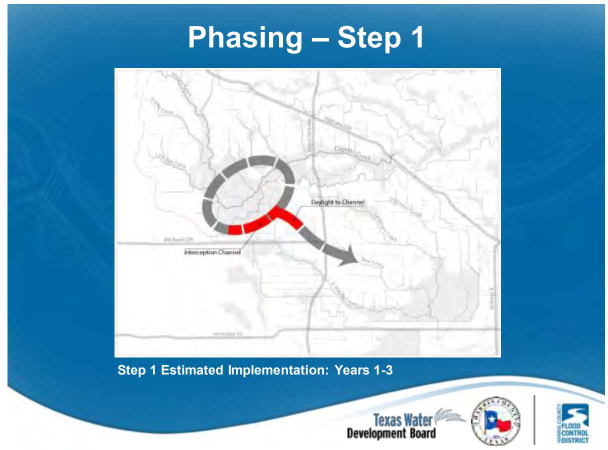
- Public Funding
- Partnerships
  - Impact Fee (Collected during Platting)
  - Ad Valorem Methods
  - Tax Increment Reinvestment Zone (TIRZ)
  - In-Kind Contributions

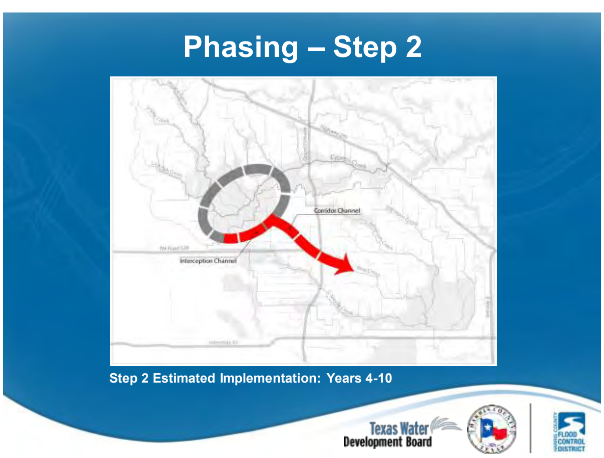
Texas Water Development Board

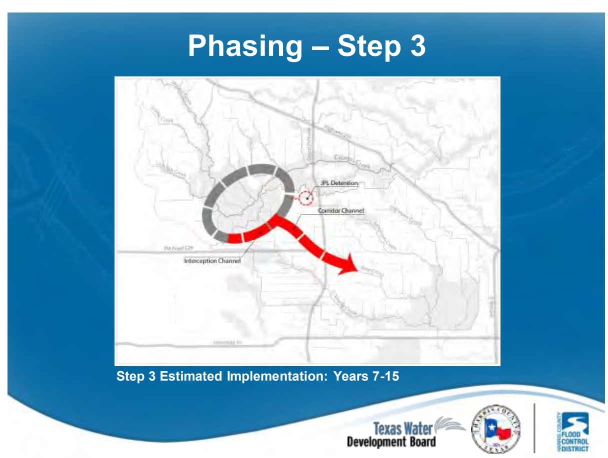
FLOOD CONTROL DISTRICT

4.3.5 Presentation









4.3.5 Presentation

Phasing – Step 4

Step 3 Estimated Implementation: Years 16-20

Texas Water Development Board

Estimated Riverine Floodplains
(1% Annual Chance Event)

Texas Water Development Board

Presentation Topics

- Background & Study Process
- Identification of Critical Conservation Areas
- Investigation of Land Use and Rainfall Runoff
- Supplemental Development Guidelines & Criteria
- Preferred Overflow Management Plans
- **Next Steps Forward**

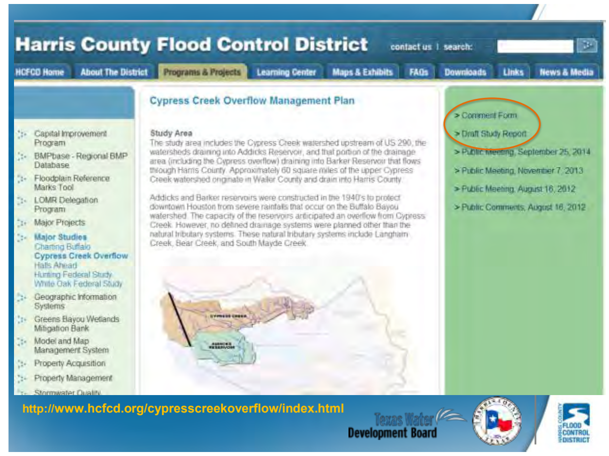
Texas Water Development Board

Next Steps Forward

- Collect Public Comments for the Report through October 25, 2014
- Submit Draft Report to the Texas Water Development Board for Review (October 31, 2014)
- Recommendation to Harris County Commissioners Court for Approval of Supplemental Development Guidelines (December 2014)
- Recommendation to Harris County Commissioners Court for Approval of Regional Overflow Management Concept Plan (December 2014)
- Investigate Strategies and Develop Recommendations for Funding a Regional Plan (2015)
- Submit Final Report to Texas Water Development Board (1st Quarter 2015)

Texas Water Development Board

4.3.5 Presentation



CYPRESS CREEK OVERFLOW MANAGEMENT PLAN

PUBLIC MEETING

SEPTEMBER 25, 2014

BEAR CREEK COMMUNITY CENTER

Transcript Provided by:
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P R O C E E D I N G S

MR. TALBOTT: Good evening, everybody. I'm Mike Talbott, the Director of the Harris County Flood Control District. We saw a few more people coming into the parking lot, but we thought we'd get started on the presentation this evening.

I would like to acknowledge we do have some elected officials here. We've got several folks with various MUD boards here, MUD board directors. Y'all out there. I don't want to call y'all out. There was a bunch of them on the list. Good to see everybody out. We've also got -- let's see -- got a representative from the city of Waller. Good to see you. Also from the city of Katy -- folks from Katy. Good to see you, too.

One of the things I want you to understand about this Cypress Creek Overflow Management study, this phenomenon in studying Cypress Creek was one of the projects I ever worked on as an engineer 36 years ago or something, and I've been interested in this overflow. It's one of the most complex and interesting natural features we have in the county that's very unusual.

And we've been looking at studying this for quite awhile. And we did manage to have the opportunity to work with the Texas Water Development Board in a grant application. The Water Development Board is represented here tonight. Gill Ward is here to see some of the fruits of the labor he's been working on. And I know -- I'm an engineer, okay, so I like this overflow stuff. It's just interesting.

But it is complex. And trying to manage it -- the title of this is the Cypress Creek Overflow Management Plan. And you see the Cypress Creek Overflow in action here on a sunny day, that wasn't even a bad one. That was a rather modest overflow that occurred.

But trying to manage this, it affects so many things. The land on the Cypress Creek side, as that area changes, you're going to see changes in the runoff which could influence the overflow, how long it overflows, how much water comes across the divide, and then the development on the Cypress Creek side of things, this overflow is trying to move through the watershed and get down into Addicks Reservoir. Then we've got Addicks Reservoir that's an issue as well on the volume and the capacity of that system as it changes over time. So it's a very complex issue. We're out ahead of it to study this thing.

Like I said, we've been aware of it for awhile, but now the development pressures are moving out this way, and we really need this management plan and you're going to hear more about that.

I also want to acknowledge that we had a very, very active steering committee that was involved in this. Again, this is the flood control district and water development board study, but we needed the perspective of others that are affected by this. And you're going to see more about who the steering committee was. We also had a stakeholders committee and we had these public meetings. This is the third and final meeting.

When we had the first meeting back in 2012, we introduced the scope of work that we were working toward and the things that we were going to do with the study and got feedback on that. Last November we had the public meeting to discuss some of the preliminary findings and the direction of the study. And what you're going to see tonight is the completed study effort, the study document itself is still being revised, and you have access to that now on the Internet. We'll have information about that if you want to review the actual study, but we're trying to -- you'll have a month to look at that. We'll go through all that schedule, but we are looking for feedback on the document itself and some of the recommendations in there.

So we're going to go through a lot of material tonight. A little bit of it will be repetitious from the previous meetings, just to set up what we're talking about. But then when we get into the details of the findings and how we've zeroed in on these last two alternatives, plus the exhibits around the room, they are duplicate sets. The same exhibits over here as there are over here if you want to get a chance to look at those after the meeting.

And so I'm going to turn this over to Dena Green. She's going to run the show here this evening. And we'll have some other speakers that come up as well. Dena...

MS. GREEN: Thanks, Mike. Hi, everyone. Thanks for coming out and coming to our meeting tonight. It's exciting to have a good crowd turn out when you put so much effort into a study and have a lot of good material to share. It's nice to see everybody here.

I do have a few business items I need to take care of. First, I've been told to remind everybody to please make sure that you signed in when you came in. If you didn't sign in, we'd love to have you sign in before you leave.

Also, when I came in, we had some comment cards up at the front. If you'd like to speak after our presentation today, we'd like to have you fill these out. If you didn't get one when you signed in as you entered, you'll have a chance to collect one after our presentation.

But after we're done presenting, we will be collecting these. So we'll have a quick break. We'll collect the comment cards and we'll have plenty of time for question and answer after our presentation today. And then the team members also will stick around after that question and answer period. We'll be back by the exhibits so if you want to come look at some of the maps and graphics we have around the room and ask questions about the study, we'll be here and answer your questions and share information with you that way as well.

Also, I wanted to let you know we handed out an agenda and you'll want to take one of these with you because as Mike said we do have a draft report that we've prepared, and we have uploaded that to the Internet, and if you'd like to access it, the website to get to the report is actually on the agenda. It's listed on the bottom. And I have a slide at the end of the presentation that will show you how to get to that as well. Make sure you pick up some of those forms at the table.

So with that, we're going to go ahead and jump right into the information. We do have a lot to share with you tonight. Can you hear this better?

AUDIENCE MEMBER: The people in the back.

MS. GREEN: Can you all hear me? I've got thumbs up. Just wave and we'll know we need to go ahead and turn up the microphone even louder.

So I wanted to recognize the Texas Water Development Board. As Mike mentioned earlier, you know we were lucky enough to be awarded a grant. We applied for that in partnership with Harris County and it was a very generous grant. We're on a cost share, 750,000 funded by the Water Development Board, 750,000 by the Harris County Flood Control District. And it was with that grant that we were able to conduct such a large complicated study and develop the information we have been able to develop throughout the course of it.

Some of you have been to a couple of our public presentations before, but we do have a lot of new faces in the crowd. So we are going to share some background information with you, information about the study area and the overflow itself to help set the context and so you can understand some of the important features about the overflow, and why flood control has an interest in the study.

The map that you have on the screen, that shows you the general area of the study effort. You can see it's highlighted there in red. It's a quite large area, almost 280 square miles. Now, most of that is in Harris County, but you can see that there is a divide there between Harris County and Waller County -- about 63 square miles actually are located in Waller County.

Our study area does include the Upper Cypress Creek Watershed and when you say Upper Cypress Creek Watershed, we're talking about the area in the Cypress Creek upstream of 290. We realize Cypress Creek is a very long watershed, but the portion included in our study is upstream of 290. Our area also does include the Addicks Reservoir watershed. So you can see the area on the map and the light tan, that would be the Cypress Creek watershed. Addicks is shown in more of a dark tan/orange color. Tonight when you hear us talking about the Cypress Creek overflow, what we're talking about is water from the Cypress Creek watershed that actually drains down into the Addicks Reservoir watershed rather than traveling east along Cypress Creek.

Here is an exhibit that shows you an aerial background of our study area. Gives you more information about the characteristics of the area. We have U.S. 290 running along the north side of the study area. I-10 is along the southern boundary.

You know what, let me get the -- I've got a laser pointer over here. I'll go ahead and press. What did I do here? Sorry about that.

So we've got U.S. 290 that runs here. Along the northern portion of the study area, there is a little bit just north of that, but for the most part that's our northern boundary and we have I-10 to the south. We've got Addicks Reservoir down here in the southeast portion of the study area.

And you can see coming out from Addicks there is quite a bit of development that's already occurred. We've got Highway 6, many of you may have come to the meeting tonight on Highway 6. It runs right down through the lower portion of our study area. And then running through it we also have FM 529 and then the Grand Parkway runs through the middle of the area.

Now, as you start leading away from Addicks Reservoir and start getting up into this portion, you'll see that it's fairly undeveloped. A lot of the land has been used for agriculture. There is large portions of undeveloped property. There are some patches of native prairie land. So it's a pretty wide open space.

This graphic helps illustrate why the

overflows occur. So you look at it and you'll notice there is a change in color on this map. And what that color change represents is change in elevation. So if you're looking up in this area, the dark reddish brown, that represents higher elevations. And that elevation tends to drop off as you start going through the orange, green and blue colors with the lower elevations being shown in blue. Now for the most part, our study area in this area, it drains off towards the southeast.

Now, the white line through the middle, that's the watershed break. That's the divide between the Cypress Creek watershed and the Addicks watershed and the blue lines are the existing channels that are within both of those watersheds.

So you'll notice that this area is pretty steep. And as water starts draining down through this area, it gets collected in Cypress Creek right through here in this north/south running portion of the channel. Right after it gets collected that channel makes a pretty steep, significant change and heads off to the east. And while the channel is making that sharp bend, the fall of the land keeps heading towards the southeast, and so it collects all this water. It slows down and makes that turn and when water starts accumulating at flow rates that exceed the channel capacity of course the elevation is going to start rising and it will start spilling out of the channel banks, and as the land heads towards the southeast, that water will travel across the land following with the land and that's what causes that overflow to occur into the Addicks Reservoir watershed.

In our next slide, we have a video clip. And so I'm going to demonstrate to you what we think that that looks like. This is a video clip that we took from the model that we've been using for our analysis. It represents that 100 year event that's about 13-inches of rainfall over a 24 hour period. Right up through here, this is that watershed divide. You just saw it on the last map shown in white. You'll see Cypress Creek right up through here. As I start playing this video, you're going to see a blue mass start appearing. And what that mass represents is that floodplain coming out of Cypress Creek and then draining across that watershed divide.

It takes a second. Accumulating water. There it goes out of the banks. Coming across that divide, across Addicks Reservoir. It's going through the tributaries now and now Bear Creek it's draining down into the Addicks Reservoir. And while we sped this up, it can go incredibly slow if you want to look at it on a computer screen. We know we had a lot of material to cover and go through tonight.

What's interesting is that whole process takes about two days. We look at that and you look at the floodway coming across the watershed divide going across that upper Addicks Reservoir watershed. It travels pretty slowly before it makes its way into the tributaries and reaches the reservoir.

This map helps sum up what we just saw. What this map is, it takes that footprint you just saw of the overflow for that 100 year event and it is shaded different colors to represent the different depths of the overflow during that storm event.

So what you'll see is -- I'm going to point out a couple of landmarks first. We looked at Grand Parkway earlier. We have that running up right through here. Here is FM 529 and there is that watershed divide. So if you look at it, it's actually not all that deep. It gets about three feet deep in the deeper parts, but what's important about this is it's quite large. It covers a vast area of land. During that 100 year event we estimate it covers almost 21,000 acres of land. And of that, just over 8,000 acres are a foot deep or more.

So that's a quite large area, very large volume of water and even for lesser events for that 10 year event, we're estimating that the overflow covers about 8600 acres of land and that inundation depth is a foot or greater for just over 2,000 acres of land. So it's quite a large area that gets influenced.

We don't have a lot of records showing the overflow event. There has been knowledge of it for quite a long time. So this graphic helps illustrate that. This is a graphic that was developed to represent a flood protection plan that the Army Corps of Engineers put together to help protect the City of Houston. This was developed back in the 1940's. And you can see in this plan right through here these two gray areas, those actually represent Addicks Reservoir to the north. You have I-10 running south of it and down in this area the Barker Reservoir. And back when this original plan was designed, they knew about the overflow. And you can see up in this area, there is actually a levee that was included in that original design and the intent of that levee was to lock the overflow and keep it from occurring and draining into the Addicks Reservoir.

Now, when it came time to start building these facilities, a few years later, economic things changed a little bit. Land costs had changed and it was determined it was more cost effective to increase the size of Addicks Reservoir and accommodate flow from

Cypress Creek rather than to go ahead and build that levee, but I think it's interesting that it was in that original plan back in the 1940's.

Flood control does have record of the overflow occurring at least five times in the last 30 years. We had two very big overflows that happened in the '90's and then two smaller overflow events -- you got to see one of the pictures on our opening slide, but we've had three more that we measured in 2002, 2003 and as recent as 2012, and I know we've had a lot of rainfall lately. A couple of months ago we had a lot of rainfall that was close. Our flood watch team was out checking out the overflow, but we didn't quite measure it at that time. But we have seen it and measured it recently.

This is a graphic that we use to show some of the land use that's out there right now. This is information that was compiled by the HGAC, and you'll notice the map has a lot of yellow down in this region. That's the area down by Addicks Reservoir and that represents a lot of development that exists. The yellow is single family residential. All the tan area that you see is actually undeveloped land. So that would be a lot of rural areas, areas used for farmland and agriculture. And then the large areas of green space are parks. There is also a lot of conservation area that's preserved. That's also shown in these green areas. So there really -- you can see most of the development contained down in this area with some sparse development scattered throughout. Here is Cypress Creek, and right through this area would be the watershed divide. And this is where the overflow occurs right through here.

Now I put this up because we know that the area is fairly undeveloped, but information that the team has been able to gather through the course of our study indicates that there is likely to be quite a lot of growth, population growth in the study area. So we were able to obtain some information from the Texas Water Development Board, population forecasts, and we looked at that and compared it with our study area. And what you'll see as the result of that, we've charted that. We've graphed it, and we estimate that over the next 60 years, that population within our study area is likely to increase from about 300 -- which was measured by the U.S. census in 2010. It's likely to grow from 300,000 up to about 550,000, and almost half of that to occur within the next decade, in the next ten years. And of course this is all an estimate, but that's pretty significant growth.

And based on past development patterns in

Harris County and the surrounding counties, we're estimating that it will take about 30,000 acres to support the residential needs, infrastructure, and all the services that that type of population growth would need. So if that occurs, you can imagine there will be a pretty substantial change in land use. Not all of that open space is likely to remain open space.

Flood control has heard from the development community and business interests that there are interests in building in that area. And while we're hearing from that community, we also know we've heard from several of the local conservation groups as well that there is a lot of interest in the area of preserving native habitat, native prairie land, our prairie grasses and plants that exist in the study area and also interest in trying to restore some of that.

So there is a lot of interest in the area. Now the flood control district's mission is to build flood damage reduction projects with appropriate regard for community and natural values. Now, we have several interests in the overflow management plan, and I'm going to go ahead and flip to the next slide and talk through some of those for a few minutes.

We've touched on them at the beginning, but I'm going to reiterate some of that. We mentioned that there is a lot of open space right now, and there is also a lot of interest in development; and if that occurs, we know that that land use is likely to change, probably some pretty significant changes in land use.

And with that, there are very unique hydrologic conditions. We've got the overflow itself. That's pretty unique in Harris County. And then we've got the existence of the reservoirs. So not only does this water overflow from Cypress Creek, its outlet is a reservoir, not necessarily another open channel system which is what you usually encounter in Harris County.

And the reservoirs are quite large. Addicks and Barker Reservoirs both have a large, large capacity of water, but it is limited, and release from those reservoirs is controlled. If too much water is released from them, then you can impact the folks that live downstream. But if you don't release enough water from the reservoirs, then you can impact people living upstream of them. So that's definitely a unique condition that needs to be considered.

We also know that we'd like to investigate our current design criteria and make sure that what we have in place works well for this area given the unique drainage conditions that exist. We'd like to make sure that as development grows and moves into the area, we want to make sure there is no adverse impacts on the future communities to come as the stormwater and the overflow is managed.

Our objectives for the planning effort were to identify a regional plan to manage overflow from Cypress Creek and help mitigate that flood risk; to balance the competing interests of land use, preservation, business interests, reservoir operations and environmental mitigation needs during the process; to develop a business plan to implement regional strategies; to implement appropriate policies to manage the unique hydrologic conditions.

And Mike mentioned we worked with a steering committee throughout the process. This is a list of the organizations that participated. It was definitely a very involved group. Their input was invaluable and we are very appreciative of it. This group met with us on average about twice a month for a couple of years. They put a lot of time and effort and they shared a lot of information with us, which was definitely very helpful, and it was considered as we moved through the study process. It was considered as we moved forward with developing the two preferred plans or plans that we determined were probably the most feasible that we'll be sharing with you in a few minutes.

Okay, before we do jump into talking about those management plans, I would like to introduce Stephen Benigno. He has been -- come on up, Stephen. Stephen is one of my co-workers at the flood control district and he's been working on a couple of the environmental related tasks that we included with the study. I'll turn this over to you.

DR. BENIGNO: Thanks, Dena. All right, so in addition to the planning that went into developing the proposed study, we also looked at a couple of environmental considerations involved with this project. And the first of which is the identification of critical conservation areas.

So for the purposes of the study, we came up with the term critical conservation areas. And it's basically defined as land within the Cypress Creek Overflow Management Area that could potentially be used for conservation purposes and, you know, conservation as we say is not necessarily just environmental conservation. It can also be a broad term, and I'll explain just now. And if we adopt either of these two proposed plans, we just want to know what are the best ways to manage the area that these two plans will cover. And that can include, as I mentioned, the environmental and ecological preservation or it could look into sociological and recreation purposes, wetland mitigation banking opportunities or simply floodplain preservation.

So to identify these critical conservation areas, we developed a list of criteria that we used to rank each of the parcels within the overflow management area. And these criteria include land connectivity, which is if the parcel of land is adjacent to a current conservation parcel, the ecological type and equality, the potential for prairie restoration, the potential for passive recreation, the potential for wetland mitigation banking opportunities, the aesthetic quality of the land and the absence of current development.

Using these criteria, we've identified a total of 7800 acres within the Cypress Creek Overflow Management Area that could be identified as critical conservation areas. And it is shown on this map here. This is the combined acreage for both of the proposed plans that we'll be showing you and each of the proposed plans has a slightly smaller footprint because of the slightly smaller area that they cover.

And so the next environmental consideration I'll talk about is the investigation of prairie restoration for flood control. One of the criteria that I mentioned in our critical conservation area investigation was the potential for prairie restoration.

And that was because prairie -- the native prairie, it's the dominant historical ecosystem in this area. That area used to be 100 percent coastal prairie about 100 years ago. And also in addition to that dominant ecosystem, the structure of the prairie is thought to have flood control properties. And this is due to the greater root depth of the prairie vegetation, and that is shown on this graph right here.

You can see that little depiction right there, that's traditional turf grasses. And you can see the native prairie grasses next to it. They are much deeper and much more dense. And this dense root system creates a more porous soil, higher water attention and water infiltration through the soil. So the relationship between native prairie and flood control is often cited, but it really only points back to a couple of studies, and these limited studies don't address the impacts within the Cypress Creek region. So the goal of this study is to understand and quantify the flood control potential of native prairie within the Cypress Creek watershed.

So to achieve this goal, we are comparing rainfall and runoff measurements on three different land types, the first of which is native prairie. And that's undeveloped and uncultivated land that supports native prairie vegetation. We have open space which is agricultural or ranch land and we have developed property which is -- we looked at both residential and commercial property. And we have two sites for each of these land types. And also I would like to clarify that the majority of land type within this study area is currently open space. So it has been cultivated at some point, agriculturally through ranch land.

Here are some pictures of the land types we're working with. You see the native prairie. There is taller ground vegetation with sparse trees throughout it. You can see the open space land cover type, the shorter turf grasses and more dominant and then developed sites, that right there is just a strip center, Kroger, and mostly impervious surfaces. We have a residential site which is single family homes and lawns.

So on each of these sites we had a monitoring station, and that was situated next to a discharge point, and it was determined that all runoff from these sites flows through this discharge point. We add the measurements that we take including rainfall runoff and groundwater monitoring. And using these measurements, the volume of runoff storage for the entire site can be calculated.

So here are some graphs that we have which show the storm event by land cover type. Each separate storm event located on the X. axis and the Y. axis shows inches whether it's absorption, runoff or rainfall. And just quickly the reason that you see the same rainfall event but different amount of rainfall, it's because in different areas we're getting varying amounts of rainfall even though they are in relatively close together locations. So the blue bar there depicts the amount of rainfall. The red bar depicts the amount of runoff which goes through that discharge pipe that you saw earlier. And the green bar is the amount of absorption.

And you can see here the developed site relative to the open space and native prairie there is a lot more runoff that occurs. Yes, sir?

AUDIENCE MEMBER: Were the topographies comparable for the native and open space?

DR. BENIGNO: Yes, they were, actually. We looked at the light off of each of the sites and we were able to determine the flow path for each of the runoff from the time of concentration and we calculated and worked it into our calculations for the data.

Just looking at all three of those land cover types, the developed site you can see obviously there is more runoff and then the native prairie site there is a lot more absorption with the open space falling somewhere in between. And looking at all the rainfall events that we looked at over the year, the average absorption goes from 39 percent from the developed up to 77 percent on the open space and then up to 88 percent in the native prairie.

Something else that we calculated from our data are curve numbers, and for those of you that don't know, it's a hydrologic parameter that is used to predict the runoff or infiltration from excess rainfall. Basically the lower your curve number, the less runoff will occur and curve numbers range from 30 all the way up to 100. So if you were to have a curve number of 100 right here, 100 percent of your rainfall will become runoff.

So here is the curve numbers that we calculated from our data: 53 for native prairie, 73 for open space, and we broke the development area out to residential and commercial with 87 and 97 right there. And so as I mentioned before, if the curve number is reduced, there is an expected decrease in runoff volume in the infiltration capacity and from looking at these numbers, we can expect that if we were to reduce the number or if we were to restore native prairie, this has the potential to offset the increased runoff from development impact.

So our initial conclusions -- they support our hypothesis that native prairie has a positive effect on runoff volume. However, having said that, more data is always better and our initial conclusion is based on a limited dataset collected over the duration of one year. And this study is going to continue for five years with additional data able to provide better conclusions.

And with that I'll turn it back over to Dena.

MS. GREEN: I know we've got a couple of new folks that came in. We have more seats over on this side of the room if anybody is having a hard time finding seating.

Before we talk to you about the regional concepts that we've come up with in the management plan, I'd like to spend a minute talking to you about some of the supplemental divide or development guidelines that we've been looking at as part of the study.

Harris County Flood Control District and Harris County both have effective policies in place to make sure there are no adverse impacts associated with management of stormwater. You know the flood control district has their policy criteria and procedures manual. A lot of people in the room tonight are very familiar with this and have seen that cover several times.

And that works well, but we also know that there are some really unique drainage conditions in the Cypress Creek overflow area. So we have been looking at what some of those conditions are and if there is a need for some additional supplemental criteria that should be implemented with land development that's likely to come with significant land development. So as we've looked into that, the team had made some general recommendations, and flood control has been working with that information and has drafted up some initial supplemental guidelines, and I'm going to talk to you about that in a minute and give you an overview of them.

But before we do, there are a couple of terms that I'd like to define and talk about so that everybody in the audience knows what they mean when we flip to the next slide. So what we're going to talk about for a minute is detention and retention. They sound very similar but they're a little bit different. So when we talk to you about detention, what we're talking about is the temporary storage of stormwater. A lot of times detention is constructed so it can help manage or control how quickly water drains from a site. So if you can imagine, you've got a piece of property, it's been engineered, constructed on and constructed in a way so it drains quickly to move that stormwater away. Then you want to go ahead and you want to slow that down before it hits your outfall channel or receiving channel. So a lot of times you're probably familiar with new developments that have detention basins. That water will drain in really quickly and that detention basin provides a place for the water -- the excess water to sit while it drains out more slowly into that receiving channel. So when we talk about detention, that's what we're talking about.

Now when we talk to you about retention, we're talking about storage, but we're talking about more of an indefinite longer term storage. Where detention helps manage how quickly water is leaving the site, we look at retention to help manage the volume of water that would be leaving a property site. So they both involve storage, but they're a little bit different. They sound the same, but they'll function a little bit differently.

I mentioned that we've been looking at some of the conditions in the area and have made recommendations on areas that additional supplemental criteria look like they would be useful or that we should be considering.

And you'll notice I have proposed underlined up here. Flood control district is preparing a draft set of those guidelines, and so I'm going to give you a quick summary of it here, but they are draft right now. But included in those is looking at detention rates. Current policy actually does have recommendations for minimum detention rates, but we're looking at increasing that somewhat in portions of the study area. We're also looking at a new criteria of retention. Stephen just spoke about some of the land uses out there, the grasses, native prairie grasses and the open space and about the volume of runoff that is anticipated if that changes. And we know that that runoff will be draining into Addicks Reservoir, so flood control has an interest in looking at volume mitigation or looking at a retention criteria to help monitor or control how much volume is being released from a property.

We're also making recommendations about dedicating flood control facilities used to convey that Cypress Creek overflow to flood control district. The overflow is pretty unique. It's very lengthy. It's something that we saw in the video. It can last up to a couple of days when a large overflow event occurs. So it's not like some rainstorm that's very intense and drains off your property and then you're dry. This is something that can be experienced for a couple of days.

We're also looking at some additional recommendations for analysis of projects that would be located within the overflow footprint. The flood control district does have recommendations for analysis, but we're looking to add a few more recommendations in the steps to doing your analysis if a project is located within that overflow footprint.

And we're also updating recommendations for how you would calculate runoff rates for small and moderately sized projects in Upper Cypress Creek Watershed. So those -- that gives you kind of a highlight or summary of the information that we've been working on in the supplemental guidelines.

And with that, I'd now like to introduce Burton Johnson. Burton has been our engineer working on the study and is going to share some information with you about the concept plans that we've developed.

MR. JOHNSON: All right, I'll kill somebody with this thing.

All right, thanks, Dena. I'm going to talk about the two plans that we've arrived at. Now, getting back to what Mike said about this being a management study, management plan, there are various components to the plan. Dena just talked about development criteria. That's one component.

I'm talking about the more physical component, what might one day be built that you might see out there. I'm going to start and back out of it and kind of give you an overview of the planning process that we arrived -- how we arrived at the plans.

And it's pretty simple. The funnel illustrates it pretty good. We started with a lot of different ideas, throw the kitchen -- everything in the kitchen sink at it. Brainstorming sessions with the steering committee and we worked all those crazy ideas into a more finite group of things. We threw out some of the more radical ones, and we developed what we called bookend strategies. So if somebody said dig a channel, we said what's the biggest channel we possibly need to solve this problem? That was the bookend. We'll never build a bigger channel than that.

We studied the bookend strategies quite a bit, really to get the insight from what those things did and did not do. And we used that to organize all that into six alternatives, played with those some more, argued about them, discussed them, and arrived at the two that the Water Development Board grant requires us to and that I'm going to talk about right now.

Before I do that, I want to introduce two concepts. Dena just gave some concepts on detention and retention. I'm going to give you two concepts, and one of them is a storage concept. And the storage concept is kind of similar to what she was talking about but just on a much bigger scale.

The storage concept berms or earth dams would be constructed in a manner that flood flows or overflows would be intercepted and impounded for some duration of time. Now if you think about Addicks and Barker reservoirs, that's exactly what they are, but I want to make a pretty distinct difference between the storage mechanisms we're talking about and those.

While ours are also pretty big, those reservoirs are gated and operated going back to the detention/retention discussion there. What we're looking at are large storage areas that would hold water for a very short duration. In fact we've come up with an analogy, we call them speed bumps as opposed to stop signs.

So they would be designed to consider the worst case rainfall. Otherwise, they could create a problem. There is something in hydrology we call the probable maximum precipitation, the most rainfall that conceivably could fall. Think of worst case. So we looked at that rainfall with a fully upstream -- fully developed upstream watershed and how much water is there. If we build something, it has to be able to manage that.

Here is a picture. What would those things look like? Almost every day they would look like the picture on the left, just open space, prairie grass, whatever it may be and look like any other land.

Every now and again, a couple of days of the year at the most, even less than that, it would fill up and hold water for a very short duration -- two, three, four, five days at the most and drain out very quickly.

Second concept is a conveyance concept -- conveyance channel concept. Now, you can think about any flood control channel and say that is a conveyance concept. I'm going to approach it just a bit different. We're talking about something that we've coined or the district has coined a stream corridor concept or sometimes a frontier channel.

It's a very wide channel that has a meandering low flow, incorporates natural features. You can do a lot of things with these things. You can use it for recreation. You can put some online additional storage in there. There is all kinds of multiuse opportunities. You couldn't just go build one of these in the middle of Houston in a developed area because they are so wide they take up a lot of land, but you can plan for them and build them out in the development frontier hence the name frontier channel.

Here is a picture. This is actually Fluellen Creek in Fort Bend County but it's the same concept, and if you look you see this channel through here. It's a nice meandering channel. In reality, the channel width goes all the way from here across to -- you can't even see the other side. Just right in here. During the big flood, the 100 year event all of this would fill up. Not the homes but up to the banks here but during normal rainfalls and normal times it's a babbling brook through here. There is lots of vegetation planted and that's good because we want this thing to convey flow, but not to convey it too fast. The vegetation helps slow it down and you have kind of a hybrid between storage and conveyance really. So when we talk about the conveyance concept, think of this picture here.

So this here shows the two plans schematically. You may recall that we said we'd started with six and worked down to two. These are the two. The first one we call the Mound Creek Reservoir with Overflow Conveyance B. Don't let that name trip you up. That was something internal while we were working through it. We like to call it Plan 3. It's a lot easier. And the other one is Plan 5, Katy Hockley North

Cypress Reservoir. I like Plan 5 best -- of the names.

So considering this conveyance and storage strategy I just talked about, we found it's not practical to manage the entire overflow with only conveyance or with only storage. Hence both of these plans utilize both. Large volumes of the runoff will be temporarily stored in these storage features, but there would still be residual overflows that would be still there, but smaller and manageable, and since they are manageable, our conveyance features can now handle those things and safely convey those downstream.

I want to present some more detail on both of these. I do want to go back to what Steve has spoke about on the critical conservation areas. Steve and his group identified areas that are more important in terms of conservation opportunities and that helped us identify physically these two locations. We found that they were also more efficient storage and as a result were able to increase the overall conservation footprint. Plan 3 will increase it by about 3100 acres and Plan 5 by about 5,000 acres.

So let's focus in on Plan 3. Plan 3 includes a large scale storage facility in the Upper Cypress Creek Watershed. This reservoir, as I said, would act like a speed bump that would help slow down water, flowing from the Upper Cypress Creek Watershed towards the overflow. And while the overflow would not be eliminated, it would be substantially reduced.

The remaining overflow would be captured by interceptor channel which would direct it into Bear Creek and prior to being captured, by the way, it would flow across an open area to kind of get it away from that overflow divide so we don't influence Cypress Creek and we call this a collection/conservation area.

To get the water -- once the water is in Bear Creek, Bear Creek has to be enlarged. Again it would be that conveyance channel similar to the picture I showed you a few minutes ago. That channel would take it all the way down to the really -- think of the edge of the existing development and the larger Bear Creek channel that exists now. By the time it makes its way all the way down there between all the storage and everything, the peak flow rates have been diminished in a manner that will not aggravate any flooding downstream in Bear Creek.

There are some similarities when we get to Plan 5. But in this case, the reservoir and the berm are located actually straddling the overflow itself. So water would be impounded both in the Cypress Creek watershed and the Addicks Reservoir watershed.

This is a larger storage area, just where it's located. And it would have outlets into both Bear Creek and to Cypress Creek because we need to maintain that flow into Cypress Creek.

One of the concerns with this plan was changing the volume relationship between Addicks Reservoir and Cypress Creek. So there would actually be an internal channel with a gate that would help us manage and maintain so that we don't shift volume from one or the other. And as I showed before, Bear Creek would be enlarged similar to this up to the edge of the existing development.

This picture shows schematically again what the berms might look like. Although that looks kind of the same, I'd like to point out that the Mound Creek berm or dam, if you want to call it that, is significantly higher. It's about 18 feet at its highest point, while the Katy Hockley north one is about 10 feet at its highest point, and the reason for the difference is really just the natural topography where all of those are located and you may recall when Dena showed the red picture up in Upper Cypress it was steeper up there. Because it's steeper we can more efficiently store a reservoir. It does require a higher dam or berm to achieve the same goal.

Still comparisons here. Both of them occupy a lot of land. Big, big key to this. Plan 3 occupies about 5400 acres, and Plan 5 occupies a little bit over 11,000 acres.

A little point of reference here, Addicks Reservoir is about 16,400 acres; and you might say, oh, my goodness, you're building Addicks Reservoir Part 2. As a footprint, it does look almost as big, but Addicks Reservoir manages substantially more water, almost ten times as much.

For example, Plan 3 will manage 15,700 acre-feet. People go what's an acre-foot? It's about 325,000 gallons, if that helps you. It doesn't really help me. But in total, Plan 3 manages about 5 billion gallons of water. Lots of water. I think we were playing around with this and said you could fill up, you know, NRG Stadium now, 2,000 times with all that water. It's a lot of water.

Plan 5 manages about 26,500 acre-feet, almost twice as much as Plan 3. So while these are big, Addicks Reservoir manages about 208,000, again, about ten times as much.

During a 100 year event which is the one that everybody is kind of interested in, Plan 3 will have a maximum depth in the reservoir of 13 feet. Although most of the reservoir will be less than that, and it will drain in about three days. So, again, real quick, there won't be a lake out there for the next two months. It will be gone in three or four days.

Plan 5, it will stay around a little longer. It won't get as deep. It will get to a maximum depth of about 8 feet and drain at about 7, maybe 8 days. Both of them, by the way, remove the overflow from about 18,000 acres of land. To be specific, Plan 3 removes it from 18,500 and Plan 5 removes it from 18,000. So it reclaims quite a bit of land.

People are always interested on what this is going to cost. You imagine they're not real cheap, especially considering all the land. The full cost for each plan is shown in the second column. I'll explain what full costs mean. The cost includes the land, the construction and the professional costs required to permit, design and construct each plan. And you can see here that land is a very large cost.

So we started looking at this, and part of our scope is to look at various implementation and funding strategies, and we've identified that some partnerships could be used to offset the cost. For example, and you know these are all just kind of ideas. There have been discussions and all that, but we're increasing the conservation footprint with these plans by 3,100 in Plan 3 and 5,000 acres in Plan 5. We'd also like to maybe use some of the existing conservation land out there as part of inundation areas that we showed for the plans. We're not looking to flood conservation land for 100 days out of the year. We're looking to flood it for a few hours every few years. I don't -- it's our belief that this would not change the conservation function of that land whatsoever.

And so in hopes that the conservation interests would allow that, we would then increase to the overall conservation footprint. So that has a potential to decrease the overall land costs substantially.

Another potential partnership is with the development community. And Dena can show the development guidelines. We're going to ask the development community to dedicate land for Bear Creek as they develop in that area and construct that new channel as they develop in that area. And that's part of the costs. So with these partner contributions, the cost goes down substantially. Still a lot, but Plan 3, the total cost is reduced from $271 million down to 178 million. Plan 5, the cost is reduced from 369 million down to 243 million. Pretty soon we're talking real money.

We then went and looked at an annual benefit cost ratio. That was one of the conditions of the Water Development Board grant. So I'm going to talk a little bit about a benefit cost ratio, and it's simply the annualized benefit. You take the benefits and put them into -- annual basis and you take all the cost and spread them out over an annual basis. Divide the benefit by the cost and that is a good indicator of the return on your investment. So to make this simple, a higher benefit cost ratio is good. And we always desire it to be greater than 1.0.

Now, sometimes people spend years and years doing benefit cost studies. Some of the benefits are real easy to get to, and some of the costs are, and some of the benefits not so much. So we put two categories of benefits together. We put quantified benefits and nonquantified benefits. Quantified benefits are those that we can easily assign a dollar value to, reduction in flood damages, impacts to land. And we made a desire to get those dollar values on what we consider the most significant and largest benefits.

But there is also what we're calling nonquantified benefits, benefits that we're acknowledging exists and recognizing we can't put that number on them -- the value of conservation -- and you know there is ways to do that, but it's a little trickier. The predictability -- what's the economic benefit of having a plan that everyone understands is manageable and predictable -- future flood emergency and management costs, impacts to the downstream channels and reservoirs, benefits to roads, parks, infrastructure, recreation and quality of life. A word you'll hear more and more in the future and you're starting to hear is carbon offsets. These are all the things that are out there that the project has the potential to provide benefit to that we weren't able to get a dollar value on.

What we do know is the actual benefit is the sum of the quantified benefit and the nonquantified benefit. I just can't put my dollar number on that. So from the quantified benefits only, the Mound Creek or Plan 3 had a benefit cost ratio of 1.14; and Plan 5, the Katy Hockley North Reservoir has a cost benefit ratio of 0.89. The nonquantified benefits looking at that list, especially with all the conservation benefits that are delivered are considered considerable. And it's our belief that the actual benefit cost ratios for both plans are greater than 1 and by a relatively comfortable margin.

Let's get into funding a little bit. Let's say this, we acknowledge that the project cost is high and it brings up this funding issue. A good funding plan relies upon those that financially benefit from the project to contribute to the cost.

So we also considered the role of the public in financing because there is a public benefit to reducing this large overflow. But as you know, with the development interests and the growth that Dena showed, there is a substantial private interest as well.

So we're not proposing today a specific funding plan. We've identified these various options and they are continued to be explored. As this project moves forward it would be appropriate to engage a more detailed study on what the best way to get there is. But the desire would be that as the area grows, that that growth would generate income that would support the development of the project.

And I'm going to show you how that might occur here with some implementation sequencing. Because if you get right down to it, you know, big reservoirs and big channels don't get built in a year or two or three or four or five. They are very large projects that can take 10, 15 maybe 20 years to build. Dena's growth chart showed the growth is coming a lot quicker than that, and I think most of us who know this area know it's coming along quicker than that.

And the district can't really say to the development community, hold tight, come see us in 20 years, we're going to work on this. So a big part of this has been developing a sequence to allow the project to gradually come online in a manner that facilitates growth in there, and it also provides an incremental income source to fund the next step of the project.

So the way we might do this, and I'm showing this with Plan 5. We have a similar one for Plan 3. It's up on the boards in the back, but I don't want to bore you with both. They are very similar. But the way this would work is that only a portion of the initial berm or dam would be constructed in the first initial phase. And this would require some seed money up front, perhaps from public funding to get the project going.

And what this initial berm would do would intercept a portion of the runoff and in essence creates a shadow behind it and that shadow behind it is an area that could start to develop. And as that land starts to develop, the funding strategy that's employed would generate income that would support the next phase, the future phases.

Phase II is actually tied to Phase I because it's just the continued construction of Bear Creek as land development activity occurs. Back in Phase I, it would require the initial upstream portion of the creek to be built just to daylight it out. But the rest of the creek would be constructed -- that wide channel -- as developers come through and build their projects.

Phase III is a different part that I didn't even talk about earlier. I should have. Another component of both plans is detention in Jean Paul's landing. Jean Paul's Landing is a Precinct 3 park that's planned. It will have lots of lakes, lots of detention will be available. Most of that detention is reserved for another project that's been in the planning stages for some time but there is some residual availability that we intend to use as well.

Further more, the construction of a channel to intercept some overflow and bring it back into Bear Creek is tied with this phase and that would open up another 3500 acres of land that could develop. So, again, as the project comes online, more land is freed up. More land is contributing income to the project which helps fund the next phases.

Phase 4 is the full construction of the upstream reservoir, the acquisition of the land and the building of the berm, and once phase 4 is done the entire project is online. And in Plan 5 18,000 acres is now contributing income to pay for the project.

As a result, this shows the riverine floodplains resulting from it and you can see that the floodplain in Bear Creek is gone for the most part. There is not much of one downstream now because the channel that's been built that's so big has been mostly successful managing floods and large floodplain that exists in that overflow area is now gone.

And by the way, while this doesn't address you know the local runoff in all these channels, it's hoped that there is opportunities to provide some reduction in flow and reduction in flooding along Bear Creek, Mayde Creek and Langham Creek. So I think that is the end of my piece. Dena, you're up.

MS. GREEN: Okay, I want to talk about next steps forward now, where we are with the study. We've been working on this for a couple of years with the grant from the Texas Water Development Board.

So we've been working on the study for a couple of years, and we've considered all these plans, and we've come down to a couple of plans that we think would be the most feasible for regional management strategy.

Right now, we've put together a draft report.

So we're going to wrap up that report. We've loaded it onto the website. We'll be collecting public comment on that for the next 30 days. And then we'll be submitting our report to the Water Development Board so that they can review it, and we'll be submitting that in late October.

So right now we've got a 30 day period if any of you want to go back and download that report, look through it, all the information we shared with you today will be included in that, and you're welcome to give us any comments you'd like or thoughts about what we have included in it.

So we'll be submitting that for review to the Water Development Board in late October. It's a very substantial report. So I imagine they'll need a little bit of time to review it. And they'll have an opportunity to provide comments back to us. And I know that -- I guess the report is probably about 160 pages and a lot of technical backup that goes along with it as well. So we're estimating that we'll be able to address those comments and then give a final report back to the Water Development Board in early 2015.

Now in the meantime, we're wrapping up that report but there are also some items associated with the project that flood control district has interest in moving forward with. One of it relates to those supplemental development guidelines. The district is working on a draft document using information that was developed as part of the study, and right now we do have a preliminary document that we've developed. We actually have it out for review right now. A lot of different folks are looking at it, and we plan to have comments back on that to be revising it and getting it updated over the next month or so, and we plan to move forward with sharing it with commissioners court and providing a recommendation to the Harris County Commissioners Court for approving of those supplemental guidelines. We're planning to do that in December.

In addition to that as well, we're also planning to move forward with taking a concept plan to commissioners court and recommending that Harris County Commissioners Court approve a regional overflow management concept plan. And by doing that, that will give us the ability to move forward with all this information that we've developed so far and refine it and develop a little bit more detail on it.

We'll talk to you about the large price tag with constructing one of these projects. There are also a lot of opportunities to set up different types of funding for one of these projects, but we need to dive into it a little bit deeper than we were able to during this study. So we'd like to look into that and explore it and come back with more information and a more detailed business plan of how to implement one of these regional overflow management plans. So we do plan on going forward to commissioners court with one of those concept plans that we can pursue further in December as well.

With that, that's the end of our presentation tonight. We're going to open up for question and answer in a minute. Here is the website where you can download our report if you'd like to download a copy and read through that. Also on the agenda you were handed out tonight and we have the comment cards. I think I have a copy down here. So you should have been given one of these when you walked in. We'd like to have folks fill this out if you'd like to ask questions or speak tonight, and in a few minute we'll come around and pick those up.

Before we move on as well I would like to acknowledge the study team. I think I have been lucky to work with a great group of professionals. You met Stephen a few minutes ago when he presented. I've also been working with Glenda Callaway from the flood control district and Kim Jackson as well. Very lucky to have them on board as well as our consultant team. Burton is sitting down and letting his throat rehydrate for a minute. He's done a terrific job, and we have James Beck and Fangyi, and all these wonderful graphics that we have to show and a lot of input as well. So thanks to everybody for all the hard work. It's been a pleasure working with all of you.

So go ahead. Fill out your comment cards. We'll come around in a few minutes to pick those up. We've got the website up here. And I'm going to scroll to the next page, too, if you wonder what that looks like when you get there. This is the study website. I have the address down here you'll need to go to. You'll come to this landing page for Cypress Creek Overflow Management site and there is this big green column on the right and you'll see study report. You just click that link, and it will take you where you need to go to download. You have a comment form up there. You're welcome to submit written comments to us if you want. This makes it very easy, and you can open up that comment form and type all your information in and send it back to us pretty easily without having to use a stamp and type -- print out a letter and put it in an envelope and send it to us. Anyway, you're welcome to do that.

Natalia has some comment forms. Please raise it and she will get them to you.

AUDIENCE MEMBER: A question on that first slide where it shows the higher flooding. Where is that? I don't recognize the area, so I'm asking.

MS. GREEN: This is off of Katy Hockley Road just off of Cypress Creek.

AUDIENCE MEMBER: Cypress Creek and what other road would that intersect in that area?

MS. GREEN: There is not a lot out there. Sharp Road is in the area.

AUDIENCE MEMBER: Is that Katy Hockley running north right there?

AUDIENCE MEMBER: That's the Katy Hockley.

MS. GREEN: And Cypress Creek is in the background here.

AUDIENCE MEMBER: My first impression is we're looking south.

MR. JOHNSON: No, looking north.

MS. GREEN: If anybody has comment cards, raise your hand and we'll come pick those up from you.

I'm going to go ahead and get started. I've got a pretty good stack right now, and I think there is just one or two more out in the audience.

So our first question is from John Singleton, representing MUD 136. And the question is what role can MUDs play in overflow management? That's a great question. Because this is a regional overflow management plan that we're looking at. So we definitely will be looking as we develop a regional plan to move forward to get input from the community, look for potential partners, look for how to involve the area in the plan. That would be something if you had a specific interest that we might be able to talk offline and find out a little bit more about the direction you might be interested in participating in.

I don't know where John is out here. Does that help -- did that help answer your question?

MR. SINGLETON: That's fine.

MS. GREEN: Okay. And I'm just going to let you know, I'm going to answer these, but if I need some backup, I know I have my study team over here and I have Mike in front over here as well. I think we'll have it all covered. We hope to at least.

So our next question is from Mary Anne Piacentini. If you plan to purchase land in Phase 4, you may find the target land areas already developed or so expensive that you cannot acquire the necessary acreage. Please respond also to why land acquisition would work --

AUDIENCE MEMBER: Would not be in Phase I.

MS. GREEN: -- would not be in Phase I.

MR. JOHNSON: I'll answer that. You know, Mary Anne, we've discussed amongst ourself whether we should use phases. A lot of times we use Element 1, Element 2, 3, 4. Phase implies that you have to finish one before you start two where in that case you would not acquire the land. And that's why phase is really probably not what we should be using, but people kind of understand phases. But there is no reason why the different elements or features can't happen in some parallel and in fact most of our funding models and implementation models we play with assume that. In fact, the land acquisition starts and goes for 20 years, you know. I can answer that one. Is there a second one?

MS. GREEN: Just talking about why not in Phase I and in talking about the challenge of the escalating land costs, and that is a challenge and a risk and something we're going to have to look into in more detail. Obviously funding is a big constraint. You want to answer something, Mike?

MR. TALBOTT: I just gave Mary Anne my

answer.

MS. GREEN: Okay. My next question is from Michael Bloom. Over here, what would development look like inside the proposed storage areas? Would development be allowed at all inside?

You know, that's a good question. Actually development inside those proposed storage areas would likely be limited. People that own existing land in there, you know, would probably be able to maintain existing land use, but it would also depend on where it's at. Certainly if you're located in areas next to the edge of a berm, it would get a little deep. So that's probably not a good idea to have a lot of structures in that area. But it would be limited -- you know we would not expect to see development within that reservoir area. But if somebody had a family farm in the area, I wouldn't expect that they would need to change their land practices because of this. There is flexibility in that.

Jim Robertson has a question. Right over here. Hi, Jim. Okay, who and how will we decide to pursue Plan 3 or 5? And when will this decision be made?

MS. GREEN: Well, we'll be making it in the next couple of months. I can tell you I believe that we're leaning towards Plan 5, but there are a lot of factors involved in that. You know, and as we move forward with a concept plan and refining it, there would be a lot more community outreach and involvement with the public to do additional public engagement beyond what we're doing with the overflow management plan.

But that's something that flood control will be working on over the next couple of months. Did that answer your question? Okay.

MR. ROBERTSON: Over the next couple of months basically?

MS. GREEN: Yes. Yes.

I have another question from Pete Smullen. Under Plan 5, what decision criteria will be used to set limits on flows sent to Cypress Creek, and if the answer is NIA --

MR. SMULLEN: NIRAI.

MS. GREEN: And can limits be overridden by Addicks Reservoir consideration? That's something we've considered during the study, and limits on Addicks Reservoir have not overridden no adverse impacts on Cypress Creek. That's something we've been very careful during this study to consider and to make sure that we are not releasing additional flow down Cypress Creek and not elevating any water surface elevations beyond what's already going down Cypress Creek. Do you have anything to add to that?

MR. JOHNSON: I would add that's true for both peak flow rate and total volume as well.

MS. GREEN: And another question from Pete. In Plan 5 early stages, will the berm interfere with overflow and cause it to go down Cypress Creek before detention is added? The berm will be partially constructed but it will not send more flow down Cypress Creek. What will happen is it would be constructed in a way that overflow will still occur, and it would manage a portion of the overflow, but there would still be parts of the Addicks Reservoir watershed that would probably be inundated by that overflow until the berm was able to be expanded. So it would not be partially constructed.

MR. JOHNSON: And really I misspeak, Dena, all the time on this. It's really a channel, a collection channel that intercepts the overflow. Now, when we dig the channel, we'll place the dirt right downstream so there is going to be a little berm there, too. But it's really a channel that collects it for that reason.

MS. GREEN: That's true. During that initial phase it's probably about three feet deep, the berm. Three or four feet deep.

And we have another question from Frank Moon.

MR. MOORE: Moore.

MS. GREEN: I'm sorry about that. He says I have a letter from Gary Bezemek, project coordination Precinct 4, that says no projects are planned including desilting. Is this a 20-year project that means there are intentions of preventing any flood in the near future on -- if Langham Creek is blocked up and doesn't drain? Do you live along Langham Creek?

MR. MOORE: Yes, I do. And it still floods. And I have pictures here of trash and all kind of stuff blocking drains.

MS. GREEN: Okay, I cannot speak to the projects on Langham Creek. I'm not familiar with our programs on that. I know that we have a regional planning effort for Langham Creek.

MR. MOORE: But what I'm saying is -- I agree with the guide, the development is happening so fast that a 20 year plan -- we're going to have to come up with some kind of maintenance on the stuff that they already have and they're not doing that.

MS. GREEN: Okay. So your concern is --

MR. MOORE: Yeah, they need to desilt stuff. Stuff is going to have to happen because 20 years from now it's going to look completely different, this whole area. I mean that may not be making the deadline on preventing any kind of major flood if that's the time frame they're looking at.

MS. GREEN: Yeah, it really is looking at having a regional management plan for that overflow because absent a regional management plan then that means as development goes in, everybody is going to have different plans. So it's not necessarily going to be a regional plan that protects the whole region where the overflow is occurring right now. It will be more of a site specific plan developed for each of those developments as they go in individually.

MR. MOORE: Right. I just wish that they would maintain the stuff that they already have because it's not being maintained right now.

MS. GREEN: Sure. I hear your frustration and understand that. Thank you.

Let's see, I have another question from -- you know what, I think I already got this one from Michael Bloom about development in proposed storage areas. And I have one more from Michael Bolton and it just says lots of questions.

MR. BOLTON: Lots of questions. Do you have that on a slide you can put up? This one right here.

MS. GREEN: The overflow. Sure.

MR. BOLTON: You have the slide on that. So Cypress Creek has quite a bend. You have a huge bend right here. It's amazing. I live right over here on Horsepen Creek. And this bend right here is a tiny little one. We flood a lot. I've had two floodplains, and the bend is right there like that. And this is a monster bend, and it's interesting this is all blue like the reservoir because you would think you know that would not be good.

MS. CALLAWAY: It wouldn't be good for housing but fine for open space.

MR. BOLTON: That's a lot of water.

MS. GREEN: Cypress Creek doesn't have a lot of capacity in the upper reach up that way, and when we've done the calculations, it looks like during large storm events more water peels off of Cypress Creek and drains into Addicks Reservoir watershed than travels east down Cypress Creek.

And if you have more questions, I can visit with you perhaps after.

MR. BOLTON: You couldn't find that?

MS. GREEN: No.

MR. BOLTON: Let me ask you a couple of others then. On cost benefit No. 5 when you only put .89. How did you get that? That would seem like the best plan, Plan 5. It was the most expensive, most land, but then you had Plan 3 at 1.4 and Plan 5 at .89 and when you did your cost benefit did you include the cost of insurance? Because according to this article, there are 24 billion in the red for flood insurance. So is that part of your cost benefit analysis?

MS. GREEN: We did not include flood insurance rights in that.

MR. BOLTON: That's a big thing.

MS. GREEN: There is more land involved in Plan 5, and the location of the property is likely more [INAUDIBLE] as well. Do you have anything you'd like to add to that?

MR. JOHNSON: No. When you do the savings to the National Flood Insurance Program, as a benefit category, you can account -- but there is very few homes in the study area that are affected right now. It's mostly undeveloped. You could only calculate that for existing structures. You can't take a benefit for a future structure in an economic sense I guess. So it doesn't show up that way. If we were doing this in hindsight 30 years from now you probably would.

MR. BOLTON: And the question you said a

100 year event, 13-inches over 24 hours. And yesterday in Austin they buried a peace officer and she got caught in the water a week ago today that was five to seven inches over by the UT Golf Club in Austin, and she somehow -- she got in the wrong area. And it took a day to find her body in the lake. She was 35. She has a 12-year-old.

So when you're doing your numbers, it can be a life or death situation if you're in the wrong part, and you're seeing a 100 year event, 13-inches over 24 hours, what about something like in Austin that happened last week that's 5 to 7? Are you taking that into account or only looking at a 24 hour period?

MS. GREEN: Okay, so I'm going to attempt to answer this with a couple of parts here. That is definitely very sad and definitely a death that should have been avoided. Drainage conditions are very different between Houston and the Austin area. So we're quite flat in this area and water tends to rain. It ponds up. It's kind of sluggish and it sits. We know when we go through some of our highways that can always be a problem when you get to low areas and they flood with water. We've got pumps to drain those out, but when we start getting into central Texas, the conditions are a lot different. It's a lot steeper. That water tends to get concentrated. It can be moving very fast and it can get deep very fast, a lot faster than people realize. So they can put themselves in dangerous situations they may not really realize how swift that water is moving or how deep it is. But it's very different topography and very different soils. So one rain that might cause a tragedy like that in Austin, it might land in a different area with different drainage conditions, different soils and tend to spread out and be a lot more shallow.

Okay, how about I answer this question and we'll come back to you later. I've got another one from Michael Bloom, and it says could the study team consider quantifying nonquantified benefits using ecosystem services, concepts currently being considered by Rice Speed Center. This would help with the benefit cost ratio.

You know that is something we could look into in the future. It wasn't something we were able to do as part of this study, but we do know that there are a lot of nonquantified benefits that could be realized by one of these regional plans. And it was something that we struggled with with this, but that we do have an interest in in learning more about that.

Any more questions? Okay, all right.

AUDIENCE MEMBER: So you said 5 times in 30 years you had records for overflowing, but in previous meetings -- and this is the third one I've been to -- it was once every ten years. So that's once every six years at that record, and if the Corps of Engineers were here back in 1940, which is 74 years ago, how come you don't have any records? Where is the data?

MS. GREEN: We have gages along the streams, so we're able to get that information and collect it during rain events, and that's what we're using along with [INAUDIBLE] field visits to be able to check on that overflow and verify when it's occurring. So Steve is here to tell us a little information about how long the gage network has been installed. We've been getting --

MR. JOHNSON: 1980's.

MS. GREEN: Since the 1980's we've been able to have the gages out. If you drive out to the study area, there is a lot of places you'll drive. You'll see homes elevated up off the ground. You'll see air conditioners several feet off the ground. I think a lot of people in the area are familiar with the overflow and the drainage conditions. But again it's pretty rural. There is not a lot of people out there. So it's just a different type of drainage condition than we see in other parts of Harris County.

AUDIENCE MEMBER: Well, okay. I have a question for the doctor. He said he wanted to do another four years of data for his study. He only has one year. So you're looking at five. But when you're looking at sheet flow, sheet flow is critical especially to people like me where the water is coming down. The plans she said were 15-inches into the soil. That's like a canopy of the tree that deflects.

DR. BENIGNO: 15 feet sometimes.

AUDIENCE MEMBER: Do you measure the sheet flow how that is coming off the hard surface?

DR. BENIGNO: Through that drainage point there is a small little measurement system in the drainage point. And we take measurements at different intervals. So we have -- we can average what's going on throughout the day. We also take measurements hourly and we can take 15 minute measurements and one minute measurements. So we have four separate data files, four programs for each of these sites. And at those intervals we can say, you know, this much depth of water is covering the little instrument at the bottom of that discharge pipe. So from that we can see basically the rate of water flowing through the system.

MS. GREEN: Okay. We've got about 25

minutes left for our meeting tonight. So I'd like to go ahead if there are no more comment cards coming in, you know, I can visit with you. We can look at some of the maps and help answer your questions, but I want to give everybody a chance also to look at the exhibits and have a chance to visit with the study team and ask some additional questions as well. Yes?

AUDIENCE MEMBER: Yeah, I submitted three questions on a piece of paper to Allen.

MS. GREEN: I forgot about that. I've got your questions here. Hopefully we helped answer some of them, and I also know that we have a meeting with the Cypress Creek Flood Control Coalition in a couple of weeks where we can help answer some more of them as well if we didn't answer those for you tonight.

Let's see, confusion exists as to what commissioners court will be asked to approve and then what you will do when this approval or disapproval occurs. So what we'd be asking commissioners court to approve would be two items: One would be supplemental development guidelines for the Upper Cypress Creek, Addicks and Barker Reservoir watershed; and then the other item would be a concept plan for regional overflow management strategy. And by getting their approval of that concept plan, that will let us be able to use the study as a springboard and develop additional details on how to put it together to establish more details on funding mechanisms and to do an additional level of investigation. Right now we're still at a very high level concept plan. So it will take more refinement before we can actually go out and start doing some design and moving forward with one of these.

AUDIENCE MEMBER: So then you would go back -- you would go into the design phase --

MS. GREEN: That will be in the future. Right now -- yes.

AUDIENCE MEMBER: In the future after you've been to commissioners court the first time. Then you go into the design phase and you go back --

MS. GREEN: Then we're going to go into more of a refining and investigating further. We need to come up with more information on funding one of these plans. You saw the cost estimates are quite large.

AUDIENCE MEMBER: Right.

MS. GREEN: So there is going to be a lot of additional steps we're going to need to work out. Partnerships. Need to do additional community involvement and make sure that it is viable to move forward with one of these plans. But we'd want to go to commissioners court with a concept plan in order to get the approval and go forward and do those additional steps to do another level of refinement to implement one of the plans.

AUDIENCE MEMBER: When you finish another level as you say, you go back to commissioners court again?

MS. GREEN: You know what, I believe so. Mike, do you want to help answer that?

MR. TALBOTT: We'd end up going to commissioners court several times. I mean, the conceptual plan and then there would be phases or whatever we'd want to call it as we design particular elements of it. We could go to court 20 times over the next 20 years getting various phases authorized and getting engineers under contract and doing a lot of things. The concept plan is the important thing. It provides the framework for everything we will go and investigate further and get additional approvals.

AUDIENCE MEMBER: Mike, will that additional approval be similar to what happened with the TC&B blue book in 1984?

MR. TALBOTT: Yes, as a concept plan. It would help guide the future as each time you go to commissioners court it's going to shape the projects as you go through the concept plan.

AUDIENCE MEMBER: Thank you.

MS. GREEN: Okay. You have another question about what will trigger implementation. Did we answer your question on that?

AUDIENCE MEMBER: I think so, yeah.

MS. GREEN: Okay, and then let's see, you have a question that says there is a significantly higher cost for plan blank. If this is what flood control is going to recommend to commissioners court, what are the offsetting benefits which justify --

AUDIENCE MEMBER: It's Plan 5.

MS. GREEN: -- for Plan 5 that justify these higher dollars? Certainly having a regional management plan that you can plan for and know what would be implemented in the area would be one benefit. And there are a lot of additional sort of nonquantified benefits we're able to realize, but we still would want to refine this a little bit further. And certainly coming up with funding mechanisms of how to fund the plan and get it in the ground is going to be a big part of that next step.

And then No. 3, please address what/where guarantees will exist to pay for implementation of the selected plan, i.e. avoid another repetition of what happened with the TC&B master plan for Cypress watershed and again with flood control's primary tributary project for Cypress Creek watershed? I have to admit I'm not familiar with what you're referring to here on the TC&B master plan for Cypress Creek watershed.

AUDIENCE MEMBER: The bottom line on it, Dena, is what assurance is there as you go through this process and submitting it to the commissioners court this time that you will end up with a financial guarantee that allows you to go ahead with execution and it doesn't just die on the vine because of lack of funding and the land not being bought up as the prices escalate.

MR. JOHNSON: I'll try, Dick. We've had this discussion before back in the day. I would take a different approach to answering that. Master plans are kind of long term visions that support the growth over the future period of time, maybe over many, many, many years. And I think we're reaching those many, many, many years today. If you look at the TC&B master plan, you know what, it has a lot of things that look a lot like Plan 3 in it and it has a lot of things that look like Plan 5, and what you're seeing today is that plan finally coming to fruition as the timing is right for that plan to be. So I don't -- I know we want to kind of say, well, that plan didn't work. It's out. Here is the next try. No, let's not think of that. That plan is still the plan. Things have come online over time and now this may be coming online. We can think about that way as well.

MS. CALLAWAY: There will also be a need for public support.

MS. GREEN: That's right. Glenda is shy and she doesn't want to get up and help me. Yeah, public support is going to be a big factor in having any of these plans implemented and having public support for the flood control district to be able to move forward with one of them.

AUDIENCE MEMBER: We're aware that Mike -- that you have all gone to the budget officer and seeking a 200 million-dollar a year -- and you're at 60 million, and we've got our full support on trying to cope with that delta. But, again, is there something that we can do to support your effort to get a financial lock on being able to buy that land before all these people come in because all that's going to do is shift the price up rapidly.

MS. GREEN: Sure. I imagine letters of support would be very helpful. All right, anything else?

Michael, I will come visit with you, okay? So we'd like to invite everybody. We've got refreshments in the back. I see there are fresh cookies we need to pop the top off, and Steve is right there to do it. And I'm going to point out I forgot a study team member, Sirish, thank you. You've been great to work with, too. Appreciate all your efforts.

(Meeting adjourned at 7:42 p.m.)

CYPRESS CREEK OVERFLOW MANAGEMENT PLAN PUBLIC MEETINGS
BEAR CREEK COMMUNITY CENTER, SEPTEMBER 25, 2014, 6:00 P.M.

4.3.7 Comments Received as of October 25, 2014

LAST NAME	FIRST NAME	AFFILIATION	MAILCITY	SOURCE	COMMENT
Bloom	Michael	R G Miller Engineers	Houston	Meeting - Verbal	What would development look like inside the proposed storage areas? Would development be allowed inside at all? Could the study team consider quantifying "non-quantified benefits" using eco-systems services concepts currently being considered by the Rice SSPEED Center? This would help the benefit-to-cost ratio.
Bolton	Michael	Hearthstone Flood Coalition	Houston	Meeting - Verbal and Written	See Meeting Transcript
Moore	Frank	Resident	Houston	Meeting - Verbal and Written	I have a letter from Gary Bezemek (HCFCD), Precinct 4 Coordinator, that state that there are no projects planned for (the area near my home) on Langham Creek, including desilting. If this is a 20-year project, that means there are no intentions of preventing any flooding in the near future. Langham Creek is blocked and does not drain.
Piacentini	Mary Anne	Katy Prairie Conservancy	Houston	Meeting - Written	If you plan to purchase land in Phase 4, you may find that the target land areas are already being developed or are so expensive that you cannot acquire the necessary acres. Please respond to why the land acquisition would not be undertaken in Phase 1?
Robertson	Jim	Cypress Creek Flood Control Coalition	Houston	Meeting - Verbal and Written	Who and how will it be decided to pursue Plan 3 or Plan 5? When will this decision be made?
Singleton	John	Harris County MUD 136	Houston	Meeting - Written	What role can MUDs play in overflow management?
Smith	Dick	Cypress Creek Flood Control Coalition	Houston	Written - Letter	See Letter in **Draft Study Report: Cypress Creek Overflow Management Plan, Appendix H: Public Outreach Program** (*4.3.7 Summary of Questions and Comments)*
Smullen	Pete	Cypress Creek Flood Control Coalition	Houston	Meeting - Written	In Plan 5 in the early stages, will the berm interfere with overflow and cause it to go down Cypress Creek (before the detention is added)? Also under Plan 5, what decision criteria will be used to set limits on the flows sent to Cypress Creek? If the answer is no adverse impact (NAI), how will that be determined? Can the limits be overridden by Addicks Reservoir considerations?

CYPRESS CREEK FLOOD CONTROL COALITION

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Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092
ATTN: Dena Green, P.E. Study Manager

October 21, 2014

Comments on "Cypress Creek Overflow Management Plan" Draft Report

Thank you for the information provided at the September 25, 2014 Public Meeting. Based on that meeting and our review of the above-referenced draft report posted on the HCFCD website, we are submitting the following comments as requested at the meeting:

1. CCFCC's understanding is the overflow study has determined the following: (1) there will be a significant increase in the volume of overflow runoff resulting from the new development expected in the Upper Cypress Creek Watershed, even with on-site detention; and (2) analysis by the HCFCD project team <u>based on current design standards in the PCPM</u> has concluded there will be no adverse impact (NAI) to residents and property located in the Cypress Creek Watershed from new development in the upper watershed with the proposed overflow project in place.

2. Previously submitted analyses performed by professional engineers for CCFCC concluded that application of the current design standards in the PCPM to new development in the Upper Cypress Creek Watershed does <u>not</u> achieve compliance with Harris County's NAI policy; this being due to the unique drainage characteristics of the undeveloped portions of that watershed, that effect both peak flow rates and runoff volumes. While significant increased runoff volume from future development is acknowledged in the study, as noted above, the study concludes that current design standards adequately address peak flow rate issues with new development. We understand that this increase in runoff volume will be mitigated by application of new development guidelines. While we agree that such mitigation of increased runoff volume is needed, we disagree that peak flow rates are being adequately addressed by current design standards, based on our previously submitted analyses, which have never been formally responded to by the HCFCD.

Thank you again for requesting public comments.

Cordially,

Richard D. (Dick) Smith
President

cc. Board of Directors
L.G. Dunbar, P.E.
James Tynan Kelly
Commissioner R. Jack Cagle

Overflow Plan Report Comments Letter

WEST HOUSTON
ASSOCIATION
Leadership in Quality Growth

October 24, 2014

Harris County Flood Control District
9900 Northwest Freeway
Houston, TX 77092
ATTN: Dena Green, Study Manager

Dear Ms. Green:

On behalf of the West Houston Association, I would like to express our appreciation for being included on the Cypress Creek Overflow Management Plan Steering Committee, and for the opportunity to comment on the final report. Unfortunately, our response will not be completed by the October 25th deadline.

We are in the process of reviewing the technical merits of the proposed Cypress Creek Overflow Management Plan ("Cypress Creek plan"). We are also reviewing the proposed supplemental guidelines and criteria for developing in the Addicks/Barker Watershed(s) and the Upper Cypress Creek Watershed ("draft guidelines"). These are both massive projects, and potentially impact each other.

Our comments on the draft guidelines will be submitted by November 20, 2014. Our comments on the Cypress Creek plan will follow no later than December 17, 2014.

Thank you for your understanding. This issue is of critical importance to the West Houston Association and our members.

Yours truly,

Peter C. Houghton
Chairman, West Houston Association

West Houston Association | 820 Gessner, Suite 1310, Houston, Texas 77024 | v 713.461.9378 | f 713.461.3065 | WestHouston.org

5 Direct Mail

January 11, 2012

ADDRESS BLOCK

RE: Texas Water Development Board Flood Protection Planning Grant Application

Dear:

On January 11, 2012, the Harris County Flood Control District in coordination with Harris County submitted an application for a Flood Protection Planning Grant in response to a solicitation issued in the Texas Register on October 7, 2011. The objective of this effort is to establish a set of policies, technical criteria, and guidelines that will allow the Harris County Flood Control District and Harris County to plan for and implement flood risk reduction programs that are reflective of the unique hydrologic conditions in the upper Cypress Creek watershed and the drainage areas upstream of the Addicks and Barker reservoirs.

The goals for the effort are to:

1. Gain consensus among key stakeholder groups representing business, environment, regulatory and other quality of life interests of the facts relating to flooding, flood volumes, flood peaks and flood risks.
2. Gain an understanding of the needs and objectives of the interested parties as it relates to land preservation, environmental mitigation, and land development.
3. Develop a consensus plan for flood risk reduction that incorporates the needs and objectives of all of the key stakeholder groups based on the collective interests involved and that is supported by all parties.
4. Establish interim criteria while adoption of the final consensus plan is ongoing.
5. Design a business plan to implement the strategies defined including the roles and responsibilities of all of the parties involved.
6. Adopt the consensus plan and the business plan at Commissioners Court.

It is anticipated this study effort can be completed within 18 months if proper resources are applied.

Should you have any questions or comments, please feel free to contact either our office or the Texas Water Development Board directly.

Applicants Official Representative:

Mr. Michael D. Talbott, P.E.
Director, Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092

Texas Water Development Board
Ms. Melanie Callahan, Executive Director
Texas Water Development Board
Stephen F. Austin Building
1700 North Congress Avenue
P.O. Box 13231
Austin, Texas 78711-3231

Any comments must be received within 30 days of the date of this letter.

Sincerely,

Michael D. Talbott, P.E.
Director

MDT:AJP: sep

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Baker Road MUD
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Region H Water Planning Group
c/o San Jacinto River Authority
Attn: Reed Eichelberger
PO Box 329
Conroe, TX 77305

~~Houston-Galveston Area Council~~
~~3555 Timmons, Ste. 120~~
~~Houston, TX 77027~~

Region H Water Planning Group
c/o San Jacinto River Authority
Attn: Reed Eichelberger
PO Box 329
Conroe, TX 77305

Region H Water Planning Group
c/o San Jacinto River Authority
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Harris-Galveston Subsidence District
Attn: Tom Michaels
1660 West Bay Area Blvd.
Friendswood, TX 77546

Harris-Galveston Subsidence District
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City of Houston
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Houston, TX 77251

City of Houston
PO Box 1562
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City of Houston
PO Box 1562
Houston, TX 77251

5.2 Letter to Government and Nonprofit Agencies about Initial Public Meeting

July 20, 2012

Address Block
Address Block
Address Block

RE: Cypress Creek Overflow Management Study
HCFCD Project ID K100-00-00-P004

Dear _____:

The purpose of this letter is to establish formal contact with your agency regarding the Cypress Creek Overflow Management Study, a flood protection planning effort being led by the Harris County Flood Control District and Harris County. The purpose of this effort is to establish a set of policies, technical criteria and guidelines that will allow the District to plan for and implement flood damage reduction programs that are reflective of the unique hydrologic conditions in upper Cypress Creek and the drainage areas upstream of Addicks and Barker reservoirs. The study is being funded in part through a grant from the Texas Water Development Board. A copy of the scope and the schedule for the planning effort is attached.

In a first step toward initiating the study, we will be hosting a public meeting on August 16, 2012 at the Harris County Precinct 3 Bear Creek Community Center. Directions to the Community Center can be found at http://www.pct3.hctx.net/cc_bearcreek/. The meeting will begin at 3:30 p.m. and conclude by 5:00 p.m. The purpose of the meeting is to describe the planning study and to solicit comments from the affected public.

Information about this effort and future updates can be found on the District's website at www.hcfcd.org/cypresscreekoverflow. If you have questions or need further information, please contact me at 713-684-4000.

Sincerely,

Mike Garmon, P.E.
Planning Department

MGG:sep
Attachments: Copy of the Project Scope and Schedule

John Hofmann
Lower/Central Basin Region Manager
Brazos River Authority
P. O. Box 7555
Waco Texas 76714

Sharon Nalls
Emergency Management Coordinator
City of Houston Office of Emergency Management
5320 N Shepherd Drive

The Honorable Don Elder, Jr.
Mayor
City of Katy
910 Avenue C
Katy Texas 77492

Marc Jordan
Fire and EMS Chief
City of Katy
1417 Avenue D
Katy Texas 77493

Jim Herrington
Region 6
Environmental Protection Agency
720 East Blackland Rd.
Temple Texas 76502

Raymond Anderson, P.E.
Floodplain Administrator
Harris County
10555 Northwest Freeway, Suite 120
Houston Texas 77092

The Honorable R. Jack Cagle
Commissioner
Harris County Precinct 4
1001 Preston, 9th Floor
Houston TX 77002

Jeff Taebel
Director of Community & Environmental Planning
H-GAC
3555 Timmons, Suite 120

Duncan Klussmann
Superintendent
Spring Branch ISD
P.O. Box 19432
Houston Texas 0

Elie Alkhoury
Design Engineer
Texas Department of Transportation, Houston District
7721 Washington Avenue

The Honorable Annise Parker
Mayor
City of Houston
P.O. Box 1562
Houston Texas 77251

Marlene Gafrick
Director
City of Houston Planning and Development Department
P.O. Box 1562

Clay & Leyendecker, Inc.
City Engineer
City of Katy
1350 Avenue D
Katy Texas 77493

David G. Anthony
Superintendent
Cypress-Fairbanks ISD
12630 Windfern Road
Houston Texas 0

Mark Lujan
NFIP Regional Manager, Region VI
FEMA, National Flood Insurance Program
P.O. Box 561356

Mark Sloan
Emergency Management Coordinator
Harris County Office of Homeland Security & Emergency Management
6922 Old Katy Road

Arthur L. Storey, P.E.
Executive Director
Harris County Public Infrastructure Department
1001 Preston Avenue, Fifth Floor

Alton L. Frailey
Superintendent
Katy ISD
6301 South Stadium Lane
Katy Texas 0

Jace Houston
Deputy General Manager
San Jacinto River Authority
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Greg Pekar
Hazard Mitigation Manager
Texas Division of Emergency Management
P. O. Box 4087

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Floodplain Administrator
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Director
City of Houston Public Works and Engineering Department
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Elaine Lutringer
Floodplain Administrator
City of Katy
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Katy Texas 77492

Clark Martinson
General Manager
Energy Corridor
14701 St. Marys Lane, Suite 310
Houston Texas 77079

The Honorable Ed Emmett
County Judge
Harris County
1001 Preston, Suite 911
Houston Texas 77002

The Honorable Steve Radack
Commissioner
Harris County Precinct 3
1001 Preston, 9th Floor
Houston TX 77002

Peter Key
Director
Harris County Toll Road Authority
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John Bremer
Coordinator
Katy ISD Office of Emergency Management
20370 Franz Road

Linda K. Vasse, P.G.
Regional Director
Texas Commission on Environmental Quality, Region 12
5425 Polk St., Ste H

Melinda Luna
Team Lead, Floodplain Mapping Services
Texas Natural Resources Information System (TNRIS)

Mike Morgan
Natural Resource Specialist
Texas Parks & Wildlife Department
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Gilbert Ward
Flood Mitigation Planning
Texas Water Development Board
1700 N Congress Avenue
Austin Texas 78711

Raul Villareal
District Conservationist, Houston Field Office
USDA Natural Resources
Conservation Service

Hon. Glenn Beckendorff
County Judge
Waller County
836 Austin Street, Ste 203
Hempstead Texas 77445

Michael Segner
State NFIP Coordinator
Texas Water Development Board
1700 N Congress Avenue
Austin Texas 78711

Charles Scheffler, P.E.
Water Control / H&H
U.S. Army Corps of Engineers
Galveston District
P.O. Box 1229

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Gene Schmidt
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Debbie Cahoon
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Emil Bethke
District Conservationist, Hempstead Field Office
USDA Natural Resources
Conservation Service

Jeff East
Data Chief
USGS Texas Water Science Center
Gulf Coast Program Office
19241 David Memorial Dr, Suite 180

Danny Twardowski
Superintendent
Waller ISD
2214 Waller Street
Waller Texas 77484

5.3 Letter to Elected Officials about Initial Public Meeting

July 26, 2012

The Honorable [Name]
Title
Jurisdiction
Address 1
Address 2

RE: Cypress Creek Overflow Management Study
HCFCD Project ID K100-00-00-P004

Dear Mayor Parker:

The purpose of this letter is to establish formal contact with you regarding the Cypress Creek Overflow Management Study, a flood protection planning effort being led by the Harris County Flood Control District and Harris County. The purpose of this effort is to establish a set of policies, technical criteria and guidelines that will allow the District to plan for and implement flood damage reduction programs that are reflective of the unique hydrologic conditions in upper Cypress Creek and the drainage areas upstream of Addicks and Barker reservoirs. The study is being funded in part through a grant from the Texas Water Development Board. The scope and the schedule for the planning project are part of the grant application, which can be found at www.hcfcd.org/cypresscreekoverflow. Information about this effort and future updates can be found on the website as well.

In a first step toward initiating the study, we will be hosting a public meeting on August 16, 2012 at the Harris County Precinct 3 Bear Creek Community Center. Directions to the Community Center can be found at http://www.pct3.hctx.net/cc_bearcreek/. The meeting will begin at 3:30 p.m. and conclude by 5:00 p.m. The purpose of the meeting is to describe the planning study and to solicit comments from the affected public. A legal notice for the Public Meeting will appear in the Houston Chronicle on August 1, 2012, and the meeting will be posted at the County Clerk's office in Harris County and Waller County.

If you have questions or need further information, please contact me at 713-684-4000.

Sincerely,

Michael D. Talbott, P.E.
Director

MDT:sep
Elected Officials:

The Honorable Annise Parker
Mayor, City of Houston
P. O. Box 1562
Houston, Texas 77251

The Honorable Don Elder, Jr.
Mayor, City of Katy
910 Avenue C
Katy, Texas 77492

The Honorable Ed Emmett
County Judge, Harris County
1001 Preston, Suite 911
Houston, Texas 77002

The Honorable Steve Radack
Commissioner, Harris County Precinct 3
1001 Preston, 9th Floor
Houston, Texas 77002

The Honorable R. Jack Cagle
Commissioner, Harris County Precinct 4
1001 Preston, 9th Floor
Houston, Texas 77002

Arthur L. Storey, P.E.
Executive Director
Harris County Public Infrastructure Dept.
1001 Preston, 5th Floor
Houston, Texas 77002

Hon. Glenn Beckendorff
County Judge, Waller County
836 Austin Street, Suite 203
Hempstead, Texas 77445

6 Written Collateral Materials

HARRIS COUNTY FLOOD CONTROL DISTRICT

Cypress Creek
Watershed

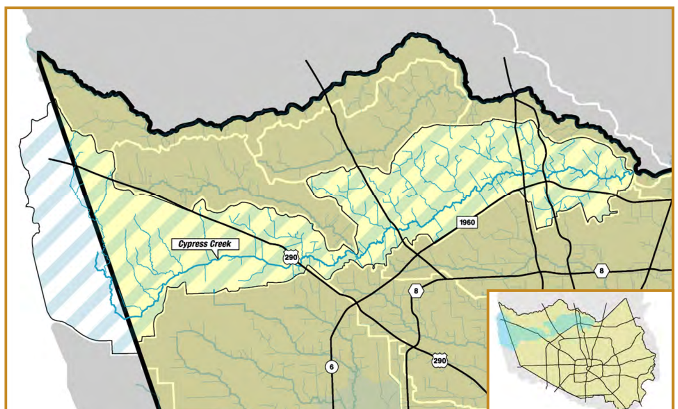
What is a watershed?
A watershed is a geographical region that drains to a common bayou, creek or other waterway.

Watershed Overview

The Cypress Creek watershed is located in northwest Harris County and extends into Waller County. Rainfall within the 267 square miles of the Cypress Creek watershed drains to the watershed's primary waterway, Cypress Creek (K100-00-00). There are 250 miles of open waterways in the Cypress Creek watershed, including Cypress Creek and its major tributaries, such as Little Cypress Creek (L100-00-00), Turkey Creek (K111-00-00), Dry Gully (K133-00-00) and Mound Creek (K166-00-00). Based on the 2010 U.S. Census, the estimated population of the Harris County portion of the Cypress Creek watershed is 347,334.The western portion of the watershed is historically rural farmland, while the eastern and central portions have developed rapidly in the past 20 to 30 years. The Cypress Creek watershed has a diverse environment with animal species ranging from the American alligator to the bald eagle. The watershed upstream of Highway 290 is part of the well-known Katy Prairie ecosystem.

Active Studies

Cypress Creek Overflow Management Plan – The Addicks Reservoir watershed occasionally receives a significant amount of natural stormwater overflow from the Cypress Creek watershed during heavy rainfall events. To understand and manage this overflow, a study has been initiated that will result in policies, technical criteria and guidelines to reduce flood risks that are acceptable to area interests and reflect the unique hydrologic conditions in the area. The study area includes upper Cypress Creek (upstream of Highway 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County have received a grant from the Texas Water Development Board to partially support this study effort. Three public meetings will be held during the course of developing the plan. See **www.hcfcd.org/cypresscreekoverflow** for further information.



Drainage Area	Watershed Population	Open Channels
267 square miles	347,334	250 miles

Active Capital Projects

In the past 20 years, the Harris County Flood Control District has spent more than nearly $33 million on capital projects in the Cypress Creek watershed. The completed capital projects include channel improvements along various tributaries, erosion repairs along Cypress Creek, home buyouts and floodplain preservation acquisitions and improvements to existing stormwater detention basins.

Voluntary Home Buyouts – Through voluntary home buyouts, the Flood Control District can purchase properties that are hopelessly deep in the floodplain, move the owners to higher ground and prevent future flood damages by removing structures from these properties. The Flood Control District has placed a major focus on voluntary home buyouts within the Cypress Creek watershed. Since 1985, the Flood Control District, acting alone and in various partnerships with the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (Corps) and Harris County, has acquired more than 300 flood-prone properties in the Cypress Creek watershed.

Cypress Park Basin Improvements – The Flood Control District is currently excavating a 50-acre stormwater detention basin at Cypress Park (K500-01-00). When complete, the basin will be able to store approximately 80 million gallons of stormwater to help reduce flooding risks and damages. The basin is located on the north bank of Cypress Creek near North Eldridge Parkway, adjacent to the Lake Estates on North Eldridge subdivision. The total design and construction cost for the basin is approximately $1.8 million, and construction is expected to be complete in early 2013.

K700-01-00-E001 – The project formally identified as K700-01-00-E001 will create and restore approximately 95 acres of native wetland habitat on the Katy Prairie near the intersection of Katy-Hockley and House Hahl roads. The area will serve to mitigate projects that will inevitably impact native wetlands, specifically the Greenhouse Stormwater Detention Basin on Langham Creek northwest of the FM 529 and Barker-Cypress Road intersection and the John Paul's Landing Stormwater Detention Basin on a Bear Creek tributary near the intersection of Katy-Hockley Cutoff and Sharp roads. The wetland project, which will include planting bog rush, swamp smartweed, duck potato, powdered thalia and maidencane, is expected to begin in late 2012 and be complete in mid-2013. The design and construction cost is approximately $350,000.

Routine and Completed Maintenance Projects

The Harris County Flood Control District oversees more than 2,500 miles (about the distance from Los Angeles to New York City) of bayous and creeks and routinely performs maintenance projects to repair bayous and stormwater detention basins that have experienced erosion, slope failure and sediment buildup. The Flood Control District also plants native grasses, wildflowers and trees to help reduce erosion and lower mowing costs along bayous and stormwater detention basins in the Cypress Creek watershed.

Mowing and vegetation maintenance – The Flood Control District performs routine cyclical maintenance, including mowing of land along bayous, creeks and stormwater detention basins in the Cypress Creek watershed. The Flood Control District also performs selective clearing of invasive trees and vegetation.

Tree and wildflower plantings – In the 2010 - 2011 planting season, the Flood Control District planted nearly 700 trees in the Cypress Creek watershed. Nuttall oak, green ash and southern magnolia are just a few of the tree species planted along the stormwater detention basin formally identified as K545-04-00. Along Cypress Creek, the Flood Control District planted bald cypress, loblolly pine and sycamore trees. The Flood Control District also planted several species of wildflowers, including showy primrose, Texas bluebonnet and bird's eyes, along Dry Gully, Faulkey Gully (K142-00-00) and a tributary formally identified as K131-03-00.

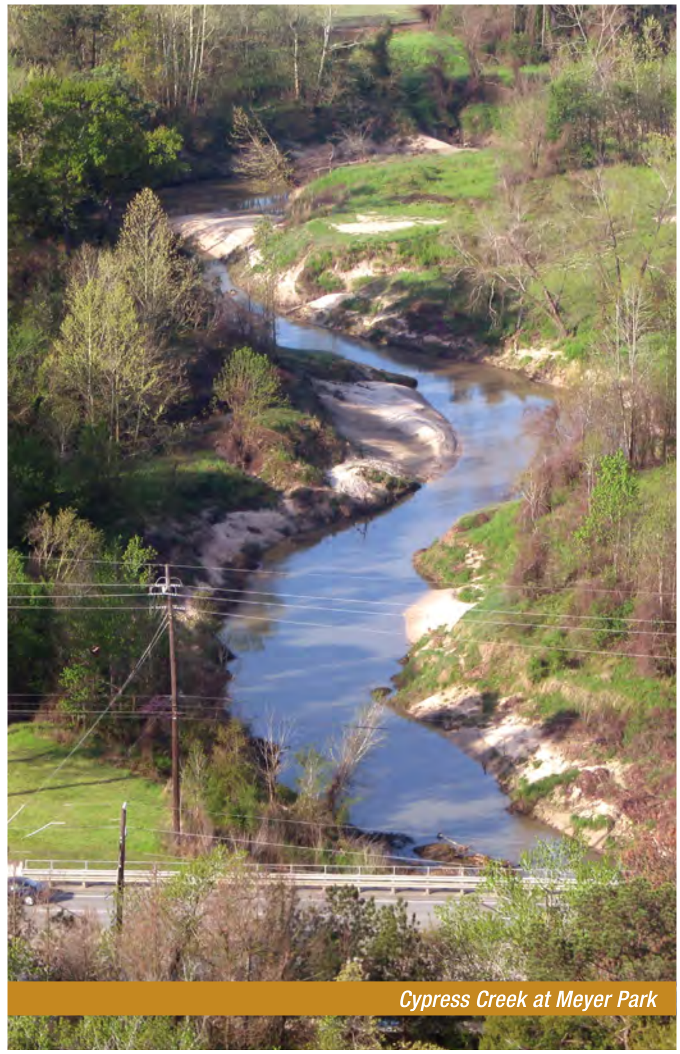
Cypress Creek Channel Restoration Project, Phase 1 – In early 2006, the Flood Control District began construction of a maintenance project to repair severe erosion along Cypress Creek near Champion Forest Drive to Stuebner-Airline Road. The first phase, formally identified as K100-00-00-X026, repaired erosion along a bend in the creek adjacent to Meyer Park, cost approximately $1.8 million and was completed in late 2006.

What We Do

The Harris County Flood Control District was initially created in 1937 to serve as a local partner to the U.S. Army Corps of Engineers to build projects that reduce flooding risks and damages from major bayous and creeks in Harris County. While the District still fulfills that role, its responsibilities and capabilities have expanded over the years. The mission of the Flood Control District is to provide flood damage reduction projects that work, with appropriate regard for community and natural values. The Flood Control District accomplishes its mission by devising flood damage reduction plans, implementing the plans and maintaining the infrastructure.

Active Maintenance Projects

Cypress Creek Channel Restoration Project, Phase 2 – This maintenance project, formally identified as K100-00-00-X028, is the second phase of the maintenance project to repair severe erosion along Cypress Creek near Champion Forest Drive to Stuebner-Airline Road. This phase spans Cypress Creek from Latson Road to Stuebner-Airline. In advance of this project, a Native American campsite was found along the banks. In accordance with state and federal laws, archeologists excavated portions of the area and recovered more than 2,000 artifacts, such as stone tools and pieces of pottery. Upon completion of the cultural resources investigation for this phase of the maintenance project, the Flood Control District was able to begin construction to repair the severe erosion within the project limits. Construction began in June 2012 and is expected to be complete in late 2013.



Cypress Creek at Meyer Park

*For more information about the Cypress Creek watershed, its studies and projects, or the Flood Control District, please visit our website at **www.hcfcd.org**. For more information on a particular study or project, please call the Harris County Flood Control District's Project and Study Information Line at (713) 684-4040.*

HARRIS COUNTY FLOOD CONTROL DISTRICT

Addicks Reservoir
Watershed

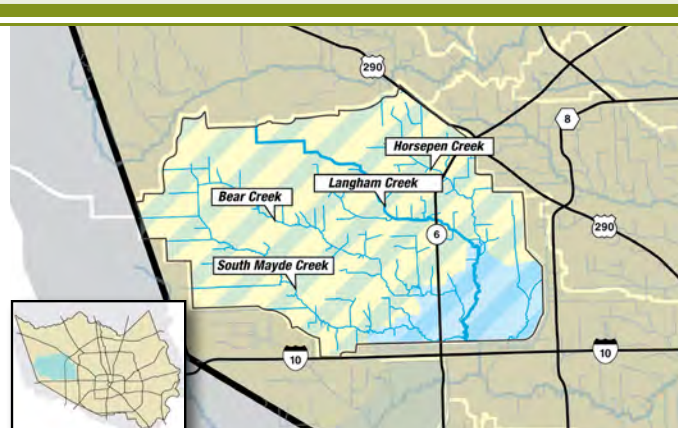
What is a watershed?

A watershed is a geographical region that drains to a common bayou, creek or other waterway.

Watershed Overview

The Addicks Reservoir watershed is located in west Harris County with a small portion crossing into eastern Waller County. Rainfall within the 138 square miles of the Addicks Reservoir watershed drains to the watershed's primary waterway, Langham Creek (U100-00-00). The Addicks Reservoir watershed occasionally receives a significant amount of natural stormwater overflow from the Cypress Creek watershed during heavy rainfall events. Stormwater runoff from this watershed eventually drains into Buffalo Bayou. Rural and agricultural uses have historically dominated the upstream regions of the watershed, but residential and commercial developments are rapidly growing. There are 159 miles of open waterways in the Addicks Reservoir watershed, including Langham Creek and its major tributaries, such as South Mayde Creek (U101-00-00), Bear Creek (U102-00-00) and Horsepen Creek (U106-00-00). Based on the 2010 U.S. Census, the estimated population of the Addicks Reservoir watershed is 295,694.

Together with Barker Reservoir, Addicks Reservoir was created as part of a federal project to reduce flooding risks along Buffalo Bayou, which runs through downtown Houston. The U.S. Army Corps of Engineers (the Corps) completed construction of Addicks Dam and the outlet facility in 1948. The Corps owns, operates and maintains the reservoir, including leases or permits for some compatible recreational uses within the basin. Operation of the outlet facilities controls the discharges from the reservoir into Langham Creek, then into Buffalo Bayou. Environmentally-sensitive areas exist within the reservoir boundaries and along the upper tributary reaches that extend into the Katy Prairie. These areas also include a wide range of wildlife habitats.



Active Studies

Addicks Reservoir Watershed Model and Map Update – The Addicks Reservoir Watershed Model and Map Update study will update the hydrologic (HEC-HMS) and hydraulic (HEC-RAS) computer models for the Addicks Reservoir watershed and produce revised Flood Insurance Rate Maps (FIRMs or floodplain maps) based on new information and technology. When this effort is complete, revised FIRMs for the Addicks Reservoir watershed will be produced based on 1-foot contour interval (rather than on 2-foot contour interval topographic maps) and based on 2008 Land Use data (rather than on 2001 Land Use data). The revised FIRMs will show flooding risks from the 1 percent (100-year) and 0.2 percent (500-year) floods. This study also will produce other map products as a result of the Harris County Flood Control District's participation in a Federal Emergency Management Agency (FEMA) pilot program called Risk MAP (Mapping, Assessment and Planning). This program is designed to form a solid foundation for risk assessment, floodplain management and actuarial soundness of the National Flood Insurance Program (NFIP). This study will focus on the "Mapping" component of the Risk MAP program and produce maps that show flooding risks from the 10 percent (10-year) and 2 percent (50-year) floods as well as the 1 percent (100-year) and 0.2 percent (500-year) floods. The maps will be made available to the public. Harris County is the first county in FEMA Region VI to participate in the Risk MAP program. The draft revised FIRMs are expected to be complete by February 2013. A public appeals and protests process will begin at that time.

Cypress Creek Overflow Management Plan – The Addicks Reservoir watershed occasionally receives a significant amount of natural stormwater overflow from the Cypress Creek watershed during heavy rainfall events. To understand and manage this overflow, a study has been initiated that will result in policies, technical criteria and guidelines to reduce flood risks that are acceptable to area interests and reflect the unique hydrologic conditions in the area. The study area includes upper Cypress Creek (upstream of Highway 290) and the drainage areas upstream of Addicks and Barker reservoirs, including Langham Creek, Bear Creek and South Mayde Creek. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County. The Flood Control District and Harris County have received a grant from the Texas Water Development Board to partially support this study effort. Three public meetings will be held during the course of developing the plan. See **www.hcfcd.org/cypresscreekoverflow** for further information.

Frontier Program – The Frontier Program is a way to accomplish an orderly drainage infrastructure in concert with future land development. Working in partnership with landowners, the Frontier Program identifies strategies unique to specific areas of the county that are distant from existing drainage infrastructure. These strategies will better mitigate increased stormwater runoff, offer opportunities to provide community amenities through development of recreation and open space areas and enhance or preserve the area's natural resources. Individual landowners and developers tend to adhere to site-specific approaches to development that result in isolated detention basins and minimum-width channels for stormwater management. In contrast to site-specific approaches, a regional plan facilitates construction of a channel corridor with wide flood benches, gentle side-slopes, storage volume within the corridor cross-section for mitigation of floodplain and development impact and outfall depth. The wider channel corridor in a regional approach allows for replacement of natural resource functions that would be lost and habitats that would be inadequate in a piecemeal site-specific approach.

Active Capital Projects

In the past 20 years, the Harris County Flood Control District has spent more than nearly $9 million on capital projects in the Addicks Reservoir watershed. The completed capital projects include channel improvements along Langham Creek and bypass channels on Bear, Langham and Horsepen creeks. Active capital projects include implementation of concepts from the Frontier program and excavation of stormwater detention basins.

Upper Langham Creek Frontier Program – The purpose of the Upper Langham Creek Frontier Program is to implement key elements, including right-of-way acquisition, pipeline adjustments, design and construction of control structures and environmental mitigation, of a regional drainage plan that embraces concepts from the Flood Control District's Frontier Program and uses funding from development impact fees. The plan includes a 700-foot wide stream corridor and its floodplain along with two detention basins. Excavation of the corridor and basins will be conducted by property owners, primarily developers, as their properties are improved or developed. This project was authorized by the Harris County Commissioners Court in January 2009 and will advance in phases.

Stormwater Detention Basin at John Paul's Landing Park – The Flood Control District is supporting Harris County Precinct 3 efforts to develop a regional park and stormwater detention basin within John Paul's Landing Park (U502-02-00), which is located in the Upper Bear Creek and Upper Langham Creek area. While the Flood Control District completes a wetlands mitigation project in support of this project, the stormwater detention basin is being excavated through an excavation and removal agreement. In 2011, the contractor removed over 100,000 cubic yards of soil from this site and plans to remove up to 1.5 million cubic yards in 2012.

U506-05-00 Detention Basin Improvements Project – The U506-05-00 Detention Basin Improvements Project is the final phase of construction of a 150-acre stormwater detention basin, commonly known as the Upper Horsepen Creek Stormwater Detention Basin, near the intersection of Barker-Cypress and West roads in northwest Harris County. The project includes constructing a weir structure, which controls the timing and amount of stormwater that flows into a detention basin, and significant regrading of the detention basin's slopes. After the weir structure is complete, rising stormwater in Horsepen Creek will flow into the detention basin, where it will be temporarily stored during times of heavy rain. The majority of the detention basin has already been excavated. After this final phase of construction, the detention basin will have the capacity to detain approximately 360 million gallons of stormwater and will help reduce flooding risks for those who live downstream along the creek's banks. Construction on this $1.36 million project began in February 2012 and is expected to be complete in late fall 2012.

K700-01-00-E001 – The project formally identified as K700-01-00-E001 will create and restore approximately 95 acres of native wetland habitat on the Katy Prairie near the intersection of Katy-Hockley and House Hahl roads. The area will serve to mitigate projects that will inevitably impact native wetlands, specifically the Greenhouse Stormwater Detention Basin on Langham Creek (U100-00-00), northwest of the FM 529 and Barker-Cypress Road intersection in the Addicks Reservoir watershed, and the John Paul's Landing Stormwater Detention Basin on a Bear Creek tributary, near the intersection of Katy-Hockley Cutoff and Sharp roads. The wetland project, which will include planting bog rush, swamp smartweed, duck potato, powdered thalia and maidencane, is expected to begin in late 2012 and be complete in mid-2013. The design and construction cost is approximately $350,000.

Routine and Completed Maintenance Projects

The Harris County Flood Control District oversees more than 2,500 miles (about the distance from Los Angeles to New York City) of bayous and creeks and routinely performs maintenance projects to repair bayous and stormwater detention basins that have experienced erosion, slope failure and sediment buildup. The Flood Control District also plants native grasses, wildflowers and trees to help reduce erosion and lower mowing costs along bayous and stormwater detention basins in the Addicks Reservoir watershed.

Mowing and vegetation maintenance – The Flood Control District performs routine cyclical maintenance, including mowing of land along bayous, creeks and stormwater detention basins in the Addicks Reservoir watershed. The Flood Control District also performs selective clearing of invasive trees and vegetation.

Tree and wildflower plantings – Cedar elm, loblolly pine and red maple are just a few of the tree species that were planted along two stormwater detention basins and a tributary identified as U119-00-00 in 2011. Along Langham Creek and U119-00-00, the Flood Control District planted several species of wildflowers, such as clasping coneflower, drummond phlox, Indian blanket and lance-leaf coreopsis in 2008 and 2011.

South Mayde Creek Channel Restoration Project – In 2009, the Flood Control District completed a two-phase maintenance project along South Mayde Creek from Greenhouse Road to Clay Road. The project repaired eroded side slopes along approximately 4 miles of the creek. Each phase of this maintenance project cost approximately $1.4 million.

Active Maintenance Projects

Horsepen Creek Maintenance Project – This maintenance project, formally identified as U106-00-00-X024, will remove accumulated sediment along a 3.25-mile section of Horsepen Creek from State Highway 6 downstream to the Addicks Reservoir. The project will also address spot erosion and pipe repairs along sections of the creek's side slopes to help reduce the amount of eroded soil that falls into Horsepen Creek. The project cost is estimated to be approximately $1.4 million. Construction began in late August 2011 and is expected to be complete in late fall 2012.

What We Do

The Harris County Flood Control District was initially created in 1937 to serve as a local partner to the U.S. Army Corps of Engineers to build projects that reduce flooding risks and damages from major bayous and creeks in Harris County. While the District still fulfills that role, its responsibilities and capabilities have expanded over the years. The mission of the Flood Control District is to provide flood damage reduction projects that work, with appropriate regard for community and natural values. The Flood Control District accomplishes its mission by devising flood damage reduction plans, implementing the plans and maintaining the infrastructure.

*For more information about the Addicks Reservoir watershed, its studies and projects, or the Flood Control District, please visit our website at **www.hcfcd.org**. For more information on a particular study or project, please call the Harris County Flood Control District's Project and Study Information Line at (713) 684-4040.*

US Army Corps
of Engineers ®
Galveston District

Fact Sheet

2000 Fort Point Rd
Galveston, Texas 77550
(409) 766-3004
swgpao@usace.army.mil

ADDICKS AND BARKER RESERVOIRS & DAMS

Addicks and Barker dams were authorized by the 1939 Flood Control Act, a modification of the 1938 River and Harbor Act, House Document No. 456, 75th Congress, 2nd Session, authorized flood control work in the Buffalo Bayou watershed.

Addicks Dam
Construction started in May of 1946
Completed in December of 1948
Earthen dam embankment, 61,166 feet long
Watershed – 136 square miles
Outlet structure - 5 conduits 8 feet high by 6 feet wide 252 feet long
Maximum release – 7,852 cubic feet per second (cfs)
High Point of Dam – 121.0 feet NAVD 1988
Natural Ground ends of Dam – North end 108.0 feet & West end 112.0 feet, NAVD1988
Approximate Boundary Gov't-owned land – 103.0 feet NAVD 1988
Record Pool March 1992 – 97.46 feet NAVD 1988
April 27-28, 2009 Flood (Second Highest Pool) – 96.9 feet NAVD 1988
Approx. shoulder elevation of State Hwy 6 – 96.0 feet NAVD 1988
Outlet Structure Invert – 67.5 feet NAVD 1988

Barker Dam
Construction started in February of 1942
Completed in February of 1945
Earthen dam embankment 71,900 feet long
Watershed – 130 square miles
Outlet structure – 5 conduits - 9 feet high by 7 feet wide 190 feet long
Maximum release – 8,734 cubic feet per second
High Point of Dam – 113.1 feet NAVD 1988
Natural Ground both ends of Dam – 104.0 feet NAVD1988
Approximate Boundary Gov't-owned land – 95.0 feet NAVD 1988
Record Pool March 1992 – 93.60 feet NAVD 1988
Approx. shoulder elevation of Westheimer Parkway – 93.21 feet NAVD 1988
April 27-28, 2009 Flood (Seventh Highest Pool) – 91.21 feet NAVD 1988
Outlet Structure Invert – 70.2 feet NAVD 1988

-MORE-

IMPROVEMENTS

Initially dams designed with four of 5 conduits uncontrolled for a maximum unregulated discharge of about 15,000 cfs.

Upon completion of Addicks Dam, two additional conduits of the four remaining uncontrolled conduits had been gated on each dam limiting flows to 7,900 cfs.

Rectification and enlargement of approximately 7.4 miles of the Buffalo Bayou channel immediately downstream of the dams (to West Belt) was completed in 1948.

Flood Control Act of 1954 authorized channel rectification of Buffalo Bayou but emphasis was placed on White Oak & Brays since reservoirs were in place.

Gating of the remaining uncontrolled conduits was completed in 1963 with releases limited to 4,000 cfs with a controlled increase to 6,000 cfs or until damages were noted.

Channelization of Buffalo Bayou in the mid 1960's, was delayed by public opposition concerned with aesthetic and environmental effect on existing stream.

Revisions to flood control releases were made in the early 1970's reducing regulated releases to 2,000 cfs at the Piney Point gage, which includes the local inflow downstream.

In February of 1976, Harris County Flood Control excavated Turkey Creek downstream of Addicks Dam; seepage was noticed with sand boils at the next high pool.

In September of 1977 the 1st of several contracts for seepage control was initiated Installation of a soil bentonite slurry trench, downstream berms and other repairs were completed in 1982.

In the mid 1980's, main portions of Addicks and Barker Dams were raised to provide the freeboard necessary to meet dam safety criteria and protect the lower ends of the dams with roller compacted concrete.

Dam safety operations were completed in 1989. Raising the main embankments above Spillway Design Flood and armoring the lower ends of the dams did NOT increase the storage capacity of the reservoirs.

The outlet structures on Addicks and Barker Dams were overhauled in 1998 and 1999, included electrical improvements, gate repairs, one new gate for each outlet structure, service bridge and original gate tower raised at Barker, complete paint restoration, the work platform areas renovated to meet safety and security recommendations.

7 HCFCD Website

7.1 Screen shot of the Cypress Creek Overflow Management Plan webpage at http://www.hcfcd.org/cypresscreekoverflow/

Harris County Flood Control District contact us | search:

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- Capital Improvement Program
- BMPbase - Regional BMP Database
- Floodplain Reference Marks Tool
- LOMR Delegation Program
- Major Projects
- **Major Studies**
  - Charting Buffalo
  - **Cypress Creek Overflow**
  - Halls Ahead
  - Hunting Federal Study
  - White Oak Federal Study
- Geographic Information Systems
- Greens Bayou Wetlands Mitigation Bank
- Model and Map Management System
- Property Acquisition
- Property Management
- Stormwater Quality
- Trails and Our Bayous
- Tree Planting Program
- TS-Allison Recovery Project
- Vegetation Management
- Watershed Environmental Baseline Program

Cypress Creek Overflow Management Plan

Study Area

The study area includes the Cypress Creek watershed upstream of US 290, the watersheds draining into Addicks Reservoir, and that portion of the drainage area (including the Cypress overflow) draining into Barker Reservoir that flows through Harris County. Approximately 60 square miles of the upper Cypress Creek watershed originate in Waller County and drain into Harris County.

Addicks and Barker reservoirs were constructed in the 1940's to protect downtown Houston from severe rainfalls that occur on the Buffalo Bayou watershed. The capacity of the reservoirs anticipated an overflow from Cypress Creek. However, no defined drainage systems were planned other than the natural tributary systems. These natural tributary systems include Langham Creek, Bear Creek, and South Mayde Creek.

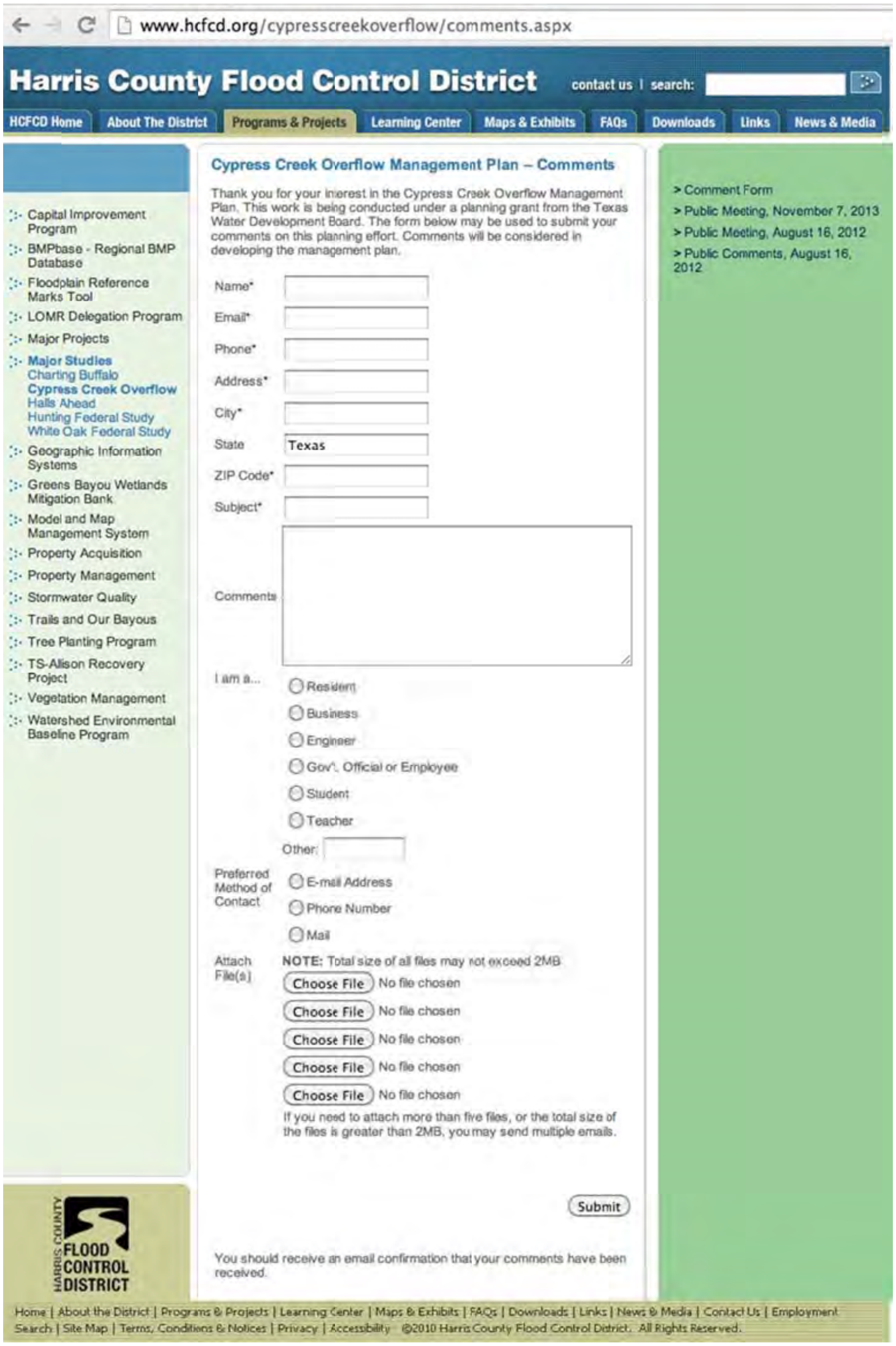
Note: The portion of Cypress Creek downstream of US 290 is not in the study area.

Background

Western and northwestern Harris County is anticipated to experience a surge of land development activities in the near future. According to Region H Regional Water Planning studies, the population of the study area, currently about 340,000, is anticipated to nearly double in the next

- > Comment Form
- > Draft Study Report
- > Public Meeting, September 25, 2014
- > Public Meeting, November 7, 2013
- > Public Meeting, August 16, 2012
- > Public Comments, August 16, 2012

7.2 Form for submitting comments to HCFCD via email at www.hcfcd.org/cypresscreekoverflow


www.hcfcd.org/cypresscreekoverflow/comments.aspx

Harris County Flood Control District

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- Vegetation Management
- Watershed Environmental Baseline Program

HARRIS COUNTY FLOOD CONTROL DISTRICT

Cypress Creek Overflow Management Plan – Comments

Thank you for your interest in the Cypress Creek Overflow Management Plan. This work is being conducted under a planning grant from the Texas Water Development Board. The form below may be used to submit your comments on this planning effort. Comments will be considered in developing the management plan.

Name*

Email*

Phone*

Address*

City*

State: Texas

ZIP Code*

Subject*

Comments

I am a...
- Resident
- Business
- Engineer
- Gov't. Official or Employee
- Student
- Teacher

Other:

Preferred Method of Contact
- E-mail Address
- Phone Number
- Mail

Attach File(s)

NOTE: Total size of all files may not exceed 2MB

Choose File No file chosen

Choose File No file chosen

Choose File No file chosen

Choose File No file chosen

Choose File No file chosen

If you need to attach more than five files, or the total size of the files is greater than 2MB, you may send multiple emails.

Submit

You should receive an email confirmation that your comments have been received.

> Comment Form
> Public Meeting, November 7, 2013
> Public Meeting, August 16, 2012
> Public Comments, August 16, 2012

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8 Draft Report Comments from the Texas Water Development Board for the Cypress Creek Overflow Management Plan

Texas Water Development Board

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

June 16, 2015

The Honorable Ed Emmett
Harris County Judge
9900 NW Freeway
Houston, Texas 77092

RE: Flood Protection Planning Grant Contract between the Texas Water Development Board (TWDB) and Harris County Flood Control District (HCFCD); TWDB Contract No. 1248321466, Draft Report Comments for Cypress Creek Overflow Management Plan

Dear Judge Emmett:

Staff members of the TWDB have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. As stated in the TWDB contract, the HCFCD will consider revising the final report in response to comments from the Executive Administrator and other reviewers. In addition, the HCFCD will include a copy of the Executive Administrator's draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit http://www.sos.state.tx.us/tac/index.shtml.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov

The HCFCD shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Gilbert Ward, the TWDB's designated Contract Manager for this project at (512) 936-3550.

Sincerely,

Edna Jackson
Deputy Executive Administrator
Operations & Administration

Enclosures

c: Gilbert Ward, TWDB

ATTACHMENT I

Review of Draft Report of Contract No. 1248321466

Harris County Flood Control District Cypress Creek Overflow Management Plan

1. Please perform a final edit for typos, grammar, and inconsistent usage of (or undefined) acronyms and abbreviations. However, please do not rely on Spell-check.
2. Section 2.1, last sentence of second paragraph (page 9); there appears to be words left out or sentence is incorrectly worded. Please amend.
3. Page 58, 2nd paragraph; B1 and B2 should be D1 and D2. Please amend.
4. Appendix A, page 22, Exhibit A3.2; the green line should be depicted as 10% overflow. Please amend.
5. The study follows standard methodologies and practice utilizing acceptable HEC modeling in the engineering aspects of hydrologic and hydraulic techniques. The modeling parameters were determined based on the calculations and engineering judgments for the various conditions. Mitigation alternatives identified by the study are eligible for funding under the Board's financial assistance programs. Application requirements and eligibility criteria is identified by Board rules specified in Section 363 of the Texas Administrative Code. The report would be appropriate for use in support of an application to the Board for financing the proposed improvements. All additional information required by Board rules, 31 TAC 363.401-404, as well as necessary information to make legal findings as required by Texas Water Code Chapter 17.771-776, would be required at the time of loan application.

Appendix I

Study of Rainfall-Runoff-Infiltration Rates on Developed, Native Prairie, and Open Space Land Cover Types

August 18, 2015

Table of Contents

Supplements

1.0 Introduction

A monitoring study was implemented to provide intensive collection of rainfall and runoff data on three land cover types for an initial period of one year, with the potential for an additional five years of data collection, subject to the availability and certification of funds. The data will be used to incorporate specific land cover type values and variables into flood control planning elements such as advanced computer modeling and infrastructure design.

1.1 Objectives

Variations in land cover type and their associated variability in vegetation composition and soil characteristics are hypothesized to have a corresponding effect on volumetric storage and discharge capacities in response to storm event runoff. A greater amount and density of groundcover vegetation, increased depth and density of plant roots, and higher percentage of soil pore spaces are thought to positively influence the ability of native prairie land cover type to absorb greater amounts of runoff from a rainfall event. The hypothesis that the native prairie land cover type will provide greater flood control benefits when compared to open space and developed land cover types was tested by conducting a rainfall and runoff analysis of each land cover type.

To conduct the rainfall and runoff analyses, specialized monitoring stations at each site were used to record rainfall and water levels. Appurtenant devices were required to provide electrical power, both send collected data and receive configuration information remotely, house the electronic components in a dry compartment, and mount the final equipment configuration. Each study site required assessment to install the monitoring station adjacent to a point of discharge such as storm sewer or culvert pipe.

A critical requirement of this study was the ability to allow for remote data collection. Consequently, an electronic modem was selected to provide each remote monitoring station the capability of receiving configuration information as well as sending data records. Water level data were collected in 15-second, one minute, hourly, and daily increments to allow for varying data reporting and analytical accuracy.

As data are collected for rainfall, depth of water within a storm sewer or culvert, and the depth of water in an adjacent shallow groundwater well, several analytical evaluations may be possible: determination of runoff and storage volumes; initial abstraction (Ia); time of concentration (Tc); time to peak (Tp); and, antecedent moisture condition (AMC). While the calculation of these analytical values may be achieved, as provided herein, the calculations related to storage and runoff volumes for each distinct land cover type were the focal parameters for this specific research topic.

The collected data was analyzed to evaluate and identify if variation in storage and runoff volumes occur in relation to land cover type activities. Variable storm event data was evaluated (i.e. less than 1-inch rainfall event, greater than 1-inch rainfall event, etc.) to identify probable differences in storage and runoff between the three identified land cover types.

1.2 Applied Prairie Restoration

While it is recognized that the remaining prairie habitats in the Harris County area represent only a fraction of their historic range (Forbes et al., 2010), the restoration of these areas, where available and appropriate, may also provide a benefit for flood storage. Native grasslands are effective in providing benefits for human aspects by increasing flood flow attenuation, erosion control, wildlife habitat, water filtration, and soil formation (Thigpen et al., 2012).

Presently, much of the scientific investigation and literature development for prairie restoration is focused on the mechanical implementation of modifying existing non-native and former prairie lands to a more native coastal prairie vegetation structure (Thurow et al., 1986), or to the benefits of wildlife (Dillard, 2000). Little quantitative data have been collected and evaluated to describe the effectiveness of prairies for flood storage (Forbes et al. 2010).

However, research has been conducted regarding several of the important physical factors relating to runoff characteristics, such as infiltration, and rates of runoff from various types of prairie rangelands. From a flood control perspective, many of the rainfall events are comprised of smaller total rainfall amounts, whereas, the less frequent significant rainfall events would be more associated with larger volumes of surface water runoff (Welch et al., 1991). It is these events that most closely correlate to the importance of collecting and attenuating flood events. Prairie restoration may provide increased watershed and flood control improvements, since it has been documented that the extensive root systems for bunchgrasses increase the water holding capacity of the soil, slow runoff, reduce erosion, and promote groundwater recharge by increasing the efficiency of water infiltration (Thigpen, et al., 2012).

The type of organic cover has been found to be less important than the amount of overlying vegetation (Thurow et al., 1986). Additionally, the increase in organic biomass of the upper soil layers as detritus builds up, results in a desirable ecological cycle where microbial activity is increased, soil aggregate stability is provided, plant nutrient availability is enhanced, and plant growth is thereby stimulated (Teague et al., 2011). These circumstances provide for better soil stability, increase soil pore availability for infiltration, and decrease erosive forces (Thurow et al., 1986).

Root systems of prairie grasses (i.e. bunchgrasses) create and maintain soil pore openings, where surface water can enter the soil more easily than for sod grasses or developed land uses. By providing a deep root system, perennial grasses, such as bunchgrasses, afford more efficient infiltration rates than shorter root turf grasses (Exhibit 5.1) (Welch et al., 1991) (McGinty et al., 1995). Also, the average time of concentration values within a restored prairie are extended and thereby contribute to flood peak discharge decreases and floods downstream (Gerla, 2011). It is these characteristics that may provide flood control hydrologists with a potential source of storage for larger storm events.

Further studies sought to determine the impact of agriculture activity on the water infiltration ability of soils, and the impact of prairie vegetation was analyzed primarily to provide a comparison (Bharati et al., 2002, Fuentes 2003). However both studies support the concept that native prairie vegetation contributes to the infiltrative capacity of the soil. Furthermore, this contribution is most significant for poorly draining soils. Bharati et al. 2002 found the infiltration rate was increased by a factor between five and ten, while Fuentes 2003 concluded the impact was on “order of magnitude.” In addition, the USGS performed a study of drainage behavior in rain gardens, and found rain gardens clay soils behaved as if they had sandy soil when native prairie vegetation is installed.

1.3 Study Area Description

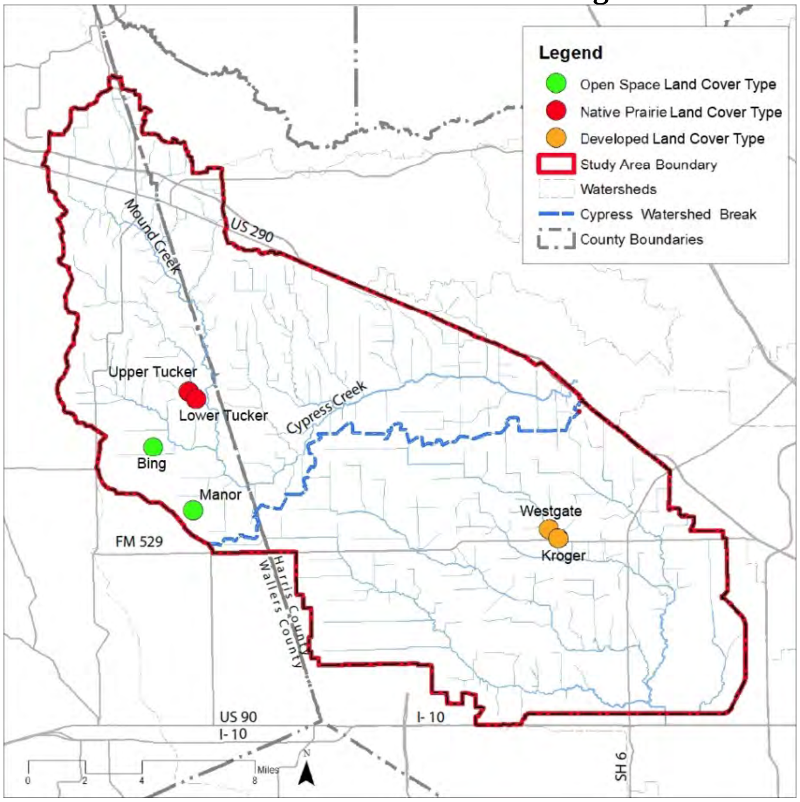
Data related to storm events, such as rainfall and runoff effects, was gathered on three varying land cover types: 1) open space; 2) native prairie; and, 3) developed (Supplement I1). Open space land cover type was defined as areas where fallow agriculture/rice crop production has been replaced by cattle grazing, or remains fallow. Native prairie land cover type was defined as areas where prairie habitat restoration or preservation has been performed. Developed land cover type was defined as areas containing significant impervious surfaces such as roadways, housing, and commercial properties.

Initial study activities included the identification of two representative monitoring sites for each land cover type (Exhibit I1.1). Following aerial photographic review of candidate sites using Geographical Information Systems (GIS) software, field reconnaissance was conducted to verify photographic signatures and to confirm the sites to be incorporated into the study. As a result, a total of six sites were confirmed.

The open space land cover type was comprised of two sites referred to as Bing and Manor, which are currently used for cattle grazing and have been previously used for agricultural/rice production (Supplement I2). The vegetation on these sites includes ruderal native herbaceous species, with forage grasses such as coastal bermudagrass. From site reconnaissance, the current land management activities may include periodic mowing; however, the frequency of mowing could not be determined. The average amount herbaceous ground cover was measured at approximately 85% absolute cover over bare soil. Soils are defined as sandy loam, and were compacted as a probable result of agricultural rice production activities (Supplement I5).

The native prairie land cover type was comprised of two sites referred to as Upper Tucker and Lower Tucker (Supplement I2). These sites are located within an area currently under conservation easement on private lands, and managed by the Katy Prairie Conservancy. While cattle are allowed to forage within these sites, land management techniques such as prescribed fire and occasional mowing have resulted in the establishment and maintenance of a native prairie plant species composition. Herbaceous vegetation covers approximately 97% of the ground space, and consists of native prairie species such as bunch grasses. Soils within these sites were identified as sandy loam, with a relatively compacted structure; however, notably less dense than that of the Bing and Manor sites (Supplement I5).

Exhibit I1.1: Rainfall and Runoff Monitoring Site Locations



Developed land cover type was chosen from a commercial property (referred to as Kroger), and a residential development (referred to as Westgate) were selected to represent the developed land cover type (Supplement I2). Since the probable development of the study area would include a predominance of commercial and residential land cover types, a representative example of each was integrated into the study. Vegetation was dominated by sod grasses such as St. Augustin grass, while soils were classified as sandy loam and sandy clay loam. Soil profiles indicated homogenization – typical of development sites where soils are disturbed and mixed during site preparation activities (Supplement I5).

On-site identification and quantification of vegetation species was conducted for each site. In addition, soil types as provided by the Natural Resources Conservation Service (NRCS) database were sampled in the field to verify soil descriptions, and the probable presence and corroboration with NRCS data. To describe each land cover type, and to establish a basis for evaluating the differences in vegetation and soils for each land cover type, three sampling locations were provided per soil type occurrence on each site. Sampling locations consisted of a 10-meter diameter circle divided into quadrants, and plant species located within the quadrants were identified and quantified to describe the vegetation characteristics of each land cover type. Significant differences in structure, speciation, and/or diversity were expected when comparing the three different land cover types. A six class, modified Daubenmire method was used for data gathering, and resulted in the characterization of percent bare ground/litter, percent vegetation cover, species identification and diversity, and individual species densities (Supplement I5). Soil core samples were collected to approximately 18-24 inches in depth. Soils were identified by visual chroma analysis (using the Munsell Color System), seasonal high water level estimates where practical, and particles described by granular coarseness, friability, etc. (Supplement I5).

Table I1.1: Monitoring Sites and Approximate Drainage Basin Areas

Land Cover Type	Station Designation	Drainage Basin Area (acres)	Approximate Location (dd)
Open Space	Bing	16	29° 55.71 N 95° 55.49 W
Open Space	Manor	19	29° 53.78 N 95° 54.07 W
Native Prairie	Upper Tucker	47	29° 57.41 N 95° 54.21 W
Native Prairie	Lower Tucker	18	29° 57.18 N 95° 53.95 W
Developed (Residential)	Westgate	18	29° 53.12 N 95° 41.46 W
Developed (Commercial)	Kroger	40	29° 52.82 N 95° 41.18 W

2.0 Monitoring Station Equipment

The following is a summary list of general equipment components that were assembled to collect, record, and transfer rainfall and runoff data:

- Rain Gauge;
- Water Sensor (water presence detector);
- Bubbler (water depth detector);
- Well Sleeve (slotted);
- Pressure Transducer (water depth detector);
- Modem;
- Weatherproof Enclosure (electronic device storage);
- Solar Panel;
- Data Logger

Exhibit I2.1: Schematic of Monitoring Station

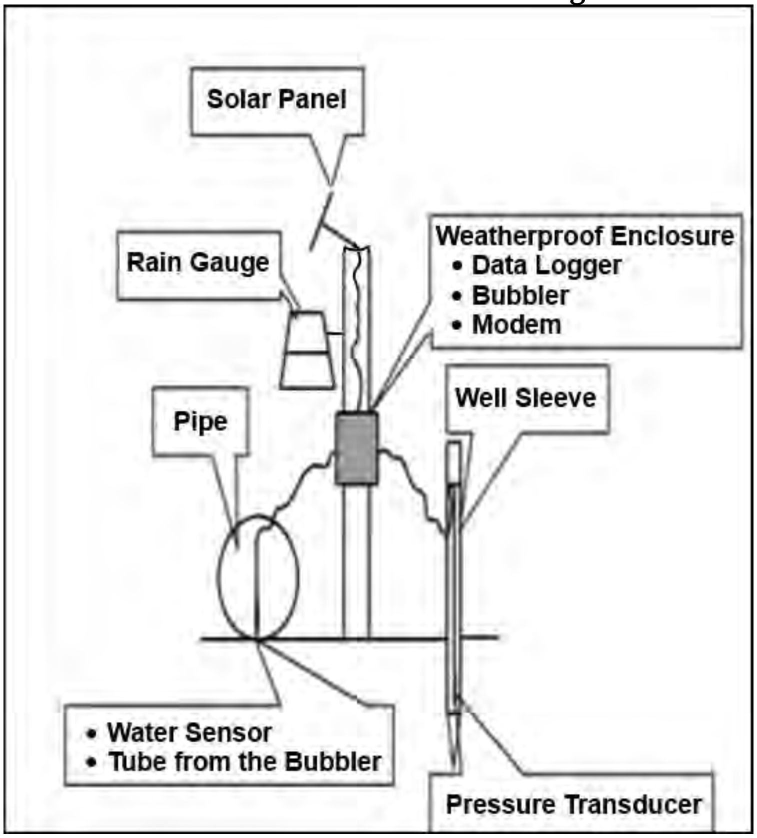


Exhibit I2.2: Photograph of Monitoring Station (Bing site)

At each site, a pipe (i.e. storm sewer/culvert) was available to measure the occurrence, timing, and depth of runoff within the pipe at the point of discharge from the site. With the exception of the two developed sites (Kroger and Westgate), each site was provided with a complete equipment configuration as identified herein. Due to the impervious condition of its land cover type, and the presence of infiltration and inflow in the conveyance infrastructure, shallow groundwater wells and water sensor devices were not required for the two developed sites.

Rainfall data collection includes the use of a tipping bucket rain gauge, where each 0.01-inch of rainfall results in the reception device “tipping” to release the collected rainfall, and creating a data point which is transmitted to the data storage device within the weatherproof enclosure.

As excess rainfall begins to enter the point of discharge at the storm sewer/culvert, a water sensor detects the initial presence of water, and transfers a signal to the data storage device. As the water level within the pipe increases, a bubbler device detects the depth of water by interpreting the pressure required to discharge a pulse (i.e. “bubble”) of air from the tubing. These data are transferred to the data storage device in various intervals as provided herein.

Shallow groundwater wells (approximately 24 inches in depth) at the open space and native prairie sites were provided with a pressure transducer placed at the bottom of the slotted well sleeve. The pressure transducer recorded the level of water within the groundwater well between and during storm events. These data may be used for evaluating AMC characteristics as well as soil pour space recovery following rainfall events.

All collected data are stored in a cellular modem mounted inside the weatherproof enclosure. The modem is capable of sending data, providing alerts that rainfall is occurring at a given site, and receiving configuration instructions for the equipment array.

Power for the equipment was provided by a solar panel mounted to the mounting pole, which charged a battery housed in the weatherproof enclosure.

Using the LOGGERNET® data logger software (Campbell Scientific, Inc.), data collection can be processed remotely, and uploaded from the equipment array for assessment and evaluation. The software provided digital files in formats that can readily be used on a variety of operating systems.

2.1 Installation

Locations for the installation of each monitoring station were determined by several factors: proximity to the pipe; proximity to the shallow groundwater well; landward of probable areas of inundation; accessibility; and, safety from cattle damage – where applicable.

Following the in-ground placement of the mounting pole (including a concrete annulus), each piece of equipment was either attached to the mounting pole (solar panel, rain gauge, and weatherproof enclosure), installed within the pipe (water sensor and bubbler tube), or within the adjacent shallow groundwater well (pressure transducer) a qualified professional (Exhibit I2.1, Exhibit I2.2).

Within the weatherproof enclosure, each electronic data device was connected to a central communications board using instructions provided by the products vendor. The bubbler device was also provided with an in-line desiccant to remove moisture that may condense on the inside of the tubing, and may lead to inaccurate data collection.

The elevation for each point of discharge (upstream and downstream) from the associated site was provided, along with the diameter and material of the pipe. Survey data also included the ground elevation adjacent to each shallow groundwater well, as well as elevation transects near the point of discharge. These data were incorporated into equations for analysis of runoff volumes and timing. The diameter, material, length, and slope of pipes were used to generate volumetric and flow velocity calculations (Table I3.1).

3.0 Data Intention

The primary use for the collected data was to evaluate and compare the amount and timing of runoff volumes produced by varying storm event intensities between each land cover type. To accomplish this, the equipment described herein was identified and installed to measure rainfall amounts and intensities at each study site, while other equipment components would collect data regarding the timing and volume of excess rainfall produced.

Both the timing and volume of runoff are important data parameters to collect, since the evaluation of their associated values could provide for the development of regionally-specific design variables to be incorporated into regional flood control assessments and modeling activities. Rainfall data may be valuable by establishing regionally-specific hyetographs for varying storms, and possibly seasonality distinctions. Timing data may result in identifying time of concentration (Tc), time of travel (Tt), and runoff hyetographs for specific land cover type conditions. Depth of groundwater preceding a rainfall event may define AMC conditions and responses for various land cover types, while post-rainfall groundwater response may provide for storage recovery estimates.

Timing and depth within point of discharge pipes would allow for the calculation of storage/absorption and runoff variables, and to identify differences in these parameters that may be attributable to varying land cover type conditions. These data and their associated analytical calculations are critical components of identifying and incorporating regionally-specific values into computer modeling analyses, and developing design elements for flood damage reduction projects.

3.1 Calculation Methodology

Elevation data (i.e. topographic data) for each study site was acquired from available Light Detection and Ranging (LiDAR) data sources, and evaluated to establish approximate preliminary drainage basin boundaries, where excess rainfall would accumulate and runoff would be conveyed to the point of discharge. Subsequent field reconnaissance verified and amended preliminary drainage basin boundaries. The field activities were conducted to assess ground-specific conditions not detectable by LiDAR technology, and to locate the point of discharge for each site.

Following the ground-truthing of each site, drainage basin boundary areas were placed into GIS software to calculate the probable flow path for each drainage basin. As a result, the volume of rainfall received at each drainage basin was calculated by multiplying the amount of rainfall reported during a specific storm event, converted from inches to feet, by the drainage basin area in square feet. This calculation produced the volume of rainfall in cubic feet.

To calculate the amount of excess rainfall discharged from each study site, data collected from the pipe was used. Since the rainfall and runoff configuration equipment collects and reports the depth of water in a pipe, data report files were used to calculate the time-depth relationship. By recording the specific pipe diameter, material, length, and slope of each point of discharge (derived from site-specific survey) (Table I3.1), a mathematical relationship between the depth of flow within a pipe to flow volume was developed (assuming free flow in the pipe and the absence of tailwater restrictions).

Once the depth-to-volume relationship was resolved, an equation was established that was integrated into a logic statement, whereby each datum point was reported as an individual volume for the period during which the datum was collected. The resulting points of datum were then added together, and graphed to produce a rainfall/runoff hydrograph, to evaluate the amount of excess rainfall produced at each study site during a specific storm event.

To calculate the amount of storage provided by each land cover type for a given storm event, the volume of runoff was subtracted from the calculated volume of rainfall received within the drainage basin. This calculation represented the amount of rainfall that was intercepted by vegetation, collected within depressional areas, and/or stored within organic litter or soil infiltration.

Table I3.1: Conveyance description at each site

Land Cover Type	Station Designation	Conveyance Information				Receiving Water Body
		Pipe Diameter (in.)	Material	Invert Elevation		
				Upstream	Downstream	
Open Space	Bing	30	CMP	184.46	183.83	Field Ditch Conveyance
	Manor	18	HDPE	180.35	180.23	Field Ditch Conveyance
Native Prairie	Upper Tucker	18	HDPE	184.88	184.47	Field Ditch Conveyance
	Lower Tucker	12	Iron	182.55	182.23	Field Ditch Conveyance
Developed	Westgate	60	RCP	-	118.23	Langham Creek
	Kroger	24	RCP	ND	ND	Langham Creek

CMP = Corrugated Metal Pipe
HDPE = High Density Polyethylene Pipe
RCP = Reinforced Concrete Pipe
ND = No Data Available

Since varying storm events (i.e. small (<0.2 inches), medium (<1.0 inches), and significant (>1.0 inches) rainfall events) may result in different runoff/storage characteristics for each land cover type, as well as comparative evaluations between various land cover types, analysis of rainfall/runoff data were relative to the intensity and volume of a given storm event. Smaller storm events are expected to provide greater storage when compared to more significant storm events, since the storage volume for each drainage basin is a physical, and non-variable, characteristic and not altered by rainfall volumes.

During site-specific field activities, survey data were collected using cross section transects adjacent to point of discharge and equipment configuration locations for the open space and native prairie sites (developed sites have their points of discharge within the storm sewer). These data included elevations along the top of earthen berm/roadway, perpendicular to conveyance flow paths, where the structure(s) occur as a physical barrier – providing volumetric storage. As a result, an elevation profile was established. In addition, should a significant storm event result in the overflow of available storage, the berm/roadway would serve as an irregular weir, where the surface water depth, as measured either within the shallow groundwater well or from bubbler data, would be used to calculate the depth of water flowing over the weir. These data can be incorporated into the specific irregular weir equation, and then integrated into the site-specific discharge equation methodology provided herein.

3.1.1 Rainfall and Runoff Measurements

The analysis provided herein is intended to evaluate recorded data at each monitoring location in relation to various rainfall and runoff parameters commonly incorporated in calculating storm event characteristics. Each data set was analyzed to produce recorded field data calculations in comparison to published parameters regularly used to determine rainfall and runoff estimations (e.g. TR-55 Manual techniques).

Following the collection of rainfall and runoff data for the initial year of study, an analysis of rainfall and runoff related parameters were performed. Since six different monitoring stations were installed, data have been collected for the majority of Year 2013. A variety of storm intensities and cumulative rainfall amounts were recorded for each station. Although at times a few stations may not have properly functioned throughout the year, there may be enough data available to evaluate common rainfall and runoff parameters, and compare these with published and commonly incorporated variables. As more data is gathered over the lifetime of the study, the current gaps and inconsistencies in the data caused by faulty equipment will become less pronounced.

Data collected at each monitoring station were used to evaluate rainfall and runoff characteristics for the following parameters: identification of the different characteristic of each storm event; time of concentration (Tc); antecedent moisture condition (AMC); runoff curve number (CN); initial abstraction (Ia); and, predictive relationship equations for absorption/storage and runoff depths. Several technical publications were reviewed to compare recorded field data with literature values provided in the technical publications. The following is a list of publications incorporated into the analyses:

- Urban Hydrology for Small Watersheds (Technical Release 55 (TR-55)), United States Department of Agriculture (USDA)/Natural Resources Conservation Service (NRCS), June 1986 (and companion computing software “Win TR-55 Small Watershed Hydrology” version 1.00.10 April 2011);
- Hydrology Training Series/Module 104 – Runoff Curve Number Computations Study Guide, USDA/Soils Conservation Service, September 1989;
- Excess Rainfall Calculation, V.M. Merwade; and,
- Part 630 Hydrology – National Engineering Handbook/Chapter 15 Time of Concentration, USDA/NRCS, May 2010.

Relevant methodology and equations were used to calculate results for incorporated standard practice values as well as recorded field data observed at each monitoring station. The analyses were conducted to correlate field data observations with published values and calculation techniques.

For each of the six monitoring stations, data records were reviewed where rainfall and runoff events produced adequate data responses for analysis. The nature of rainfall event variation resulted in an array of distinct data for each monitoring location. Consequently, no two monitoring stations produced the same set of storm event data – each having their own unique data record for evaluation (Table I3.1).

Data summary graphs located in Supplement I3 have been created to represent varying rainfall events (i.e. a range of events varying from smaller to larger rainfall occurrences). It should be noted that there may have been some data irregularities with the collection systems due to inevitable technical glitches; therefore, the data may be subject to inaccuracies and are to be considered provisional.

3.1.2 Curve Number

To estimate the runoff that may occur from storm events, the TR-55 Manual (Chapter 2 – Estimating Runoff) uses the SCS technique for calculating the runoff curve number (CN) based on soils (i.e. the hydrologic soil group (HSG)), antecedent moisture condition (AMC), cover type, treatment, and hydrologic condition. These parameters describe the land characteristics of a given area of study in relation to vegetation cover, soils, and land management practices. A higher CN value infers less rainfall would be stored, and the resulting amount of runoff would be greater when compared to lower CN values. The TR-55 Manual provides several tables for use in selecting an estimated CN given a variety of soil and land characteristics. Within the TR-55 Manual, Table 2-2a lists CNs for urban areas (e.g. the Kroger and the Westgate sites), Table 2-2b identifies CNs for cultivated agricultural lands (e.g. the Bing and the Manor sites), while Table 2-2c describes CNs for other agricultural lands (e.g. the Upper Tucker and the Lower Tucker sites).

Incorporating site characteristics into the TR-55 Manual Curve Number assessment, the following CN estimations result:

Kroger and Westgate sites (TR-55 Table 2-2a)
Since both sites have been developed and the soils can be considered as homogenized (i.e. mixed), a range of CNs should be considered. For Kroger, Table 2-2a would identify the cover description of "Urban Districts: Commercial and Business" with an average percent impervious area of 85 percent. Selecting these descriptors, a range of CNs from 89 to 95 would result based on a range of soil types. A conservative CN of 95 was selected for the analyses herein. Westgate would be described in Table 2-2a as "Residential Districts by Average Lot Size: ¼-acre" with an average percent impervious area of 38 percent. The resulting range of CNs from 61 to 87 would occur. To be conservative, based on the homogenization of developed area soils, a CN of 87 was selected for analysis.

Bing and Manor sites (TR-55 Table 2-2b)
Both sites have been identified as open space, and are characterized as remnant agricultural crop lands currently being used for cattle forage. Consequently, Table 2-2b would identify these tracts as "Fallow: Crop Residue Cover (CR)" with a "Good" Hydrologic Condition, where the hydrologic condition has "factors encourage average and better than average infiltration and tend to decrease runoff". SCS data, along with collected field soils data, approximate the HSG as type "C". As a result, a CN of 88 was selected for the analyses provided herein.

Upper Tucker and Lower Tucker sites (TR-55 Table 2-2c)
The Upper Tucker and the Lower Tucker sites are identified as native prairie, where native vegetation species dominate the species composition, and land management practices include prescribed fire with minimal cattle forage. Each has a variety of HSG soils. Consequently, a weighted CN was generated from TR-55 values describing the tracts as "Other Agricultural Lands: Pasture, Grassland, or Range – Continuous Forage for Grazing" with a "Good" Hydrologic Condition, where the hydrologic condition is described as "> 75% ground cover and

lightly or only occasionally grazed". Given the variable soil conditions at each tract location, a composite CN of 75 was computed for Upper Tucker, and a composite CN of 65 was computed for Lower Tucker.

The TR-55 Manual also provides for computing CN based on observed field data (Chapter 2 – Estimating Runoff) using Equation 2-1 by using the following:

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S}$$

where: Q = Runoff (in.);
P = Rainfall (in.);
S = Potential Maximum Retention After Runoff Begins (in.); and,
Ia = Initial Abstraction (in.)

Whereas the TR-55 Manual assumes an initial abstraction equal to 20% of S, recorded field data were used to compute S, then compute the CN from Equation 2-4 by solving for CN using the following:

$$S = (1000/CN)-10$$

Using field data for computing initial abstraction (analysis of computing initial abstraction (Ia) provided in Section 3.2.5) for several storm events at each monitoring station, an average CN was calculated for each land cover type (with the exception of the Manor site, where equipment irregularities resulted in suspect data) (Table I4.2). In addition, the amount of runoff calculated for the Upper Tucker site was negligible, resulting in an incalculable equation.

3.1.3 Time of Concentration and Flow Path

In Chapter 3, "Time of Concentration and Travel Time", of the TR-55 Manual, three significant factors affecting the time of concentration are identified as: 1) surface roughness; 2) channel shape and flow patterns; and, 3) slope. In addition, the length of the flow path and CN were used in the Win TR-55 computer software program to calculate the approximate time of concentration. Using LiDAR-generated topography, flow paths and surface slope were estimated for the open space and native prairie land cover types. Surface roughness analyses (i.e. Manning's Roughness) were estimated based on site reconnaissance.

Time of concentration (Tc) for the open space and native prairie land cover types can also be calculated using collected field data using Equation 15-4b in the SCS "Hydrology Training Series Module 104 – Runoff Curve Number Computations" publication as follows:

$$Tc = \frac{\ell^{0.8}(S+1)^{0.7}}{1140(Y^{0.5})}$$

where: ℓ = Flow Length (ft.);
S = (1000/CN)-10; and,
Y = Slope (%)

Since the TR-55 Manual, as well as the Win TR-55 software, compute Tc values based on a 2-Year storm return frequency (4.75 inches for the Harris County study area), collected field data Tc values were calculated using Equation 15-4b (Table I4.3).

Flow paths were determined for the native prairie and open space land cover types based on available LiDAR topography and HydroCAD software, where the longest flow path with the least slope elevation was projected on recent aerial photography. In addition, on-site reconnaissance was incorporated with the LiDAR elevation interpretation to verify projected flow paths. Field observations were conducted to confirm site-specific obstructions or ditching was not present, since LiDAR contour generation may not be sensitive to small changes on the land surface.

Supplement I2 provides illustrations of derived flow paths for study parcels – with the exception of developed land cover types (since their stormwater management systems have been constructed and lie beneath the ground). The Westgate site flow path is depicted in Supplement I2, and is a result of acquiring as-built construction drawings for the site as approved by the Harris County Flood Control District. No design information was available for the Kroger site.

3.1.4 Absorption/Storage and Runoff

Rainfall and runoff data for each study site were incorporated into an analysis to describe probable relationships between the amount of runoff and absorption/storage for a variety of storm events. These data may be used to develop predictive rainfall/runoff/absorption/storage calculations for each associated land cover type.

Using the data collected and illustrated in Supplement I3, a best fit curve analysis was performed for each study parcel – with the exception of the Manor site as previously referenced (Table I4.4). By executing the identified equation for a specific study site, an approximation of absorption/storage and runoff characteristics was calculated for a range of rainfall events.

3.1.5 Initial Abstraction

Initial abstraction is defined as rainfall that is captured by vegetation, evapotranspiration, infiltration, and depressional storage prior to the initiation of surface runoff. Although Ia values can be variable, they are typically correlated to soil and vegetative cover parameters (TR-55 Manual). An analysis of recorded field data was used to compare TR-55 Manual computational techniques with observed storm event data.

The TR-55 Manual, from the analysis of small agricultural watersheds, defines initial abstraction as approximately 20% of the potential maximum retention after runoff begins (S), or Ia = 0.2S.

Where field data were available, monitoring station observations were used to calculate potential initial abstraction for each land cover type. Equipment inoperability resulted in the absence of Manor site data analysis; whereas, runoff data from the Upper Trucker site were incalculably low – resulting in a minimal depth of runoff. An equation developed to calculate the constant rate of initial abstraction (i.e. the "Φ-Index Method") has been used to describe the relationship between observed rainfall, depth of direct runoff, the number of intervals of rainfall contributing to direct rainfall, and the selected interval of rainfall measurement.

The depth of direct rainfall runoff was calculated by dividing the recorded amount of surface water runoff at a given monitoring station for a given rainfall event by the total drainage basin surface area by the following equation:

$$r_d = \frac{V_d}{A}$$

where: r_d = Depth of Runoff (in.);
V_d = Volume of Observed Direct Runoff (ft^3); and,
A = Watershed Area (ft^2)

Once a depth of runoff was calculated for specific storm events, incorporation of total rainfall depth and duration was used to solve the equation for computing approximate excess rainfall by the following:

$$r_d = \Sigma(R_m - \Phi\Delta t)$$

where: r_d = Depth of Runoff (in.);
R_m = Observed Precipitation Values (in.);
Φ = Excess Rainfall (in.); and,
Δt = Time Between Rainfall Observations (hr.)

Computing the amount of excess rainfall using the Φ-Index Method equation resulted in the ability to calculate the constant rate of initial abstraction by subtracting the excess rainfall from the total amount of rainfall for a referenced storm event. As provided herein, Table I4.5 provides a comparison of TR-55 Manual calculation technique results for initial abstraction with the procedure described above using recorded field data.

3.1.6 Antecedent Moisture Condition (AMC)

Another parameter for evaluating rainfall and runoff characteristics for drainage basins is the antecedent moisture condition (AMC). To account for variations in CN values over storm event differences, the AMC was derived as an index to describe potential runoff. Three AMC situations are defined as: dry AMC I – soils are dry but not at wilting point values; average AMC II – no heavy rainfall within 5 days; and, wet AMC III – heavy rainfall or light rainfall with low temperatures within the previous 5 days. As indicated, AMC II is typically used in lieu of specific data.

AMC is also useful for calculating values for the Green-Ampt infiltration equation, where depth to groundwater, soil infiltration characteristics, and depth of surface water are important parameters for computational evaluation of watersheds. Excess rainfall depth may be incorporated into the Green-Ampt infiltration equation as depth of infiltrating surface water, while shallow groundwater depth at the initiation of a storm event may also be useful (Table I4.6). It should be noted there are no groundwater data for the Kroger or the Westgate sites, as those sites have significant impervious surface and runoff conditions are less affected by soil conditions.

3.1.7 Evapotranspiration

Given the complexity of technical equipment necessary to measure small-scale evapotranspiration rates, a broader scale approach was taken when investigating evapotranspiration within the study area. Supplement I4 provides multiple methods to calculate evapotranspiration using nearby regional stations, with referenced facts from review articles.

4.0 Results and Discussion

The following narrative provides a discussion of the observed field data in comparison with standard hydrologic techniques primarily incorporated into the TR-55 Manual – Urban Hydrology for Small Watersheds. Although some data from monitoring stations may be missing or unreliable, recent technical problems have been corrected. However, there may be sufficient data collected to date to compare field data values with published data analysis and computing techniques. In addition, as more data is gathered over the lifetime of the study, subject to the availability and certification of funds, the current gaps and inconsistencies in the data will become less pronounced.

Table I4.1: Rainfall, Runoff, and Absorption/Storage Data[1]

Land Cover Type	Station Designation	Total Rainfall (in.)	Absorption/ Storage (in.)	Runoff (in.)	% Absorption
Open Space	Bing	0.79	0.68	0.11	86%
		2.01	1.55	0.46	77%
		3.02	2.04	0.98	68%
		4.86	2.82	2.04	58%
Native Prairie	Upper Tucker	0.33	0.33	0.001	100%
		0.63	0.6	0.03	95%
		0.95	0.94	0.01	99%
		1.76	1.72	0.04	98%
Native Prairie	Lower Tucker	0.64	0.63	0.01	98%
		0.97	0.9	0.07	93%
		1.7	1.47	0.23	86%
		3.53	2.66	0.87	75%
Developed (Commercial)	Kroger	0.26	0.13	0.13	50%
		1.81	0.59	1.22	33%
		4.54	1.59	2.95	35%
Developed (Residential)	Westgate	0.29	0.12	0.17	41%
		1.31	0.95	0.36	73%
		1.75	0.26	1.49	15%

[1] Manor site monitoring station with functional errors – data suspect and not included in the table.

4.1 Rainfall and Runoff Measurements

Table I4.1 provides recorded field data for a range of storms used for rainfall, runoff, and absorption/storage evaluation. Although there were a variety of storm event data incorporated into the analysis of other parameters, the data in Table I4.1 illustrate a summary of rainfall and runoff responses for the range of data analyzed.

4.2 Curve Number

From Table I4.2, there appears to be a general consistency between TR-55 Manual and field observation data. In particular, open space land cover type (i.e. the Bing site) correlated lower than the TR-55 Manual calculation; however, field data were calculated as an average of two separate events, where rainfall event data were representative of a broad range of total rainfall recorded (i.e. 0.79 inches and 4.86 inches). As provided in the TR-55 Manual, curve number estimation varies in response to total rainfall values, and is calculated based on several assumptions. Given that the TR-55 Manual assumes a 2-Year return frequency storm (4.75 inches in west Harris County, Texas) – along with other assumptions related to a unit hydrograph for rainfall, AMC II, uniform vegetation cover, etc., and the field data were averaged over a range of two storms, the TR-55 Manual and observed data calculations seem reasonably similar.

Table I4.2 Curve Number Analysis[1]

Land Cover Type	Station Designation	TR-55 Manual Technique	Field Data Computation
Open Space	Bing	88	73
Open Space	Manor	88	N/A[1]
Native Prairie	Upper Tucker	75	N/A[1]
Native Prairie	Lower Tucker	65	53
Developed (Commercial)	Kroger	95	97
Developed (Residential)	Westgate	87	87

[1] Data for Manor site suspect due to equipment malfunction and runoff data for Upper Tucker site incalculably low.

For the native prairie land cover types (i.e. the Lower Tucker site), there was a similar correlation to TR-55 CN values as those for the "open land" designation. The lower calculated CN values from field data may be a result of direct site reconnaissance and site-specific data collection; whereas, TR-55 Manual computations rely on average conditions for particular land cover type. Another factor for dissimilarity may be that runoff from the Lower Tucker site was less than 0.5 inches. As described in the TR-55 Manual: "The CN procedure is less accurate when runoff is less than 0.5 inch". In addition, the inherent ability of native prairie to store rainfall within its soils may result in lower CN values than the general assumptions provided within the TR-55 Manual computational techniques.

For the developed land cover types, CN values computed from field data are very similar to published TR-55 Manual procedure results (Table I4.2). This may be a result of the consistency of developed sites – including the similarity in impervious surface factors when compared to the varying values of pervious land cover types of open space and native prairie.

4.3 Time of Concentration and Flow Path

The time of concentration (Tc) for each of the open space and native prairie monitoring stations that provided reliable data were calculated using TR-55 Manual techniques (calculated from the Win TR-55 program), and were separately calculated from field data using Equation 15-4b in Chapter 15 of Part 630 - National Engineering Handbook (equation provided herein). Tc data for the developed land cover types were not used since their monitoring stations are located at "end of conduit" systems that may have additional interconnectivity with other upstream systems. Table I4.3 was developed to provide a synoptic comparison of results incorporating the two methodologies.

Table I4.3: Time of Concentration (Tc) Data[1]

Land Cover Type	Station Designation	TR-55 Technique Tc (hr.)	Calculated Tc (hr.)
Open Space	Bing	1.38	1.75
Open Space	Manor	2.82	1.93
Native Prairie	Upper Tucker	0.65	1.31
Native Prairie	Lower Tucker	0.44	0.97

[1] Stormwater management systems at the Developed sites have been constructed and lie beneath the ground

For the open space land cover types (i.e. the Bing and the Manor sites), both computational method results were similar, while those of native prairie land cover type (i.e. the Lower Tucker and the Upper Tucker sites) were dissimilar. In fact, the observed field data Tc calculations for the native prairie land cover types were approximately double the TR-55 Manual calculations. The TR-55 Manual equation accounts for surface roughness (Manning's "n"), flow length divided into overland flow and shallow concentrated flow, surface slope, and assumes a 2-Year return frequency storm. The field observed data calculation, using the equation referenced above, relies on data for a single slope factor (i.e. it does not differentiate between shallow and concentrated surface flows), it does not include a surface roughness factor or a rainfall value; however, the equation does include a storage factor.

The dissimilarity between the TR-55 Manual and field data calculations for the native prairie land cover type may be a result of the storage factor. As discussed, storage factor calculations for the native prairie land cover type appear to be significant. Consequently, this available storage may have affected the computation of Tc values, and result in increasing the time for excess rainfall to reach the point of Tc measurement.

4.4 Absorption/Storage and Runoff

Observed field data were analyzed and relational best fit curve equations were produced (Table I34.4). The resulting equations may be used to predict probable absorption/storage and runoff values for various rainfall events. These equations may also be useful to hydrologists, as a means to approximate hydrologic response to various storm events for undeveloped and developed land uses within the area of study.

Table I4.4: Best Fit Curve Equations for Absorption/Storage and Runoff[1]

Station Designation	Absorption/Storage (in.)		Runoff (in.)	
	Curve Type	Equation	Curve Type	Equation
Bing	Rational Model	$y = (a+bx)/(1+cx+dx^2)$ a = -0.43, b = 1.79, c = 0.61, d = -0.04	Rational Model	$y = (a+bx)/(1+cx+dx^2)$ a = -0.01, b = 0.12, c = -0.32, d = 0.03
Upper Tucker	Rational Model	$y =(a+bx)/(1+cx+dx^2)$ a = 0.10, b = 0.54, c = -0.54, d = -0.18	Exponential Association	$y = a(b-e^{-cx})$ a = 0.17, b = 0.23, c = 4.52
Lower Tucker	Rational Model	$y = (a+bx)/(1+cx+dx^2)$ a = 0.09, b = 0.85, c = 0.009, d = 0.01	Rational Model	$y = (a+bx)/(1+cx+dx^2)$ a = -0.09, b = 0.15, c = -0.17, d = 0.008
Kroger	Ratkowski Model	$y = a/(1+e^{b-cx})$ a = 1.70, b = 2.80, c = 1.20	Vapor Pressure Model	$y =e^{a+(b/x)+c(\ln x)}$ a = -0.26, b = -0.14, c = 0.914
Westgate	Gompertz Relation	$y = ae^{-e\wedge b-cx}$ a = 2.28, b = 1.18, c = 0.48	Farazdaghi-Harris	$y = 1/(a+bx^c)$ a = 6.15, b = -2.15, c = 1.68

[1] Data for Manor suspect due to equipment malfunction.

4.5 Initial Abstraction

The calculations indicated significant differences between TR-55 Manual versus the Φ-Index Method (observed field data calculation) for open space, native prairie, and developed land cover type designations. While the TR-55 Manual methodology assumes an initial abstraction value approximately equal to 20% of the storage availability for the 2-Year storm return frequency, the Φ-Index Method uses site-specific data values excess rainfall, observed rainfall by user-determined time step, and watershed area.

The significant difference between TR-55 Manual and the Φ-Index Method evaluations may be a result of the storage data observed from field data when compared to TR-55 Manual assumptions that initial abstraction can be estimated at approximately 20% of the storage value. The importance of using site-specific field observations in lieu of global assumptions in the TR-55 Manual may provide hydrologists with a useful data set for which watershed-based approaches to storage and effective runoff values could be incorporated into future watershed analyses. However, the significant difference in observed data calculated values in comparison to TR-55 Manual results indicates further field data should be gathered and evaluated prior to the use of Table I4.5 values for hydrologic modeling.

Table I4.5: Initial Abstraction (Ia) Data Comparison[1]

Station Designation	Observed Field Data				Initial Abstraction TR-55 Manual[3] (in.)
	Total Rainfall (in.)	Depth of Storage (in.)	Excess Rainfall[2] (in.)	Initial Abstraction (in.)	
Bing	0.79	0.68	0.10	0.69	0.14
	3.02	2.04	0.95	2.07	0.41
	4.86	2.82	2.00	2.86	0.56
Lower Tucker	0.64	0.63	0.01	0.63	0.13
	0.97	0.90	0.07	0.90	0.18
	1.70	1.47	0.23	1.47	0.29
Kroger	0.26	0.13	0.13	0.13	0.03
	1.81	0.59	1.21	0.60	0.12
	4.54	1.59	2.96	1.58	0.32

[1] Data for Manor site suspect due to equipment malfunction, data for Upper Tucker site incalculably low, and Westgate site data indicate almost complete runoff. Consequently these data were not applicable for the Ia analysis.
[2] Computed using field data and Φ-Index Method.
[3] Computed assuming Ia = 0.2S.

4.6 Antecedent Moisture Condition

The use of the antecedent moisture condition (AMC) is important when calculating results for the Green-Ampt infiltration equation. Given the values for depth to soil moisture provided in Table I4.6, as well as other data collected during the initial year of investigation such as excess rainfall depth and soil characteristics, hydrologists may incorporate these data into development of site-specific Green-Ampt infiltration equation relationships. From the data, it appears as the AMC II condition may be an appropriate factor for integrating into stormwater runoff modeling for the proposed study area.

Table I4.6: Excess Rainfall and Depth to Groundwater Data[1]

Station Designation	Total Rainfall (in.)	Excess Rainfall (in.)	Depth to Groundwater at t = 0(ft.)
Bing	0.79	0.14	2.5
	3.02	0.95	2.2
	4.86	0.36	2.2
Lower Tucker	0.64	0.13	>2.0[2]
	0.97	0.15	1.9
	1.70	0.21	1.9

[1] Data for Manor site suspect due to equipment malfunction, data for Upper Tucker site incalculably low, and Kroger and Westgate sites were not equipped with wells due to a high percentage of impervious surfaces.
[2] Well depth = 2.0 ft

5.0 References

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Supplement 1.0
Monitoring Site Photographs

Native Prairie (Upper Tucker site pictured)

Open Space (Bing site pictured)

Developed (Kroger site pictured)

Bing Site (Open Space)

Manor Site (Open Space)

Upper Tucker Site (Native Prairie)

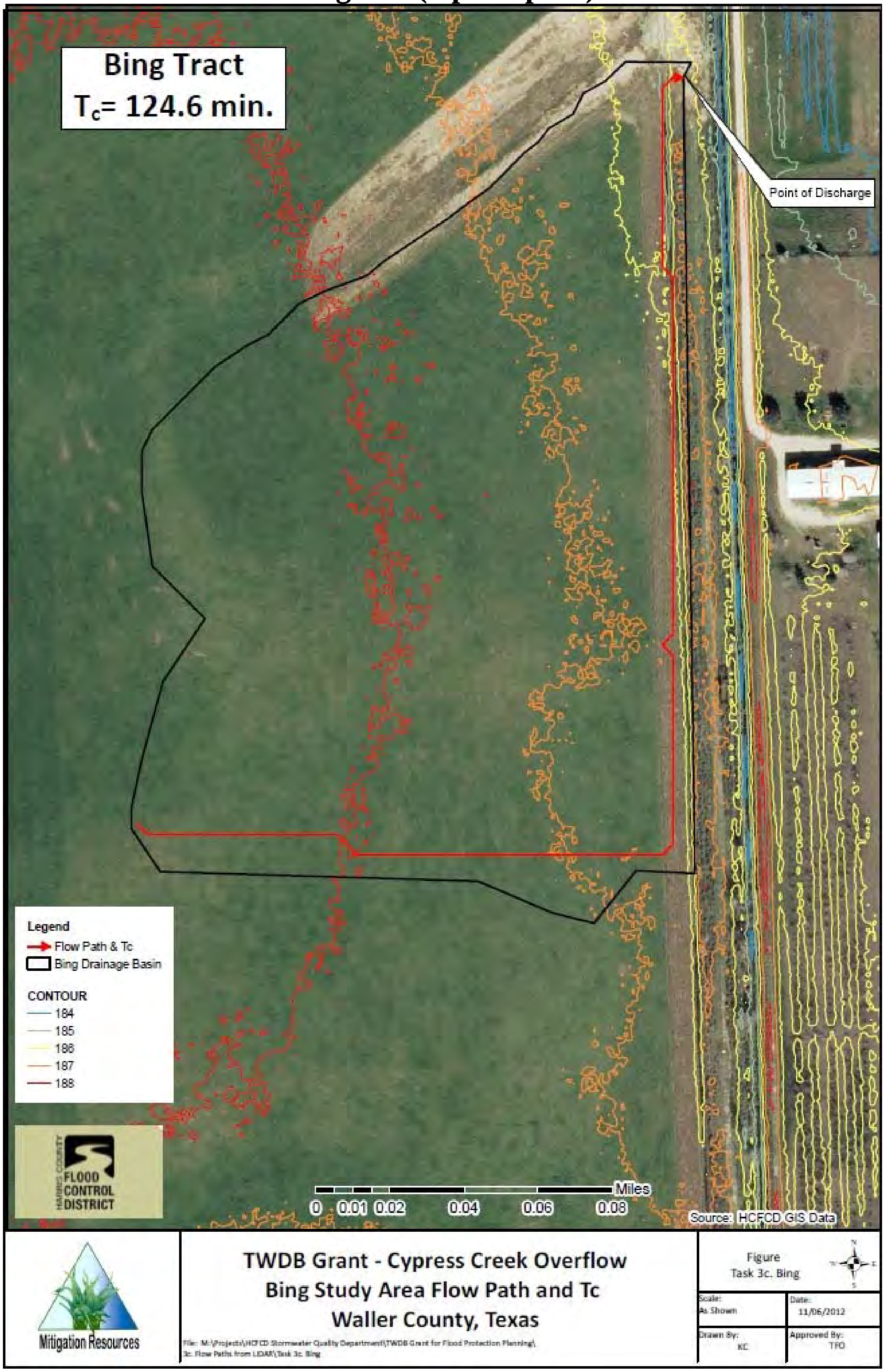
Lower Tucker Site (Native Prairie)

Kroger Site (Developed Commercial)

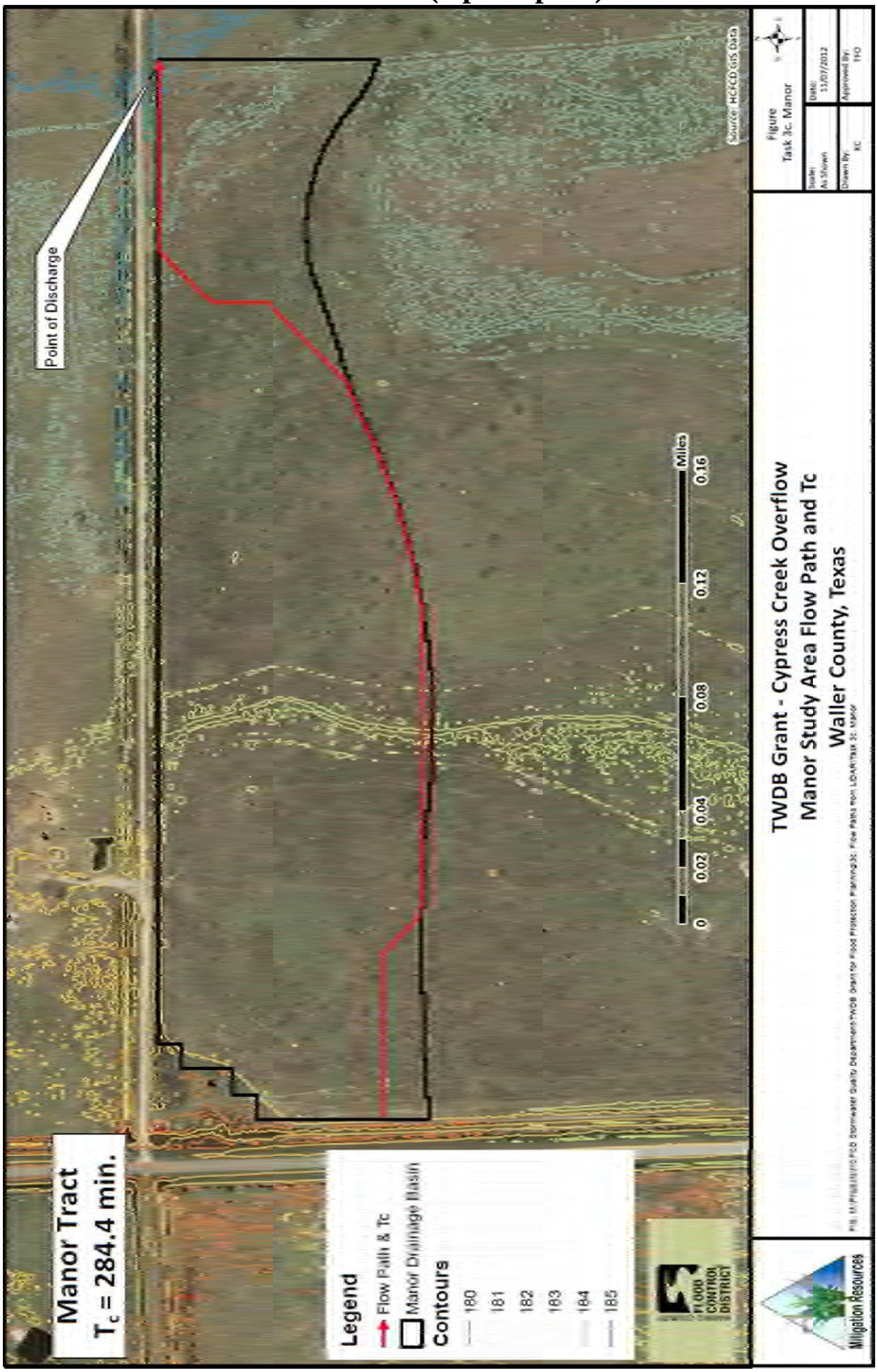
Westgate Site (Developed Residential)

Supplement 2.0
Aerial View and Flow Path of Drainage Basins

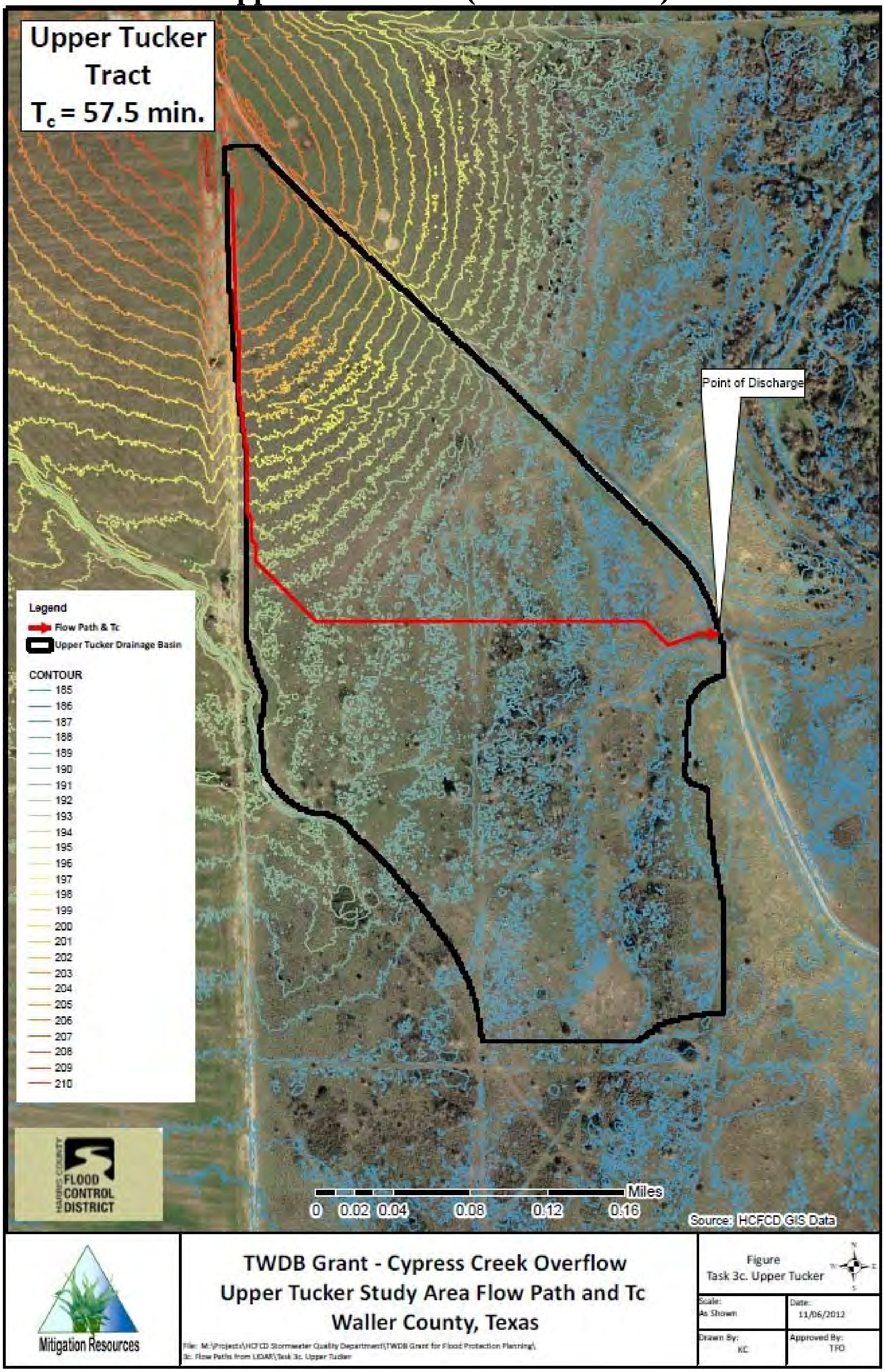
Bing Site (Open Space)



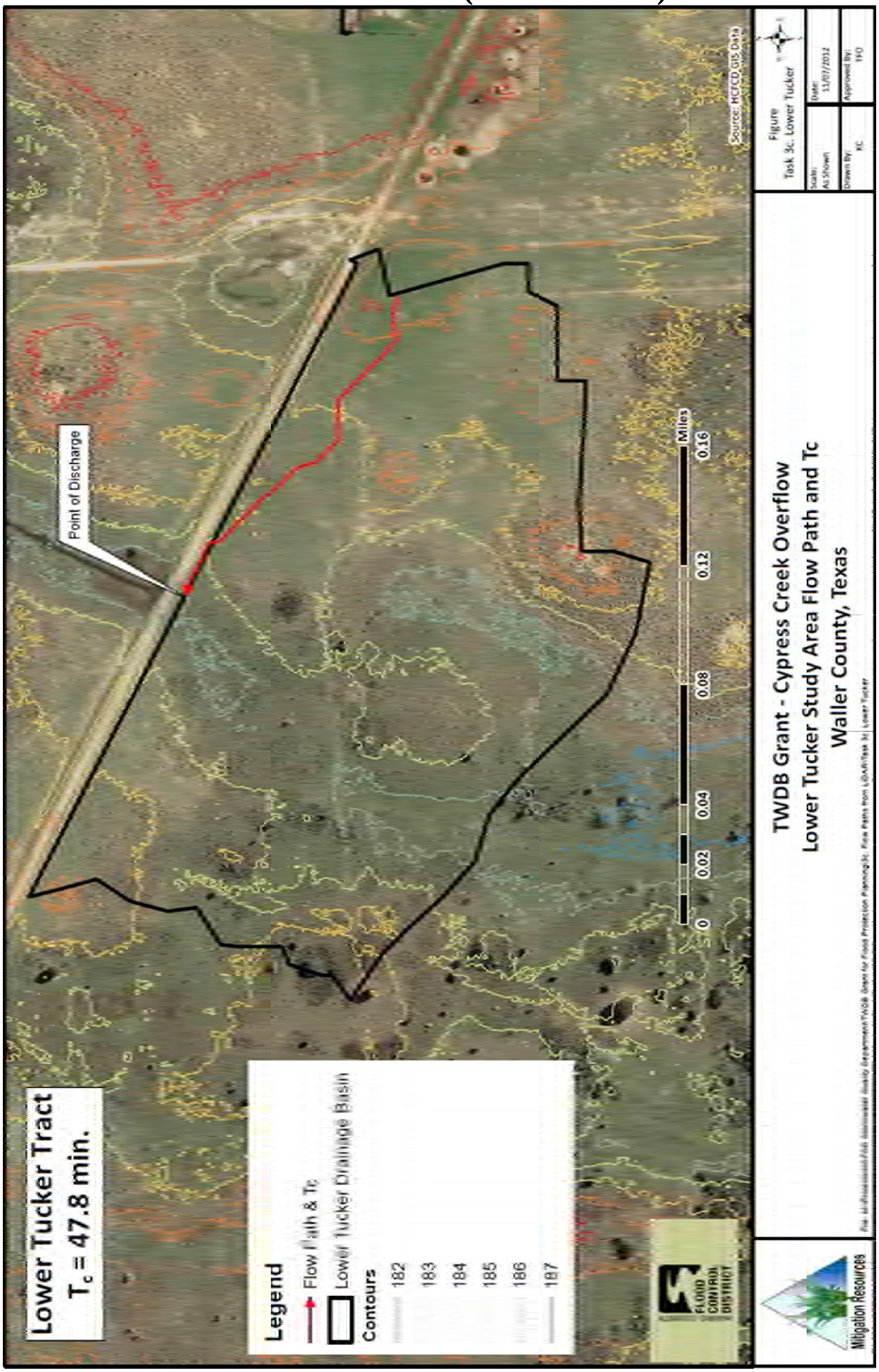
Manor Site (Open Space)



Upper Tucker Site (Native Prairie)

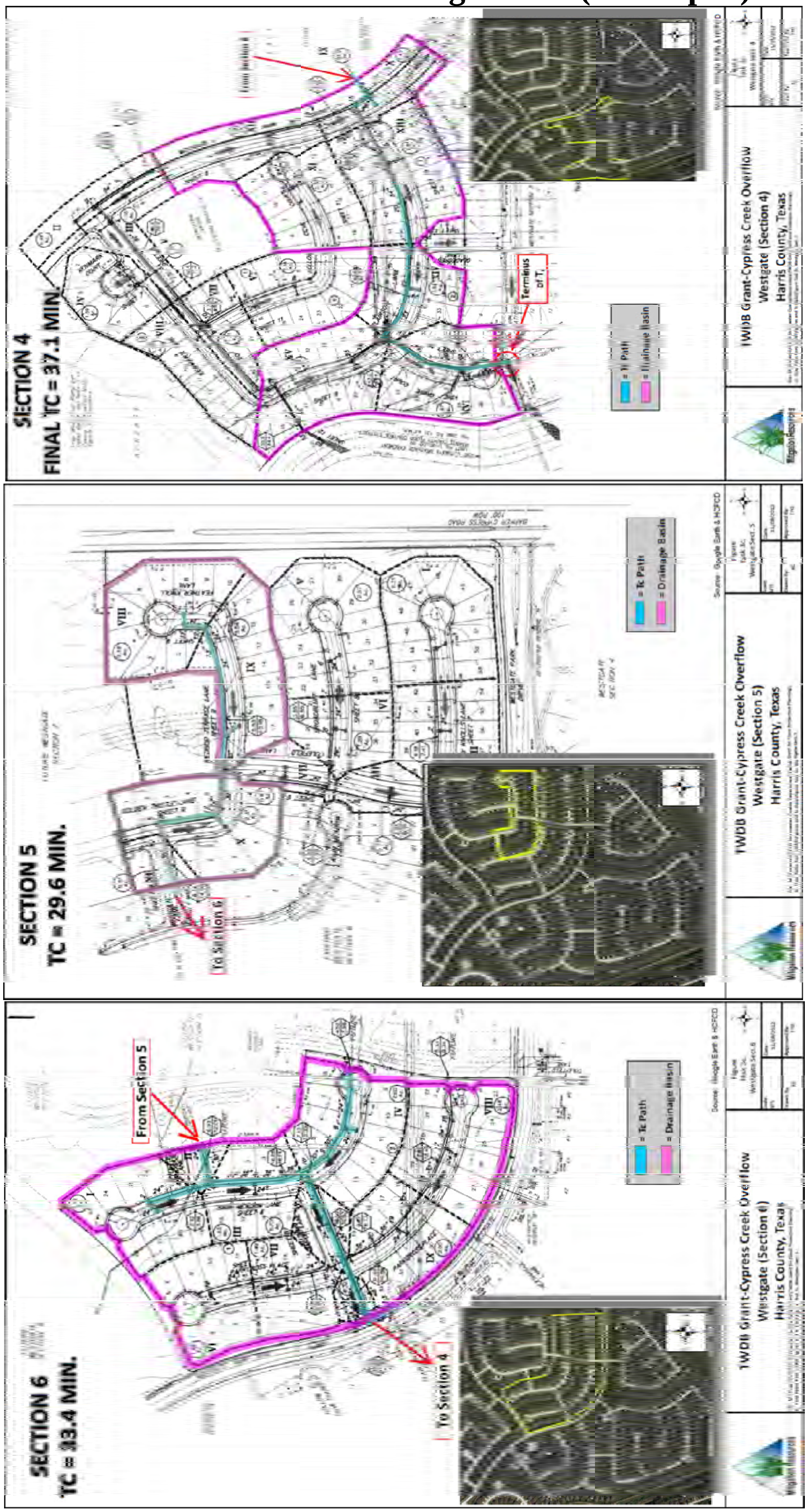


Lower Tucker Site (Native Prairie)

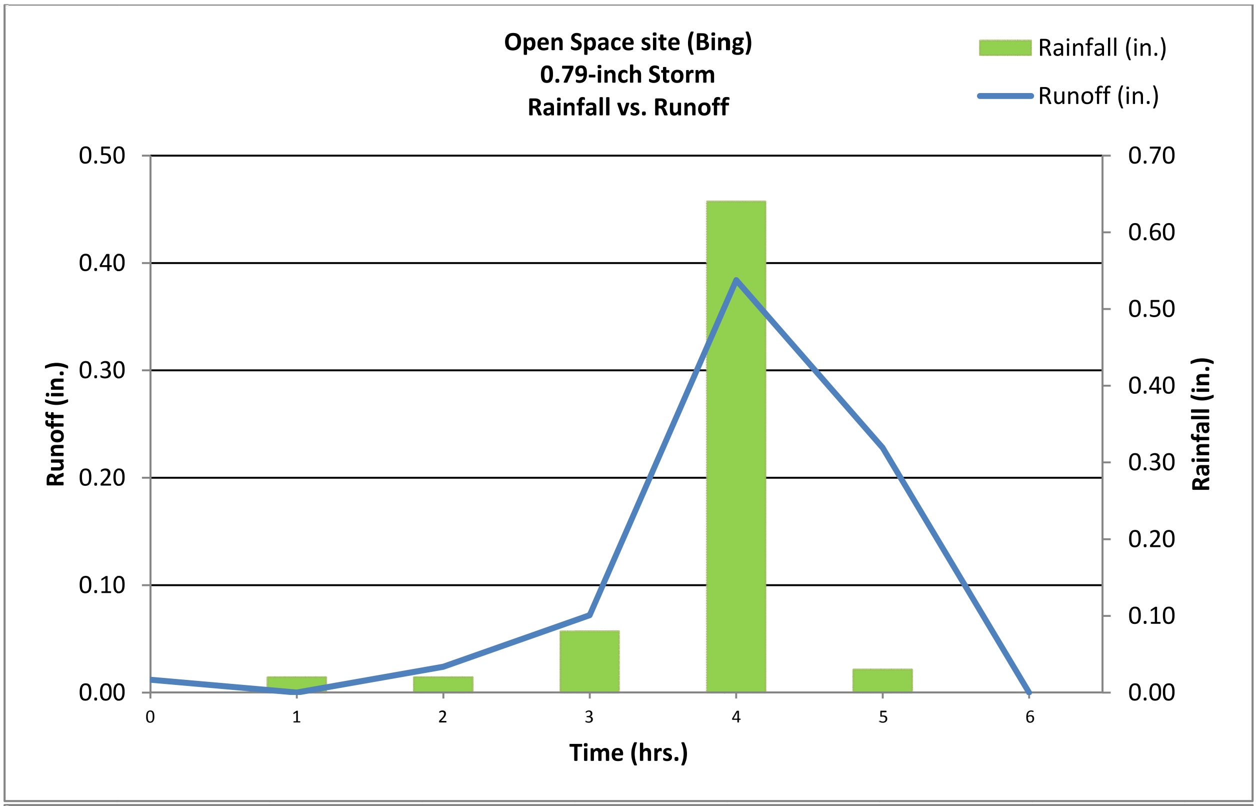


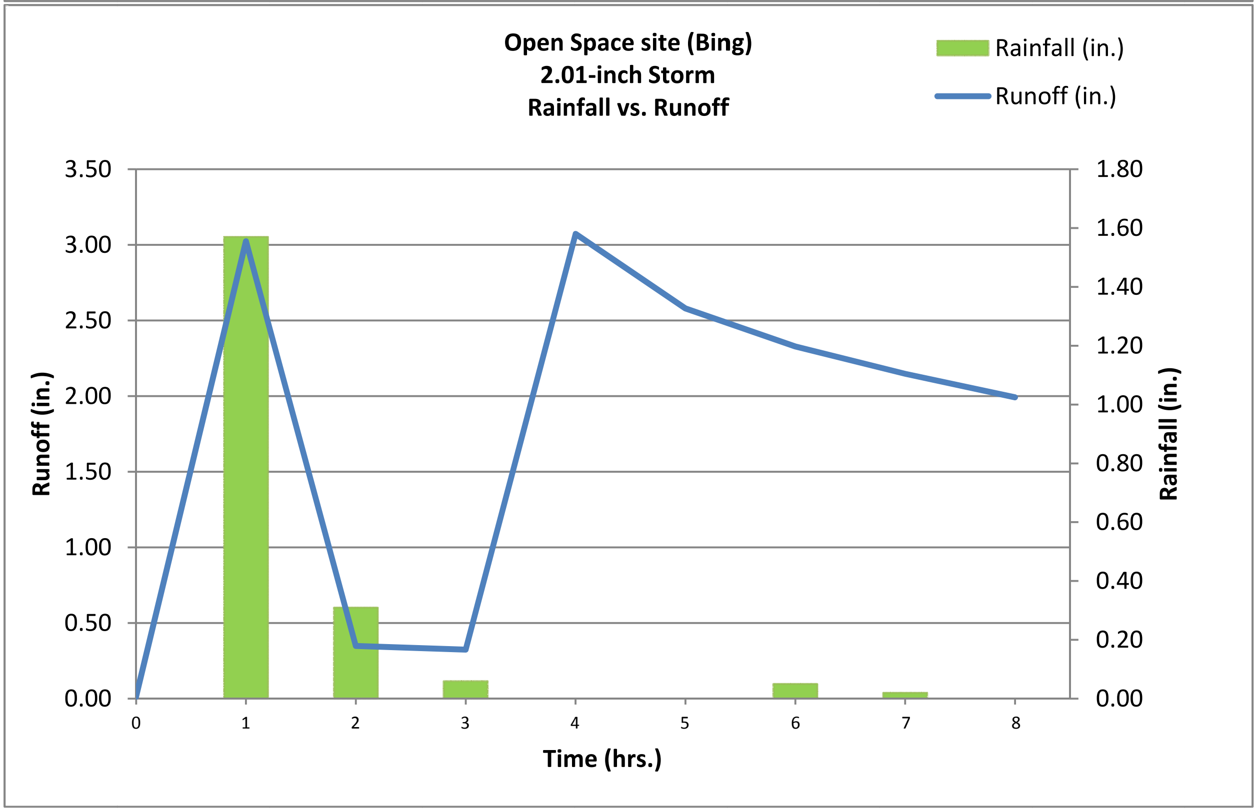
Kroger and Westgate Sites (Developed)

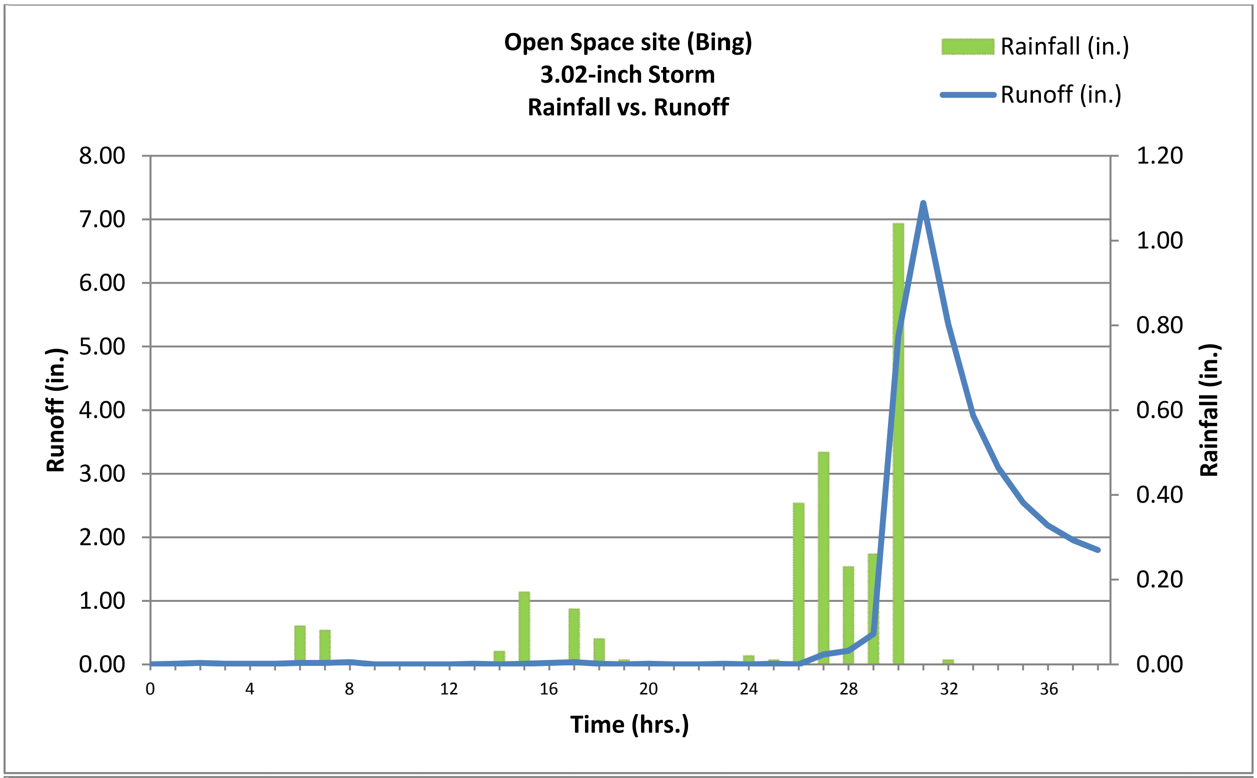
Detailed Flow Path at Westgate Site (Developed)

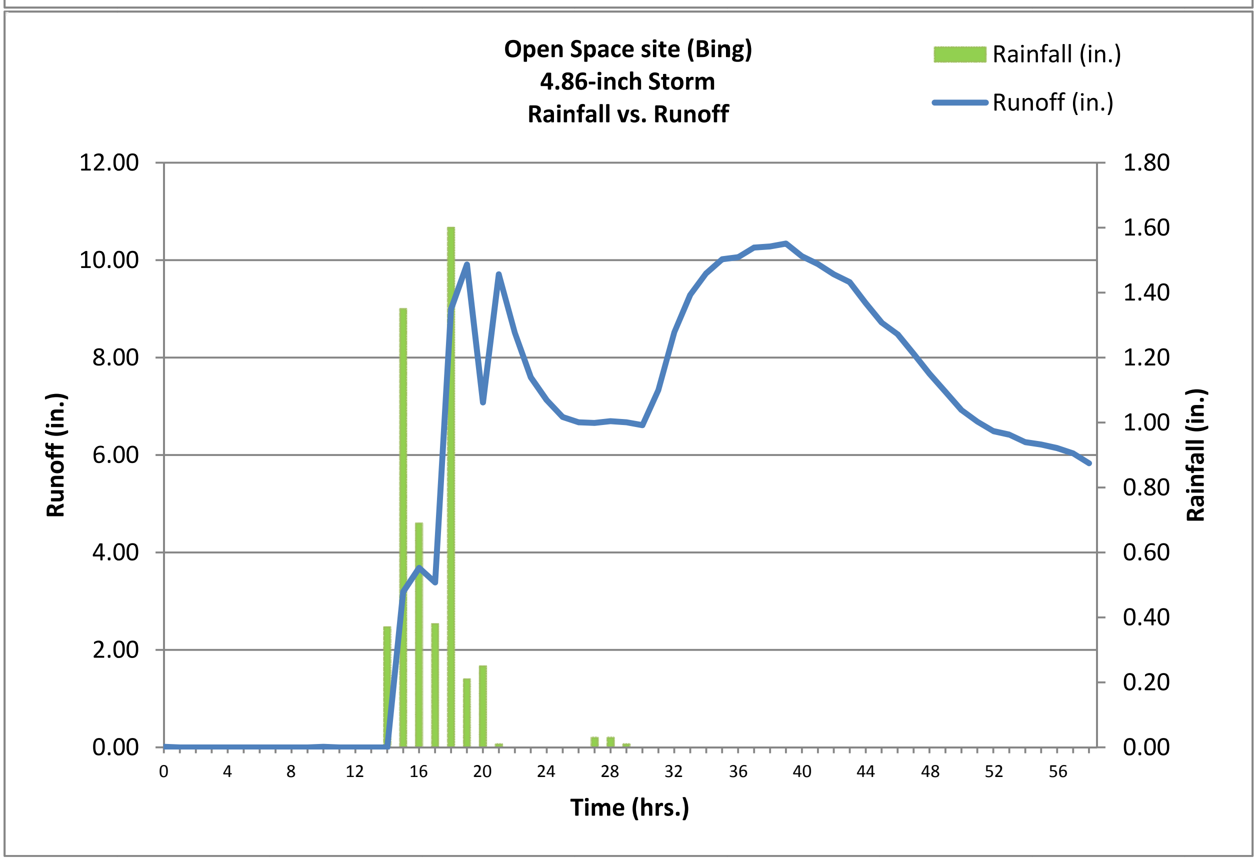


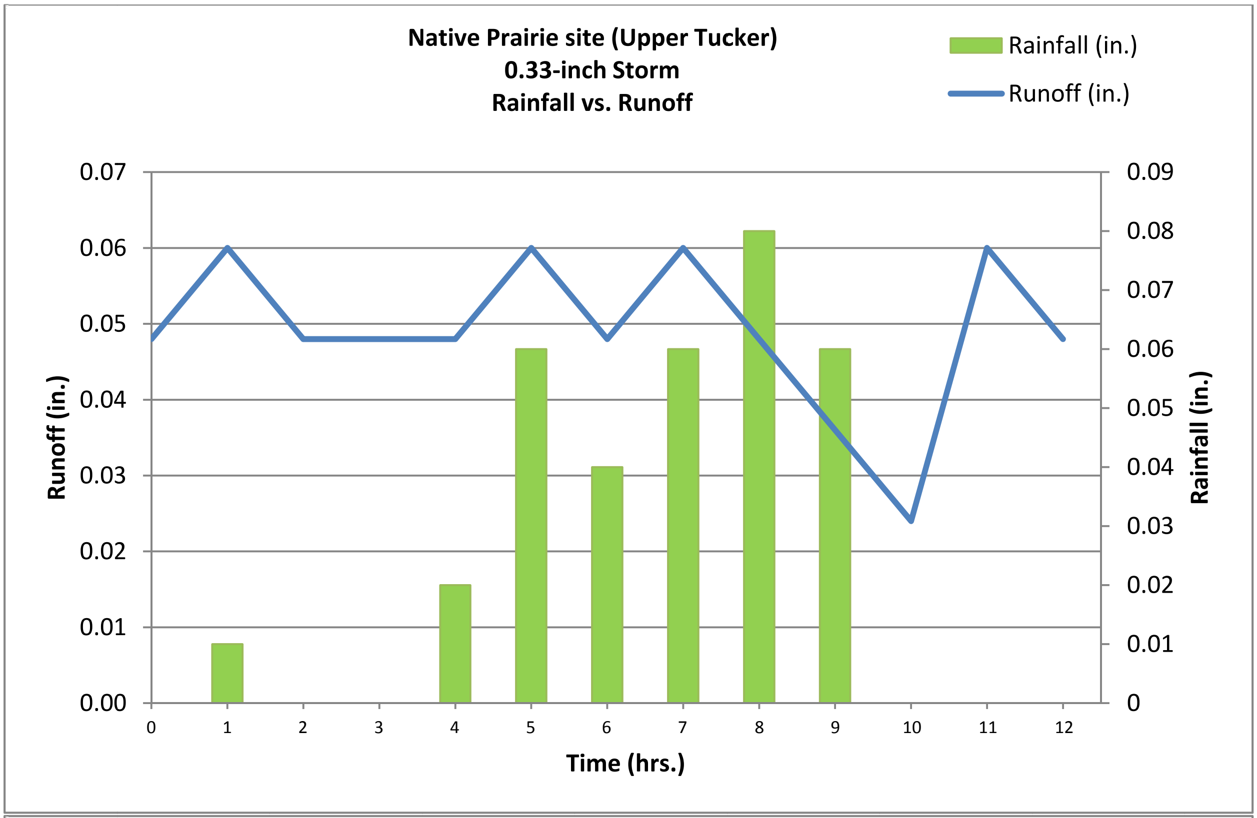
Supplement 3.0
Rainfall vs Runoff Graphs


Open Space site (Bing)
0.79-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0
1
2
3
4
5
6


Open Space site (Bing)
2.01-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
0
1
2
3
4
5
6
7
8


Open Space site (Bing)
3.02-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
4
8
12
16
20
24
28
32
36


Open Space site (Bing)
4.86-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56


Native Prairie site (Upper Tucker)
0.33-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.09
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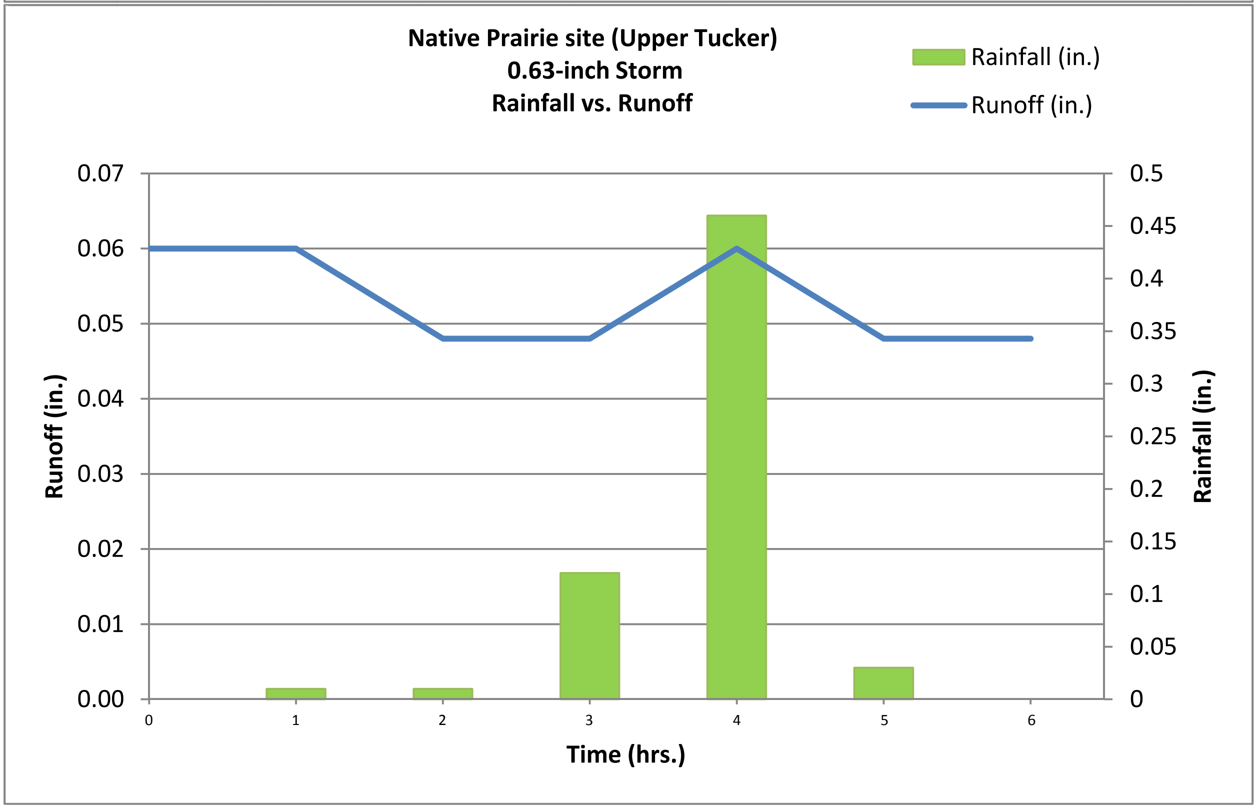
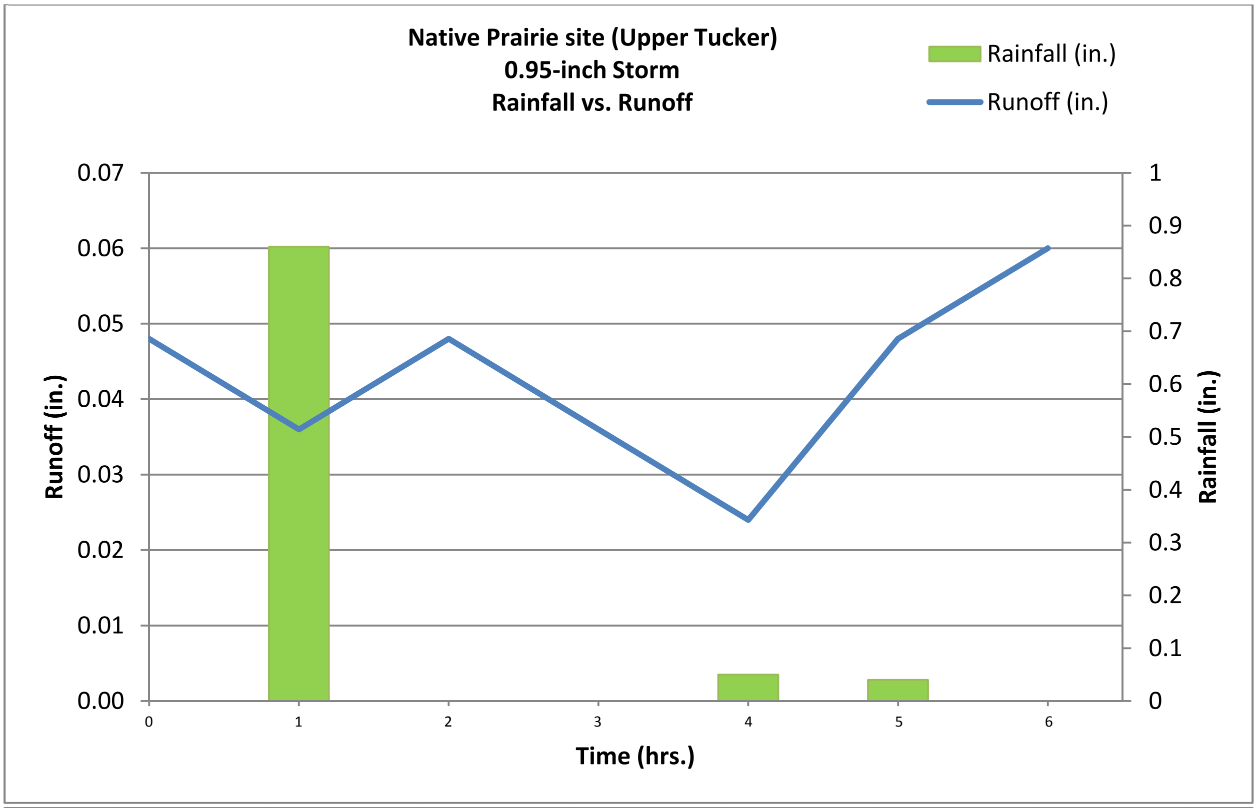
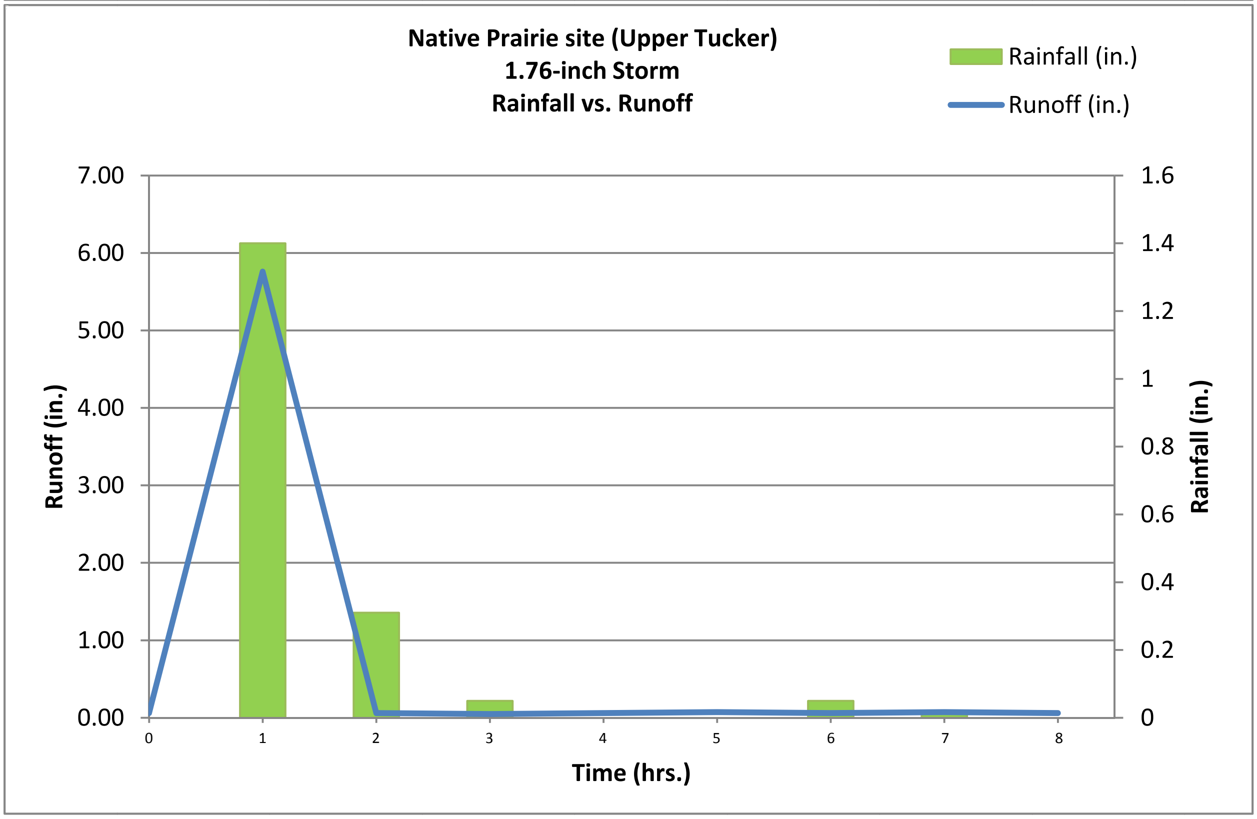
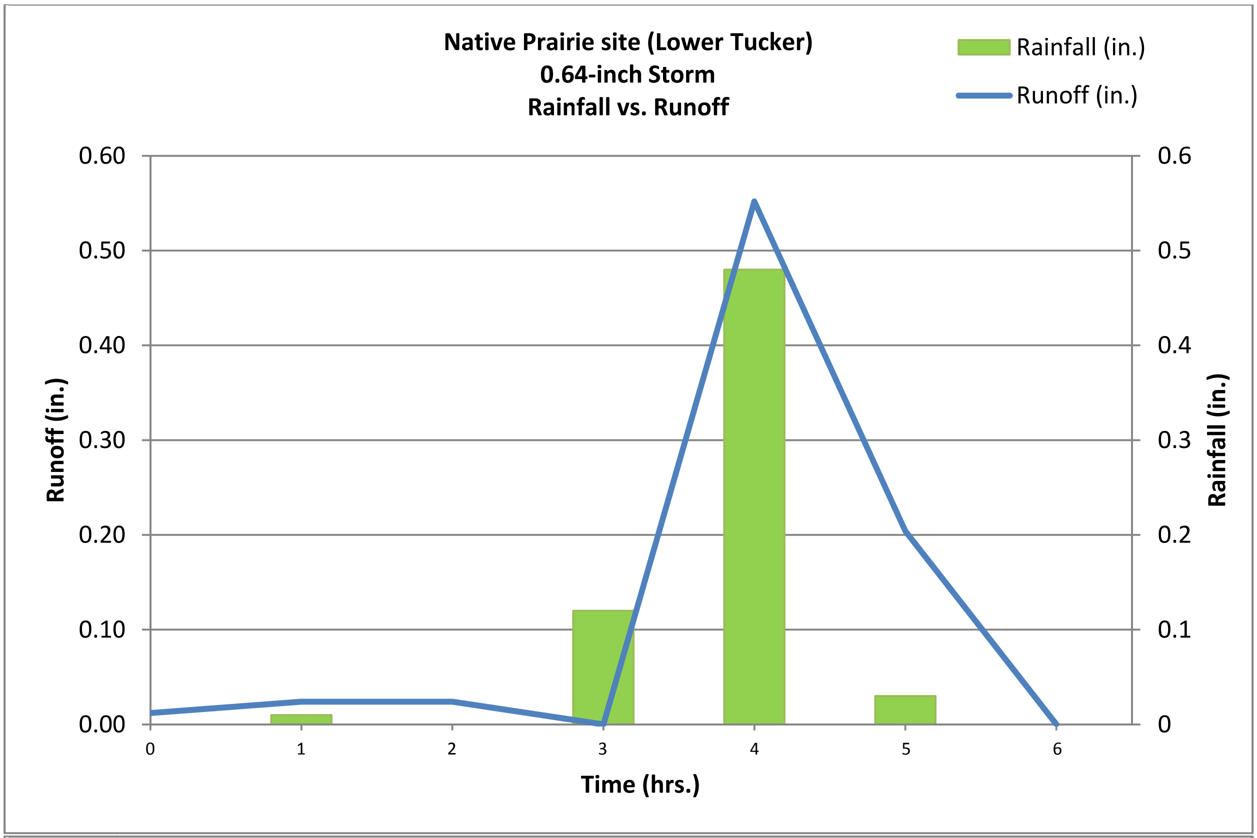
0 1 2 3 4 5 6 7 8 9 10 11 12


Native Prairie site (Upper Tucker)
0.63-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6


Native Prairie site (Upper Tucker)
0.95-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Rainfall (in.)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
Time (hrs.)


Native Prairie site (Upper Tucker)
1.76-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Rainfall (in.)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
7
8
Time (hrs.)


Native Prairie site (Lower Tucker)
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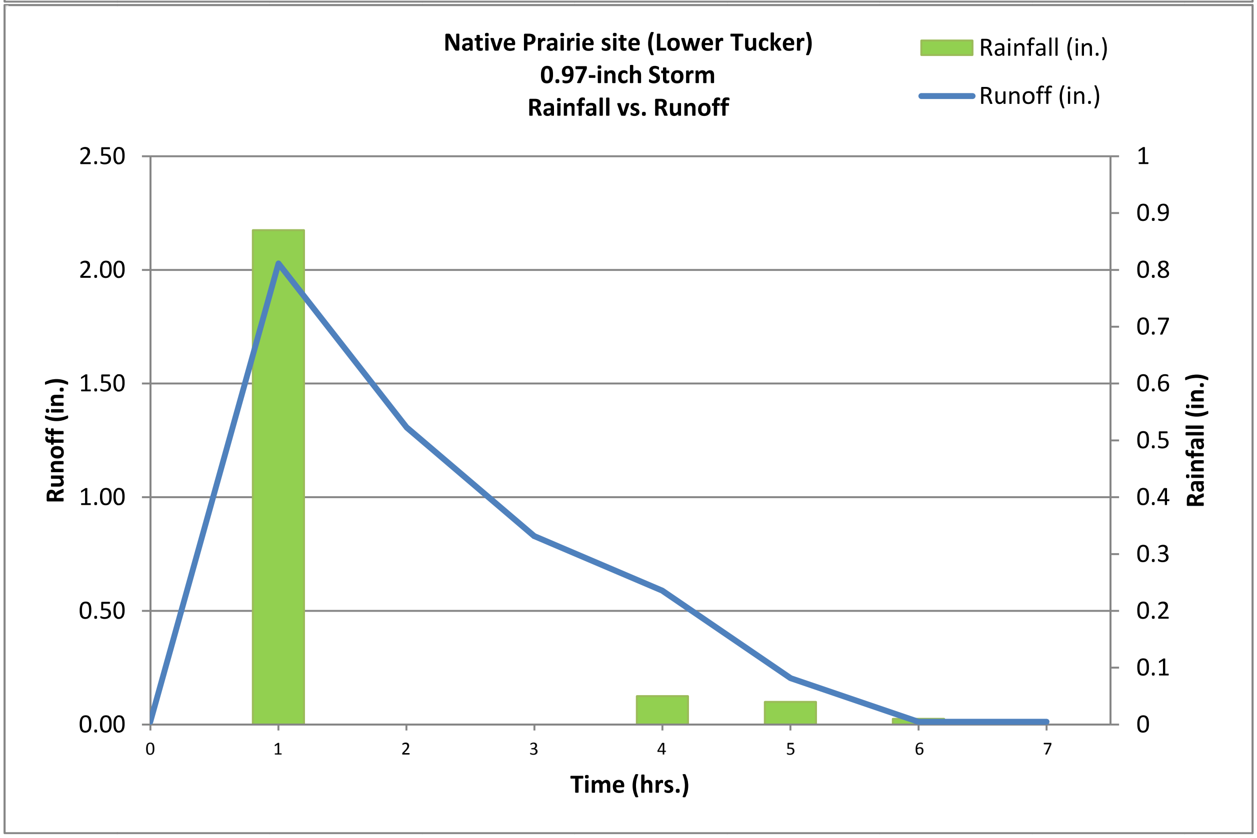
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6


Native Prairie site (Lower Tucker)
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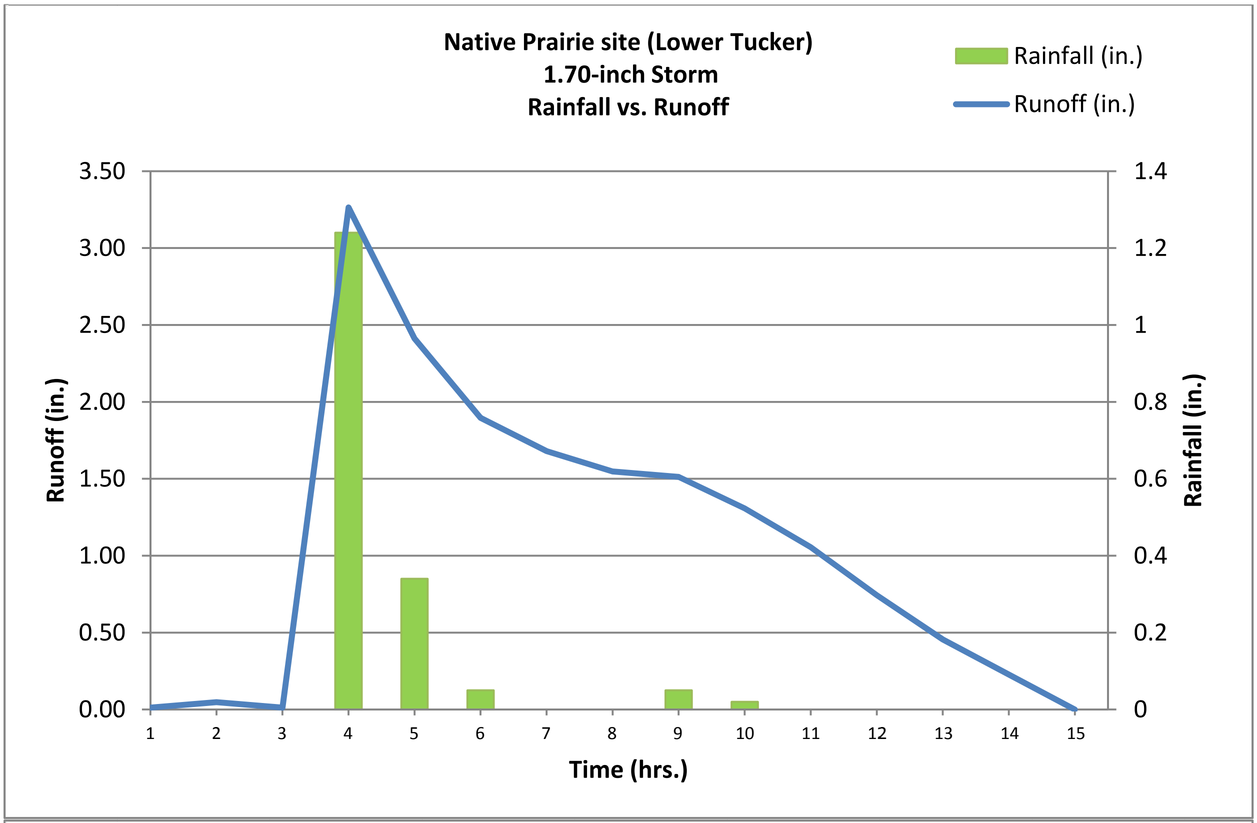
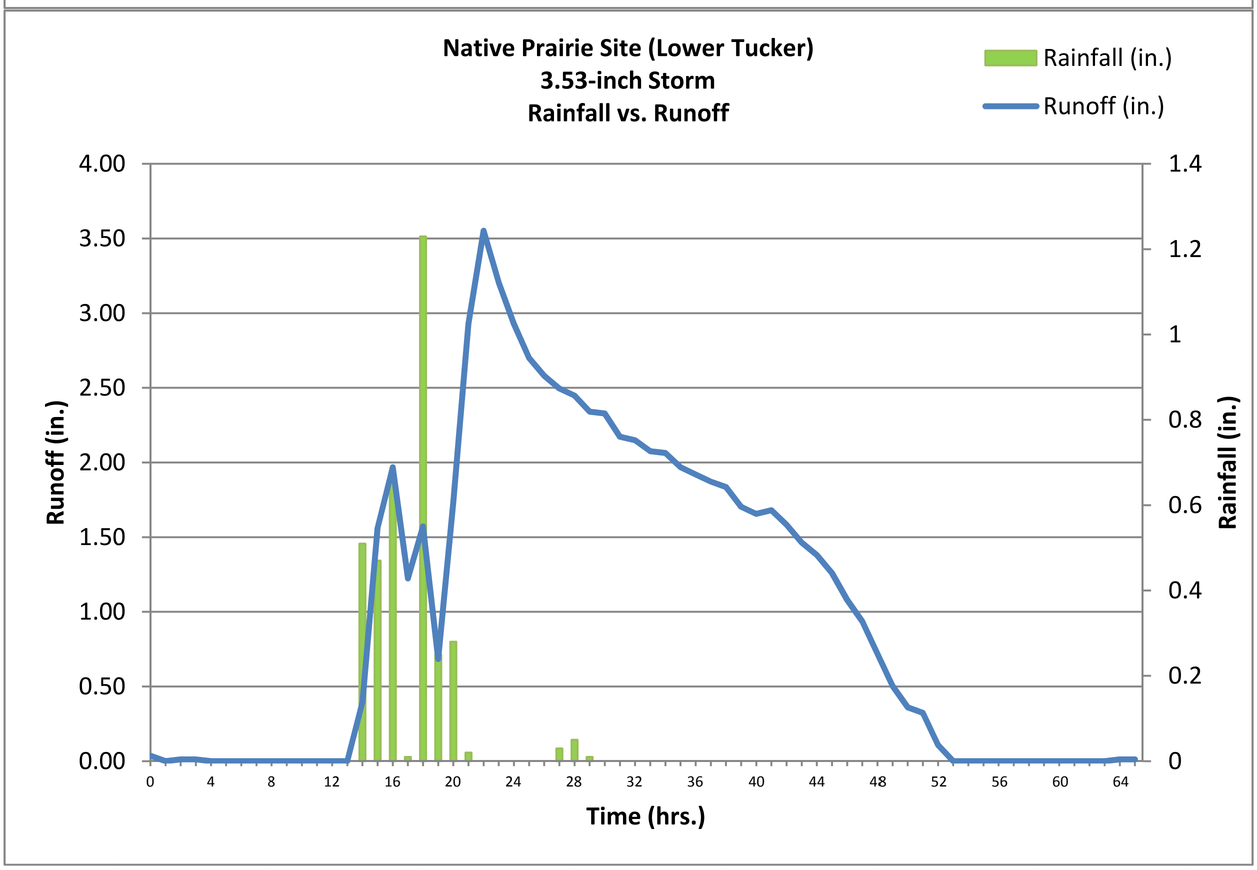
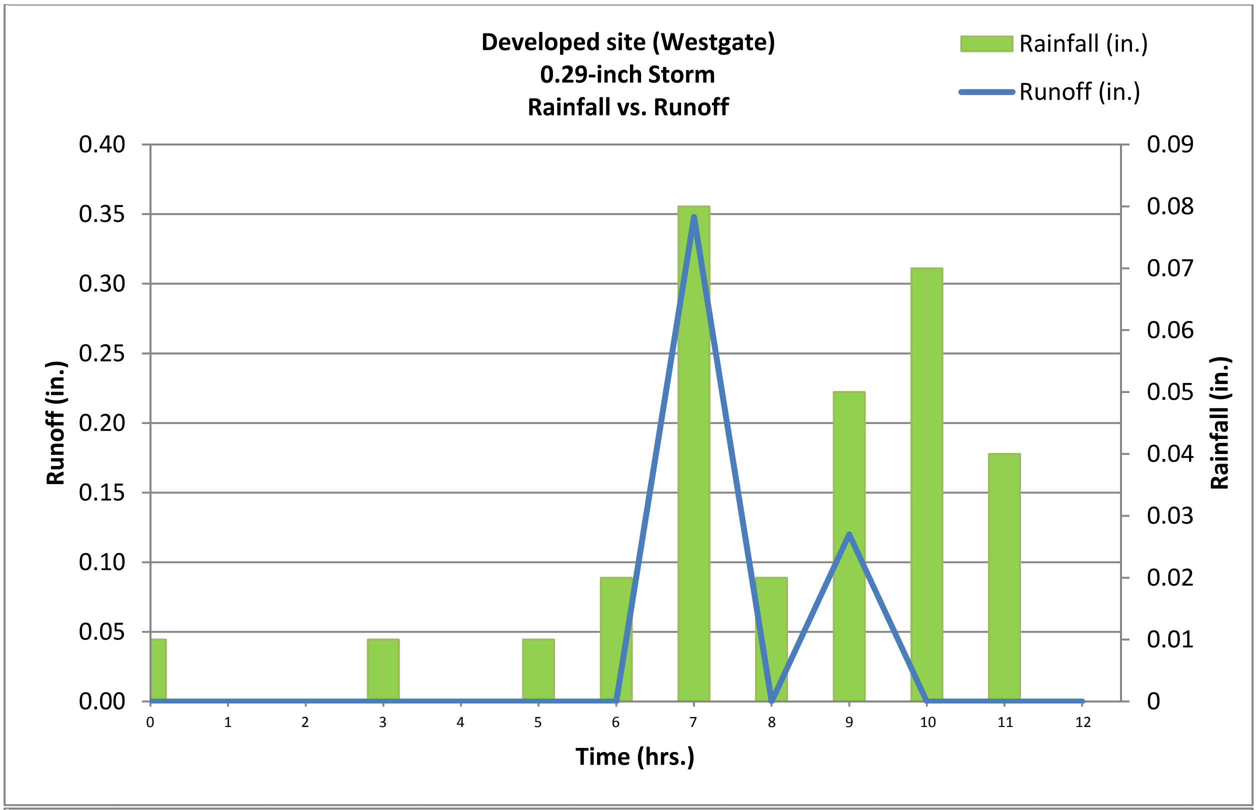
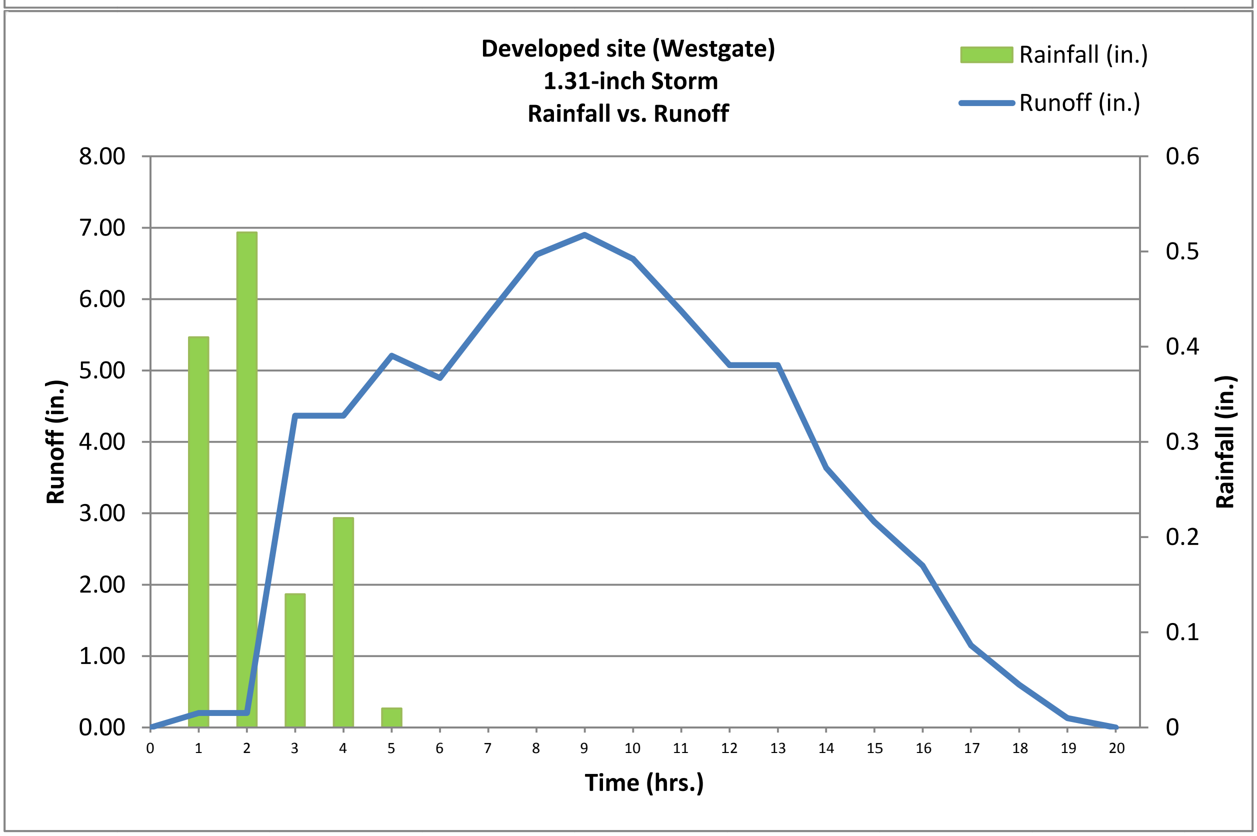
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
2.50
2.00
1.50
1.00
0.50
0.00
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7


Native Prairie site (Lower Tucker)
1.70-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

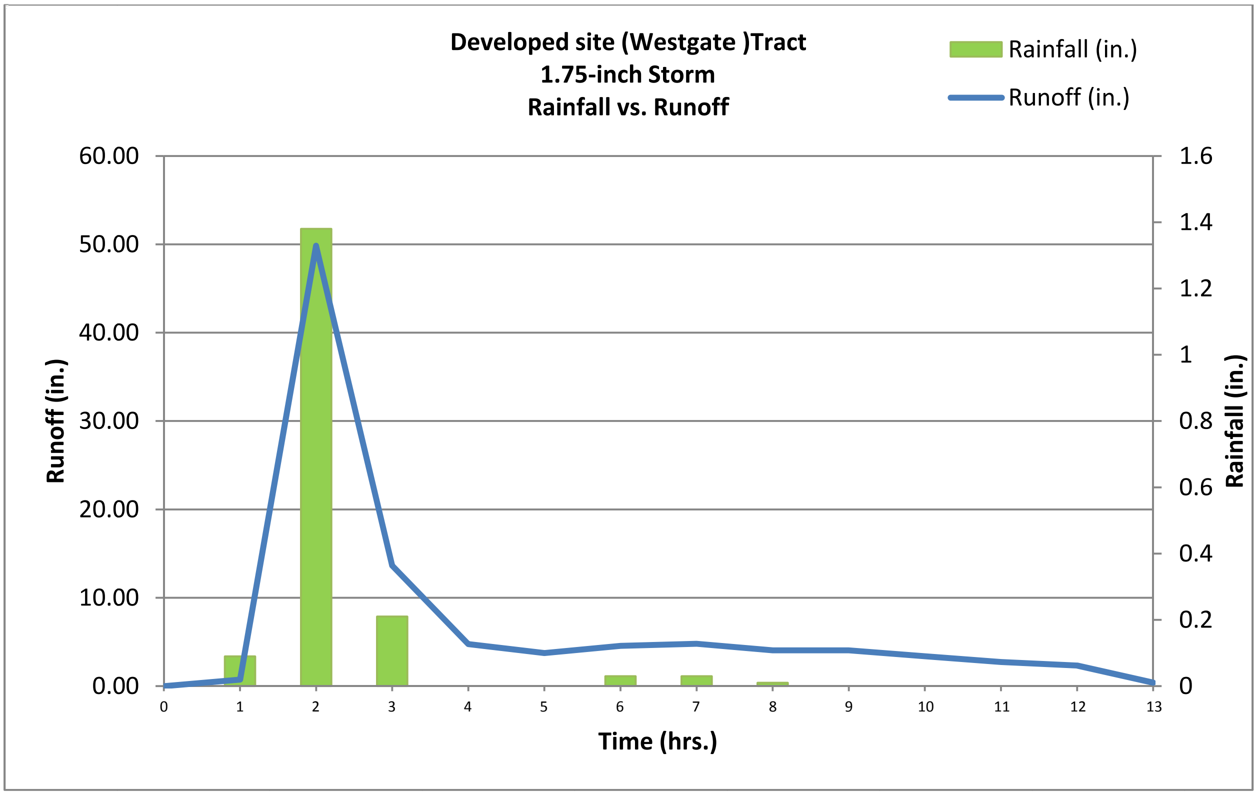

Native Prairie Site (Lower Tucker)
3.53-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64

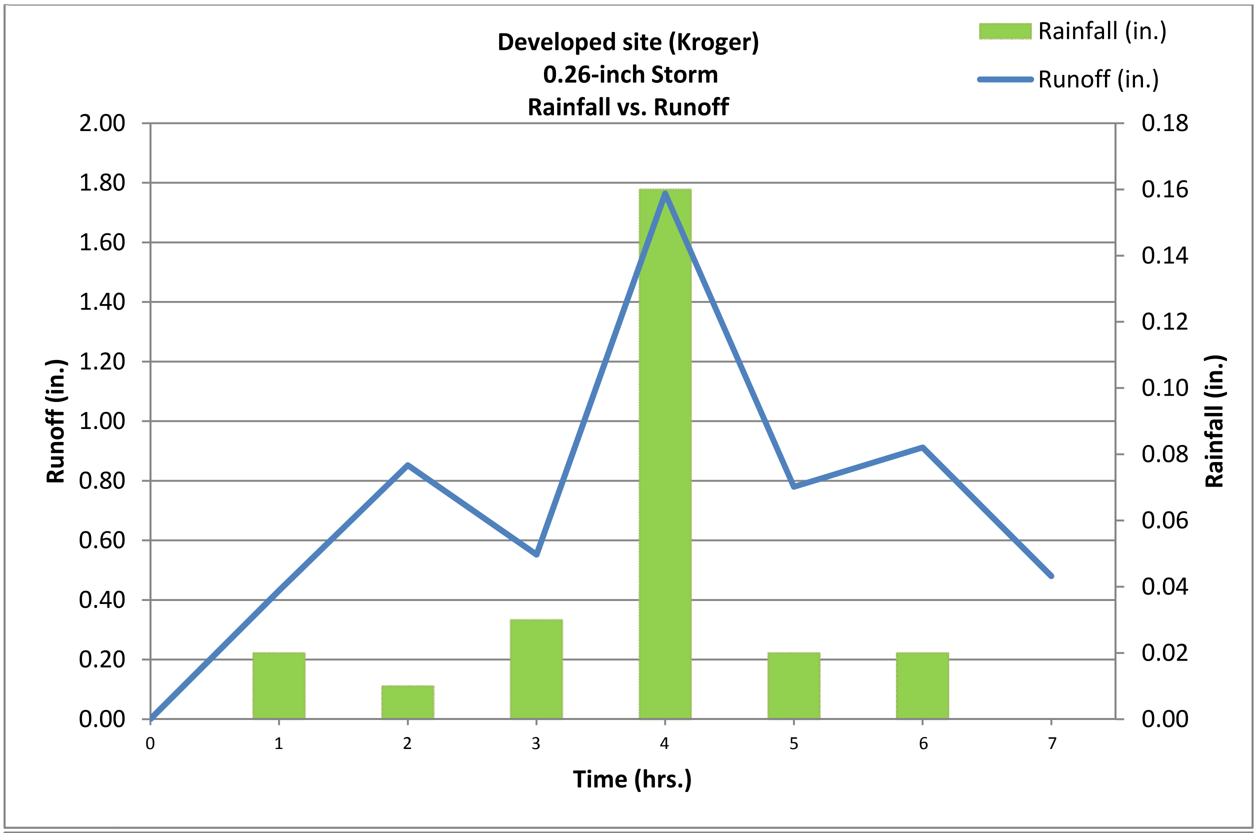


Developed site (Westgate)
0.29-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0 1 2 3 4 5 6 7 8 9 10 11 12

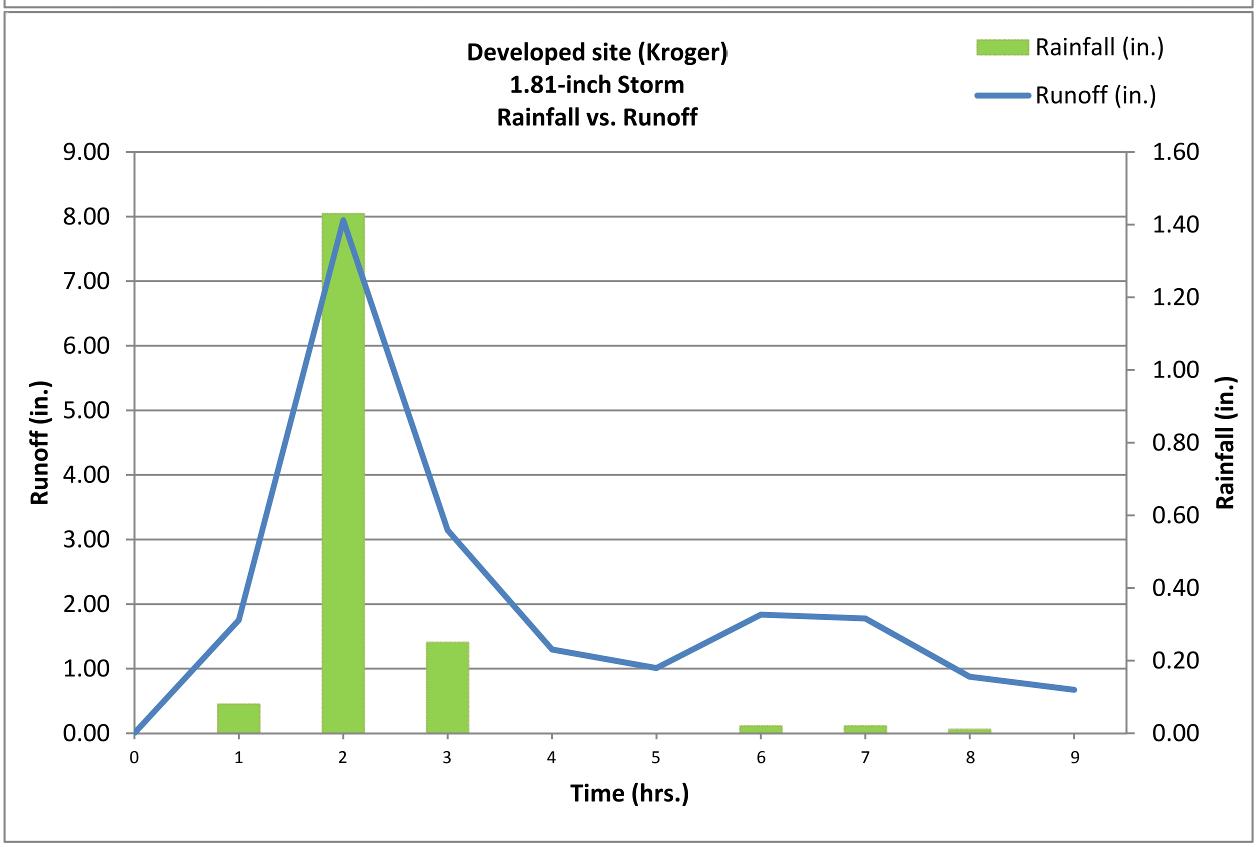


Developed site (Westgate)
1.31-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

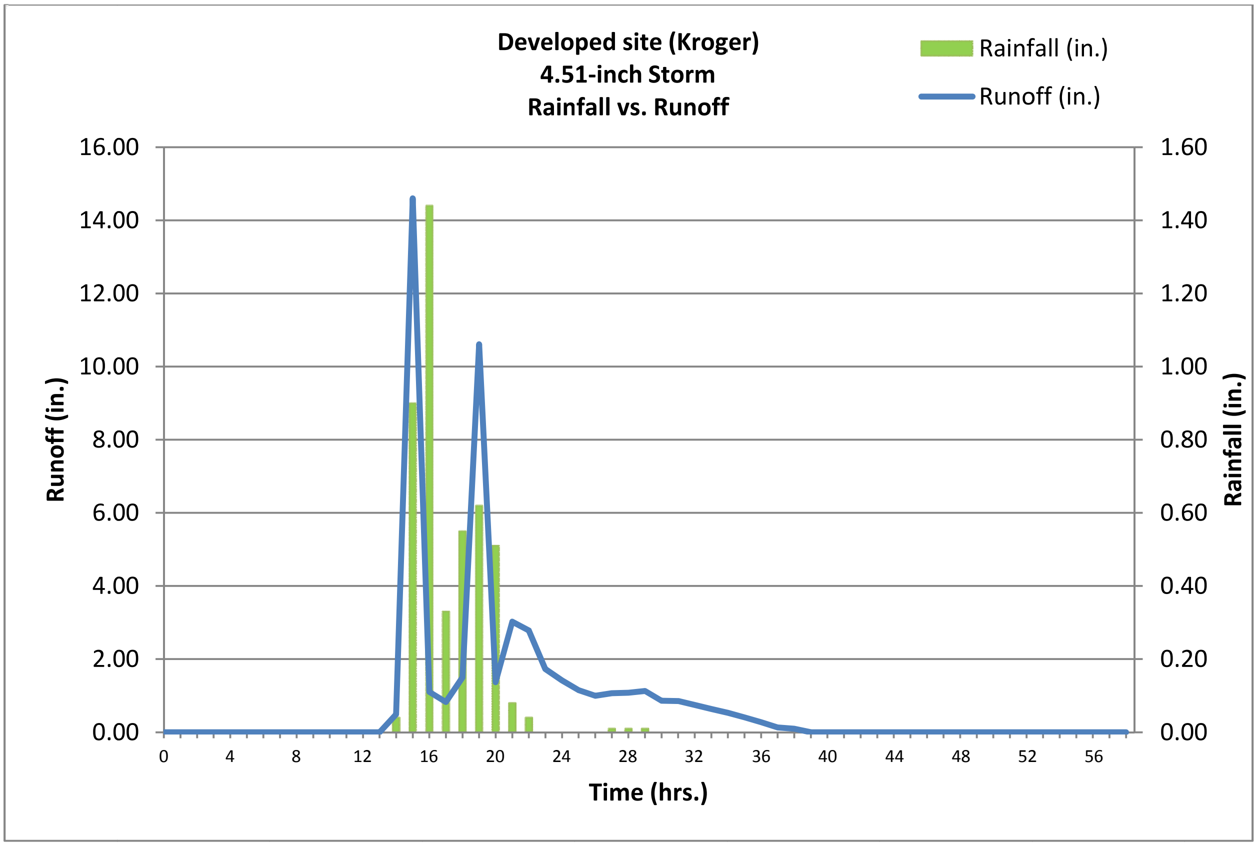

Developed site (Westgate)Tract
1.75-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13



Developed site (Kroger)
0.26-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0 1 2 3 4 5 6 7
Time (hrs.)



Developed site (Kroger)
1.81-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0 1 2 3 4 5 6 7 8 9
Time (hrs.)


Developed site (Kroger)
4.51-inch Storm
Rainfall vs. Runoff
Rainfall (in.)
Runoff (in.)
Runoff (in.)
Rainfall (in.)
Time (hrs.)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56

Supplement 4.0
Investigation of Evapotranspiration

This supplement provides the framework to collect and gather evapotranspiration (ET) data for the project area. Multiple methods are supplied along with referenced facts from reviewed articles. Websites are provided at the end of the supplement to show where these ET data can be located as well as a detailed article written by the Food and Agriculture Organization (FAO) about how to correctly calculate and retrieve evapotranspiration data.

Schuster, J.L. "Soil and Vegetation Management: Keys to Water Conservation on Rangeland." Texas Agricultural Extension Services Leaflet E-168.

Evapotranspiration accounts for 90-96 percent of water loss from Texas rangelands. This is a reason to retain as much water as possible in the area. Water loss is affected mostly by leaf index ratio of vegetation. Smaller root systems lose less water, having lower evapotranspiration rates, making soil water content greater under grassy land. Texas grass cover is the most desirable cover because of its water efficiency, which leads to importance on restoring and maintaining prairie grasses. By measuring the evapotranspiration rate we can identify the amount of water needed to grow or maintain the correct amount of prairie grasses on the sites.

Bremer, D.J., Auen, L.M., Ham, J.M., Owensby, C.E. 2001. "*Evapotranspiration in a Prairie Ecosystem" Effects of Grazing by Cattle"*. Dep. of Agron. KSU. 93:338-348.

One of the most important climatic variables in determining ecosystem structures, function, and productivity in grasslands is the balance between precipitation and evapotranspiration. Few ET data are available for grasslands. In order to measure ET, multiple variables must be measured. These variables are: aboveground biomass, leaf area index (LAI), radiation, soil temperatures, soil water content, and albedo. Multiple methods can be used to gather these data along with multiple equations.

Shuttleworth, J.W. 2008. "Evapotranspiration Measurement Methods". Southwest Hydrology.

There are four different methods to measure ET: water budget measurements, water vapor transfer methods, components of evaporation, large-scale evaporation. Within these four methods the water budget method and the water vapor transfer method are known to be the most common types of measurement methods used. With more research through multiple articles, the Penman-Monteith method is the accepted method through the nation, but many articles researched used both the eddy correlation which calculates 20-60 minute time averages between fluctuations in vertical wind speed and atmospheric humidity measured at high frequency and the Bowen Ratio- Energy Budget method. The Bowen Ratio-Energy Budget method calculates the evaporation at latent heat from the surface energy budget using the ratio of sensible to latent heat. Given that these two methods would require a lot of time, research, installation of instruments and money the Penman-Montieth method is highly recommended.

Natural Resources Management and Environment Department. *"Crop evapotranspiration - Guidelines for computing crop water requirements"*. FAO Corporate Document Repository.

The Penman-Monteith method can be used to calculate ET from near-by weather station data due to the climatic parameters of ET. This method requires radiation, air temperature, air humidity, and wind speed data. Several organizations, such as the International Committee on Irrigation and Drainage and the Water Requirements Committee of the American Society of Civil Engineers, have proposed establishing the Penman-Monteith method as a world-wide standard. Because of this standard and easy access of data, using the Penman-Monteith method would be best advised. Calculation procedures to derive climatic parameters from meteorological data and to estimate missing meteorological variables required for calculating ET are presented in the *"Crop Evapotranspiration - Guidelines for Computing Crop Water Requirements"* reference. Below is the given equation and variables needed for the calculations.

(Equation 1)

$$\lambda ET = \frac{\Delta (R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)}$$

where: R_n = the net radiation;

G = the soil heat flux;

$(e_s - e_a)$ = the vapor pressure deficit of the air;

r_a = the mean air density at constant pressure;

c_p = the specific heat of the air;

D = the slope of the saturation vapor pressure temperature relationship;

g = the psychometric constant; and,

r_s and r_a = the (bulk) surface and aerodynamic resistances.

The Penman-Monteith equation is a combination of multiple equations that include an aerodynamic resistance equation (r_a) and a surface resistance equation (r_s).

(Equation 2)

$$r_a = \frac{\ln\left[\frac{z_m - d}{z_{om}}\right]\ln\left[\frac{z_h - d}{z_{oh}}\right]}{k^2 u_z}$$

(Equation 3)

$$r_s = \frac{r_l}{LAI_{active}}$$

where: r_a = aerodynamic resistance [s m^{-1}];
z_m = height of wind measurements [m];
z_h = height of humidity measurements [m];
d = zero plane displacement height [m];
z_{om} = roughness length governing momentum transfer [m];
z_{oh} = roughness length governing transfer of heat and vapor [m];
k = von Karman's constant, 0.41 [-];
u_z = wind speed at height z [m s^{-1}];
r_s = bulk surface resistance [s m^{-1}];
r_l = bulk stomatal resistance of the well-illuminated leaf [s m^{-1}]; and,
LAI_{active} = active (sunlit) leaf area index [m^2 (leaf area) m^{-2} (soil surface)]

These variables are an extension from the four main data variables: radiation; air temperature; air humidity; and, wind speed data. These data can be accessed through the Fort Bend weather station website, the Texas Water Development Board website, and/or the Texas A&M Agrilife Extension website. Each website gives the potential evapotranspiration (PET) data, which is the estimated water requirement for a crop, that is pre-calculated using the Penman-Monteith method. This data however is for crop averages only, which is a well watered 4 inch tall grass growing in deep soil. Coefficients can be used for various plants and entered into a crop water requirement equation (Equation 4), but the coefficients (Kc) given on the Texas Agrilife Extension website are not specifically for prairie grasses.

(Equation 4) PET x Kc = crop water requirements

The most practical ET data for use by hydrologists may be acquired by accessing the Texas A&M University database, where ET data are calculated each day in the City of Rosenberg, Fort Bend County, Texas. The proximity of the collection and data evaluation station provides near site-specific ET data on a daily basis. The following information is provided regarding contacting the Texas A&M University for ET data:

Texas A&M University
Dr. Guy Fipps, PhD., P.E.
Professor and Extension Agricultural Engineer
Irrigation, Water Management
Texas A&M University Department of Biological and Agricultural Engineering

To access the daily ET data:
http://texaset.tamu.edu
"Current Station - Select A Station": Rosenberg Station
Fort Bend County, Texas
Texas Agrilife Extension
1402 Band Road #100
Rosenberg, Texas 77471
(281) 342-3034

Variables and Data Information Websites.

1) ET data for all year by day.
   http://texaset.tamu.edu/date.php?stn=81&ampspread=14

2) Precautions on Measuring Evapotranspiration and calculations
   http://www.fao.org/docrep/X0490E/x0490e05.htm#TopOfPage

3) Coefficients given to use in Equation 4.
   http://texaset.tamu.edu/cropcoe.php

4) Section 812 monthly ET and Precipitation data since 1954
   http://midgewater.twdb.texas.gov/Evaporation/evap.html

Supplement 5.0
Soil and Vegetation Characteristics of the Study Sites

On-Site Soils Data
Bing Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
1	1-1	0-5	10YR5/3	Sandy Loam	100
1	1-1	5-12	10YR5/3	Sandy Loam	85
1	1-1	5-12	10YR5/8	Redox, Concentrate & Pore Lines	15
1	1-1	12-18	10YR6/8	Bright	40
1	1-2	0-5	10YR5/3	Sandy Loam	100
1	1-2	5-12	10YR5/3		85
1	1-2	5-12	10YR6/8	Pore Lines	15
1	1-3	0-7	10YR5/8	Sandy Loam	100
1	1-3	7-12	10YR5/8		90
1	1-3	7-12	10YR6/8	Pore Lining	10
1	1-3	12-18	10YR5/8		85
1	1-3	12-18	10YR6/8	Pore Lining	15
1	1-3	18	10YR5/8		80
1	1-3	18	5YR5/8		20
1	1-4	0-7	10YR5/3	Sandy Loam	100
1	1-4	7-12	10YR5/3		90
1	1-4	7-12	7.5YR6/8		10
1	1-4	12-18	10YR5/3		85
1	1-4	12-18	5YR5/8		15
1	2-1	0-5	10YR4/3	Sandy Loam	100
2	2-1	5-6	10YR4/3	Sandy Loam	90
2	2-1	5-6	7.5YR6/8	Pore Linings	10
2	2-1	6-12	10YR4/3	Sandy Loam	85
2	2-1	6-12	5Y5/8		15
2	2-1	12-18	10YR5/4	Sandy Loam	85
2	2-1	12-18	7.5YR5/6	Soft Masses	15
2	2-2	0-8	10YR3/3	Sandy Loam	100
2	2-2	8-14	10YR3/3		90
2	2-2	8-14	10YR5/4	Soft Masses	10
2	2-2	14	10YR3/3		85
2	2-2	14	7.5YR5/8	Soft Masses	15
2	2-3	0-5	10YR4/2	Sandy Loam	100
2	2-3	5-12	10YR5/3		85
2	2-3	5-12	7.5YR5/8	Soft Masses/ Pore Linings	15
2	2-3	12-18	10YR5/3	Sandy Loam	90
2	2-3	12-18	5YR5/8		10

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Bing Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
2	2-3	18-24	10YR5/4	Sandy Loam	90
2	2-3	18-24	7.5YR5/8		10
2	2-4	0-6	10YR4/3		95
2	2-4	0-6	5YR5/8	Soft Masses	5
2	2-4	6-12	10YR5/3		90
2	2-4	6-12	7.5YR5/6	Ped Faces And Pore Linings	10
2	2-4	12-18	10YR5/4		85
2	2-4	12-18	5YR5/8	Soft Masses	15
3	3-1	0-6	10YR4/3	Sandy Loam	100
3	3-1	6-12	10YR4/3	Sandy Loam	85
3	3-1	6-12	5YR5/8	Soft Masses/Pore Linings	15
3	3-1	12-18	10YR5/4	Sandy Loam	85
3	3-1	12-18	5Y4/8	Soft Masses	15
3	3-2	0-6	10YR4/3	Sandy Loam	100
3	3-2	6-12	10YR4/3	Sandy Loam	90
3	3-2	6-12	5YR5/8		10
3	3-2	12-18	10YR5/4	Sandy Loam	90
3	3-2	12-18	5YR5/8	Soft Masses/Pore Linings	10
3	3-3	0-6	10YR4/3	Sandy Loam	95
3	3-3	0-6	7.5YR5/8		5
3	3-3	6-12	10YR4.5/3		90
3	3-3	6-12	7.5YR5/8	Ped Faces/ Pore Linings	10
3	3-3	12-18	10YR5/3	Sandy	85
3	3-3	12-18	7.5YR5/8	Pore Linings/Ped Faces	15
3	3-4	0-6	10YR4/3	Sandy Loam	95
3	3-4	0-6	7.5YR5/8	Sandy Loam, Pore Linings And Soft Masses	5
3	3-4	6-12	10YR4/3	Sandy Loam	90
3	3-4	6-12	7.5YR5/6	Pore Linings/Ped Faces	10
3	3-4	12-18	10YR4/3	Sandy Loam	85
3	3-4	12-18	5YR5/8	Sandy Loam	15

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Manor Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
1	1-1	0-5	10YR5/3	Sandy Loam	100
1	1-1	5-12	10YR5/3	Sandy Loam	85
1	1-1	5-12	10YR5/8	Redox, Concentrate & Pore Lines	15
1	1-1	12-18	10YR6/8	Bright	40
1	1-2	0-5	10YR5/3	Sandy Loam	100
1	1-2	5-12	10YR5/3		85
1	1-2	5-12	10YR6/8	Pore Lines	15
1	1-3	0-7	10YR5/8	Sandy Loam	100
1	1-3	7-12	10YR5/8		90
1	1-3	7-12	10YR6/8	Pore Lining	10
1	1-3	12-18	10YR5/8		85
1	1-3	12-18	10YR6/8	Pore Lining	15
1	1-3	18	10YR5/8		80
1	1-3	18	5YR5/8		20
1	1-4	0-7	10YR5/3	Sandy Loam	100
1	1-4	7-12	10YR5/3		90
1	1-4	7-12	7.5YR6/8		10
1	1-4	12-18	10YR5/3		85
1	1-4	12-18	5YR5/8		15
1	2-1	0-5	10YR4/3	Sandy Loam	100
2	2-1	5-6	10YR4/3	Sandy Loam	90
2	2-1	5-6	7.5YR6/8	Pore Linings	10
2	2-1	6-12	10YR4/3	Sandy Loam	85
2	2-1	6-12	5Y5/8		15
2	2-1	12-18	10YR5/4	Sandy Loam	85
2	2-1	12-18	7.5YR5/6	Soft Masses	15
2	2-2	0-8	10YR3/3	Sandy Loam	100
2	2-2	8-14	10YR3/3		90
2	2-2	8-14	10YR5/4	Soft Masses	10
2	2-2	14	10YR3/3		85
2	2-2	14	7.5YR5/8	Soft Masses	15
2	2-3	0-5	10YR4/2	Sandy Loam	100
2	2-3	5-12	10YR5/3		85
2	2-3	5-12	7.5YR5/8	Soft Masses/ Pore Linings	15
2	2-3	12-18	10YR5/3	Sandy Loam	90
2	2-3	12-18	5YR5/8		10

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Manor Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
2	2-3	18-24	10YR5/4	Sandy Loam	90
2	2-3	18-24	7.5YR5/8		10
2	2-4	0-6	10YR4/3		95
2	2-4	0-6	5YR5/8	Soft Masses	5
2	2-4	6-12	10YR5/3		90
2	2-4	6-12	7.5YR5/6	Ped Faces And Pore Linings	10
2	2-4	12-18	10YR5/4		85
2	2-4	12-18	5YR5/8	Soft Masses	15
3	3-1	0-6	10YR4/3	Sandy Loam	100
3	3-1	6-12	10YR4/3	Sandy Loam	85
3	3-1	6-12	5YR5/8	Soft Masses/Pore Linings	15
3	3-1	12-18	10YR5/4	Sandy Loam	85
3	3-1	12-18	5Y4/8	Soft Masses	15
3	3-2	0-6	10YR4/3	Sandy Loam	100
3	3-2	6-12	10YR4/3	Sandy Loam	90
3	3-2	6-12	5YR5/8		10
3	3-2	12-18	10YR5/4	Sandy Loam	90
3	3-2	12-18	5YR5/8	Sm/Pore Linings	10
3	3-3	0-6	10YR4/3	Sandy Loam	95
3	3-3	0-6	7.5YR5/8		5
3	3-3	6-12	10YR4.5/3		90
3	3-3	6-12	7.5YR5/8	Ped Faces/ Pore Linings	10
3	3-3	12-18	10YR5/3	Sandy	85
3	3-3	12-18	7.5YR5/8	Pore Linings/Ped Faces	15
3	3-4	0-6	10YR4/3	Sandy Loam	95
3	3-4	0-6	7.5YR5/8	Sandy Loam, Pore Linings And Soft Masses	5
3	3-4	6-12	10YR4/3	Sandy Loam	90
3	3-4	6-12	7.5YR5/6	Pore Linings/Ped Faces	10
3	3-4	12-18	10YR4/3	Sandy Loam	85
3	3-4	12-18	5YR5/8	Sandy Loam	15

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Upper Tucker Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
1	1-1	0-6	10YR5/4	Sandy	60
1	1-1	0-6	10YR4/3	Sandy	38
1	1-1	0-6	7.5YR5/8	Sandy	2
1	1-1	6-12	10YR5/3		98
1	1-1	6-12	5YR5/8	Ped Faces/Pore Linings	2
1	1-1	12-18	10YR5/3		95
1	1-1	12-18	7.5YR5/8	Ped Faces	5
1	1-2	0-6	7.5YR4/3	Sandy	95
1	1-2	0-6	5YR5/8	Ped Faces/Pore Linings	5
1	1-2	6-12	7.5YR4/3	Sandy	95
1	1-2	6-12	2.5YR4/8	Ped Faces	5
1	1-2	12-18	10YR4/5	Sandy	95
1	1-2	12-18	7.5YR5/8	Ped Faces/Sandy	5
1	1-3	0-6	10YR4/3		97
1	1-3	0-6	7.5YR5/8	Ped Faces/Pore Linings	3
1	1-3	6-12	10YR4/3	Sandy	97
1	1-3	6-12	7.5YR5/8	Sandy/Ped Faces	3
1	1-3	12-18	10YR5/3	Sandy	60
1	1-3	12-18	10YR4/1	Sandy	39
1	1-3	12-18	7.5YR5/8	Ped Faces	1
1	1-4	0-6	10YR4/3	Sandy	99
1	1-4	0-6	7.5YR5/8	Ped Faces/Pore Linings	1
1	1-4	6-12	10YR4/3	Sandy	98
1	1-4	6-12	7.5YR5/8	Sandy/Ped Faces/Pore Linings	2
1	1-4	12-18	10YR4/3	Sandy	95
1	1-4	12-18	7.5YR5/8	Sandy/Ped Faces/Pore Linings	5
2	2-1	0-6	7.5YR3/2	Sand	99
2	2-1	0-6	2.5YR4/8	Pore Linings	1
2	2-1	6-12	7.5YR4/3	Sandy	100
2	2-1	12-18	10YR5/4	Sandy Loam	100
2	2-2	0-6	10YR3/3	Sandy	99
2	2-2	0-6	7.5YR4/8	Sandy/Ped Faces	1
2	2-2	6-8	10YR3/2	Sandy	99
2	2-2	6-8	7.5YR4/6	Sandy	1
2	2-2	8-12	10YR3/2	Loam/Clay	90
2	2-2	8-12	10YR6/8	Loam/Clay	10
2	2-2	12-18	10YR5/3	Sandy	97
2	2-2	12-18	7.5YR5/8	Sandy	3
2	2-3	0-4	10YR4/2	Sandy	100

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Upper Tucker Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
2	2-3	4-6	10YR4/2	Sandy	98
2	2-3	4-6	7.5YR5/8	Sandy/Ped Faces/Pore Linings	2
2	2-3	6-12	10YR4/2	Sand	90
2	2-3	6-12	10YR6/8	Sandy	8
2	2-3	6-12	5YR4/8	Sandy/Ped Faces	2
2	2-3	12-18	10YR4/3	Sandy	98
2	2-3	12-18	7.5YR5/8	Sandy/Ped Faces	2
2	2-4	0-6	10YR 4/2	Sandy	95
2	2-4	0-6	10YR6/6	Loam/Clay	4
2	2-4	0-6	7.5YR5/8	Sandy/Ped Faces/Pore Linings	1
2	2-4	6-12	10YR3/3	Sandy	99
2	2-4	6-12	7.5YR5/8	Sandy/Ped Faces	1
2	2-4	12-18	10YR4/3	Loam/Clay	98
2	2-4	12-18	7.5YR5/8	Ped Faces/Clay/Loam	2
3	3-1	0-6	10YR5/3	Loam/Clay	97
3	3-1	0-6	5YR5/8	Loam/Clay/Ped Faces	3
3	3-1	6-12	10YR5/2	Loam/Clay	95
3	3-1	6-12	7.5YR5/8	Loam/Clay/Ped Faces	5
3	3-1	12-18	10YR4/2	Loam/Clay	97
3	3-1	12-18	7.5YR5/8	Loam/Clay/Ped Faces	3
3	3-2	0-6	10YR4/2	Loam/Clay	97
3	3-2	0-6	7.5YR5/8	Loam/Clay/Ped Faces/Pore Lining	3
3	3-2	6-12	7.5YR5/2	Loam/Clay	95
3	3-2	6-12	7.5YR5/8	Loam/Clay/Ped Face/Pore Linings	5
3	3-2	12-18	7.5YR5/2	Loam/Clay	95
3	3-2	12-18	7.5YR5/8	Loam/Clay/Pore Linings/Ped Faces	5
3	3-3	0-6	1OYR5/2	Loam/Clay	95
3	3-3	0-6	7.5YR5/8	Loam/Clay/Pore Linings/Ped Faces	5
3	3-3	6-12	10YR5/2	Loam/Clay	95
3	3-3	6-12	7.5YR5/8	Loam/Clay/Pore Linings/Ped Faces	5
3	3-3	12-18	10YR5/2	Loam/Clay	90
3	3-3	12-18	5YR5/8	Loam/Clay/Soft Masses/Ped Faces/Pore Linings	10
3	3-4	0-6	10YR4/3	Loam/Clay	97
3	3-4	0-6	7.5YR5/8	Loam/Clay/Pore Linings	3
3	3-4	6-12	10YR4/3	Loam/Clay	93
3	3-4	6-12	7.5YR5/8	Loam/Clay/Pore Linings/Ped Faces	7
3	3-4	12-18	10YR4/3	Loam/Clay	93
3	3-4	12-18	5YR5/8	Loam/Clay/Ped Faces	7

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Upper Tucker Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
4	4-1	0-6	10YR4/3	Sandy	98
4	4-1	0-6	5YR5/8	Sandy/Ped Faces/Pore Linings	2
4	4-1	6-12	10YR4/3	Sandy	98
4	4-1	6-12	5YR5/8	Sandy/Ped Faces	2
4	4-1	12-18	10YR4/3	Sandy	95
4	4-1	12-18	7.5YR5/8	Sandy/Ped Faces	5
4	4-2	0-6	10YR4/3	Sandy	95
4	4-2	0-6	7.5YR5/8	Sandy/Ped Faces	5
4	4-2	6-12	10YR4/3	Loam/Clay	93
4	4-2	6-12	10YR4/3	Loam/Clay/Ped Faces	7
4	4-2	12-18	10YR4/3	Loam/Clay	93
4	4-2	12-18	5YR5/8	Loam/Clay/Ped Faces	7
4	4-3	0-6	10YR4/3	Sandy	97
4	4-3	0-6	7.5YR5/8	Sandy/Ped Faces	3
4	4-3	6-12	10YR4/3	Sandy	97
4	4-3	6-12	7.5YR5/8	Sandy/Ped Faces	3
4	4-3	12-18	10YR4/3	Sandy	97
4	4-3	12-18	7.5YR5/8	Sand/Ped Faces	3
4	4-4	0-6	10YR4/3	Sandy	95
4	4-4	0-6	7.5YR5/8	Sand/Ped Faces	5
4	4-4	6-12	10YR4/3	Loam/Clay	95
4	4-4	6-12	7.5YR5/8	Loam/Clay/Ped Faces	5
4	4-4	12-18	10YR5/8	Loam/Clay	95
4	4-4	12-18	7.5YR5/8	Loam/Clay/Ped Faces	5

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Lower Tucker Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
1	1-1	0-6	10YR4/2.5	Sandy Loam	95
1	1-1	0-6	7.5YR5/8	Sandy Loam/Ped Faces/Pore Linings	5
1	1-1	6-12	10YR4/3	Sandy	98
1	1-1	6-12	7.5YR5/8	Sand/Ped Faces	2
1	1-1	12-18	10YR4/3	Sandy	98
1	1-1	12-18	7.5YR5/8	Sand/Ped Faces	2
1	1-2	0-6	10YR4/3	Sandy Loam	97
1	1-2	0-6	7.5YR5/8	Sandy Loam/Ped Faces/Pore Linings	3
1	1-2	6-12	10YR4/3	Sandy Loam	97
1	1-2	6-12	7.5YR5/8	Sandy Loam/Ped Faces	3
1	1-2	12-18	10YR4/3	Sandy Loam	80
1	1-2	12-18	7.5YR6/4	Sandy Loam	15
1	1-2	12-18	5YR5/8	Sandy Loam/Ped Faces	5
1	1-3	0-6	10YR4/3	Sandy Loam	95
1	1-3	0-6	7.5YR5/8	Pore Linings/Ped Faces	5
1	1-3	6-12	10YR4/3	Sandy Loam	95
1	1-3	6-12	7.5YR5/8	Pore Linings/Ped Faces	5
1	1-3	12-18	10YR4/3	Sandy Loam	95
1	1-3	12-18	7.5YR5/8	Pore Linings/Ped Faces	5
1	1-4	0-6	10YR4/3	Sandy Loam	97
1	1-4	0-6	7.5YR5/8	Sandy Loam/Ped Faces/Pore Linings	3
1	1-4	6-12	10YR4/3	Sandy Loam	90
1	1-4	6-12	7.5YR6/4		7
1	1-4	6-12	7.5YR5/8	Sandy Loam/Ped Faces	3
1	1-4	12-18	10YR4/3	Sandy Loam	90
1	1-4	12-18	7.5YR6/4		7
1	1-4	12-18	7.5YR5/8	Sandy Loam/Ped Faces	3
2	2-1	0-6	7.5YR4/3	Sandy	100
2	2-1	6-12	7.5YR4/3	Sandy	100
2	2-1	12-18	10YR4/3	Sany Loam	100
2	2-1	18-24	10YR4/3	Sandy Loam	97
2	2-1	18-24	7.5YR5/8	Sandy Loam/Ped Faces	3
2	2-2	0-6	7.5YR4/3	Sandy	100
2	2-2	6-12	7.5YR4/3	Sandy	100
2	2-2	12-18	7.5YR4/3	Sandy	100
2	2-2	18-24	10YR4/3	Sandy Loam	98
2	2-2	18-24	7.5YR5/8	Sandy Loam/Ped Faces	2

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Lower Tucker Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma[1]	Comments	Percentage Occurrence in Sample
2	2-3	0-6	7.5YR4/3	Sandy	100
2	2-3	6-12	7.5YR4/3	Sandy	100
2	2-3	12-18	7.5YR4/3	Sandy	100
2	2-3	18-24	10YR4/3	Sandy Loam	98
2	2-3	18-24	7.5YR5/8	Sandy Loam/Ped Faces	2
2	2-4	0-6	7.5YR4/3	Sandy	100
2	2-4	6-12	7.5YR4/3	Sandy	100
2	2-4	12-18	7.5YR4/3	Sandy	100
2	2-4	18-24	10YR4/3	Sandy Loam	98
2	2-4	18-24	7.5YR5/8	Sandy Loam/Ped Faces	2

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Kroger Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma1	Comments	Percentage Occurrence in Sample
1	1-1	0-6	10YR4/3		60
1	1-1	0-6	10YR7/1	Sandy Clay/Loam	30
1	1-1	0-6	10YR5/8		10
1	1-1	6-12	10YR5/3		45
1	1-1	6-12	10YR7/1		45
1	1-1	6-12	7.5YR5/8		10
1	1-1	12-18	10YR5/3		60
1	1-1	12-18	10YR7/1		35
1	1-1	12-18	2.5YR6/8		3
1	1-1	12-18	10YR6/8		2

[1] Chroma = Munsell Color Chart Observation

On-Site Soils Data
Westgate Site

Plot Number	Soil Bore	Layer Depth (in.)	Chroma1	Comments	Percentage Occurrence in Sample
1	1-1	0-6	10YR4/3	Sandy Clay/Loam	90
1	1-1	0-6	10YR8/1		5
1	1-1	0-6	7.5YR5/8		3
1	1-1	0-6	2.5YR4/8		2
1	1-1	6-12	10YR4/3		90
1	1-1	6-12	10YR4/1		5
1	1-1	6-12	10YR5/8		3
1	1-1	6-12	2.5YR4/8		2
1	1-1	12-18	10YR5/3		95
1	1-1	12-18	10YR7/1		1
1	1-1	12-18	2.5YR6/8		2
1	1-1	12-18	2.5YR4/8		2

[1] Chroma = Munsell Color Chart Observation

Groundcover Vegetation Sampling Data
Bing Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Cynodon dactylon	BERMUDAGRASS	A	FACU	27.36%
Croton capitatus var. lindheimeri	WOOLLY CROTON	N		19.91%
Bareground				15.96%
Unknown Cyperus				11.40%
Sida acuta	COMMON WIREWEED	N		5.32%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	5.32%
Cyperus rotundus	NUTGRASS	A	FACU	4.86%
Paspalum sectaceum	THIN PASPALUM	N	FAC	1.52%
Cyperus retrorsus	PINEBARREN FLATSEDGE	N	FACU	1.06%
Rubus sp.				0.91%
Diodia teres	POOR JOE; ROUGH BUTTONWEED	N	FACU	0.91%
Cyperus sp.				0.76%
Panicum dichotomiflorum	FALL PANICGRASS	N	FACW	0.76%
Polygonum hydropiperoides	WATERPEPPER	N	OBL	0.76%
Chamaesyce maculata	SPOTTED SANDMAT	N	FACU	0.76%
Verbena scabra	SANDPAPER VERVAIN; HARSH VERVAIN	N	FACW	0.30%
Digitaria ciliaris	SOUTHERN CRABGRASS	N	FAC	0.30%
Panicum dichotomiflorum	FALL PANICGRASS	A	OBL	0.15%
Cyperus polystachyos	MANYSPIKE FLATSEDGE	N	FACW	0.15%
Helenium amarum	SPANISH DAISY; BITTERWEED	N	FACU	0.15%
Heliotropium procumbens	FOURSPIKE HELIOTROPE	A	FACW	0.15%
Lythrum alatum var. lanceolatum	WINGED LOOSESTRIFE	N	FACW	0.15%
Phyla nodiflora	TURKEY TANGLE FOGFRUIT; CAPEWEED	N	FACW	0.15%
Polyeonum pluctatum	DOTTED SMARTWEED	N	FACW	0.15%
Polygonum punctatum	DOTTED SMARTWEED	N	FACW	0.15%
Setaria parviflora	YELLOW BRISTLEGRASS; KNOTROOT FOXTAIL	N	FAC	0.15%
Unknown Asteraceae				0.15%
Urochloa platyphylla	BROADLEAF SIGNALGRASS	N	FAC	0.15%
Iva annua	ANNUAL MARSHELDER	N	FAC	0.15%
TOTAL VEGETATION COVERAGE				**84.04%**

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Manor Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Croton capitatus var. lindheimeri	WOOLLY CROTON	N		23.36%
Bareground				15.57%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	11.25%
Aristida longispica	SLIMSPIKE THREEAWN	N	FACU	11.25%
Cynodon dactylon	BERMUDAGRASS	A	FACU	11.25%
Agalinis fasciculata	BEACH FALSE FOXGLOVE	N	FAC	6.92%
Helenium amarum	SPANISH DAISY; BITTERWEED	N	FACU	6.06%
Chrysposis pilosa	SOFT GOLDENASTER	N		5.54%
Euthamia caroliniana	SLENDER FLATTOP GOLDENROD	N	FAC	1.90%
Cyperus sp.				1.21%
Cyperus retrorsus	PINEBARREN FLATSEDGE	N	FACU	1.04%
Diodia teres	POOR JOE; ROUGH BUTTONWEED	N	FACU	0.87%
Eragrostis secundiflora subsp. *Oxylepis*	RED LOVEGRASS	N	FAC	0.87%
Dichanthelium oligosanthes var. scribnerianum	SCRIBNER'S ROSETTE GRASS	N		0.87%
Conyza canadensis	CANADIAN HORSEWEED	N	FACU	0.35%
Linum medium var. texanum	STIFF YELLOW FLAX	N	FAC	0.35%
Andropogon glomeratus var. hirsutior	BUSHY BLUESTEM	N	FACW	0.35%
Verbena scabra	SANDPAPER VERVAIN; HARSH VERVAIN	N	FACW	0.17%
Eupatorium serrotinum	LATEFLOWERING THOROUGHWORT	N	FAC	0.17%
Iva annua	ANNUAL MARSHELDER	N	FAC	0.17%
Chamaecrista fasciculata	PARTRIDGE PEA	N	FACU	0.17%
Polygonum punctatum	DOTTED SMARTWEED	N	FACW	0.17%
Urochloa platyphylla	BROADLEAF SIGNALGRASS	N	FAC	0.17%
TOTAL VEGETATION COVERAGE				**84.43%**

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Upper Tucker Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Paspalum urvillei	VASEYGRASS	N	FAC	14.52%
Bidens bipinnata	SPANISH NEEDLES	N		7.74%
Euthamia caroliniana	SLENDER FLATTOP GOLDENROD	N	FAC	7.36%
Gaura lindheimeri	LINDHEIMER'S BEEBLOSSOM	A		7.26%
Schizachyrium scoparium var. divergens	LITTLE BLUESTEM	N	FACU	7.26%
Schizachyrium scoparium var. divergens	LITTLE BLUESTEM	N	FACW	7.26%
Paspalum setaceum	THIN PASPALUM	N	FAC	6.29%
Boltonia diffusa	SMALLHEAD DOLL'S DAISY	N	FAC	5.81%
Bareground				4.36%
Dichanthelium scoparium	VELVET WITCHGRASS	N	FACW	3.97%
Sorghastrum nutans	YELLOW INDIANGRASS	N	FACU	3.48%
Polygonum hydropiperoides	MILD WATERPEPPER; SWAMP SMARTWEED	N	OBL	3.39%
Steinchisma Hians	GAPING GRASS	N		3.00%
Guara lindheimeri	LINDHEIMER'S BEEBLOSSOM	A		2.90%
Eragrostis intermedia	PLAINS LOVEGRASS	N	FAC	2.90%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	1.45%
Rubus sp.				0.97%
Panicum virgatum	SWITCHGRASS	N	FAC	0.97%
Croton capitatus var. lindheimeri	WOOLLY CROTON; HOGWORT	N		0.68%
Setaria parviflora	YELLOW BRISTLEGRASS; KNOTROOT FOXTAIL	N	FAC	0.58%
Agalinis fasciculata	BEACH FALSE FOXGLOVE	N	FAC	0.58%
Rudbeckia hirta	BLACKEYED SUSAN	N	FACU	0.58%
Chrysposis pilosa	SOFT GOLDENASTER	N		0.58%
Myrica cerifera	SOUTHERN BAYBERRY; WAX MYRTLE	N	FAC	0.48%
Liatris acidota	SHARP GAYFEATHER	N	FACW	0.48%
Baccharis halimifolia	GROUNDSEL TREE; SEA MYRTLE	N	FAC	0.48%
Panicumsp.				0.48%
Paspalum urvillei	VASEYGRASS	A	FAC	0.48%
Conyza canadensis	CANADIAN HORSEWEED	N	FACU	0.48%
Bidens aristosa	TICKSEED SUNFLOWER	N	FACW	0.48%
Eupatorium serotinum	LATEFLOWERING THOROUGHWORT	N	FACW	0.48%
Cyperus retrorsus	PINEBARREN FLATSEDGE	N	FACU	0.19%
Dichanthelium oligosanthes var. scribnerianum	SCRIBNER'S ROSETTE GRASS	N		0.19%

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Upper Tucker Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Chamaecrista fasciculata	PARTRIDGE PEA	N	FACU	0.19%
Commelina erecta	WHITEMOUTH DAYFLOWER	N		0.10%
Conoclinium coelestinum	BLUE MISTFLOWER	N	FAC	0.10%
Axonopus fissifolius	CARPET GRASS	N	FACW	0.10%
Croton michauxii	RUSHFOIL; MICHAUX'S CROTON	N		0.10%
Cyperus croceus	BALDWIN'S FLATSEDGE	N	FAC	0.10%
Cyperus polystachyos	MANYSPIKE FLATSEDGE	N		0.10%
Cyperus sp.				0.10%
Eupatorium serotinum	LATEFLOWERING THOROUGHWORT	N	FAC	0.10%
Unknown Panicum				0.10%
Helenium amarum	SPANISH DAISY; BITTERWEED	N	FACU	0.10%
Heterotheca subaxillaris	CAMPHORWEED	N	FACU	0.10%
Juncus dichotomus	FORKED RUSH	N	FACW	0.10%
Linum medium var. texanum	STIFF YELLOW FLAX	N	FAC	0.10%
Oxalis Latifolia	GARDEN PINK SORREL	A		0.10%
Rubus sp.		N	FACW	0.10%
Sesbania herbacea	DANGLEPOD	N	FACW	0.10%
Diodia teres	POOR JOE; ROUGH BUTTONWEED	N	FACU	0.10%
TOTAL VEGETATION COVERAGE				**95.64%**

N = Native species
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OBL = Obligate Wetland species
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FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Lower Tucker Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Croton capitatus var. lindheimeri	WOOLLY CROTON; HOGWORT	N		16.70%
Paspalum notatum	BAHIAGRASS	A	FACU	15.66%
Schizachyrium scoparium var. divergens	LITTLE BLUESTEM	N	FACU	7.31%
Gaura lindheimeri	LINDHEIMER'S BEEBLOSSOM	N		6.47%
Aristida longespica	SLIMSPIKE THREEAWN	N	FACU	6.26%
Diodia teres	POOR JOE; ROUGH BUTTONWEED	N	FACU	6.26%
Bidens aristosa	TICKSEED SUNFLOWER	N	FACW	6.26%
Sesbania herbacea	DANGLEPOD	N	FACW	6.26%
Eupatorium serotinum	LATEFLOWERING THOROUGHWORT	N	FACW	6.26%
Paspalum setaceum	THIN PASPALUM	N	FAC	6.26%
Bareground				2.09%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	2.09%
Cyperus retrorsus	PINEBARREN FLATSEDGE	N	FACU	1.25%
Polygonum hydropiperoides	MILD WATERPEPPER; SWAMP SMARTWEED	N	OBL	1.04%
Rubus sp.				1.04%
Setaria parviflora	YELLOW BRISTLEGRASS; KNOTROOT FOXTAIL	N	FAC	1.04%
Unknown Panicum				1.04%
Steinchisma hians	GAPING GRASS	N		1.04%
Tridens strictus	LONGSPIKE TRIDENS	N	FACW	1.04%
Dichanthelium scoparium	VELVET WITCHGRASS	N	FACW	1.04%
Dichanthelium oligosanthes var. scribnerianum	SCRIBNER'S ROSETTE GRASS	N		1.04%
Chrysopsis pilosa	SOFT GOLDENASTER	N		0.21%
Clematis crispa	SWAMP LEATHER-FLOWER	N	FACW	0.21%
Axonopus fissifolius	CARPET GRASS			0.21%
Conoclinium coelestinum	BLUE MISTFLOWER	N	FAC	0.21%
Cyperus polystachyos	MANYSPIKE FLATSEDGE	N		0.21%
Agalinis fasciculata	BEACH FALSE FOXGLOVE	N	FAC	0.21%
Eupatorium capillifolium	DOGFENNEL	N	FACU	0.21%
Monarda punctata	SPOTTED BEEBALM	N	FAC	0.21%
Myrica cerifera	SOUTHERN BAYBERRY; WAX MYRTLE	N	FAC	0.21%
Panicum virgatum	SWITCHGRASS	N	FAC	0.21%
Solanum viarum	TROPICAL SODA APPLE	A		0.21%
Eragrostis intermedia	PLAINS LOVEGRASS	N	FAC	0.21%
TOTAL PERCENT COVER				97.91%

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Kroger Site

Scientific Name	Common Name	Native Status	Wetland Status	Percent Cover
Cynodon dactylon	BERMUDAGRASS	A	FACU	38.07%
Chloris cilaris				15.23%
Mimosa strigillosa	POWDERPUFF	N	FAC	15.23%
Paspalum notatum	BAHIAGRASS	A	FACU	15.23%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	2.54%
Bareground				2.54%
Bothriochloa ischaemum var. songarica	KING RANCH BLUESTEM; YELLOW BLUESTE	A		2.54%
Ipomoea cordatotriloba	TIEVINE	N	FACU	2.54%
Panicum diffusum	WEST INDIAN PANICGRASS		UPL	2.54%
Setaria parviflora	YELLOW BRISTLEGRASS; KNOTROOT FOXTAIL	N	FAC	2.54%
Cenchrus spinifex	COASTAL SANDBUR	N		0.51%
Sida acuta	COMMON WIREWEED	A		0.51%
TOTAL VEGETATION COVERAGE				**97.46%**

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Groundcover Vegetation Sampling Data
Westgate Site

Scientific Name	Common Names	Native Status	Wetland Status	Percent Cover
Stenotaphrum secundatum	ST. AUGUSTINEGRASS	N	FAC	60.68%
Cynodon dactylon	BERMUDAGRASS	A	FACU	14.56%
Digitaria ciliaris	SOUTHERN CRABGRASS	N	FAC	14.56%
Ambrosia psilostachya	WESTERN RAGWEED	N	FAC	2.43%
Chamaesyce maculata	SPOTTED SANDMAT	N	FACU	2.43%
Lespedeza sp.				2.43%
Neptunia lutea	YELLOW PUFF	N	FACU	2.43%
Bareground				0.49%
TOTAL VEGETATION COVERAGE				**99.51%**

N = Native species
A = Non-Native species
OBL = Obligate Wetland species
FACW = Facultative Wetland species
FAC = Facultative species
FACUP = Facultative Upland species

Appendix J

Identification of Critical Conservation Areas

August 18, 2015

Table of Contents

1.0 Introduction

Parcels of land within the proposed study area may be preferable to remain as open space for environmental restoration for reasons of unique flood control management, environmental habitat, wetland characteristics, or the potential for societal enhancement. These land parcels have been defined as critical conservation areas. A list of criteria was created to aid the identification of critical conservation areas. The selection criteria were developed as an interdependent relationship of ecological principles and engineering concepts/requirements. The criteria aided in guiding recommendations for conservation and management of land parcels associated with the Cypress Creek Overflow Management Plan.

2.0 Methodology

The current condition of land parcels within the proposed study area were gathered using multi-spectral and infrared photography for large-scale land cover classification, while field signatures, raster based image analysis, and ground-truthing allowed for classification of soils and land cover differentiation. Light Detection and Ranging (LiDAR) were used to model topographic information and conveyance zone data over land-use information. Potential wetland areas were mapped using existing data from the National Wetland Inventory and HCFCD databases, while additional mapping of land cover type and ecological quality were accessed through the Houston-Galveston Area Council GIS database.

Each of the criteria has been given either a high or moderate priority ranking of their potential for conservation. A site suitability score was produced for each land parcel, depending on the number of criteria it met and the weight of its priority ranking. A score of 0-3 was awarded to each land parcel, with three (3) being the highest, zero (0) being the lowest. Land parcels with the highest site suitability score were prioritized in the study recommendations to preserve and expand existing floodplains, improve and conserve ecological quality, and create passive recreation and wetland mitigation bank opportunities.

3.0 Conservation Criteria

3.1 Land Connectivity

With the rapid expansion of development in western Harris County and eastern Waller County, it was important to identify and preserve existing lands that will be enhanced or restored to native habitat or historic conditions during the Cypress Creek Overflow Management planning study. However, these areas were evaluated based on their adjacency to other existing protected land parcels, such as those conserved by the Katy Prairie Conservancy (KPC) – or other existing conservation easements. Isolated land parcels were not favored when compared to land parcels that may extend the contiguity of existing conservation areas, and reconnect land parcels that have been isolated and fragmented as a result of land conversion practices.

An essential aspect of conserving land for ecological value is to provide a suitable amount of contiguous land with the ability to support a functioning ecosystem. Smaller, fragmented land parcels, even those that are considered pristine native plant and wildlife habitat, cannot function viably or provide the capacity for genetic diversity that is necessary to sustain species health. Consequently, locating and designating land parcels where enhancement and restoration activities will result in expanded and connected native habitat will be critical to ensure the sustainability of a functioning ecosystem. The ability of species to increase their home range will provide additional benefits for sustainability and propagation.

Land parcels directly connected to existing conservation areas were given a high priority ranking. Additional land parcels may connect to protected areas if an intermediary land parcel is acquired, and will subsequently be given a moderate priority ranking. Land parcels without potential to connect to an existing protected area or conservation easement were not considered, given the conservation success of a small and fragmented area is very low.

3.2 Ecological Type and Quality

The following are descriptions of land cover types typically found within the study area (Table J3.1). Descriptions were incorporated from Houston – Galveston Area Council (HGAC) definitions or developed specifically for land cover types observed during the observation of aerial signatures or ground-truthing.

A high priority ranking was given to land parcels designated as ‘high quality’, when applicable (Exhibit J3.1), and to land parcels containing forested or non-forested wetlands, as well as forested, pine forest and pine hardwood forest, grassland and scrub-shrub land cover types. The remaining land cover types listed in Table J3.1 were given a moderate priority ranking (bare ground, cropland, pastureland, and low intensity and open space developed).

A high priority ranking was given to land parcels designated with a ‘coastal prairie’ ecological signature, regardless of quality (Exhibit J3.1). Coastal prairie designated as ‘high quality’ may currently exhibit flood reduction characteristics, while those of ‘intermediate’ and ‘low quality’ may have high potential for restoration and therefore the greatest uplift in terms of flood reduction characteristics.

Exhibit J3.1 Ecological Type and Quality (HGAC)

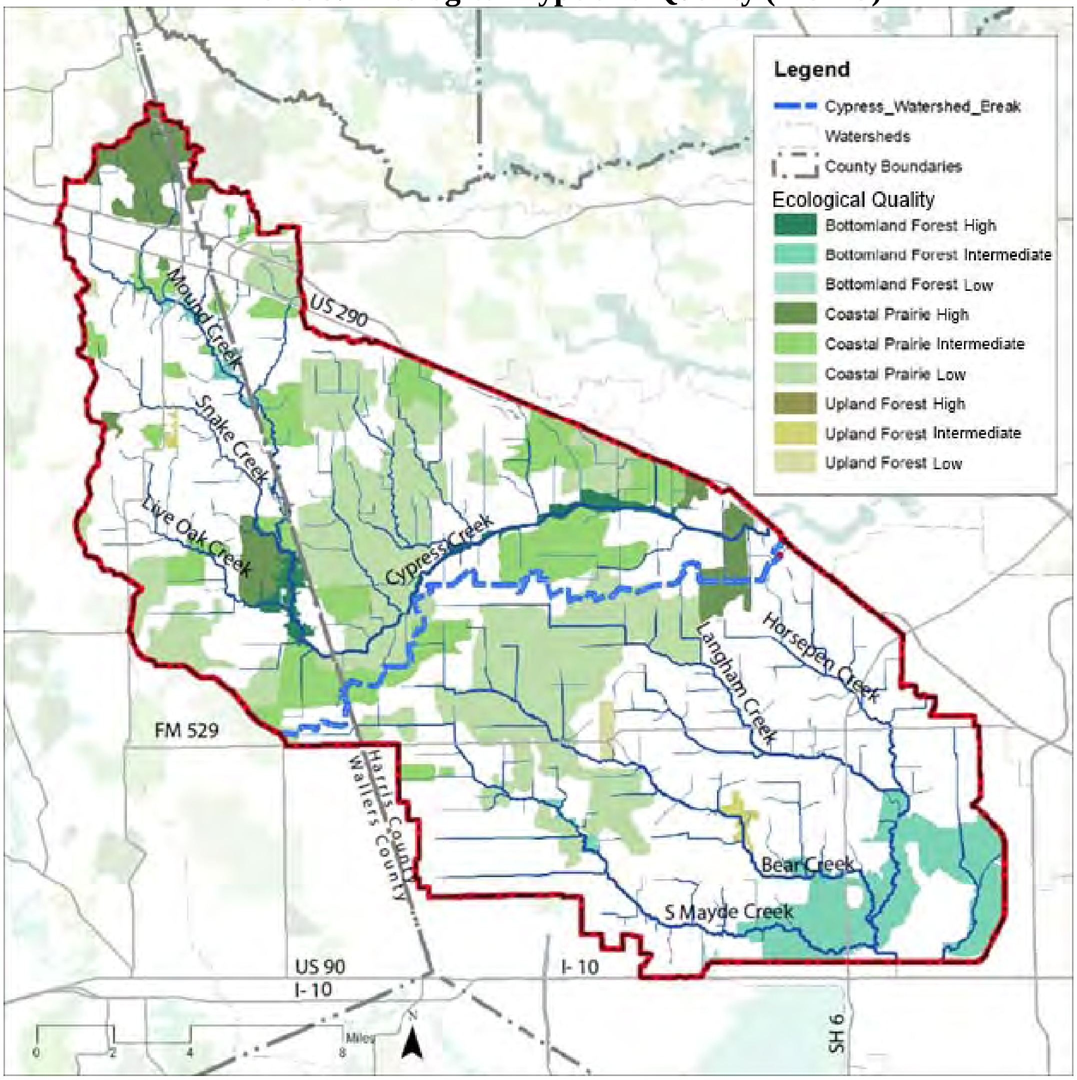


Table J3.1 Ecological Types found within the Study Area

Land Cover Type		Description
Bare Ground		Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.
Bottomland Forest	High Quality	Forests that are of high quality and relatively old growth hardwood trees, usually large unbroken sections with a minimal amount of invasive species, minimal site disturbance and not immediately threatened by development, also may protect critical watersheds or riparian (along a stream) zones.
	Intermediate Quality	Forests that have been logged during the early to mid-20th century but still contain some fairly high-quality hardwood bottomland trees, may or may not be in large continuous sections. Offer some protection to watersheds and riparian zones, but may be fragmented and somewhat threatened by development.
	Low Quality	Forests that have been highly degraded. Invasive species or shrubs may make up the largest percentage of the canopy. May be a small tract, severely fragmented or highly threatened by development. These areas do not offer much watershed or riparian zone protection.
Coastal Prairie	High Quality	No indication of excavation or topographic alterations. Historic/native topographic signatures are readily discerned and visible. Remnant native vegetation with cattle grazing probable. Heavy brush may be present.
	Intermediate Quality	May have moderate excavation or topographic alterations, but native/historic topography remains intact. Some rural/low level development may occur. Remnant native vegetation species almost absent.
	Low Quality	Evident topographic signature of areas being excavated or disturbed. Represented by abandoned farm fields, or may be fallow rice fields/pastures. Native vegetation is effectively absent.
Cropland		Topography has been altered to cultivate agricultural products such as rice. Aerial signature indicates rows, parallel berms or swales. Surface water control features, such as ditches, are present. Native vegetation removed to ditches and right-of-ways. These areas also include where cattle grazing is evident. This may include fallow and former cropland, and may either be devoid of native vegetation or contain a variety of native and non-native pasture grasses. Soils may be comprised of both upland and wetland soils.
Forested		Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); trees account for

Land Cover Type	Description
	25-100 percent of the cover.
Forested Wetland	Canopy systems occurring within the floodplain – as evaluated using both aerial photography and National Wetlands Inventory/USDA soils database. May show evidence of silviculture activities such as logging or thinning.
Grassland	Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. This designation can include both cultivated and coastal prairie land uses.
Low Intensity Developed	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
Non-Forested Wetland	Herbaceous habitats occurring within wetland areas – as evaluated using both aerial photography and National Wetlands Inventory/USDA soils database. May be isolated or connected to larger wetland systems – including other herbaceous or forested habitats. Vegetation may include some shrub species cover.
Open Space Developed	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Pastureland	Areas where cattle grazing is evident. This may include fallow and former cropland, and may either be devoid of native vegetation or contain a variety of native and non-native pasture grasses. Soils may be comprised of both upland and wetland soils.
Pine Forest	Upland land use comprised of more than 67% pine trees (*Pinus* sp.), and may be present as rowed plantation or naturally recruited and occurring individuals.
Pine Hardwood Forest	Upland land use where neither pine tree species (*Pinus* sp.), nor hardwood tree species, comprise more than 50% of the canopy cover.
Scrub-Shrub	The Scrub-Shrub land use includes wetland areas dominated by woody/shrubby vegetation less than 20 feet in height. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. May be isolated or connected to larger wetland systems – including other herbaceous or forested habitats.

Land Cover Type		Description
Upland Forest	High Quality	Forests that are of high quality and relatively old growth hardwood trees, usually large unbroken sections with a minimal amount of invasive species, minimal site disturbance and not immediately threatened by development, also may protect critical watersheds or riparian (along a stream) zones.
	Intermediate Quality	Forests that have been logged during the early to mid-20th century but still contain some fairly high quality hardwood bottomland trees, may or may not be in large continuous sections. Offer some protection to watersheds and riparian zones, but may be fragmented and somewhat threatened by development
	Low Quality	Forests that have been highly degraded. Invasive species or shrubs may make up the largest percentage of the canopy. These areas do not offer much watershed or riparian zone protection.

3.3 Potential for Prairie Restoration

Historically, western Harris County and eastern Waller County have supported native coastal prairie habitat. Due to topography, soils, and proximity to the Houston metropolitan area, the native coastal prairie habitat in this region has been displaced by agriculture and ranching in recent times. Restoration activities, in addition to monitoring and successful land management, can promote the establishment of a robust and diverse native coastal prairie habitat in the western Harris County and eastern Waller County area.

The ecological benefits of prairie restoration to ecosystems and humans are numerous. Primary production attributes such as seed dispersal, nutrient dispersal, and nutrient cycling will occur in areas where existing land-use activities do not promote these essential ecosystem functions. On a more regional basis, these restored habitats will provide waste decomposition, flood control (water quantity attenuation, See Appendix I), water quality treatment, and sequestration of carbon. Community services such as recreational use for hiking and fishing, as well as scientific research, will also be an added social benefit.

The valuation of determining ecological services is complicated by several factors. It is difficult to assign human economic values to natural systems using a common relationship. In addition, there may be a conflict between a landowner interest and the value of the ecosystem to the general public. On a more landscape-level basis, the valuation of extending native coastal prairie habitat corridors is complicated when attempting to enumerate its importance using a common factor.

Land parcels containing the coastal prairie ecological type (Section 3.2, Exhibit J3.1), along with appropriate soils and topography to potentially facilitate prairie restoration, were given a high priority ranking. Land parcels lacking these features were given a moderate priority ranking.

3.4 Potential for Passive Recreation

Another criterion for assessing critical conservation areas was the potential for a land parcel to provide recreational opportunities such as hunting, fishing, and hiking. Since hunting may not be a desirable activity when integrated with passive recreational uses such as hiking and fishing, it was given a lower priority ranking. However, hiking and fishing are generally considered to be activities compatible with conservation areas, and were therefore preferred.

Each land parcel was considered as a restored native coastal prairie habitat when assessing passive recreation. The desirability and appropriateness of passive recreational use was assessed on several factors. If a land parcel was large (+300 acres), the site was awarded a high priority ranking due to the existence of a large ecotone buffer (approximately 300 ft.) to reduce negative effects to wildlife habitat. Smaller land parcels could also be assigned a high priority ranking if several adjacent land parcels were aggregated. This would reduce or eliminate any negative ecotone buffer effects that may occur if the land parcel had been considered individually.

Accessibility to the public was also considered when weighting the priority ranking of land parcels for passive recreational use. Adjacency to public roadways resulted in a high priority ranking, since the public will be able to readily access the site. However, smaller land parcels without current road access were also awarded a high priority ranking score if they are accessible as a result of their connection to adjacent land parcels.

3.5 Potential for Wetland Mitigation Bank

Incorporating wetland mitigation bank opportunities into critical conservation areas will provide a regionally significant benefit to the natural habitat and to the public of western Harris County and eastern Waller County. When considering the incorporation of a wetland mitigation bank, each land parcel was ranked by the following characteristics: 1) containing greater than 50% USDA Soil Conservation Service (SCS) classified hydric soils (including partially hydric classification), 2) having a suitable size and/or location (+300 acres, connection to current conservation land parcels), 3) a high proportion of native wetland species compared to invasive species, and 4) being located within the 100-year floodplain.

A unique benefit of wetland mitigation banks is this land-use meets the Cypress Creek Overflow Management Plan objective to store surface water for flood attenuation. Storing flood waters will provide the necessary surface water volume to sustain potential wetland mitigation bank areas, as opposed to allowing this excess runoff volume to flow downstream in drainage routing systems.

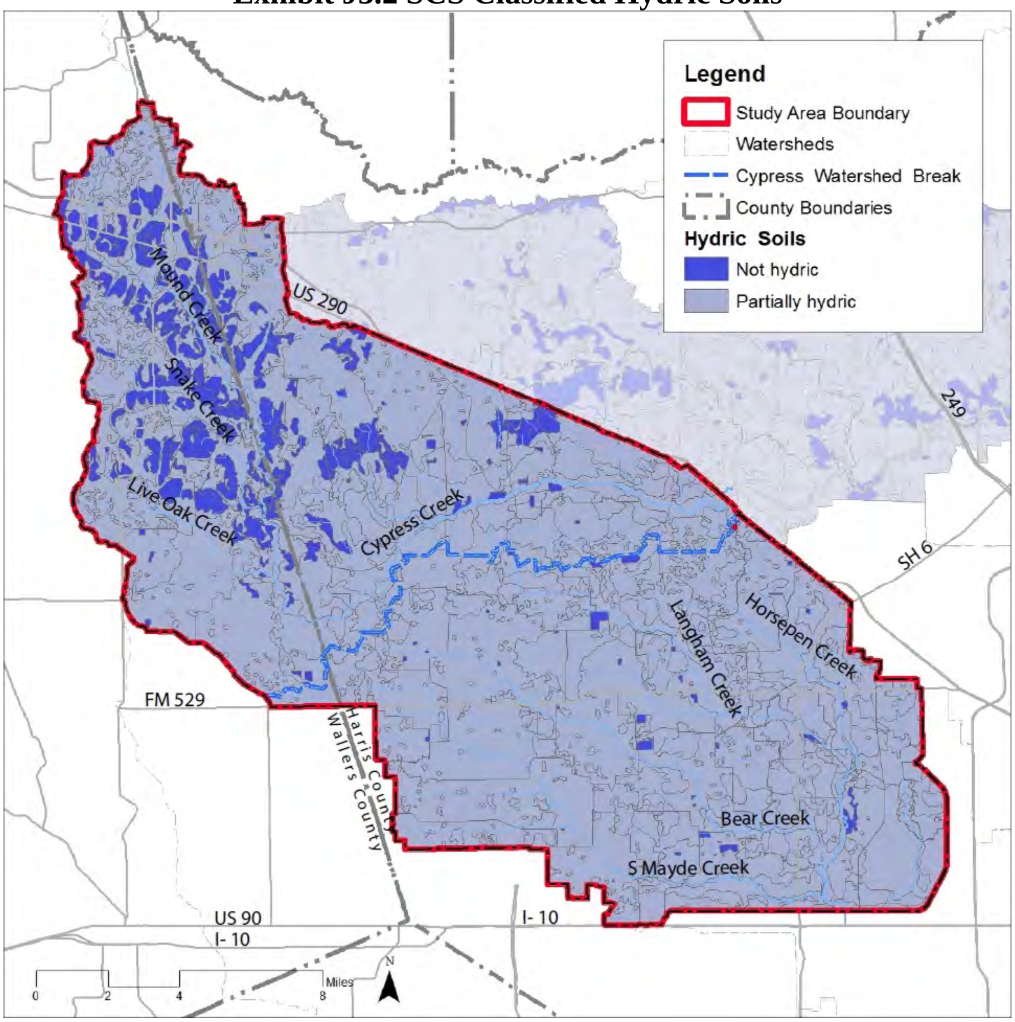
3.5.1 Ability to Support Wetland and Upland Species

Wetland mitigation banks are most effective when native wetland plants and animal species occur, or partially occur, within the land parcel being evaluated. Their presence may be an indication of appropriate and desirable baseline conditions to establish a wetland mitigation bank. The ability of the land parcel to partially support upland plant and animal species also increases wetland mitigation bank effectiveness by providing additional community structure and ecological functions. The occurrence of both wetland and upland species within a specific land parcel necessitates a high priority ranking, since it is of regional significance to protect and restore remnant native plant and wildlife habitats.

3.5.2 Presence of Hydric Soils

The presence of hydric and partially hydric soils is a critical factor for the appropriateness and suitability of developing a wetland mitigation bank (Exhibit J3.2). Wetlands require hydric soils to provide desirable anaerobic soil characteristics for wetland plant species to survive. It is not imperative that all soils within an assessed parcel are hydric, since adjacent upland habitats provide enhanced diversity and life cycle benefits to wetland dependent species. Additionally, wetlands may be created through the excavation of existing upland areas where shallow subsurface soil characteristics may provide adequate hydrologic conditions to sustain wetland vegetation species. Land parcels with at least 50% SCS classified hydric soils or greater were given a high priority ranking.

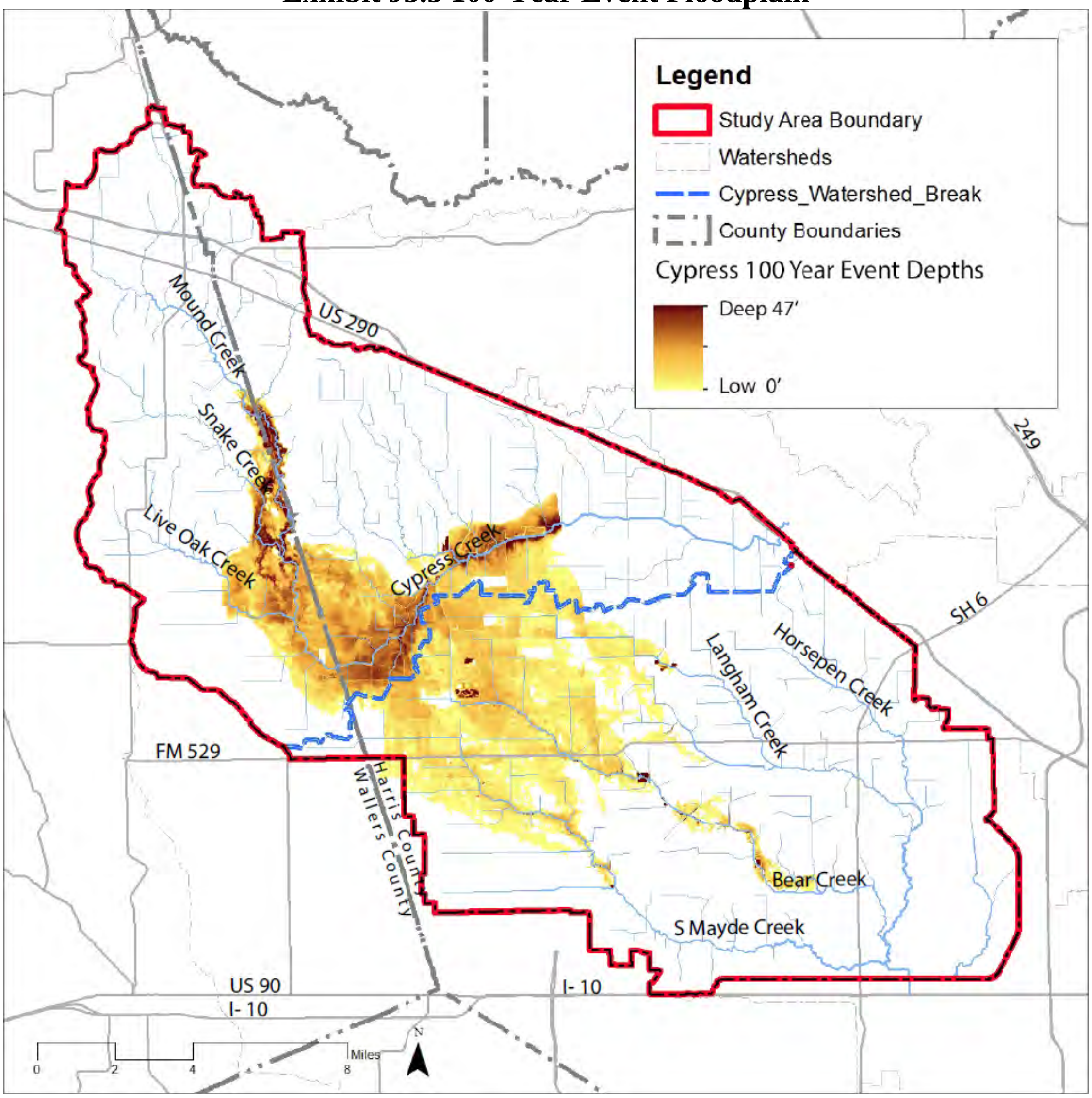
Exhibit J3.2 SCS Classified Hydric Soils



3.5.3 Preferable Hydrology

Another essential factor when considering the incorporation of a wetland mitigation bank into a critical conservation area is the ability to sustain wetland habitats through the provision of adequate hydrology. Although existing natural conditions such as flow ways and depressions are important, wetland mitigation banks may also be created with the excavation of artificial depressions. This technique is commonly used where appropriate hydric soils may occur, but depressional areas may not be currently present. Land parcels located entirely within the current boundaries of the 100-year floodplain possess suitable hydrology for a wetland mitigation bank, and were therefore be given a high priority ranking (Exhibit J3.3).

Exhibit J3.3 100-Year Event Floodplain



3.6 Aesthetic Quality

As rapidly developing urban areas emphasize the importance of natural areas, adjacency to conservation lands will be an amenity for land owners and may result in an increase in land values. Adjacent developed areas may assign a land cost premium for abutting conservation property. Consequently, the enhancement or restoration of existing open space to native coastal prairie habitat may result in a positive effect in land values adjacent to, or near, these natural areas. Given their scarcity and pristine condition, land parcels exhibiting the 'high quality' ecological designation (Section 3.2) were given a high priority ranking based on existing aesthetic quality (Exhibit J3.1).

3.7 Absence of Current Residential or Commercial Development

Enhancement and restoration of native coastal prairie habitat will be most effectively and efficiently achieved wherever land parcels are undeveloped. Implementation costs will be reduced, along with the ability to reestablish the basic occurrences of desirable native species that will occur in non-residential or non-commercial land parcels. Consequently, land parcels absent of current residential or commercial development were subsequently awarded a high priority ranking when considering conservation status (Exhibit J3.4 and J3.5).

Priority rankings also included the cost of acquisition for developed land parcels. In general, land parcels with occupied structures, such as houses and commercial buildings (along with appurtenant infrastructure: roadways; water; and, wastewater systems), are associated with higher land costs. These elevated land costs may result in the ability to acquire less land area for restoration, and/or the inability to fully implement restoration projects. The estimated price per acre of land parcels will contribute toward a high or moderate priority ranking.

Exhibit J3.4 Land-Use Type (HGAC)

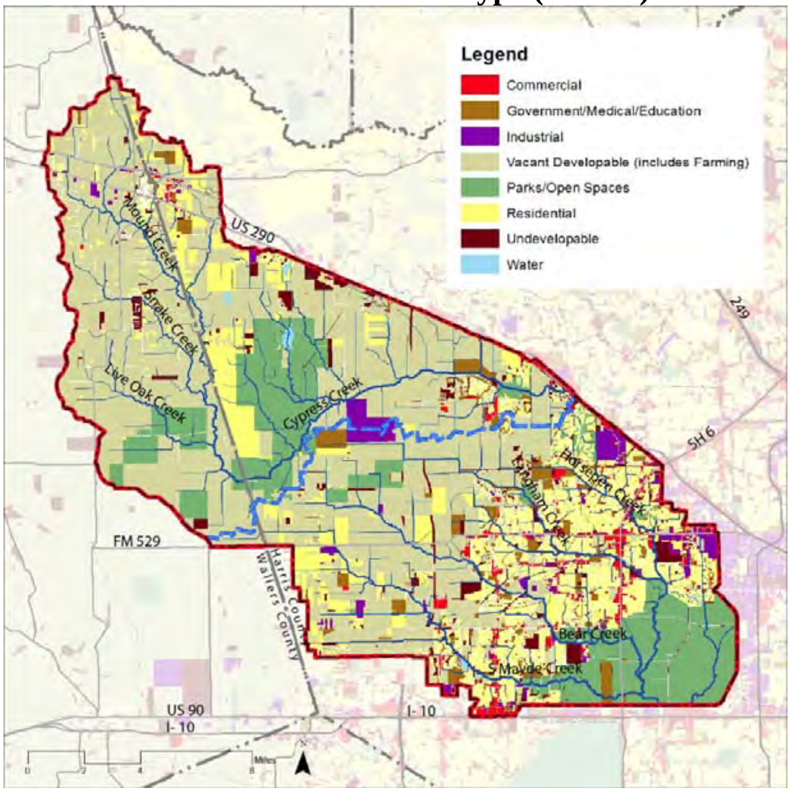
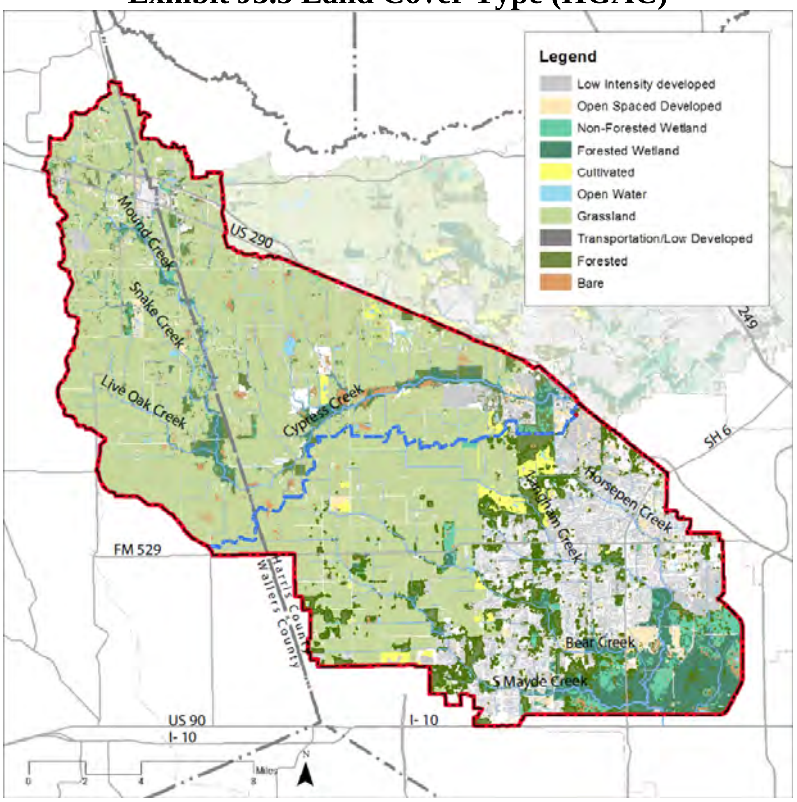


Exhibit J3.5 Land Cover Type (HGAC)



Appendix K

Estimated Impacts of Impounding Water on Coastal Prairie Vegetation

August 18, 2015

Table of Contents

Supplements

1.0 Introduction

Given the altered hydrology associated with the proposed strategies introduced in this report, areas of land supporting native prairie vegetation may be exposed to increased inundation. In this appendix, the potential impact of increased inundation on native coastal prairie vegetation has been given special consideration by: 1) reviewing the past literature of the effects of inundation on prairie vegetation; 2) performing an onsite species inventory of vegetation from native prairie, open space, and developed land cover types; and, 3) comparing two-dimensional (2D) inundation models within the study area of the existing depth and duration versus the altered depth and duration.

2.0 Data Sources

2.1 Literature Review

There has been little available research from published sources concerning the effect of inundation on coastal prairie species found within the study area. Relevant information has been searched and evaluated for the appropriateness and applicability to this report, such as similar environmental conditions, species, and location. The measurement of the effects of inundation on vegetation is difficult to accurately measure in the field and has been difficult to access from published sources.

During the winter of 1991-92, exceedingly high levels of rainfall resulted in record levels of detention inside Addicks Reservoir. Assessment of inundation damage to the vegetation was conducted at selected sites throughout the reservoir and presented in the following report: S.A. Damico & Associates, Inc. Environmental Consultants. *"Assessment of Flooding Impacts on Vegetation in Addicks Reservoir Harris County, Texas."* Five factors were found to be critical in determination of a species' response to inundation:

1. *Time of year* - Flooding during the dormant season may have limited harmful effects to vegetation. However, if flooding occurs during growing season, vegetation could become adversely affected.

2. *Flood frequency* - Flooding strongly influences understory vegetation. Herbaceous species may increase as long as flooding frequency decreases and water remains at low levels.

3. *Flood duration* - Herbaceous species are more likely to survive during short periods of inundation. However, if inundated in the beginning of growing season, even for short periods of time, vegetation mortality may occur. Long term inundation at any time, increases the mortality probability.

4. *Water depth* - Vegetation mortality is likely to occur if water depth is high, due to submersion of seedlings.

5. *Siltation* - If sediment is highly dense with chemicals and organic matter, vegetation could become damaged. This reduces oxygen concentration causing limited oxygen for the growth of herbaceous species.

Of the above five factors, the authors concluded that time of year and flood duration are the most critical factors in determining growth and survival for a given species.

The results from this report were strictly observational and taken over one growing season, and no long term or specific species data was presented. However, the report concluded that the plant communities within Addicks Reservoir were remarkably healthy and exhibited no detrimental effects from inundation except for isolated observations. The detrimental effects observed (sedimentation, delayed germination, reduced growth) occurred in the borrow area directly behind the dam, suggesting that areas which accumulate water and debris will experience the most negative inundation effects.

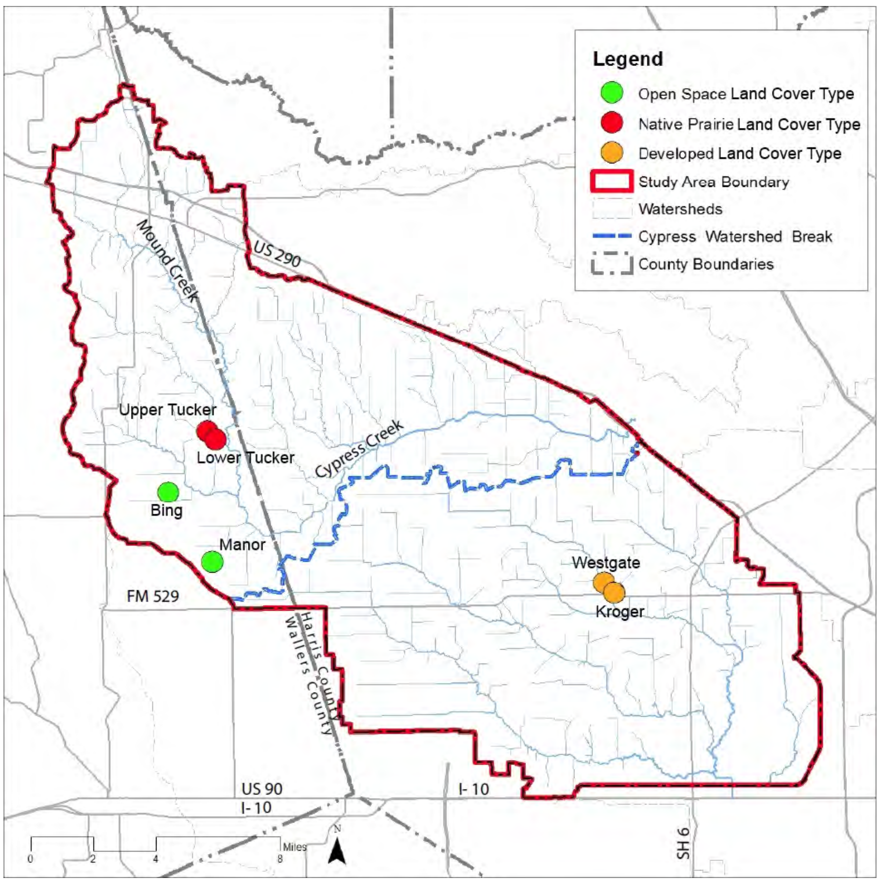


Exhibit K2.1
Vegetation Sampling Site Locations

2.2 Onsite Species Inventory

Vegetation was sampled at each of the six monitoring sites described in Appendix I: two sites each of native prairie, open space, and developed land cover types (Exhibit K2.1). Detailed descriptions of these land cover types can be found in Appendix I. A series of 10 x 10 m quadrats was used to sample plant species at each site. Identification of different species of forbs, grasses, and shrubs were recorded along with estimates of percent cover for each species. Dominant species have been identified in Table K.1 for each of the six sites, along with a "yes" or "no" indication for flood tolerance determined by each species' National Wetland Indicator status**.**

2.3 Comparison of Inundation Models

A large proportion of the study area falls within the current 100-year floodplain (Supplement K1). Even during a 2, 5, and 10-year rainfall event, this area has been shown to currently experience a significant amount of flooding. To simulate the inundation depth and duration caused by the altered conditions of both Strategy 3 and Strategy 5, 2D models were created. The depth and duration of inundation was modelled using hydrographs at specific points (locations labeled in Supplement K). Each hydrograph point (location) was compared between existing and altered conditions. Graphs of these comparisons were created to visually depict the potential changes in inundation caused by the two strategies (Supplement K1).

3.0 Discussion

Incorporating the conclusions from the Addicks Reservoir report, the 2D model comparisons of inundation depth and duration, and the regional soil and native vegetation characteristics, a general profile of inundation effects may be proffered. However, no empirical data exist that can expressly determine the effects of inundation on specific native coastal prairie vegetation. Therefore, best professional judgment may be the most reliable source of assessing probable negative effects that may occur as a result of periodic inundation for any proposed action considered within this report. As indicated from the Addicks Reservoir report, seasonality and duration are influential in the response of herbaceous vegetation to inundation, and priority should be given to these two factors when monitoring any future events.

Many of the areas identified as coastal prairie habitat (Exhibit K3.1) within the study area are located within hydric and partially hydric soils according to the United States Department of Agriculture – National Resource Conservation Service (Exhibit K3.2). The occurrence of these soil types is an important feature when considering the effects of inundation on vegetation due to periodic flooding, since duration of flooding is a primary factor that can negatively influence vegetation. As a result, vegetation likely to occur on these soil types would be genetically predisposed to long term sustainability under anaerobic conditions, i.e. hydric or partially hydric soils. As provided in Table K.1, observed vegetation for the native prairie land cover types have several existing native coastal prairie vegetation that are tolerant of flooding.

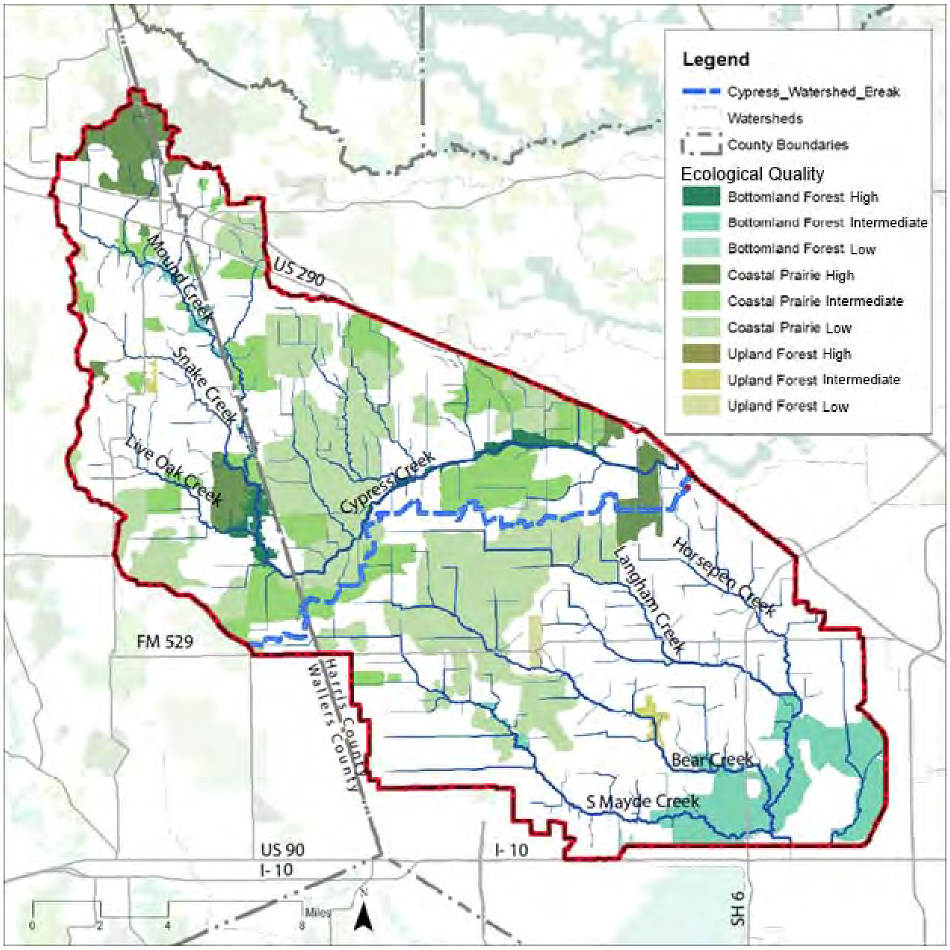


Exhibit K3.1
Ecological Type and Quality (HGAC)

Should inundation during the growing season result in negative effects to vegetation, native coastal prairie vegetation may respond quickly to regeneration and colonization, both as a result of the inherent growth rate and recovery of herbaceous vegetation, as well as response to germination from the intact seed bank within the upper surface soil stratum. The rapid response and recovery of native coastal prairie vegetation may also be capable of outcompeting invasive exotic/nuisance vegetation species, as areas where viable vegetation have been converted to detritus/thatch cover may serve to suppress colonization and establishment of invasive exotic/nuisance vegetation species, while supporting and encouraging re-establishment of desirable native coastal prairie vegetation. However, following repeated significant storm and flooding events, diligent routine monitoring in these areas should be conducted to observe regeneration effects, and to eliminate the occurrence of undesirable invasive exotic/nuisance vegetation establishment.

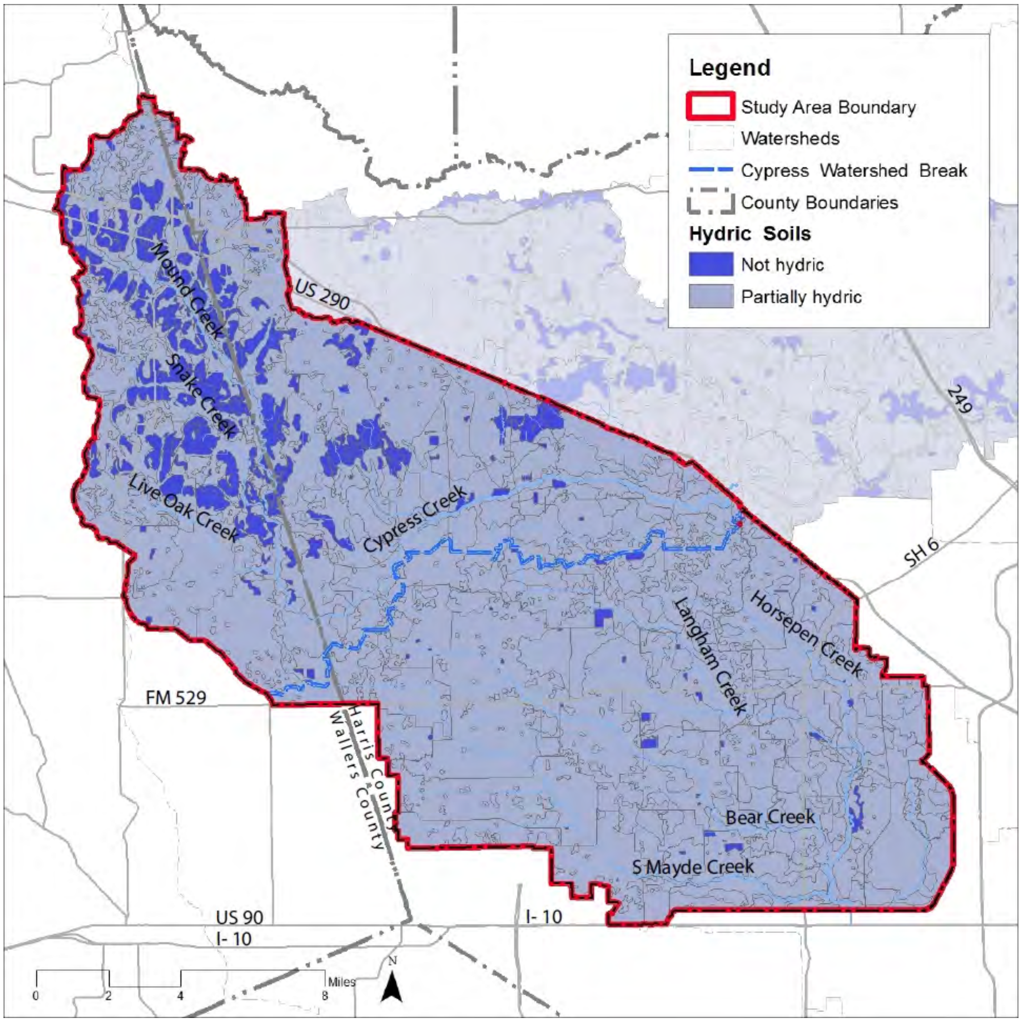


Exhibit K3.2

National Resource Conservation Service **Classified Hydric Soils**

Given the current prevalence of hydric soils and the inherent ability of native coastal prairie vegetation to survive periodic inundation, the changes in depth and/or duration of inundation within the majority of the study area are not frequent or severe enough to negatively affect native coastal prairie vegetation (Supplement K1). While the depth and duration of inundation was shown to be altered under the proposed strategies, the total area of inundated land and frequency of inundation does not significantly change. Under existing conditions, the study area is largely inundated by 2, 5, 10, and 100-year rainfall events (Supplement K1), and this area will not be significantly expanded under the proposed strategies (Supplement K1). Differences in the magnitude of inundation under both existing and altered conditions are dependent on location, severity of rainfall event, and current land use. The hydrographs located closer to the proposed berms can be expected to experience greater depth and duration of inundation (Supplement K1). However, the hydrographs that experience the greatest differences between existing and altered conditions are located in habitat not currently supporting native coastal prairie vegetation (ex. locations 7 and 9 are located within active sand mines) or are located in areas that experience high inundation depth and duration under existing conditions (locations 5 and 6). The majority of the hydrographs from the 2D model comparisons do not predict significant increases in inundation duration during more frequent rainfall events (2, 5, or 10-year) to have an effect on vegetation composition. Even during a 100-year rainfall event, duration of inundation is not predicted to increase significantly under the proposed strategies (Supplement K1).

In the 2009 Master Plan for Addicks and Barker Reservoirs developed by the U.S. Army Corps of Engineers, land-use within Addicks and Barker Reservoirs prior to construction was described primarily as ranching, rice farming, and dairying, with native coastal prairie and some woodland habitats. With the cessation of farm practices and suppression of the natural fire regime, woody vegetation gradually encroached throughout the reservoirs. This abrupt land management shift accelerated the conversion of native coastal prairie and farm land into bottomland forests, and contributed to the invasion of Chinese Tallow (*Triadica sebifera*) and deep-rooted sedge (*Cyperus entrerianus*).

4.0 Conclusions and Recommendations

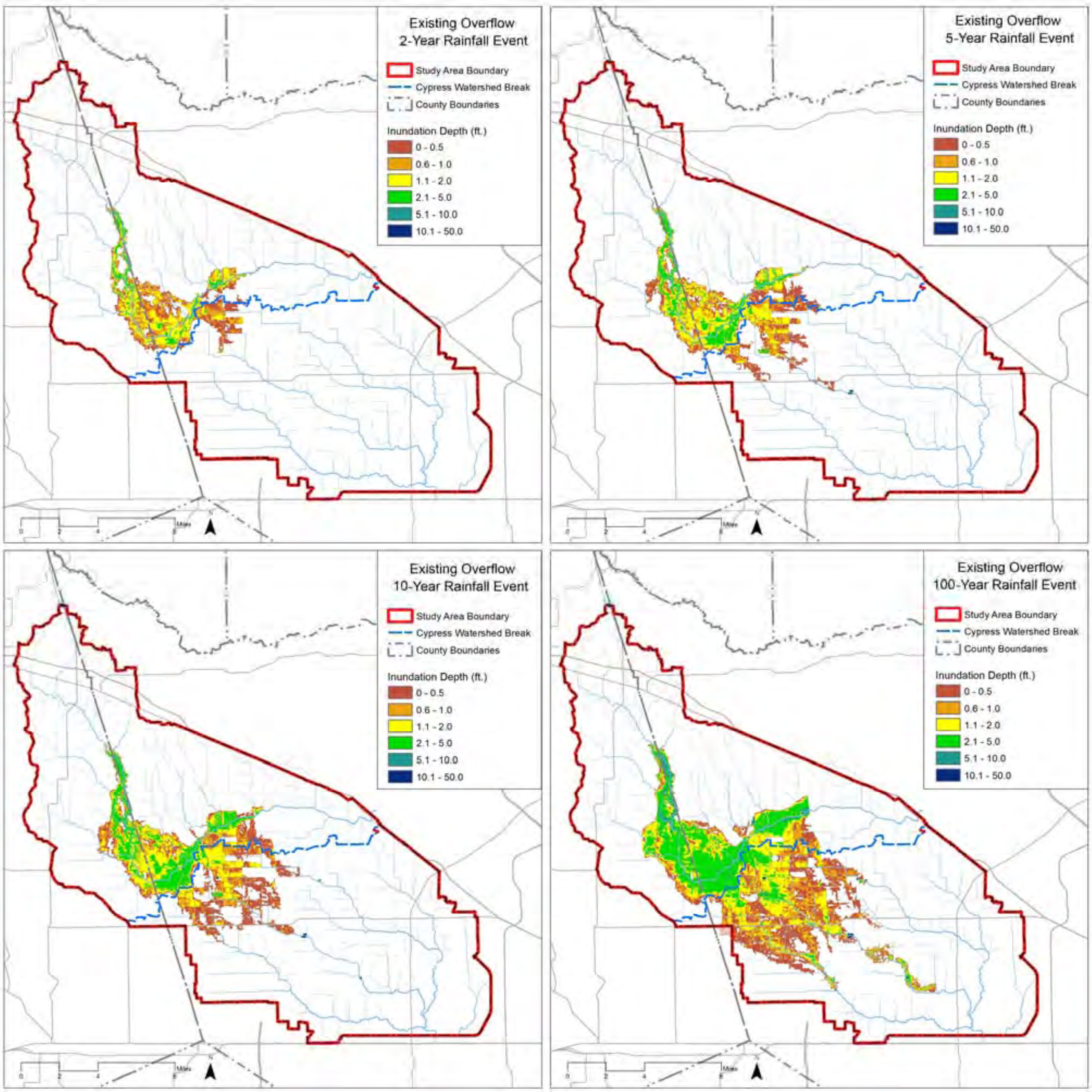
Land management practices appear to have a greater influence on native coastal prairie vegetation than the altered inundation conditions associated with the proposed strategies. With the absence of grazing or periodic burns, native coastal prairie habitat, along with fallow ranch or farmland, would gradually become out-competed by encroaching woody vegetation and invasive species. Prescribed burning combined with an intermittent light grazing regime would be the preferred land management technique to maintain the openness of native coastal prairie habitat; however in many instances prescribed burning cannot be implemented due to permitting or proximity to developed areas. If prescribed burning is unable to occur, other land management practices should be considered (i.e. routine mowing). If mowing is the management practice of choice, then it should be noted that the mowing deck height be raised to a minimum of one foot above the ground surface. This will minimize the undesirable shrub and woody vegetation, leaving native coastal prairie vegetation in place. In order to sustain desirable native coastal prairie habitat, mowing should occur annually.

Table K.1: Dominant Species for Study Areas by Land Cover Type (FT = Flood Tolerant)

Open Space						Native Prairie						Developed					
Bing			**Manor**			**Upper Tucker**			**Lower Tucker**			**Westgate**			**Kroger**		
Species	**% Cover**	**FT**	**Species**	**% Cover**	**FT**	**Species**	**% Cover**	**FT**	**Species**	**% Cover**	**FT**	**Species**	**% Cover**	**FT**	**Species**	**% Cover**	**FT**
Bermuda Grass *Cynodon dactylon*	90.0%	NO	Woolly Croton *Croton capitatus var. lindheimeri*	52.5%	NO	Little Bluestem *Schizachyrium scoparium var. divergens*	75.0%	NO	Woolly Croton *Croton capitatus var. lindheimeri*	40.0%	NO	St. Augustine Grass *Stenotaphrum secundatum*	62.5%	YES	Bermuda Grass *Cynodon dactylon*	37.5%	NO
Woolly Croton *Croton capitatus var. lindheimeri*	65.5%	NO	SlimSpike Threeawn *Aristida longispica*	32.5%	NO	Vaseygrass *Paspalum urvillei*	75.0%	YES	Bahiagrass *Paspalum notatum*	37.5%	NO	Southern Crabgrass *Digitaria ciliaris*	15.0%	YES	Bahiagrass *Paspalum notatum*	15.0%	NO
Common Wireweed *Sida acuta*	17.5%	NO	Western Ragweed *Ambrosia psilostachya*	32.5%	YES	Spanish Needles *Bidens bipinnata*	40.0%	YES	Little Bluestem *Schizachyrium scoparium var. divergens*	17.5%	NO	Bermuda Grass *Cynodon dactylon*	15.0%	NO	Powderpuff *Mimosa strigillosa*	15.0%	YES
Western Ragweed *Ambrosia psilostachya*	17.5%	YES	Bermuda Grass *Cynodon dactylon*	30.0%	NO	Slender Flattop Goldenrod *Euthamia caroliniana*	38.0%	YES	Lindheimer's Beeblossom *Gaura lindheimeri*	15.5%	YES						
Nutgrass *Cyperus rotundus*	16.0%	NO	Beach False FoxGlove *Agalinis fasciculata*	20.0%	NO	Lindheimer's Beeblossom *Gaura lindheimeri*	37.5%	YES	Tickseed Sunflower *Bidens aristosa*	15.0%	YES						
			Spanish Daisy Bitterweed *Helenium amarum*	17.5%	NO	Thin Paspalum *Paspalum sectaceum*	32.5%	YES	Lateflowering Thoroughwort *Eupatorium serotinum*	15.0%	YES						
			Soft Goldenaster *Chrysposis pilosa*	15.0%	NO	Smallhead Doll's Daisy *Boltonia diffusa*	30.0%	YES	Thin Paspalum *Paspalum sectaceum*	15.0%	YES						

Supplement K1
2D Inundation Models

Existing Overflow
2, 5, 10, and 100-Year Rainfall Events



Management Plan 3 Overflow
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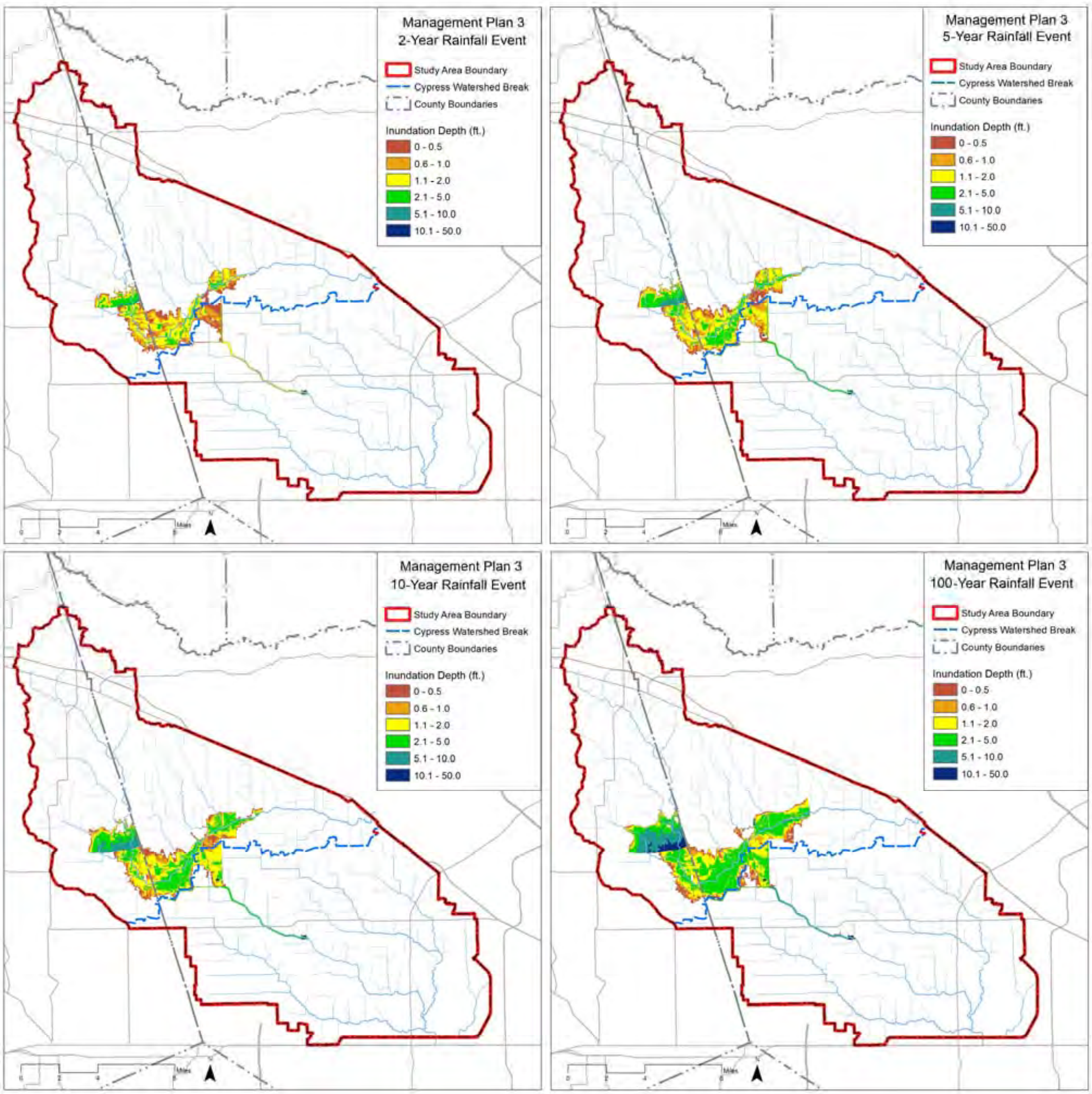

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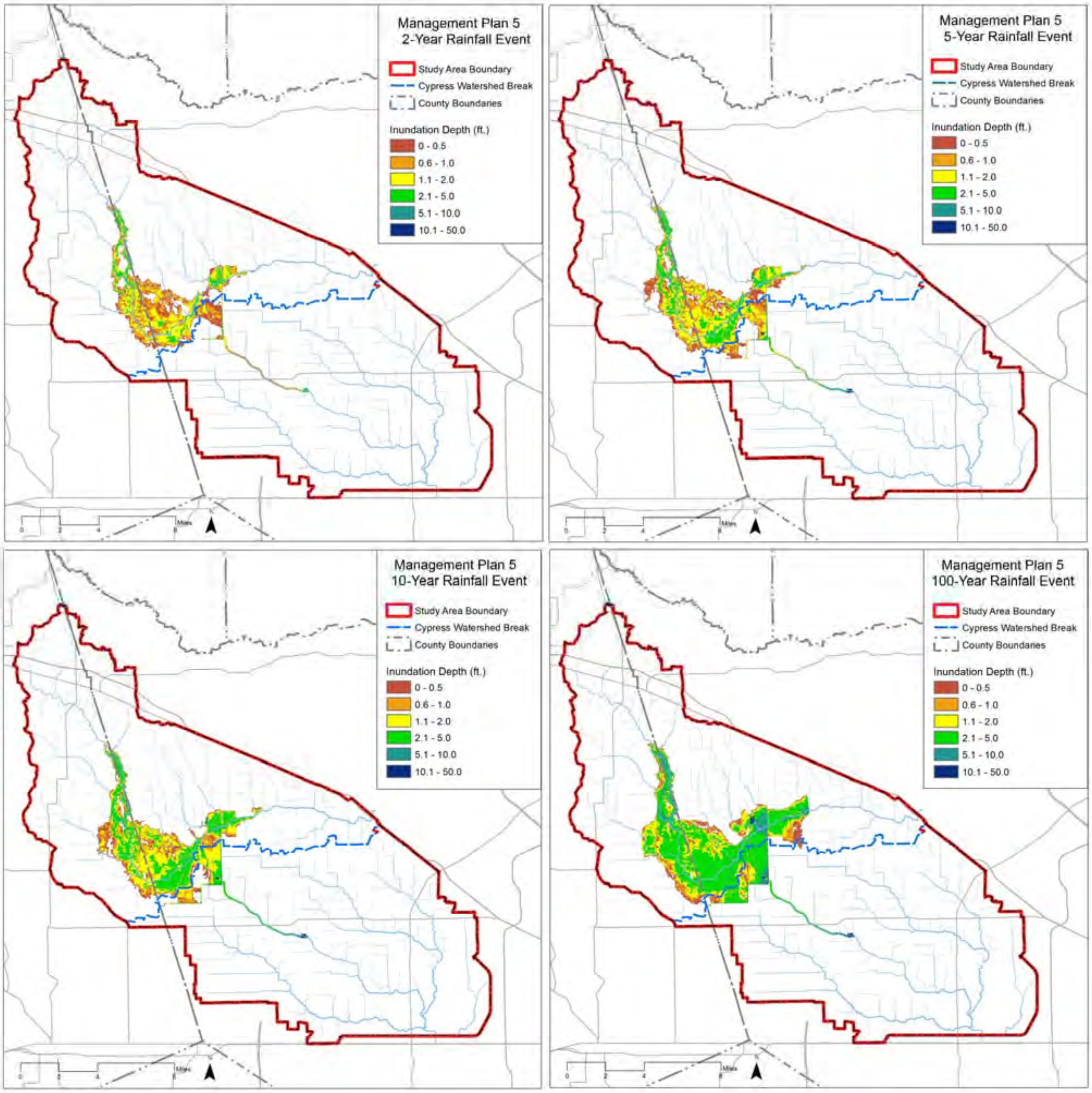
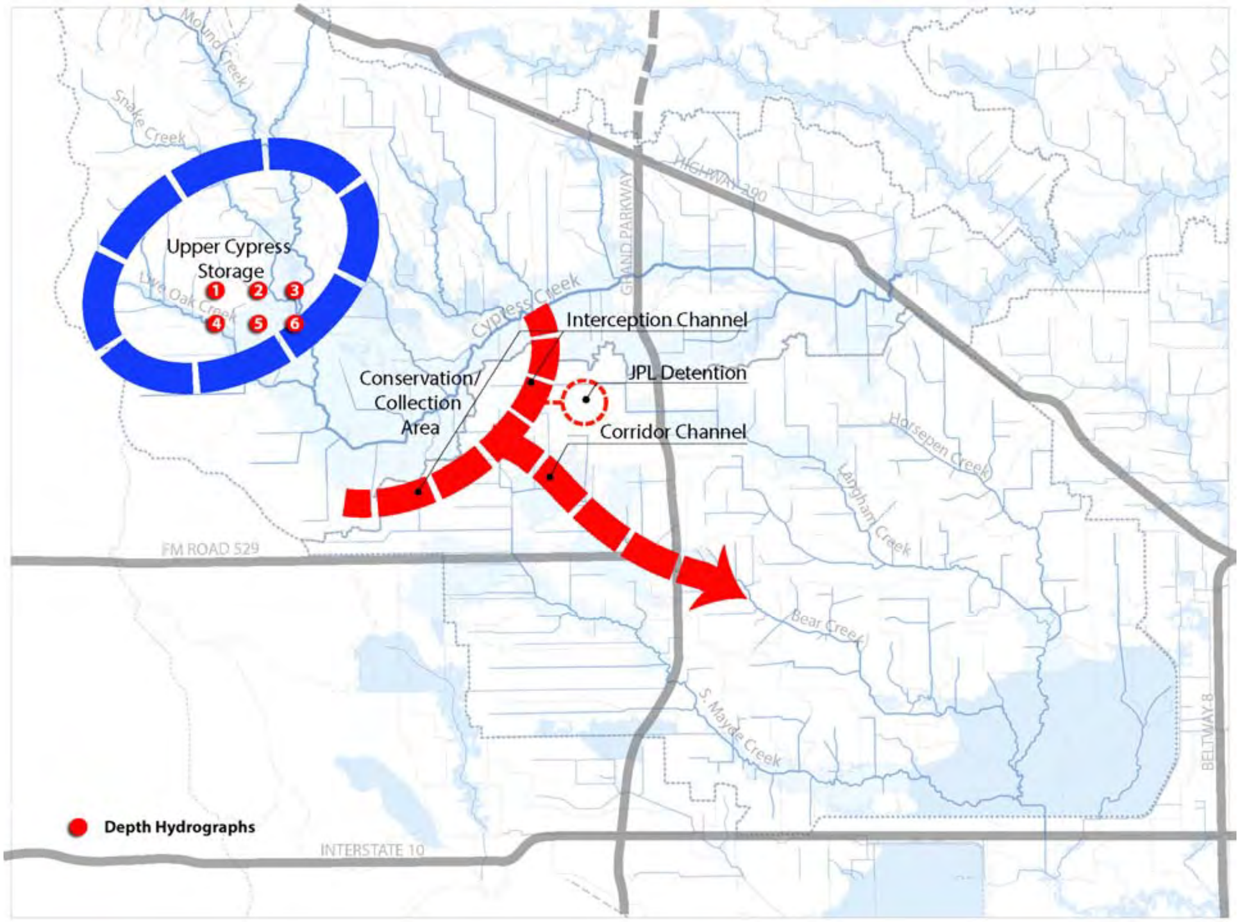
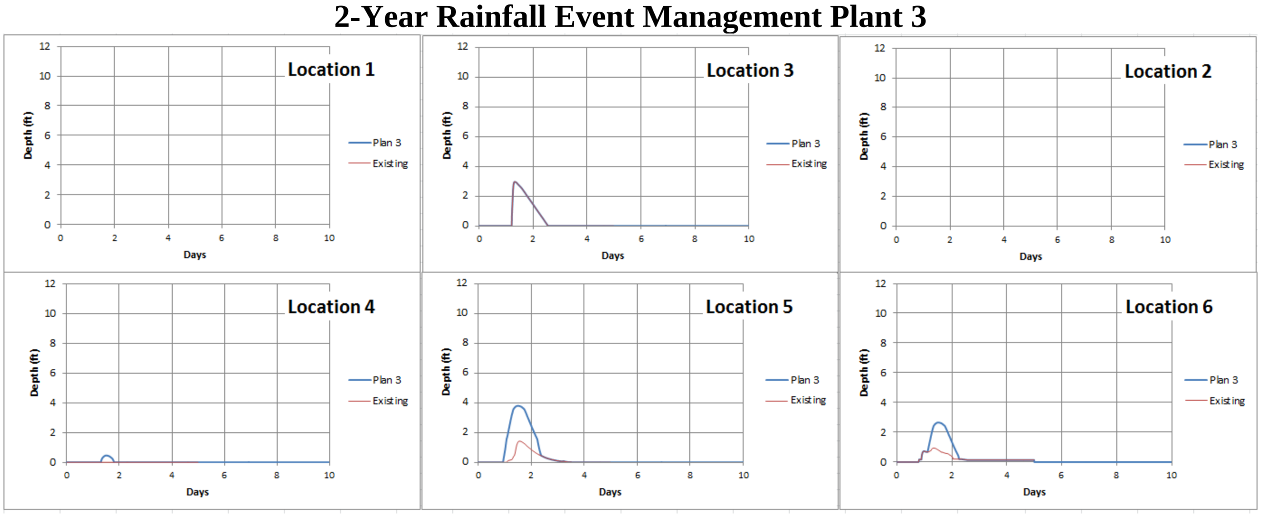
2, 5, 10, and 100-Year Rainfall Events



Management Plan 3 vs Existing Overflow
Depth and Duration Hydrograph Locations



2-Year Rainfall Event Management Plant 3



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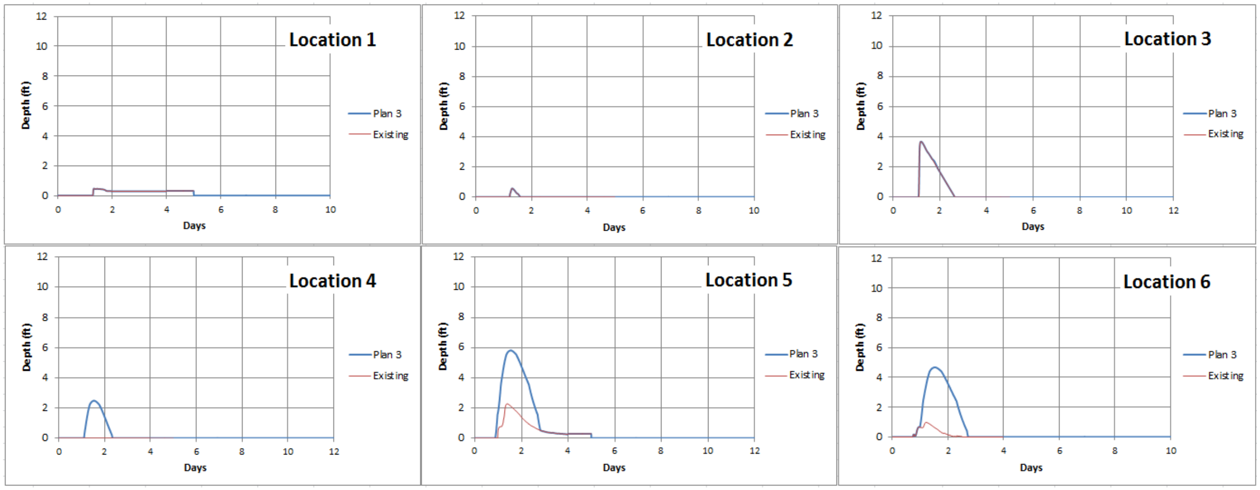

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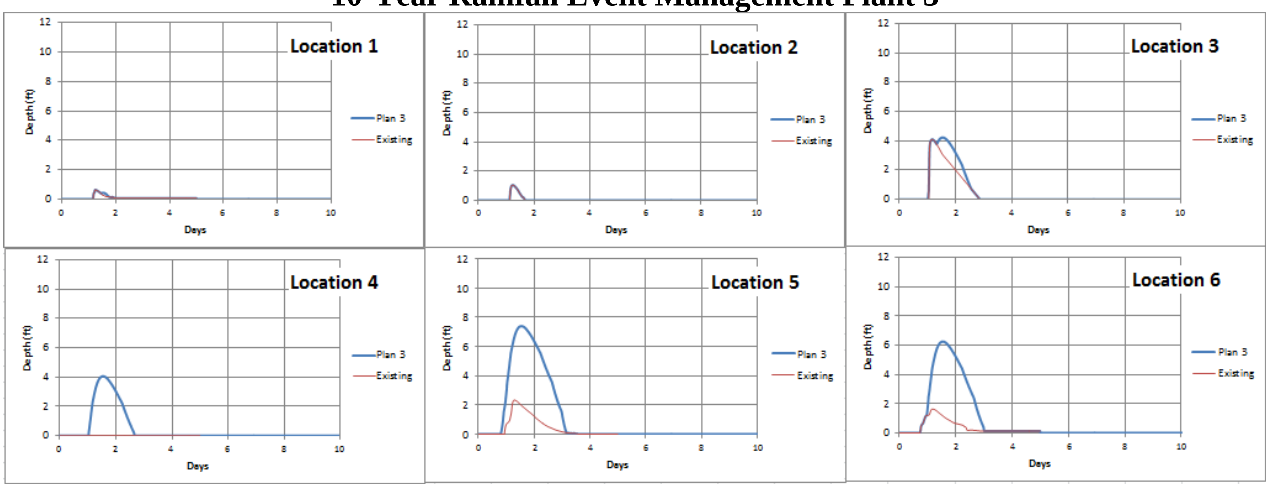

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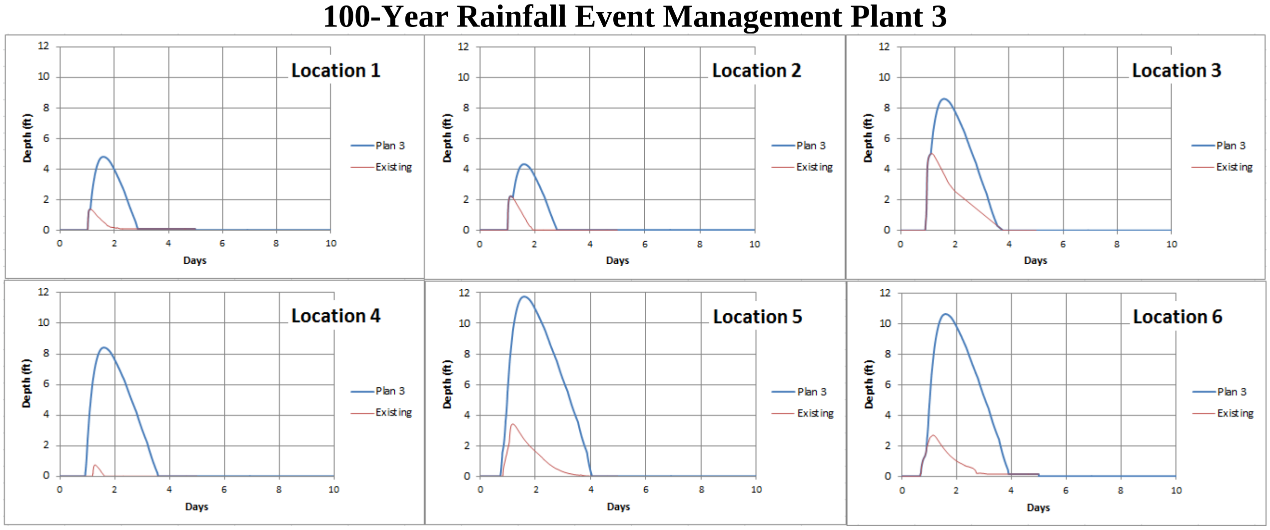
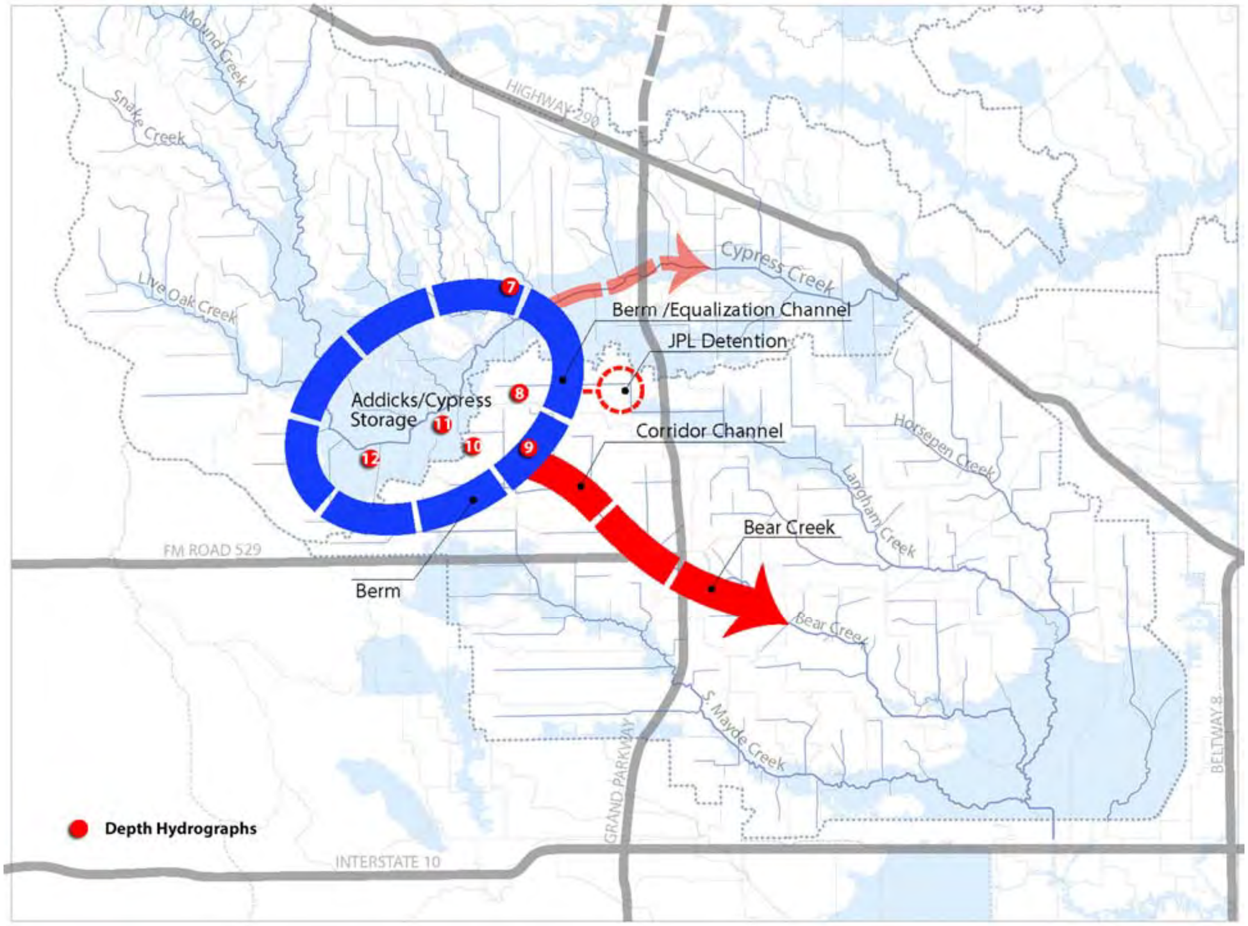


Management Plan 5 vs Existing Overflow
Depth and Duration Hydrograph Locations



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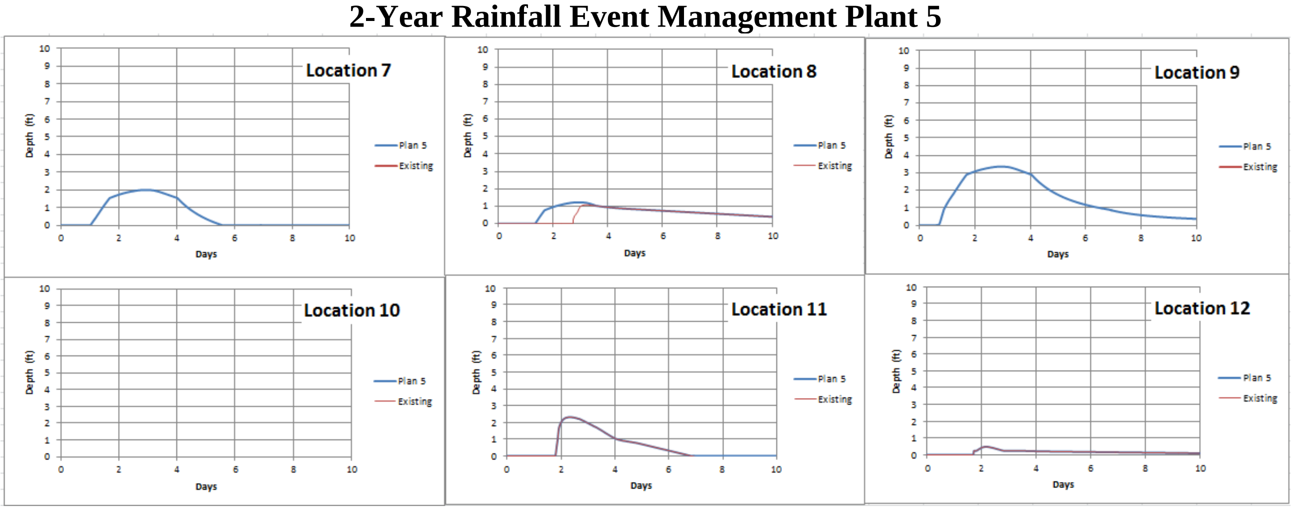

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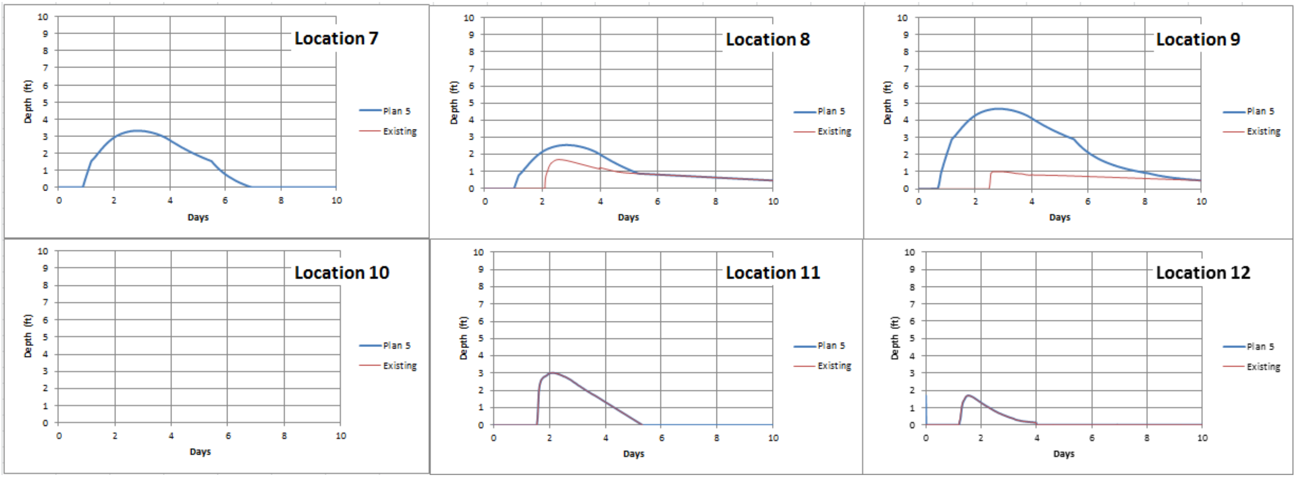

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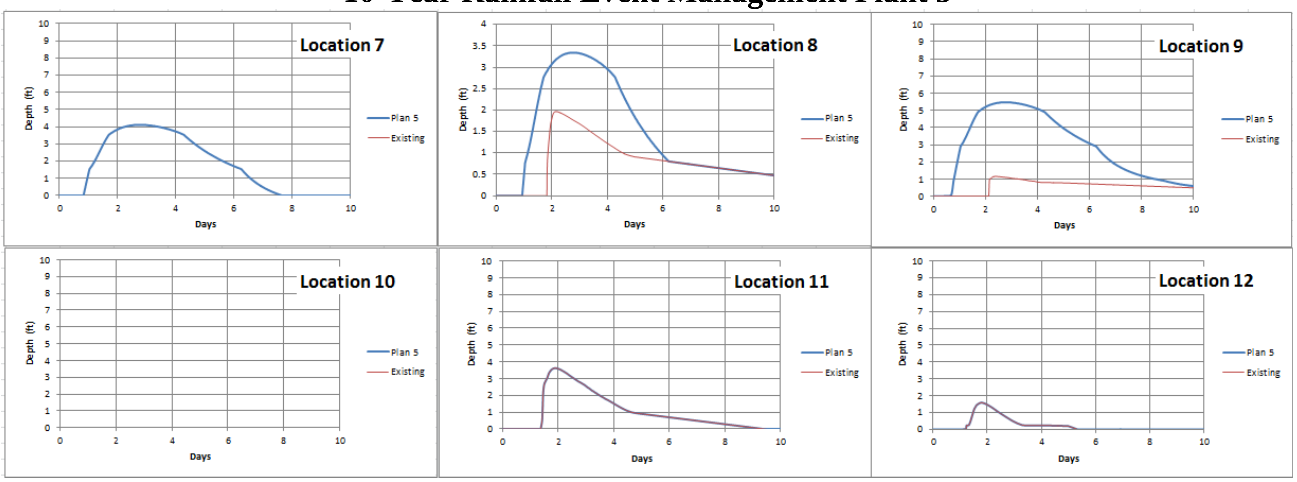

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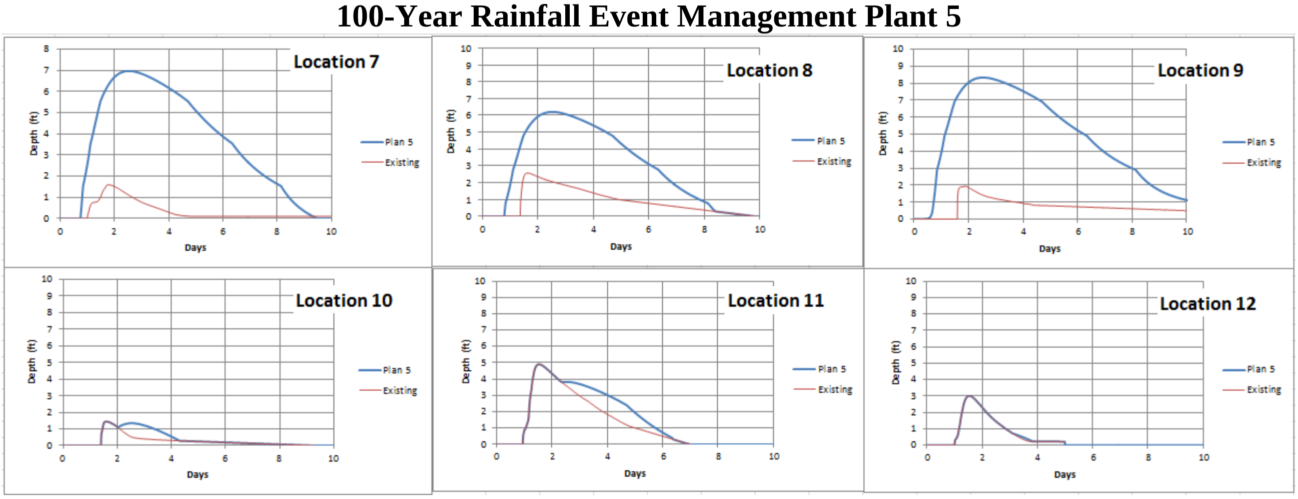

Appendix L
Soil Assessment of Land Cover Types

August 18, 2015

Table of Contents

Supplements

List of Chemical Symbols and Terms

Anion	Negatively-charged ion
Cation	Positively-charged ion
CEC	Cation exchange capacity
TEC	Total exchange capacity
BS	Base saturation percentage
SAR	Sodium Adsorption Ratio
pH	Acid-alkaline scale
EC	Electrical conductivity
C:N	Carbon-to-nitrogen ratio
ppm	Parts per million
meq	Milliequivalents
USDA	United States Department of Agriculture
USDA-SCS	U.S.D.A. Soil Conservation Service
USDA-NRCS	U.S.D.A. Natural Resources Conservation Service

Symbols and Names of Elements Used in Soil Science			
Anion		**Cation**	
Symbol	**Name**	**Symbol**	**Name**
S	Sulfur	Ca	Calcium
SO_4	Sulfate	Mg	Magnesium
P	Phosphorus	K	Potassium
P_2O_5	Phosphate	Na	Sodium
NO_3-N	Nitrate	NH_4-N	Ammonium
HCO_3	Bicarbonate	Al	Aluminum
Cl	Chloride	H	Hydrogen
Trace Elements		**Heavy Metals**	
B	Boron	As	Arsenic
Fe	Iron	Ba	Barium
Mn	Manganese	Cd	Cadmium
Cu	Copper	Pb	Lead
Zn	Zinc	Li	Lithium
Mo	Molybdenum	Mr	Mercury
Co	Cobalt	Se	Selenium
Ni	Nickel	Ag	Silver
Cl	Chloride	Sr	Strontium
		Sn	Tin
		V	Vanadium
Other			
N	Nitrogen		
C	Carbon		

1.0 Executive Summary

An assessment of soils in the Cypress Creek Overflow was conducted for Harris County Flood Control District (HCFCD) in *Task 3 – Benefits of Prairie Restoration for Flood Control* of their Flood Protection Planning Grant through the Texas Water Development Board (TWDB). The purpose of this assessment was to compare soil physical, chemical, and biological properties of three land cover types- native prairie, open space (agricultural or ranch land), and developed - in the Cypress Creek Overflow. It is widely believed that prairie grasses and forbs - by virtue of their robust, deep-roots capable of penetrating claypan soils and the cumulative influence of biodiversity, organic matter deposition and root-microbial interactions on soil quality properties - improve rainfall infiltration and thus warrant conversion of pastures and abandoned rice fields into restored prairies for use in flood retardation.

The study area focused on watersheds affected by Cypress Creek Overflow in eastern Waller County and western Harris County, subsequently draining into Addicks Reservoir (Langham Creek, Bear Creek, and South Mayde Creek) and Barker Reservoir (Mason Creek). Two sites for each land cover type were selected for assessment. Native prairie land cover type (e.g., remnant prairies) included Upper Tucker and Lower Tucker sites in eastern Waller County, open space land cover type (e.g., former rice farms converted to pasture) included Manor and Bing sites in eastern Waller County, and developed land cover type (e.g., disturbed urban soils) included the Westgate (residential neighborhood) and Kroger (commercial tract) sites in western Harris County.

Soil samples were collected at each of the six sites in September 2012. Samples were sent to Wallace Laboratories (California) and Logan Labs (Ohio) for physical and chemical soil analysis and to Soil Foodweb-New York (New York) for soil foodweb analysis. Follow-up field sampling, which focused on water infiltration measurements, took place in January 2013 and August 2013.

Alfisols were present at all six sites; five sites were classified as sandy loams while the Kroger site had sandy clay loam. Soil types included Katy Fine Sandy Loam, Hockley Fine Sandy Loam, Wockley Fine Sandy Loam, Monaville Loamy Fine Sand, and Waller Loam, Depressional.

Results for soil pH, soil organic matter, and CEC were typical of Alfisols in the Katy Prairie; intermixing of clays on the developed sites and past agricultural activity on the open space sites may account for some variability. While abnormally high sodium occurs in some parts of the Lissie Formation, sodium levels were normal at the project sites. No issues with heavy metals were found. Levels of desired nutrients were very low to relatively normal; supplementation with organic, biological, and mineral soil amendments prior to vegetation establishment will enhance revegetation efforts.

Outstanding results included the Average Infiltration Rate per Land Cover Type by the single ring infiltrometer method, which showed substantially higher infiltration rates in the Native Prairie sites (8.21 in/hr) compared to open space (1.98 in/hr) and developed (0.45 in/hr) sites. Likewise, soil foodweb assessments showed a similar trend; there were greater number of favorable soil biology properties in native prairie sites compared to open space and developed sites. Implications are discussed in this report.

2.0 Introduction

Harris County is located at the center of the Houston - Sugar Land - Baytown metropolitan area and is one of the largest urban counties in the U.S. with 4.1 million people (U.S. Census Bureau, 2011) living within its 1,778 square mile boundary. Located in the Gulf coastal plain in southeastern Texas, much of the terrain in Harris County is flat, low lying, and poorly drained. The average precipitation is 48 inches per year but on occasion the metroplex experiences torrential rainfall (i.e., 20-30 inches of precipitation) from hurricanes and tropical storms which leads to severe flooding.

Harris County Flood Control District (HCFCD) - established by the Texas Legislature in 1937 as a special purpose district to mitigate flooding in the Houston area - plans, constructs, and manages flood control detention basins and earthen conveyance channels in the twenty-two watersheds located in Harris County. Flood control channels alone total about 2,500 miles in length on more than 1,500 channels. While HCFCD's jurisdiction is limited to Harris County, some creeks and watersheds originate or flow through adjoining counties, thus multi-county governmental collaborations and datasets are common.

One of the key engineering and environmental planning activities the District performs is hydrological studies - the measurement of rainfed water flows in streams, rivers, and floodplains - to develop flood management criteria. In response to the projected surge of development in the western and northwestern areas of Harris County, the HCFCD is working on a Flood Protection Planning Grant through the Texas Water Development Board (TWDB) which will provide a comprehensive assessment of hydrology, land use, environmental mitigation and other factors that could potentially reduce flooding risk in the study area.

The study area, which encompasses 278 square miles of targeted watersheds, drains into the Addicks and Barker reservoirs which are designed to mitigate flooding along the Buffalo Bayou and downtown Houston. Approximately 60 square miles of the upper Cypress Creek watershed originates in Waller County and drains into Harris County. When rainstorms exceed a 10-year storm event, runoff overflows from the Cypress Creek watershed across pasture- and prairie-lands into the tributary watersheds draining into the Addicks and Barker reservoirs. The study area will include the Cypress Creek watershed upstream of US 290, watersheds (including Langham Creek, Bear Creek, and South Mayde Creek) draining into Addicks Reservoir, and that portion of the Barker Reservoir watershed (including Mason Creek) affected by Cypress Creek overflow.

The western half of Harris County was historically occupied by the Katy Prairie, an inland tall-grass coastal prairie occurring on nearly level, light-colored loamy topsoils with poorly drained clayey subsoils, popularly known as the "flatlands". Geographically, this coastal prairie - also known as the Katy-Hockley Prairie - extended eastward to the 610 Loop in Houston, north to the edge of the pine-hardwood forests along Spring Creek north of US 290, southwest to the Brazos River in Fort Bend County, and west to the Brazos River in Waller County (Katy Prairie

Conservancy, undated). While the original prairie spread across 750,000 acres, encroachment from Houston development has displaced more than 75% of the Katy Prairie (Newman, 2000).

Coastal prairies are characterized as grasslands supporting a diverse mixture of 150 to 400 species of deep-rooted grasses, legumes, and forbs occupying vast, level expanses interspersed with trees and shrubs occurring as mottes and in riparian strips. The undisturbed Katy Prairie was interspersed with hundreds of thousands of wetlands in a complex of small depressions or “prairie potholes” and small hillocks or “pimple mounds”, the latter occurring as circular to elliptical sandy loam knolls elevated one to four feet in height above the surrounding terrain (Moulton and Jacob, 2000). These micro-habitats and seasonal wetlands - one half acre to 20 acres in size - provided important functions such as wildlife habitat, plant species diversity, water retention, and slow infiltration. Other ecosystem services provided by the Katy Prairie include carbon sequestration, nutrient filtration, nutrient cycling, and flood mitigation (Maczko and Hidinger, 2008).

Rice farming was introduced to the claypan soils of the Gulf coastal prairies in the late 1800s and experienced rapid growth in the early 1900s with the introduction of improved farming equipment, irrigation systems, and seed varieties. By 1919, over 6,000 acres of Harris County land had been converted to rice cultivation (USDA Soil Survey, 1928). Rice acreage in Harris County peaked in 1954 with 60,273 acres (U.S. Census of Agriculture, 1954). In 1973, Harris County ranked sixth in the state for rice producing counties with a total of 31,288 acres (NRCS, 1976). However, rice production in Harris County declined in the ensuing decades with less than 10,000 acres in 1985, less than 5,000 acres in 1999, and less than 1,000 acres in 2007 (Texas AgriLife, 2011). Today these former rice fields are largely managed for pasture grazing and haying, turfgrass sod farms, and limited production of wheat, corn, milo, and sorghum-sudan.

In preparation of paddy rice cultivation, prairie lands were leveled and agricultural berms were formed in order to flood irrigate the fields, maintain prescribed water levels during the crop’s life cycle, and to control weeds. As a consequence, the wetland systems endemic to the Katy Prairie, the prairie pothole and pimple mound complexes, were widely displaced. At the same time, bermed rice fields - functioning as water impoundments - served as surrogate wetlands and provided related ecosystem services to the coastal prairie. While most of these former rice farms have been converted to improved pastures consisting of Bermuda grass and Bahia grass, intact agricultural berms are common. Thus, they continue to function as temporary water impoundments and mitigate downstream flooding while providing filtration, wildlife habitat, and aquifer recharge. With the anticipated population growth and development in the Cypress Creek Overflow study area, however, there is concern the existing ecosystem services of the Katy Prairie and abandoned rice fields will be displaced and downstream flooding will be exacerbated.

The present soil assessment is part of *Task 3 – Benefits of Prairie Restoration for Flood Control* in the Cypress Creek Overflow Study. The following report summarizes the physical, chemical, and biological soil parameters of three land cover types in the Cypress Creek Overflow.

3.0 Environmental Setting

3.1 Vegetation of Harris County

The Texas Parks and Wildlife Department (TPWD, 1984) identified seven vegetational types in Harris County: 1. Urban; 2. Bluestem Grassland; 3. Crop Lands; 4. Other Native and Introduced Grasses; 5. Pine-Hardwood Forest, and to a minor degree, 6. Pecan-Elm Forest and 7. Marsh-Barrier Island.

Historical land-use descriptions in the early 1880s noted three-fourths to four-fifths of Harris County was covered in open prairie (Spaight, 1882; Loughridge, 1884). The Katy Prairie occupied the western and northwest portions of the county on nearly level, sandy loam and loamy soils. The southern and southeastern part of Harris County was occupied by a coastal prairie on nearly level, clayey soils. Native grasses of coastal prairies in Harris County include upland dominants such as Little Bluestem, Indian Grass, Brownseed Paspaulum, and Big Bluestem and lowland dominants such as Eastern Gama Grass, Bushy Bluestem, Switchgrass, and Longtom Paspalum (Smeins, 1991; NatureServe, 2013). However, vegetation associations in localized Gulf coast prairies vary depending on soil type, topography, and moisture gradients (Oliver, 1990; Smeins, 1986).

3.2 Vegetation of the Katy Prairie

Vegetation of the Katy Prairie has been described as a diverse mosaic of emergent wetlands, upland grasslands, and riparian hardwoods (Newman, 2000). The influence of man’s activities - hunting, grazing, farming, road construction - over the last 170 years has dramatically influenced the current landscape. The conversion of prairie to rice farming, the introduction of improved forage grasses possessing an invasive and persistent characteristic, abandonment of rice fields, burning, overgrazing, and decades of succession are major influences. Encroachment of woody species is common. A few remnant prairies exist as hay meadows on private ranches and preserves managed by the Katy Prairie Conservancy (KPC), while scattered native grasses and wildflowers can be found along roadsides, pastures, fence rows, and forest edges.

Detailed studies on the vascular flora of remnant coastal prairies have been published for the Nash Prairie in Brazoria County, Texas and the Cajun Prairie in southwestern Louisiana. While some variation exists between sites, like the Katy Prairie, they are located in the Gulf Coastal Prairie and Marsh ecoregion. Thus, related studies can provide indicators of species composition and be useful in seed and plant selections for prairie restoration.

Nash Prairie is a remnant prairie located 70 miles southwest of Houston in an area known as the Columbia Bottomlands in the Brazos River watershed. Part of an historic ranch, Nash Prairie has been managed as a hay meadow and reportedly has never been plowed. Rosen (2007), while conducting an intensive survey of 296 acres at Nash Prairie for the U.S. Fish and Wildlife Service, found 311 species of vascular plants representing 63 families and 197 genera. Of these, native flora comprised 289 species distributed in 63 families, including 117 species of monocots (grasses, rushes, sedges) and 172 species of eudicots (legumes, forbs and wildflowers). Several rare and endemic coastal prairie species were identified in this study.

The Cajun Prairie is the coastal prairie region of southwestern Louisiana located between the Atchafalaya and Sabine rivers. Prior to agricultural development, the prairie occupied 2,470,000 acres, however only a few remnant stands remain, primarily along railroad right-of-ways. Allen and Vidrine et al (2001) compiled a detailed flora of these remnant stands in Acadia, Allen, and Jefferson Davis counties over a twelve year period, between1987-1999. The vascular flora of the remnant railroad strips, plus a few other remnant sites, included 512 taxa in 92 families and 277 genera. A total of 235 taxa (45.9%) were identified from disturbed sites along edges of the remnant strips. The remaining 244 taxa (47.6%) constituted the Cajun Prairie Flora. Species were further rated as common, uncommon, or rare.

An informal plant checklist of the Tucker Prairie, a remnant stand located on a ranch in Waller County that is held in a conservation easement by the Katy Prairie Conservancy, was compiled by Dr. Larry Brown, botanist (Brown, undated manuscript). The checklist included 144 species of grasses, sedges, legumes, forbs, wildflowers, vines, and woody plants.

The flora of Armand Bayou Nature Center located in southeast Harris County - a prairie, forest and wetland preserve - was analyzed for species composition in a master's thesis completed through Rice University in 1990 (Oliver, 1990). The study identified 149 taxa composed of 54 graminoids, 82 forbs and 13 woody species. Brownseed Paspalum, Panic Grass, Cherokee Sedge, Broomsedge Bluestem, and Little Bluestem were the dominant graminoids.

In a study of sixty-three upland True (Great Plains) and Upper Coastal Prairie grasslands, Diamond and Smeins (1988) determined temperature, precipitation, and soil gradients influence vegetational composition. Seven community types were recognized and six were described in detail. The Upper Coastal Prairies of Texas form a *Schizachyrium scoparium – Paspalum plicatulum - Sorghastrum nutans* community type. Secondary graminoids include *Fimbristylis puberula*, *Paspalum floridanum*, *Scleria ciliata*, and *Sporobolus asper*. 156 taxa, including 39 graminoids, 116 forbs, and 1 shrub, occurred across all sampling sites.

Exhibit L3.1 Diverse native vegetation on the Katy Prairie, August 2012

3.3 Soils of Harris and Waller Counties, Texas

Soils of Harris County were deposited in the Tertiary and Quatenary periods. The uppermost geological formations, from youngest to oldest, include the Beaumont, Lissie, and Willis Formations which occur in belts lying approximately parallel to the present coast line. The generalized Geologic Map of Texas (Univ. of Texas, 1992) illustrates their successive exposure in Harris County with the Beaumont lying south of Addicks Reservoir, the Lissie running across the upper half of the county, and the Willis in the far northwest.

Table L3.1, compiled from the SSURGO database (USDA, 2006), contains the taxonomic classification scheme of the major soils in Harris County. Soil scientists use this system to group soils according to Order, Suborders, Great Groups, Subgroups, Families, and Series.

Table L3.1: Taxonomic Classification of the Major Soil Series, Harris County (USDA 2006)

Soil Series	Soil Order	Taxonomic Description
Addicks	Mollisol	Coarse-loamy, siliceous, thermic Typic Argiaquolls
Aldine	Alfisol	Fine-silty over clayey, siliceous, thermic Aeric Glossaqualfs
Aris	Alfisol	Fine, montmorillonitic, thermic Typic Glossaqualfs
Atasco	Alfisol	Fine, mixed, thermic Aquic Glossudalfs
Beaumont	Vertisol	Fine, montmorillonitic, hyperthermic Chromic Dystraquerts
Bernard	Mollisol	Fine, montmorillonitic, thermic Vertic Argiaquolls
Clodine	Alfisol	Coarse-loamy, siliceous, thermic Typic Ochraqualfs
Edna	Alfisol	Fine, montmorillonitic, thermic Vertic Hapludalfs
Gessner	Alfisol	Coarse-loamy, siliceous, thermic Typic Glossaqualfs
Hockley	Alfisol	Fine-loamy, siliceous, thermic Plinthic Paleudalfs
Katy	Alfisol	Fine-loamy, siliceous, active, hyperthermic Aquic Paleudalfs
Lake Charles	Vertisol	Fine, montmorillonitic, hyperthermic Typic Hapluderts
Segno	Alfisol	Fine-loamy, siliceous, thermic Plinthic Paleudalfs
Verland	Alfisol	Fine, smectitic, hyperthermic Chromic Vertic Epiaqualfs
Wockley	Alfisol	Fine-loamy, siliceous, active, hyperthermic Plinthaquic Paleudalfs

Based on this classification scheme, the major soils in Harris County can be broadly categorized as Vertisols, Mollisols, and Alfisols (see Figure A-1).

Vertisols - which include the Beaumont and Lake Charles series above - lay south and east of Addicks Reservoir on the nearly level, clayey coastal prairie region. Vertisols are smectite-rich (montmorillonitic) clay soils with high shrink-swell potential that develop deep, wide cracking under dry conditions. These soils are commonly known as “gumbo” or “black waxy” due to their sticky clay content which, in turn, leads to impermeable conditions with a slow rate of rainfall infiltration. These soils are considered fertile and productive due to their high cation exchange capacity and moisture retention; conversely, in the Gulf Coastal Plain they require field drainage to shed water. Vertisols in the Gulf Coastal Plain formed on marine and alluvial floodplains under grassland vegetation.

Mollisols - which include the Bernard series above - are found in the coastal prairie region in association with the Lake Charles series above. Addicks is another Mollisol but is distributed more widely. Mollisols have a distinctive dark colored surface that is enriched with organic matter and base cations (calcium and magnesium) having developed under grassland vegetation with dense rooting. The Vertic Argiaquolls are the moist group of Mollisols with a high content of expanding clays which supports moisture-loving coastal prairie vegetation. Similarly, they can support productive farmland with tile or ditch drainage.

Alfisols - which include the Aris, Katy, Hockley, and Wockley series above - lay to the west and northwest of Addicks Reservoir which coincides with the nearly level, loamy Katy Prairie. Alfisols are moderately leached with medium fertility, at least 35 percent base saturation (calcium, magnesium, potassium, sodium), and a clay-rich subsurface accumulation known as argillic horizon. Alfisols developed under forest and grassland vegetation. The Udalfs such as Katy, Hockley, and Wockley are known for poor drainage and permeability due to underlying clays. The characteristic leaching of calcium carbonate and thus proportionally higher sodium, loss of organic matter, and accumulation of fine clays in the B horizon are conditions that lead to dispersive clays on Alfisols in the Lissie Formation in Northwest Harris County.

Table L3.2: Taxonomic Classification of Selected Soil Series, Waller County (USDA 2001)

Soil Series	**Soil Order**	**Taxonomic Description**
Hockley	Alfisol	Fine-loamy, siliceous, semiactive, hyperthermic Plinthic Paleudalfs
Katy	Alfisol	Fine-loamy, siliceous, active, hyperthermic Oxyaquic Paleudalfs
Monaville	Alfisol	Loamy, siliceous, semiactive, hyperthermic Arenic Plinthic Paleudalfs
Waller	Alfisol	Fine-loamy, siliceous, active, thermic Typic Glossaqualfs
Wockley	Alfisol	Fine-loamy, siliceous, semiactive, hyperthermic Plinthaquic Paleudalfs

4.0 Soil Analysis, Cypress Creek Overflow

4.1 Site Descriptions, Soil Conditions, and Sampling Methods

Harris County Flood Control District identified three land cover types for the Cypress Creek Overflow Study: open space, developed, and native prairie (Exhibit L4.1). Two representative sites for each of the three land cover types were identified through the use of LiDAR maps and ground surveys by District staff and project consultants. Photographs of site conditions and vegetative cover are displayed in Supplement L1.

4.1.1 Native Prairie Land Cover Type

Upper Tucker – The Upper Tucker site is a remnant prairie located on a private ranch held in a conservation easement through the Katy Prairie Conservancy, situated off Berry Road, approximately 2 miles northeast of the KPC Field Headquarters in eastern Waller County. The Cypress Creek Overflow Study location was a native hay meadow to the west of the ranch road. According to aerial maps in the *Soil Survey of Austin and Waller Counties, Texas* (USDA-SCS,1984), the soil type is HoB – Hockley Fine Sandy Loam, 1 to 3 percent slope. According to the *SoilWeb* online soil survey (UC-Davis, 2012) — which maps SSURGO data generated by USDA onto Google Earth® — the soil type is WoA – Wockley Fine Sandy Loam, 0 to 1 percent slope. Cattle were present on the ranch at the time of soil sampling. Vegetation was a mixture of native grasses and forbs with a few trees present. Soil conditions at the time of sampling in late September were suitable for collecting 3/4-inch cores to a six inch depth using a standard soil probe.

Lower Tucker – The Lower Tucker site is a remnant prairie located in a native hay meadow on the same property as Upper Tucker above, approximately 2,400 feet to the southeast. According to the *SoilWeb* online soil survey (UC-Davis, 2012), the soil type is MvC – Monaville Loamy Fine Sand very near Wa – Waller Loam, Depressional. Vegetation was a mixture of native grasses and forbs with Guara (*Guara lindheimeri)* occurring in abundance at the time of sampling. Soil conditions and sampling methods were the same as Upper Tucker above.

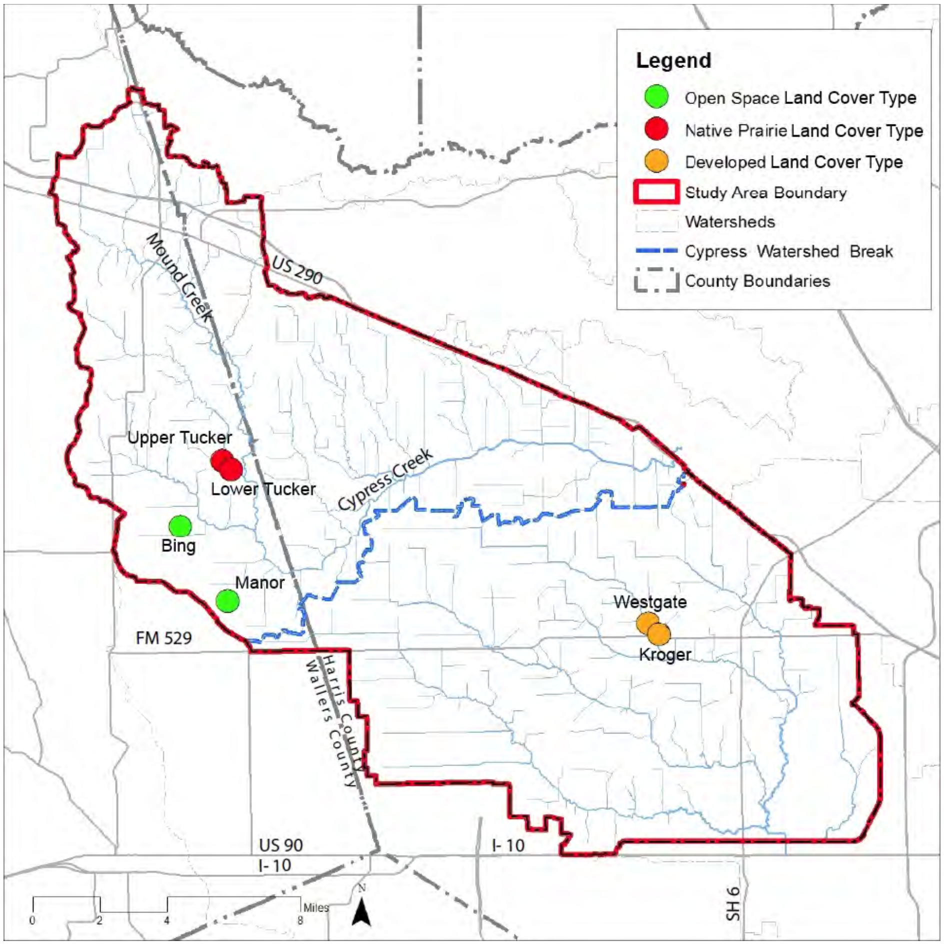

Exhibit L4.1: Soil Sampling Locations

4.1.2 Open Space Land Cover Type

Manor – The Manor site is a Katy Prairie Conservancy holding known as the Mary Manor Preserve, located on Pattison Road in eastern Waller County. The preserve is a 632-acre tract of land featuring both upland and wetland vegetation. The Cypress Creek Overflow Study location was in the upland field near an agricultural berm. According to information gathered from the *Soil Survey of Austin and Waller Counties, Texas* (USDA-SCS,1984), and the *SoilWeb* online soil survey (UC-Davis, 2012), the soil type was KaA – Katy Fine Sandy Loam, 1 to 3 percent slope. The field, formerly in a rice-pasture rotation, had a vegetative mixture of native and introduced grasses and forbs and was in use for cattle grazing; forbs such as Guara (*Guara lindheimeri*) and Wooly Croton (*Croton capitatus*) dominated the site. At the time of soil sampling in early September, soils conditions were extremely dry. A modified version of the Sweatless Soil Sampler (Kress, Arnall and Zhang, 2003) developed at Oklahoma State University — using 3/4-inch and 1-inch ship's auger drill bits — was used to collect soil samples to a depth of six inches.

Bing – The Bing site is a Katy Prairie Conservancy holding known as the Buller/Bing Preserve, located adjacent the KPC Field Headquarters on Hebert Road in eastern Waller County. The Cypress Creek Overflow Study location was in a field south of an earthen water impoundment.

Likewise, the soil type was Katy Fine Sandy Loam, 1 to 3 percent slope. The field was managed for pasture and was in use for cattle grazing; coastal bermudagrass (*Cynodon dactylon)* dominated the sampling location with profuse Wooly Croton (*Croton capitatus*) in the adjoining large field. Soil sampling methods (dry conditions, sweatless soil sampler) and sampling depth were the same as Manor.

4.1.3 Developed Land Cover Type

Westgate – This residentially developed site was in the Westgate urban neighborhood off of Barker-Cypress Road, near the corner of FM 529 & Barker-Cypress Road in western Harris County. The Cypress Creek Overflow Study location was an easement between the Vine Grove Court cul-de-sac and a small community park. According to information compiled from the *Soil Survey of Harris County, Texas* (USDA-SCS,1976), and the *SoilWeb* online soil survey (UC-Davis, 2012), the soil type was Kf – Katy Fine Sandy Loam. Vegetation at the site was a landscape quality St. Augustine turf grass. Soil sampling methods (dry conditions, sweatless soil sampler) and sampling depth were the same as Manor. Additionally, a pick-axe was used to penetrate soils at this site.

Kroger – This commercially developed site was adjacent to the Kroger shopping center off of FM 529, near the corner of FM 529 & Barker-Cypress Road in western Harris County. The Cypress Creek Overflow Study location was an easement between commercial buildings and Langham Creek. The soil type, as above, was Katy Fine Sandy Loam; however, intermixed clays suggest the subsoil was exposed during construction. Vegetation at the site was a mixture of bermudagrass, lower successional grasses, and weeds. Soil sampling methods (dry conditions, sweatless soil sampler, pick-axe) and sampling depth were the same as Westgate above.

4.1.4 Soil Biology

Soil biology samples were collected at each site with a hand trowel. Round plugs of soil, four inches deep, were sampled next to plants to include roots for mycorrhizal colonization assessment. Approximately six soil plugs were collected from each site and pooled as the soil biology sample. Selection of sampling sites for soil biology was intended to represent dominant and secondary vegetation in order to provide roots for bioassay.

4.2 Soil Sampling Locations

Collection of soil samples was concentrated within a 30-foot square, or thereabouts, at each of the three land cover sites. The GPS coordinates for Degrees, Minutes, Decimal Minutes (DD MM.MMM) listed in Table L4.1 match those used on the U.S. Geological Survey's GeoPDF topographic map series; online converters can be used to access GPS coordinates on Google Maps (DDD.DD) or Google Earth (DD MM SS.SS).

Table L4.1 – Soil Sampling Locations

Native Prairie - Upper Tucker	**Latitude**	**Longitude**
Lower Right (SE)	N°29 57.397'	W°095 54.313'

Upper Right (NE)	N°29 57.400'	W°095 54.315'
Upper Left (NW)	N°29 57.399'	W°095 54.320'
Lower Left (SE)	N°29 57.395'	W°095 54.316'
Native Prairie - Lower Tucker	**Latitude**	**Longitude**
Lower Right (SE)	N°29 57.115'	W°095 54.002'
Upper Right (NE)	N°29 57.120'	W°095 54.002'
Upper Left (NW)	N°29 57.122'	W°095 54.007'
Lower Left (SW)	N°29 57.118'	W°095 54.008'
Open Space - Manor	**Latitude**	**Longitude**
Lower Right (NE)	N°29 53.636'	W°095 54.075'
Upper Right (NW)	N°29 53.635'	W°095 55.080'
Upper Left (SW)	N°29 53.639'	W°095 55.081'
Lower Left (SE)	N°29 53.638'	W°095 55.075'
Open Space - Bing	**Latitude**	**Longitude**
Lower Right (NE)	N°29 55.696'	W°095 55.490'
Upper Right (NW)	N°29 55.697'	W°095 55.496'
Upper Left (SW)	N°29 55.691'	W°095 55.495'
Lower Left (SE)	N°29 55.692'	W°095 55.488'
Developed - Westgate	**Latitude**	**Longitude**
Lower Right (E)	N°29 53.123'	W°095 41.459'
Upper Right (N)	N°29 53.120'	W°095 41.467'
Upper Left (W)	N°29 53.119'	W°095 41.467'
Lower Left (S)	N°29 53.123'	W°095 41.460'
Developed - Kroger	**Latitude**	**Longitude**
Lower Right (NE)	N°29 52.841'	W°095 41.181'
Upper Right (NW)	N°29 52.839'	W°095 41.187'
Upper Left (SW)	N°29 52.832'	W°095 41.184'
Lower Left (SE)	N°29 52.834'	W°095 41.174'

4.3 Analytical Methods and Data Parameters Employed at Soil Laboratories

Laboratory methods and analytical parameters reported by the three soil laboratories are summarized in Table L4.2 and ensuing descriptions to provide context to analytical findings.

Table L4.2: Comparison of Laboratory Methods and Soil Property Indicators

Laboratory	Analytical Parameter	Soil Property Indicator [1]
Logan Labs	CEC	Chemical, Soil Texture
	pH	Chemical
	OM	Physical, Biological
	EC	Chemical, Physical
	Bicarbonate	Chemical, Physical
	Anions	Chemical
	Cations	Chemical
	Base Saturation	Chemical, Physical
	Trace Elements	Chemical
Wallace Laboratories	Desired Nutrients	Chemical
	Heavy Metals	Chemical
	CEC	Chemical, Soil Texture
	Base Saturation	Chemical, Physical
	pH	Chemical
	EC	Chemical, Physical
	SAR	Chemical, Physical
	Infiltration Rate/Hr	Physical
	Soil Texture	Physical
	Half Saturation Percentage	Physical
	Moisture Content of Soil	Physical
	Estimated Gypsum Requirement	Chemical, Physical
	Total Carbon, Total Nitrogen, C:N	Chemical, Physical, Biological
	OM	Physical, Biological
Soil Foodweb, Inc.	Total and Active Fungi	Biological, Soil Structure
	Total and Active Bacteria	Biological
	Fungal Hyphal Diameter	Biological
	Protozoas and Nematodes	Biological
	Mycorrhizal Colonization	Biological, Soil Structure

[1] Indicators of physical, chemical, and biological soil conditions. Soil texture and structure are physical indicators.

4.3.1 Logan Labs, LLC (Ohio)

Logan Labs offers an Albrecht soil test, based on the work of Dr. William A. Albrecht, professor of soils at the University of Missouri from 1916-1959, who upon retirement helped refine soil testing protocols at Brookside Laboratories in Ohio. The complete soil test provides two sets of lab results. The Mehlich-3 universal extract is used to report exchangeable soil nutrients while the Saturated Paste method is used to report water soluble nutrients. Organic matter is reported by Loss on Ignition.

The soil test report provides TEC; pH; OM; Anions (sulfur (S), phosphorus (P)); Exchangeable Cations (calcium (Ca), magnesium (Mg), potassium (K), sodium (Na)); Base Saturation (percent

Ca, Mg, K, Na); and Trace Elements (boron (B), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), aluminum (Al)); plus ammonium (NH4-N) and nitrate (NO3-N).

The saturated paste report provides pH, soluble salts, chloride (Cl), bicarbonate (HC03), plus the soluble amounts of anions, cations, percent cations, and trace elements as reported on the soil test.

4.3.2 Wallace Laboratories (California)

Wallace Labs was established as a commercial laboratory by Dr. Arthur Wallace (deceased) and Dr. Garn Wallace when the soils laboratory at University of California-Riverside was discontinued as a public service. The ammonium bicarbonate/DTPA universal extractant, developed at Colorado State University, is used for soil nutrient determination. Organic matter is calculated from total carbon.

The comprehensive soil test offered by Wallace Laboratories (Standard Agricultural Soil Suitability Analysis) includes pH, EC, SAR, estimated gypsum requirement, moisture content, half saturation percentage, and elemental analysis for plant nutrients (Ca, Mg, Na, K, P, Fe, Mn, Zn, Cu, B, S, molybdenum (Mo), nickel (Ni)) and heavy metals (aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), cobalt (Co), lead (Pb), lithium (Li), selenium (Se), silver (Ag), scrontium (Sr), tin (Sn), vanadium (V)).

Additional tests requested for the TWDB sites included an Organic Matter test (Total N, Total C, C:N ratio, and OM based on total Carbon), CEC test (cation exchange capacity and base saturation), Soil Texture test (USDA soil texture classification), and Water Percolation test (water infiltration rate per hour).

4.3.3 Soil Foodweb New York (New York)

Soil Food New York (SFW-NY) uses the assessment methods formalized by Dr. Elaine Ingham in the mid-1990s, through Soil Foodweb, Inc. (SFI), based on microbiological methods she developed at Oregon State University and Colorado State University. These SFI laboratories use direct look microscopy (Differential Interference Contrast with epifluorescence) and staining procedures, as well as culturing of protozoas with the most probable number (MPN) method, to assess soil foodweb organisms.

The soil foodweb analysis report includes total and active bacteria; total and active fungi; fungal hyphal diameter; numbers of protozoa (flagellates, amoeba, and ciliates); numbers of nematodes; nematode feeding group (beneficial and detrimental types); percent mycorrhizal colonization; and estimated nitrogen release.

4.4 Soil Analytical Results and Interpretive Summary

Analytical results from each of the three soil laboratories are provided in Supplement L3. The following section provides an interpretive summary of key findings as they relate to soil conditions among three land cover types in the Cypress Creek Overflow.

4.4.1 Appearance

Soil samples varied in appearance with respect to color and texture between each of the three land cover types, while the two site samples from the same cover type had a similar appearance (Supplement L1). The interaction of soil type and vegetative cover are presumably major influences. The Katy Fine Loam soils of Manor and Bing had a light color with very fine texture. The urban soils at the Kroger and Westgate sites, originally situated on Katy Fine Sandy Loam, had intermixed clays in the topsoil suggesting subsoil disturbance during construction. The Tucker Prairie soils had a brown sandy loam appearance.

4.4.2 Texture

U.S.D.A. soil texture classification was conducted by Wallace Laboratories. Table L4.3 lists the soil texture classification for each site as well as the percentage of sand, silt, and clay for each soil sample. The Westgate site had sandy clay loam, while the five other sites had sandy loam. The developed sites had a substantially greater percentage of clay, which suggests subsoil exposure and intermixing during construction since they otherwise lay on the same soil type as open space (i.e, Katy Fine Sandy Loam).

Table L4.3: Soil Texture Composition and Classification [1]

	Soil Texture Composition			**Classification**
Land Cover Type	**Sand %**	**Silt %**	**Clay %**	
Prairie				
Upper Tucker	64.8	26.7	8.5	Sandy loam
Lower Tucker	66.4	29.7	3.9	Sandy loam
Open Space				
Manor	62.8	31.2	6.0	Sandy loam
Bing	61.6	27.6	10.9	Sandy loam
Developed				
Westgate	52.2	25.1	22.7	Sandy clay loam
Kroger	55.6	25.9	18.5	Sandy loam

[1] Wallace Laboratories data for 6 soil samples

4.4.3 pH, Organic Matter, and CEC

Table L4.4 compares the pH, Organic Matter, and CEC findings from Wallace Laboratories and Logan Labs.

Soil pH measurements by Wallace Laboratories ranged from 5.34 to 7.41 while those from Logan Labs ranged from 6.0 to 7.10. The highest pH, occurring on the Kroger site, was abnormally high which suggests adverse effects from construction and disturbance. Soils on the native prairie sites were slightly acidic to very acidic. Diamond and Smeins (1985) found an identical pH of 5.8 on both vertisol and alfisol coastal prairies. The higher pH readings from Logan Labs on the open space sites suggest lime applications from past agricultural activity, while those from Wallace Laboratories suggest a normal range for historically prairie soils. The substantially greater CEC on the developed sites are indicative of greater clay percentages.

Table L4.4: pH, OM, and CEC for Soils[1]

	pH		OM %		CEC	
Land Cover Type	**Wallace**	**Logan**	**Wallace**	**Logan**	**Wallace**	**Logan**
Prairie						
Upper Tucker	5.36	6.20	1.81	2.02	6.45	4.39
Lower Tucker	5.54	6.10	1.96	1.49	5.73	3.59
Open Space						
Manor	5.84	6.60	0.91	0.93	3.52	7.48
Bing	6.18	6.50	1.03	0.93	5.91	3.36
Developed						
Westgate	6.07	6.00	2.40	3.63	13.80	11.72
Kroger	7.41	7.10	1.21	2.03	14.58	9.89

[1] Wallace Laboratories and Logan Labs data for 6 soil samples

Soil organic matter - the debris of plants and animals, the living biomass, and the brown amorphous humic substances produced by their activity - gives resilience and vitality to soils. Soil organic matter positively influences all three components of the soil: the physical (e.g., aggregate stability and bulk density), chemical (e.g., cation exchange capacity and nutrient cycling), and biological (e.g., food and habitat for soil biota). Soil humus, a stable form of soil organic matter with sponge-like properties, greatly improves soil water-holding capacity.

Organic matter data from Wallace Laboratories ranged from 0.91% to 2.4% while those from Logan Labs ranged from 0.93% to 3.63%. Prairie soils showed greater amounts of organic matter than open space soils. Since these sites are located within 2 miles of each other on similar soil types, these differences may indicate the influence of longterm prairie vegetation vs agricultural tillage. The developed sites had similar or slightly higher amounts of organic matter. The highest amount of organic matter occurred on the Westgate residential site suggesting the influence of landscape soil amendments and root deposition from manicured St. Augustine grass.

4.4.4 Cation Exchange Capacity

Cation exchange capacity (CEC), or the variation known as total exchange capacity (TEC), is the sum total of exchangeable cations adsorbed or retained on negatively-charged sites in the soil, namely clay and humus. CEC is measured and reported as milliequivalents per 100 grams of soil or meq/100 g. Sandy soils have a lower CEC and clayey soils have increasingly higher CEC. Low CEC soils (because they lack clay and humus) have lower water and nutrient holding capacity and may require more frequent additions of fertilizers and amendments to maintain productive stands of vegetation.

CEC measurements from Wallace Laboratories ranged from 3.52 to 14.48 while those from Logan Labs ranged from 3.36 to 11.72. The most striking difference was the high CECs at the developed sites which further suggests intermixing of subsoil clays during construction. The native prairie and open space sites had low to very low CECs.

4.4.5 Carbon-to-Nitrogen (C:N) Ratio and Moisture Content

Table L4.5 summarizes data from Wallace Laboratories on the Carbon-to-Nitrogen (C:N) ratio and percent moisture content of soils in the Cypress Creek Overflow. The C:N ratio is an indicator of soil stability and maturity. *Soil Chemical and Physical Criteria for Reuse, Import, or Reclamation*, a guideline published by Wallace Labs, states the C:N ratio should be about 10. The higher than normal levels for C:N at the developed sites indicate disturbed urban soils. The moisture content of the open space sites illustrates the extremely dry condition of the Katy Prairie in early September 2012. The prairie sites, 2 miles away, had received rain in the week prior to sampling in late September 2012 and reflect a slightly higher soil moisture. Improved moisture-holding capacity in the prairie soils - a consequence of higher organic matter and higher microbial biomass - is another possible factor. The developed sites, due to higher clay content and moisture holding capacity, or perhaps irrigation and parking lot runoff, had substantially greater moisture content.

Table L4.5: C:N Ratio and Moisture Content [1]

Land Cover Type	C:N	Moisture %	Comments
Prairie			
Upper Tucker	11.0	7.2	Dry moisture
Lower Tucker	11.5	5.0	Dry moisture
Open Space			
Manor	11.0	1.1	Very dry moisture
Bing	11.2	3.3	Very dry moisture
Developed			
Residential	12.2	12.7	Higher moisture; higher C:N
Commercial	13.6	10.4	Higher moisture; higher C:N

[1] Wallace Laboratories data for 6 soil samples

4.4.6 Base Saturation and Soil Structure

The percentage of CEC occupied by the major cations (calcium, magnesium, potassium, sodium) is known as percent base saturation. The ideal cation ratios listed on the Logan Labs soil test - calcium 60-70%, magnesium 10-20%, potassium 2-5%, sodium 0.5-3% - aim for good soil structure and plant nutrition. There is flexibility in their usage, for example calcium saturations of 75% and 85% may be more appropriate for alkaline soils and Ca:Mg ratios may vary from 4:1 to 7:1. While not universally accepted in soil science, they help explain characteristics of soil structure and provide guidance for optimum fertility and are widely used by consulting agronomists.

The levels of calcium, magnesium, and sodium in soil affect soil aggregation. Calcium, a divalent cation (Ca^{++}), is strongly attracted to clay platelets which promotes flocculation or clumping together of clay particles into stable microstructures. Flocculation of clay particles (1—5 µm) proceeds, through microbial interaction, to formation of micro-aggregates (20—250 µm) and macro-aggregates (>250 µm). A well aggregated soil has adequate macro- and micro-pore spaces, it resists wind and water erosion, promotes seed germination and growth of plant roots, has good water infiltration and drainage capacity during wet periods and better water-holding capacity during dry periods, and provides habitat for soil foodweb organisms.

Conversely, soil structure is adversely affected by an overabundance of sodium (Na+). When soils become wet the strong hydration of Na^+ ions causes clay swelling. The increased distance between clay particles effectively decreases their attraction and deflocculation may occur, the clay particles disperse or disaggregate and go into solution and plug soil pores. The result is loss of soil structure and porosity, tight and compacted soils, restricted root growth, and poor water infiltration; conditions which promote water runoff and soil erosion.

Base saturation data from Wallace Laboratories and Logan Labs (Supplement L3) reflected a relatively normal range for slightly acidic to acidic soils; i.e., lower calcium and higher hydrogen percentages. No sodium imbalances or structural issues were indicated. The percentage of exchangeable calcium and hydrogen, as well as potassium and magnesium, are commonly used to make agronomic recommendations for limestone, gypsum, and fertilizer such as the attached Wallace Laboratories recommendations

4.4.7 Saturated Paste Extract (SPE)

The saturated paste extract was developed by the U.S. Salinity Laboratory in 1954 as a procedure to determine electrical conductivity (EC) and sodium adsorption ratio (SAR) of soil samples (USDA, 1954). It has since been adopted by a number of commercial soil labs as a water extractable test for pH, EC, SAR, and soluble nutrients.

Saturated paste data reported by Logan Labs includes pH, soluble salts (EC) in ppm, chloride, and bicarbonate in ppm, and anions, cations, and trace elements in ppm. Saturation extract data reported by Wallace Labs includes pH, EC in mmhos/com, SAR, plus anions and cations in ppm.

4.4.8 SPE: Soluble Salts and SAR

Soluble salts are measured with an EC meter and reported in mmhos/cm or in ppm by a multiplication factor of 640. The EC reading is an indicator of soluble salts in the soil solution, principally the cations sodium, calcium, and magnesium and the anions chloride and sulfate. Salts that occur in minor amounts include the cations potassium and ammonium and the anions bicarbonate, carbonate, and nitrate.

By definition, saline soils have an EC of 4 mmhos/com or greater (USDA, 1954). Saline soils usually occur in arid, western lands. In humid regions where leaching from rainfall prevents salinity buildup, saline soil conditions occur locally near marine environments. Conversely, low salinity (less than 0.5 mmhos/cm and especially below 0.2 mmhos/cm) - in soils or irrigation water - is corrosive and may leach minerals, especially calcium, thus influencing stable soil structure (FAO, 1985).

Tables L4.6 and L4.7 provide interpretive ranges for soluble salt levels such as tolerance level of crops and degree of salinity.

Table L4.6: Tolerance Level of Crops for Soluble Salts[1]

Conductivity mmhos/cm	Parts per million	Interpretation
0 – 1.5	0 – 960	Satisfactory for most turf grasses and crops
1.5 – 4	960 – 2,560	Affects sensitive turf grasses and crops
4 – 8	2,560 – 5,120	High for many turf grasses and crops
> 8	> 5,120	Very high for most turf grasses and crops
[1] Modified from *Soil Test Explanation*, Colorado State University		

Table L4.7: Relationship between Conductivity and Salinity Using Saturated Paste[1]

Degree of Salinity				
Non-Saline	Slightly Saline	Moderately Saline	Strongly Saline	Very Strongly Saline
mmhos/cm				
0.2 – 2.0	2.1 – 4.0	4.1 – 8.0	8.1 – 16.0	16 +
[1] Adapted from *Recommended Chemical Soil Test Procedures for the North Central Region*, NCR 221				

Table L4.8 summarizes data from Wallace Laboratories on the soluble salts and Sodium Adsorption Ratio of soils in the Cypress Creek Overflow. While some sites in the Lissie Formation have high SAR levels due to intermixing of subsoil clays during construction (e.g., flood detention basins and earthen embankments managed by HCFCD), topsoils in the Cypress Creek Overflow had very low to low SAR measurements. None of the sites had salinity or sodium-imbalance issues.

Table L4.8 – Soluble Salts (EC) and SAR [1]

Land Cover Type	**EC mmhos/cm**	**SAR**	**Comments**
Native Prairie			
Upper Tucker	0.20	0.5	Both very low
Lower Tucker	0.15	0.5	Both very low
Open Space			
Manor	0.15	0.7	Both very low
Bing	0.21	0.4	Both very low
Developed			
Westgate	0.41	1.2	Very low EC; Low SAR
Kroger	0.31	0.3	Both very low
[1] Wallace Laboratories data for 6 soil samples			

4.4.9 Water Infiltration Rate

Water infiltration rate is a measure of the permeability of soils, usually by rainfall but it likewise applies to irrigation water. Infiltration rate can be a holistic soil quality test in that it reflects the sum total effect of soil physical (soil structure and porosity), chemical (Ca:Mg ratio and SAR), and biological (soil foodweb structure and function) characteristics of a site. More specifically, infiltration rate is affected by soil texture, soil structure, soil organic matter, and surface features such as slope, vegetation, thatch, soil crusting, and roughness. Infiltration rate helps determine the ability of soils to receive rainfall without runoff and attendant erosion and flooding potential.

Soil Chemical and Physical Criteria for Reuse, Import, or Reclamation, a guideline published by Wallace Labs, states the permeability rate "shall be one inch per hour nor more than 20 inches per hour." Tables L4.9 and L4.10 summarize general infiltration rates for different soil textures and general ratings for water infiltration for interpretative comparison. Table L4.11 summarizes infiltration rate data in the Cypress Creek Overflow via laboratory bench methods, while Table L4.12 summarizes infiltration rate data via on-site field measurements.

Table L4.9: General Infiltration Rates for Different Soil Textures[1]

Soil Texture	Infiltration Rate/hr
Gravel and coarse sands	> 0.8 inches
Sandy loams	0.4 to 0.8
Loams	0.2 to 0.4
Silty clay loams & clay soils	< 0.2

[1] Adapted from Cornell University, *Northeast Region Certified Crop Advisor*

Table L4.10: General Ratings for Water Infiltration[1]

Water Infiltration Rate (in/hr)	Rating
Less than 0.2	Very Low
0.2 to 0.4	Low
0.4 to 0.75	Moderately Low
0.75 to 1.25	Moderate
1.25 to 1.75	Moderately High
1.75 to 2.5	High
More than 2.5	Very High

[1] Adapted from *Soil Survey of Colorado County, Texas* (2006)

Table L4.11: Infiltration Rates (in/hr) via Laboratory Bench Methods [1]

Land Cover Type	IR (in/hr)	Comments	Re-Test (in/hr)	Average IR per Land Cover Type (Re-Test)	Rating
Prairie					
Upper Tucker	5.39	Very High	-	4.37	Very High
Lower Tucker	3.35	Very High			
Open Space					
Manor	0.55	Moderately Low	-	1.01	Moderate
Bing	1.46	Moderately High			
Developed					
Westgate	6.60	Very High	-	3.46	Very High
Kroger	18.03*	Very High	0.29*		

[1] Wallace Laboratories data for 6 soil samples
*A re-test was issued due to an extraordinarily high value. However, the re-test produced a significantly dissimilar value from the first test, and a field trial was issued to obtain more reliant results (Table L4.12).

4.4.9.1 Laboratory Bench Method

Wallace Laboratories uses Method 34b - Hydraulic Conductivity of Disturbed Soils in the USDA Agriculture Handbook No. 60, *Diagnosis and Improvement of Saline and Alkali Soils*, to measure infiltration rate by the laboratory bench method. This method involves packing air-dried soil passing a 2mm screen into brass cylinders, followed by hydraulic conductivity measurements.

By comparing General Ratings for Water Infiltration in Table L4.10 to infiltration rates obtained by the laboratory bench method in Table L4.11, water infiltration in the Cypress Creek Overflow Study ranged from moderately low to very high (Column 2 in Table L4.11). The abnormally high rating for the Kroger sample (18.03 in/hr), was out of synch with the corresponding Westgate sample (6.60 in/hr) for developed sites. In addition, based on the appearance of clays in the Kroger soil cores - typical of disturbed urban soils in the Lissie Formation - this consultant presumed the developed sites would have a very low infiltration rate. Subsequently, a second soil sample was collected at the Kroger site in early January 2013 and sent to Wallace Laboratories for analysis. The re-test showed an infiltration rate of 0.29 inches/hour. The extreme differences in water infiltration results for the same site may be explained by differences in moisture content and clay swelling. Soils were very dry in September versus moist in January resulting in sample cores with moist, sticky clays. The average IR per land cover type (Re-Test) shows higher infiltration rates in the native prairie (4.37 in/hr), followed by developed (3.46 in/hr), and ppen space (1.01 in/hr).

4.4.9.2 Field Measurements

To obtain a dataset based on field measurements, the NRCS Single Ring Infiltrometer Test featured in the USDA Soil Health Test Kit was conducted in September 2013. In this method, a 6-inch aluminum pipe with beveled edges on the bottom is driven into the soil with a sledge hammer. A plastic sheet is tucked inside the pipe, then filled with 450 milliliters of water which is equivalent to one (1) inch of applied water. At the moment the plastic sheet is pulled away to allow water to enter the soil, beginning time is recorded. When 100% of the water is absorbed by the soil inside the single ring infiltrometer, end time is recorded. The minutes and seconds for infiltration time (IT) is converted to infiltration rate (IR), where IR = 1/IT x 60.

Two IR measurements were conducted back-to-back. The first IR measurement pre-wets the soil while the second IR measurement was recorded as the actual IR. In addition, three single ring infiltrometer measurements per site — taken within the 30’ x 30’ sample site located by GPS - were conducted to obtain an average IR per site.

The infiltration rates reported in Table L4.12, averaged from three plots per site, were calculated from average infiltration time (Column 2). Field measurements show an expected trend for infiltration rates per land cover type. The average IR per land cover type by the single ring infiltrometer method showed substantially higher infiltration rates in the native prairie (8.21 in/hr), followed by open space (1.98 in/hr), and developed (0.45 in/hr).

Supplement L4 contain the complete dataset and comparative calculations for single ring infiltrometer measurements in the Cypress Creek Overflow.

Table L4.12: Infiltration Rates (in/hr) via Field Measurements [1]

Land Cover Type	IR by Average Time (in/hr)	Rating	Average IR per Land Cover Type (in/hr)	Rating
Prairie				
Upper Tucker	2.69	Very High	8.21	Very High
Lower Tucker	13.73	Very High		
Open Space				
Manor	2.26	High	1.98	Moderately High
Bing	1.69	Moderately High		
Developed				
Westgate	0.50	Moderately Low	0.45	Moderately Low
Kroger	0.40	Low		
[1] NRCS Single Ring Infiltrometer Method				

Exhibit L4.2: Soil Infiltration Rate Field Measurements using a Single Ring Infiltrometer

4.4.10 Soil Penetrometer Measurements

A soil penetrometer was used to measure the extent of soil compaction at each site. A measurement of 300 psi is generally accepted as the value at which plant root growth becomes inhibited in soil.

Table L4.13: Depth of Root Growth Inhibiting Value in Soil (300psi)

Land Cover Type	Averaged Depth to 300 psi
Native Prairie	22.2 in.
Open Space	4.7 in.
Developed	1.5 in.

4.4.11 Elemental Concentration of Heavy Metals

Levels of heavy metals are summarized Table L4.13. Results from Wallace Laboratories demonstrate there are no heavy metal contamination issues at the project sites.

Table L4.14: Levels of Heavy Metals [1]

Element	**Level Found (ppm)** [2]						**MPC (ppm)** [3]	**pH < 6.0 (75%)** [4] **(ppm)**
	Upper Tucker	**Lower Tucker**	**Manor**	**Bing**	**Westgate**	**Kroger**		
Arsenic	0.24	0.13	0.21	0.16	0.28	0.24	1	0.25
Barium	4.09	4.00	1.75	2.62	1.41	3.14	NA	
Cadmium	0.03	0.04	0.01	0.02	n.d.	0.01	1	0.25
Chromium	0.07	0.06	0.14	0.02	n.d.	n.d.	10	2.5
Cobalt	0.03	0.04	0.04	0.03	0.06	0.04	2	0.50
Lead	2.17	2.07	2.30	1.67	1.44	1.11	30	7.5
Lithium	0.17	0.20	0.10	0.23	0.25	0.27	NA	
Mercury	n.d. [5]	n.d.	n.d.	n.d.	n.d.	n.d.	1	
Nickel	0.42	0.41	0.13	0.19	0.46	0.39	5	2.15
Selenium	0.06	n.d.	0.10	n.d.	n.d.	n.d.	3	0.75
Silver	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	
Strontium	1.12	1.05	0.80	1.00	1.01	0.88	NA	
Tin	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	NA	
Vanadium	0.30	0.31	1.18	0.45	0.19	0.20	1	0.75

[1] Wallace Laboratories data for heavy metals
[2] Ammonium Bicarbonate/DTPA Extraction
[3] Criteria for Maximum Permissible Concentration (MPC) established by Wallace Laboratories
[4] MPC adjusted for greater availability of trace elements/ heavy metals with increasing acidity
[5] No detect

4.4.12 Elemental Concentration of Desired Nutrients

Logan Labs data for levels of desired nutrients (plant essential elements) in the Cypress Creek Overflow Study sites are summarized in Table L4.14. The Desired Levels column provides an interpretive guideline for low, medium, and high levels geared to crop production. Restored prairies may not require these optimum levels, however specific nutrients (N, P, K, S, B, Cu, Zn), limestone and gypsum may be needed on a site by site basis; the attached Wallace Laboratories amendment recommendations, for example, reflect one such approach.

Table L4.15: Levels of Desired Nutrients [1]

Soil Test Data	Upper Tucker	Lower Tucker	Manor	Bing	Westgate	Kroger	Desired Levels [2]
TEC	4.39	3.59	7.48	3.36	11.72	9.89	
Soil pH	6.2	6.1	6.6	6.5	6.0	7.1	6.4-6.8
Organic Matter %	2.02	1.49	0.93	0.93	3.63	2.03	3-5%
Anions							
Sulfur (S as ppm)	8	6	9	7	10	10	50-150
Phosphorus (P205lbs/ac)	37	53	98	88	56	37	>250
Exchangeable Cations	**(lbs/ac)**						
Calcium (Ca)	1032	861	2082	786	2990	3079	
Magnesium (Mg)	215	154	271	164	352	376	
Potassium (K)	74	72	205	179	212	113	
Sodium (Na)	30	14	37	29	54	26	
% Base Saturation							
Calcium (60-70%)	58.8	60.0	69.5	58.5	63.78	77.82	60-85%
Magnesium (10-20%)	20.4	17.9	15.1	20.3	12.5	15.8	8-20%
Potassium (2-5%)	2.16	2.57	3.51	6.83	2.32	1.46	3-7%
Sodium (0.5-3%)	1.49	0.86	1.06	1.90	0.99	0.58	0.5-2.5%
Other Bases (Variable)	5.20	5.20	4.80	4.90	5.40	4.30	
Hydrogen (10-15%)	12.00	13.50	6.00	7.50	15.00	0.00	
Trace Elements (ppm)							
Boron (B)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	1-3
Iron (Fe)	222	160	245	317	168	114	100-200
Manganese (Mn)	62	101	41	29	49	38	30-50
Copper (Cu)	0.6	0.63	1.64	0.6	1.19	0.57	4-10
Zinc (Zn)	0.67	0.75	1.85	0.53	1.48	0.91	8-20
Aluminum (Al)	347	351	319	246	303	315	<500
Nitrogen (ppm)							
Ammonium (NH4-N)	4.3	0.3	10.7	10.9	10.5	1.2	20
Nitrate (NO3-N)	1.7	2.7	15.7	9.8	5.4	4.9	20

[1] Logan Labs data for 6 soil samples
[2] Desired Levels provided as an interpretive guideline for Low, Medium, High

4.4.13 Soil Foodweb Assessment

Soil biota — the most diverse and complex assemblage of organisms on earth — is comprised of micro-flora, micro-fauna, meso-fauna, and macro-fauna. A community of soil organisms (and their competition, mutualism, and predator-prey interactions) is known as a soil foodweb.

A healthy soil foodweb performs multiple ecosystem functions and positively influences soil structure; nutrient retention; nutrient cycling; suppression of disease and insect pests; colonization of leaf and root surfaces on plants; production of plant-growth promoting substances; and decomposition of toxic compounds. Measurements of soil foodweb diversity and density can therefore be used as an indicator of the biological soil fertility and resiliency of a landscape.

Soil foodweb assessments, determined by Soil Foodweb New York (SFW-NY), were obtained for each of the six samples. Soil samples were collected next to grasses and forbs to include living roots in order to assess percent mycorrhizal colonization.

Total fungi and total bacteria measure the total microbial biomass (µg/g) while active fungi and active bacteria measure how much of these microbial pools are actively metabolizing. Assessment methods used by SFI do not distinguish which genera of fungi and bacteria are present, but it can be assumed greater microbial biomass represents increasing microbial diversity.

The Fungal-to-Bacterial Ratio (F:B) is an indicator of plant succession which is the change in species structure of a landscape over time, from pioneer species to climax vegetation. Invasive weeds are strongly bacterial dominated, improved pasture and turf grasses are slightly bacterial-dominated, and native grasses and trees are increasingly fungal dominated. Table L4.15 illustrates this principle by summarizing typical F:B for early- to late-successional plants (where F:B is the weight of fungal biomass in proportion to weight of bacterial biomass). Table L4.16 summarizes the soil foodweb assessment of three land cover types in the Cypress Creek Overflow.

Table L4.16: Typical Fungal-to-Bacterial Ratios (F:B) for Plant Types [1]

Plant Type	**F:B** (µg/g)
Pioneer Weeds	0.1 to 0.3 : 1
Early Grasses (KR Bluestem, Bahia Grass)	0.3 to 0.6 : 1
Later Grasses & Turf (Bermuda, St. Augustine)	0.75 to 0.85 : 1
Row Crops	0.95 to 1.2 : 1
Shrubs, Vines, Native Grasses & Forbs	4 to 10 : 1
Trees	10 to 100 : 1

[1] Adapted and modified from Soil Foodweb, Inc.

The Hyphal Diameter (µm) is an indicator of fungal group. Wider diameters indicate increasingly evolved and beneficial types of fungi. Hyphal diameters of 2.0 µm indicate mostly actinomycete hyphae, 2.5 µm indicate mostly ascomycetes, and 3.0 µm or higher indicate the presence of basidiomycetes fungal community which are known for their ability to improve soil structure.

Mycorrhizal colonization is a measure of the percentage of roots with associated endomycorrhizal or ectomycorrhizal fungi. Endomycorrhizal fungi (ca 130 species) develop symbiotic associations with approximately 90% of all vascular plants including grasses, forbs, shrubs, and trees. The ectomycorrhizal fungi (ca 5,000 species) are much more specific and will only associate with roughly two dozen genera of trees including pecan, oak, and pine. The endomycorrhizae - also known as vesicular arbuscular mycorrhizae (VAM) or simply arbuscular mycorrhizae (AM fungi) - help plants acquire water and nutrients, but just as important, AM fungi secrete a sticky glycoprotein known as glomalin which promotes soil structure and builds organic matter.

Table L4.17: Soil Foodweb Assessment [1]

Microbial Biomass (µg/g)	Upper Tucker	Lower Tucker	Manor	Bing	Westgate[2]	Kroger[2]	Comments
Total Fungi	1044	1107	462	846	659	267	Excellent; Kroger was Good
Total Bacteria	207	241	485	776	771	847	Excellent; Prairies were Good
Active Fungi	37.5	18.1	7.61	21.4	27.5	16.6	Westgate & Prairies Excellent
Active Bacteria	33.2	24.1	5.71	8.26	18.0	23.5	Prairies Excellent
F:B	5.05	4.58	0.95	1.09	0.85	0.32	Model example of succession
Fungal Indicators							
Hyphal Diameter (µm)	3.25	3	3	3.25	2.5	2.5	Model example of hyphal diameter
Endo Mycorrhizal Colonization	8%	12%	12%	7%	28%	17%	Highest was Westgate St. Augustine grass
Protozoa (Number/g)							
Flagellates	2316	1456	140	592	510	154	Higher in Prairies
Amoebae	9001	4482	2169	4763	3320	2379	Higher in Prairies
Ciliates	15	60	0	143	0	0	Low numbers are better
Nematode Indicators							
Nematode (Number/g)	5.26	5.45	2.61	3.93	5.17	2.38	Higher in Prairies
Nematode Type	B,F, F-R, R	B,F,F-R, R	B, F, F-R, R	B,F,R	B,F,P,R	B,F,F-R, P, R	
Plant Available N (lbs/ac)	50-75	50-75	<25	50-75	<25	<25	Higher in Prairies

[1] Soil Foodweb New York data for 6 soil samples
[2] Westgate is the Residential site, Kroger is the Commercial site

Protozoas and Nematodes, expressed in number/gram, are known as bacterial and fungal grazers because they feed on microflora. Ammonia, a byproduct of microfaunal grazing, is released into the rhizosphere where it becomes available for immediate plant uptake or transformation to nitrate-N. The relationship between microbial biomass and microfaunal numbers (the protozoas and nematodes) is reported as plant available nitrogen in lbs/acre on the SFW-NY soil test. In addition, nematodes are identified by feeding group which includes bacterial and fungal feeders, the switchers known as fungal/root, and plant parasitic types known as root feeders.

The soil foodweb assessment highlights the influence of land cover type and land use history on soil biological properties in the Cypress Creek Overflow. Greater soil microbial numbers are equated to greater ecosystem functioning and favorable soil properties such as nutrient retention and nutrient cycling, carbon sequestration, soil moisture-holding capacity, soil structure and porosity, and water infiltration. The Upper Tucker remnant prairie - a diverse mixture of native grasses, forbs, and occasional trees - had the greatest number of favorable soil biological properties (total fungal biomass, active fungi, active bacteria, fungal-to-bacterial ratio, flagellate and amoeba protozoas, nematode numbers). The Lower Tucker prairie site had the second most favorable biology indicators. The Westgate site, with landscape quality St. Augustine turf grass, had the highest percent of mycorrhizal colonization. Conversely, the Kroger site had the lowest numbers for total fungal biomass, fungal-to-bacterial ratio, and nematode numbers.

Data for fungal:bacterial in the Cypress Creek Overflow (Table L4.16), when correlated with expected fungal:bacterial ratio for plant type (Table L4.15), illustrates a model example of soil foodweb succession in concert with plant succession, (Table L4.17). Similarly, the developed sites had smaller fungal hyphal diameters while the open space and native prairie sites had greater hyphal diameters, a further indication of fungal succession.

Table L4.18: Fungal-to-Bacterial Ratios of Land Cover Types [1]

Plant Type	F:B (µg/g)	Cypress Creek Overflow (F:B)	
Pioneer Weeds	0.1 to 0.3 : 1		
Early Grasses (KR Bluestem, Bahia Grass)	0.3 to 0.6 : 1	Kroger	0.31 : 1
Turf Grasses (Bermuda, St. Augustine)	0.75 to 0.85 : 1	Westgate	0.85 : 1
Row Crops	0.95 to 1.2 : 1	Manor & Bing	0.95 to 1.09 : 1
Shrubs, Vines, Native Grasses & Forbs	4 to 10 : 1	Native Prairies	4.58 to 5.05 : 1
Trees	10 to 100 : 1		

[1] Correlation of data between Tables L4.14 and L4.15

While Ingham *et al*. (1989) concluded grasslands are bacterial-dominated, their early soil foodweb assessments were based on shortgrass prairies in eastern Colorado. This consultant, based on soil foodweb assessments of remnant prairies in Erath County, Texas, presented data on fungal-dominated tallgrass prairies (F:B of 7.2) at the Texas Society for Ecological Restoration in 2008 (Diver, 2008). Bailey et al (2002), in a study of tallgrass prairie and agricultural soils at the Fermi National Laboratory in Batavia, Illinois, found restored prairies had a F:B ratio of 13.5 compared to a neighboring corn field with a F:B ratio of 0.85. While Allison et al (2005) obtained conflicting results on fungal:bacterial ratios in further studies of restored prairies and agricultural fields at the Fermi National Laboratory, they agreed soil fungi contribute to carbon sequestration through their role in improved soil structure and inputs of recalcitrant compounds.

Two studies from Texas examined the influence of land cover type and land use management on soil biology parameters. Using molecular profiling, Dr. Phil Lyons at University of Houston-Downtown found greater fungal diversity, including ascomycetes and basidomycetes, in native coastal prairie soils compared to farmed coastal soils near Houston, Texas (Lyons, undated). Teague et al (2011), in a study of grazing management impacts on vegetation and soil properties, found a significantly greater fungal:bacterial ratio under multi-paddock grazing systems compared to continuous grazing systems. They further concluded the improved fungal:bacterial ratio indicated superior water-holding capacity and nutrient availability and retention.

These findings are especially relevant in context of the Cypress Creek Overflow Study because they support the concept that soil foodweb succession mirrors an above-ground plant succession. Using this knowledge, land managers can (through reverse ecological engineering) employ soil inputs in prairie restoration efforts in the Creek Overflow study area - including bio-augmentation and bio-stimulation amendments, composts, mycorrhizal fungi, and native soil inocula - that favor fungal-dominated natives grasses and forbs while pushing back against lower-successional invasive pasture grasses; in other words, plant succession can be driven by application of organic and biological soil amendments through their influence on soil foodweb succession.

5.0 Summary and Conclusions

- Characteristics of the Katy Prairie - including diverse vegetation, ecosystem services of prairies and rice fields, and claypan Alfisols - were summarized to provide context to the Cypress Creek Overflow study area.

- Three land cover types in the Cypress Creek Overflow were identified from LiDAR maps and ground surveys: native prairie (Upper Tucker, Lower Tucker), open space (Manor, Bing), and developed (Westgate, Kroger)

- Soil samples were collected from two representative sites for each of three land cover types in the Cypress Creek Overflow. The physical/chemical sample set was split and sent to Wallace Laboratories (California) and Logan Labs (Ohio). Separate samples were collected for soil biology assessment and sent to Soil Foodweb–New York.

- Surface soils on the project sites and surrounding land were coastal prairie Alfisols which commonly feature impermeable subsoil clays and intermittent hydric conditions.

- Katy Fine Sandy Loam, Hockley Fine Sandy Loam, Monaville Loamy Fine Sand, Waller Loam (Depressional), and Wockley Fine Sandy Loam were soil types found at sampling sites and adjoining land.

- Soils on the open space and native prairie land cover types may be characterized as fine sandy loams and loamy sands having an acidic pH, low organic matter content, low CEC, and stable C:N.

- Soils on the developed land cover types may be characterized as fine sandy loam and sandy clay loam with intermixed subsoil clays having an acidic to alkaline pH, medium to high organic matter, medium to high CEC, and higher C:N compared to the other land cover types.

- Soil chemical properties (base saturation, salinity, SAR) that would indicate potential soil structural problems (tight soils, dispersed clays, impermeability) were normal.

- Infiltration rates (IR), measured as water infiltration rate in inches/hour (in/hr), were conducted by the laboratory bench method and by field measurements using the NRCS single ring infiltrometer test.

- Laboratory bench method: Due to an abnormally high (18.03 in/hr) and out of sync lab result for the Kroger site, a second soil sample was collected and sent to Wallace Laboratories. The re-test showed a low (0.29 in/hr) reading, just the opposite. One plausible explanation for this variation was very dry versus wet soil conditions at the time of sampling and thereby the influence of clay swelling.

- Field measurements: The average IR per land cover type using the single ring infiltrometer test showed substantially higher infiltration rates in the native prairie (8.21 in/hr) compared to open space (1.98 in/hr) and developed (0.45 in/hr).

- Historic and recent land use management has increased the extent of soil compaction at the open space and developed land cover types. Native prairie soils are still loose with over 2ft depth before roots begin to become inhibited. This may have an effect on vegetation composition and water infiltration.

- Heavy metals were below threshold guidelines.

- Desired nutrient levels were summarized from Logan Labs data. Some plant essential elements were low to extremely low (sulfur, boron, copper, zinc) while others were in a moderate range. Based on recommendations per site, application of organic and mineral fertilizers, secondary and trace elements, agricultural limestone and gypsum can remedy any nutrient deficiencies and promote plant growth.

- Soil foodweb organisms were assessed by the Soil Foodweb New York laboratory. The Prairie sites had the greatest number of favorable soil biological properties (total fungal biomass, active fungi, active bacteria, fungal-to-bacterial ratio, flagellate and amoeba protozoas, nematodes). The Westgate site had the highest percent mycorrhizal colonization. The Kroger site had the lowest numbers for total fungal biomass, fungal-to-bacterial ratio, and nematodes.

- Greater soil microbial numbers are equated to greater ecosystem functioning and favorable soil properties such as nutrient retention and nutrient cycling, carbon sequestration, soil moisture-holding capacity, soil structure and porosity, and water infiltration.

- The correlation of SFW-NY data for fungal:bacterial in the Cypress Creek Overflow with expected fungal:bacterial for plant type illustrated a model example of soil foodweb succession in concert with plant succession. The Kroger site (F:B of .33) represented lower-successional grasses and weeds, the open space sites represented a cropland succession (F:B of .95 to 1.09), and the native prairie sites represented a fungal-dominated prairie succession (F:B of 4.58 to 5.05).

- The soil fertility and biology data in this soil assessment will enable land managers to formulate appropriate soil amendments in efforts to establish restored prairies and manage pastures and tree crops in the Cypress Creek Overflow study area.

- Fertilizers, secondary and trace elements, agricultural limestone and gypsum can be used to enhance the fertility of soils, correct pH and nutrient deficiencies, and promote plant growth.

- Using the soil foodweb data, land managers can tailor organic and biological soil amendments for prairie restoration - including bio-augmentation and bio-stimulation products, composts, mycorrhizal fungi, and native soil inocula - that favor fungal-dominated natives grasses and forbs while pushing back against lower-successional invasive pasture grasses.

- The agronomic assessment of the Cypress Creek Overflow - in particular water infiltration rates and favorable soil foodweb properties - support the premise of the study; that is, prairie restoration can provide important ecosystem services and mitigate downstream flooding by virtue of improved soil quality parameters.

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Supplement 1.0
Site Photographs

Vegetation at Upper Tucker Site	Vegetation at Lower Tucker Site
	
	
	

Vegetation at Manor Site	Vegetation at Bing Site
	
	
	

Vegetation at Westgate Site	Vegetation at Kroger Site
	
	
	

Soil Image: Prairie – Upper Tucker

Soil Image: Prairie – Upper Tucker

Soil Image: Prairie – Lower Tucker

Soil Image: Prairie – Lower Tucker (closeup)

Soil Image: Open Space – Manor

Soil Image: Open Space – Manor (closeup)

Soil Image: Open Space – Bing

Soil Image: Open Space – Bing (closeup)

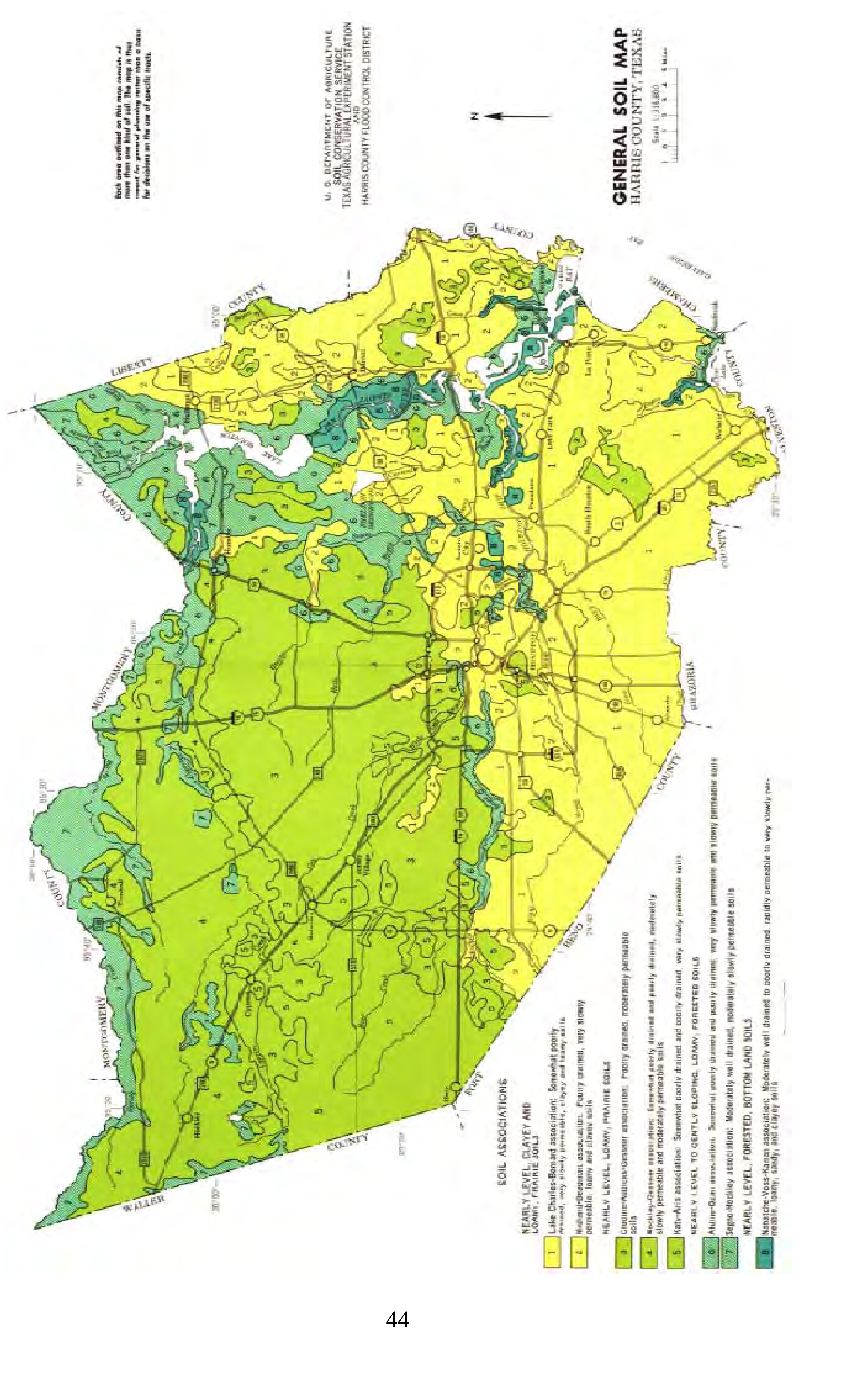
Soil Image: Developed – Westgate

Soil Image: Developed – Westgate (closeup)

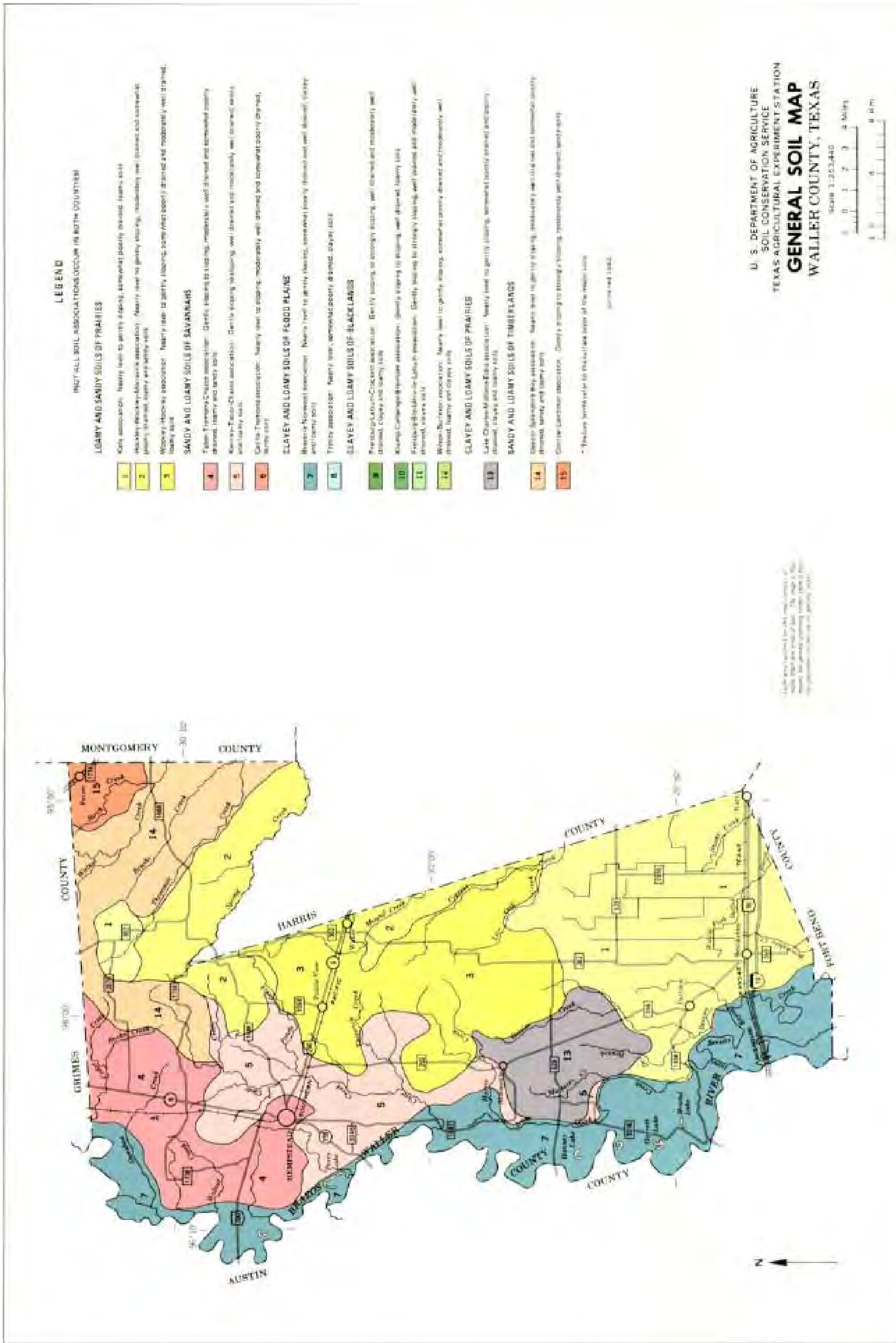
Soil Image: Developed – Kroger

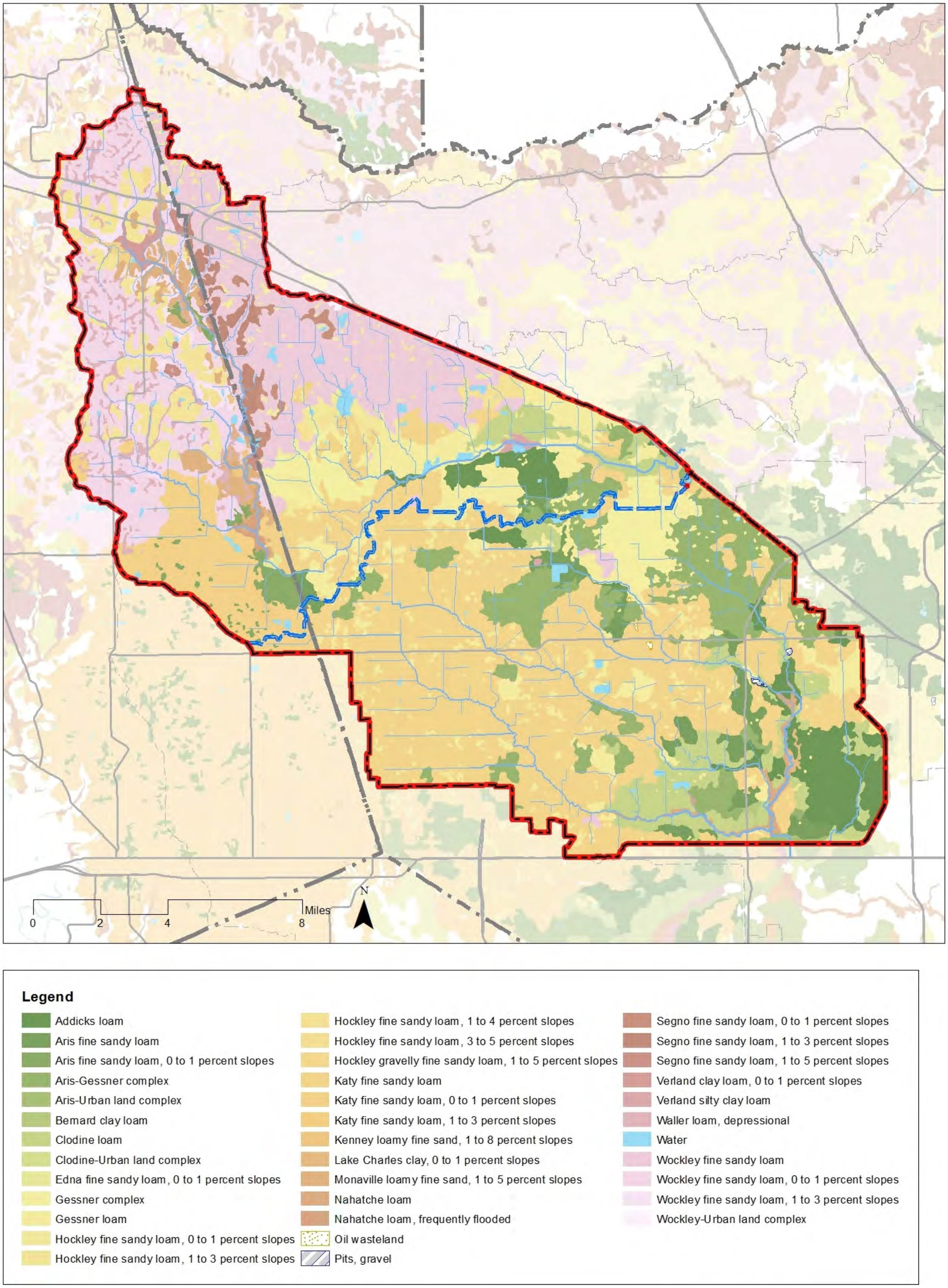
Soil Image: Developed – Kroger (closeup)

Supplement 2.0
Soil Maps for Harris and Waller Counties, Texas



GENERAL SOIL MAP
HARRIS COUNTY, TEXAS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEXAS AGRICULTURAL EXPERIMENT STATION
AND
HARRIS COUNTY FLOOD CONTROL DISTRICT
N
SOIL ASSOCIATIONS
NEARLY LEVEL, CLAYEY AND LOAMY, PRAIRIE SOILS
1 Lake Charles-Bernard association: Somewhat poorly
2 permeable, loamy and clayey soils
NEARLY LEVEL, LOAMY, PRAIRIE SOILS
3 Poorly drained, moderately permeable soils
4 Hockley-Gessner association: slowly permeable and moderately permeable soils
5 Katy-Aris association: Somewhat poorly drained and poorly drained, very slowly permeable soils
NEARLY LEVEL TO GENTLY SLOPING, LOAMY, FORESTED SOILS
6
7 Segno-Hockley association: Moderately well drained, moderately slowly permeable soils
NEARLY LEVEL, FORESTED, BOTTOM LAND SOILS
8 Nahatche-Voss-Kanan association: Moderately well drained to poorly drained, rapidly permeable to very slowly permeable, loamy, sandy, and clayey soils
WALLER
MONTGOMERY
COUNTY
LIBERTY
CHAMBERS
BRAZORIA
FORT
BEND
HOUSTON
Hockley
Cypress
Humble
Pasadena
La Porte
Webster


LEGEND
LOAMY AND SANDY SOILS OF PRAIRIES
SANDY AND LOAMY SOILS OF SAVANNAHS
CLAYEY AND LOAMY SOILS OF FLOOD PLAINS
CLAYEY AND LOAMY SOILS OF BLACKLANDS
CLAYEY AND LOAMY SOILS OF PRAIRIES
SANDY AND LOAMY SOILS OF TIMBERLANDS
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEXAS AGRICULTURAL EXPERIMENT STATION
GENERAL SOIL MAP
WALLER COUNTY, TEXAS
MONTGOMERY COUNTY
GRIMES COUNTY
HARRIS COUNTY
AUSTIN COUNTY
FORT BEND COUNTY
WALLER
HEMPSTEAD
BRAZOS RIVER
N


N
0
2
4
8
Miles
Legend
Addicks loam
Aris fine sandy loam
Aris fine sandy loam, 0 to 1 percent slopes
Aris-Gessner complex
Aris-Urban land complex
Bernard clay loam
Clodine loam
Clodine-Urban land complex
Edna fine sandy loam, 0 to 1 percent slopes
Gessner complex
Gessner loam
Hockley fine sandy loam, 0 to 1 percent slopes
Hockley fine sandy loam, 1 to 3 percent slopes
Hockley fine sandy loam, 1 to 4 percent slopes
Hockley fine sandy loam, 3 to 5 percent slopes
Hockley gravelly fine sandy loam, 1 to 5 percent slopes
Katy fine sandy loam
Katy fine sandy loam, 0 to 1 percent slopes
Katy fine sandy loam, 1 to 3 percent slopes
Kenney loamy fine sand, 1 to 8 percent slopes
Lake Charles clay, 0 to 1 percent slopes
Monaville loamy fine sand, 1 to 5 percent slopes
Nahatche loam
Nahatche loam, frequently flooded
Oil wasteland
Pits, gravel
Segno fine sandy loam, 0 to 1 percent slopes
Segno fine sandy loam, 1 to 3 percent slopes
Segno fine sandy loam, 1 to 5 percent slopes
Verland clay loam, 0 to 1 percent slopes
Verland silty clay loam
Waller loam, depressional
Water
Wockley fine sandy loam
Wockley fine sandy loam, 0 to 1 percent slopes
Wockley fine sandy loam, 1 to 3 percent slopes
Wockley-Urban land complex

Supplement 3.0
Soil Laboratory Reports

Soil Report

Job Name **HCFCD** Date 10/9/2012

Company Agri-Horticultural Consulting Submitted By Steve Diver

			Manor	Bing	Residential	Commercia	Upper
Sample Location			Manor	Bing	Residential	Commercia	Upper
Sample ID							Tucker
Lab Number			16	17	18	19	20
Sample Depth in inches			6	6	6	6	6
Total Exchange Capacity (M. E.)			7.48	3.36	11.72	9.89	4.39
pH of Soil Sample			6.60	6.50	6.00	7.10	6.20
Organic Matter, Percent			0.93	0.93	3.63	2.03	2.02
ANIONS	**SULFUR:**	p.p.m.	9	7	10	10	8
ANIONS	**Mehlich III Phosphorous:**	as (P_2O_5) lbs / acre	98	88	56	37	37
EXCHANGEABLE CATIONS	**CALCIUM:** lbs / acre	Desired Value	2035	914	3187	2690	1194
		Value Found	2082	786	2990	3079	1032
		Deficit		-128	-197		-162
	MAGNESIUM: lbs / acre	Desired Value	215	200	337	284	200
		Value Found	271	164	352	376	215
		Deficit		-36			
	POTASSIUM: lbs / acre	Desired Value	233	200	365	308	200
		Value Found	205	179	212	113	74
		Deficit	-28	-21	-153	-195	-126
	SODIUM:	lbs / acre	37	29	54	26	30
BASE SATURATION %	Calcium (60 to 70%)		69.54	58.47	63.78	77.82	58.75
	Magnesium (10 to 20%)		15.09	20.33	12.51	15.84	20.40
	Potassium (2 to 5%)		3.51	6.83	2.32	1.46	2.16
	Sodium (.5 to 3%)		1.06	1.90	0.99	0.58	1.49
	Other Bases (Variable)		4.80	4.90	5.40	4.30	5.20
	Exchangable Hydrogen (10 to 15%)		6.00	7.50	15.00	0.00	12.00
TRACE ELEMENTS	Boron (p.p.m.)		< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
	Iron (p.p.m.)		245	317	168	114	222
	Manganese (p.p.m.)		41	29	49	38	62
	Copper (p.p.m.)		1.64	0.6	1.19	0.57	0.6
	Zinc (p.p.m.)		1.85	0.53	1.48	0.91	0.67
	Aluminum (p.p.m.)		319	246	303	315	347
OTHER	NH4-N (p.p.m.)		10.7	10.9	10.5	1.2	4.3
	N03-N (p.p.m.)		15.7	9.8	5.4	4.9	1.7

Logan Labs, LLC

Soil Report

Job Name HCFCD | Date 10/9/2012

Company Agri-Horticultural Consulting | Submitted By Steve Diver

Sample Location			Lower				
Sample ID			Tucker				
Lab Number			21				
Sample Depth in inches			6				
Total Exchange Capacity (M. E.)			3.59				
pH of Soil Sample			6.10				
Organic Matter, Percent			1.49				
ANIONS	SULFUR:	p.p.m.	6				
	Mehlich III Phosphorous:	as (P_2O_5) lbs / acre	53				
EXCHANGEABLE CATIONS	CALCIUM: lbs / acre	Desired Value	975				
		Value Found	861				
		Deficit	-114				
	MAGNESIUM: lbs / acre	Desired Value	200				
		Value Found	154				
		Deficit	-46				
	POTASSIUM: lbs / acre	Desired Value	200				
		Value Found	72				
		Deficit	-128				
	SODIUM:	lbs / acre	14				
BASE SATURATION %	Calcium (60 to 70%)		60.00				
	Magnesium (10 to 20%)		17.89				
	Potassium (2 to 5%)		2.57				
	Sodium (.5 to 3%)		0.86				
	Other Bases (Variable)		5.20				
	Exchangable Hydrogen (10 to 15%)		13.50				
TRACE ELEMENTS	Boron (p.p.m.)		< 0.2				
	Iron (p.p.m.)		160				
	Manganese (p.p.m.)		101				
	Copper (p.p.m.)		0.63				
	Zinc (p.p.m.)		0.75				
	Aluminum (p.p.m.)		351				
OTHER	NH4-N (p.p.m.)		0.3				
	N03-N (p.p.m.)		2.7				

Logan Labs, LLC

Saturated Paste Report

Job Name **HCFCD** Date 10/9/2012

Company Agri-Horticultural Consulting Submitted By Steve Diver

			Manor	Bing	Residential	Commercia	Upper
Sample Location			Manor	Bing	Residential	Commercia	Upper
Sample ID							Tucker
Lab Number			52757	52758	52759	52760	52761
Water Used			DI	DI	DI	DI	DI
pH			6.6	6.5	6	7.1	6.2
Soluble Salts		ppm	18	31	54	112	28
Chloride (Cl)		ppm	8	9	8	8	9
Bicarbonate (HCO3)		ppm	102	81	41	34	34
ANIONS	**SULFUR**	ppm	1.5	4.12	4.78	2.59	3.18
	PHOSPHORUS	ppm	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
SOLUBLE CATIONS	**CALCIUM**	ppm	2.36	3.17	8.2	25.77	3.15
		meq/l	0.12	0.16	0.41	1.29	0.16
	MAGNESIUM	ppm	0.62	1.09	1.74	3.5	1.34
		meq/l	0.05	0.09	0.14	0.29	0.11
	POTASSIUM:	ppm	2.28	3.74	4.57	3.58	1.91
		meq/l	0.06	0.10	0.12	0.09	0.05
	SODIUM	ppm	1.22	3.18	4.06	1.94	2.69
		meq/l	0.05	0.14	0.18	0.08	0.12
PERCENT	Calcium		41.79	32.70	48.22	73.31	36.12
	Magnesium		18.39	18.79	17.04	16.60	25.68
	Potassium		21.03	20.02	13.96	5.28	11.37
	Sodium		18.79	28.49	20.78	4.80	26.83
TRACE ELEMENTS	Boron (p.p.m.)		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	Iron (p.p.m.)		1.74	2.49	2.4	1.02	1.23
	Manganese (p.p.m.)		0.05	0.03	0.05	< 0.02	0.04
	Copper (p.p.m.)		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
	Zinc (p.p.m.)		0.04	< 0.02	0.03	< 0.02	0.02
	Aluminum (p.p.m.)		3.57	5.95	5.84	2.33	4.52
OTHER							

Logan Labs, LLC

Saturated Paste Report

Job Name HCFCD — Date 10/9/2012

Company Agri-Horticultural Consulting — Submitted By Steve Diver

Sample Location			Lower				
Sample ID			Tucker				
Lab Number			52762				
Water Used			DI				
pH			6.1				
Soluble Salts		ppm	24				
Chloride (Cl)		ppm	6				
Bicarbonate (HCO3)		ppm	41				
ANIONS	**SULFUR**	ppm	2.02				
	PHOSPHORUS	ppm	< 0.03				
SOLUBLE CATIONS	**CALCIUM**	ppm	3.56				
		meq/l	0.18				
	MAGNESIUM	ppm	1.03				
		meq/l	0.09				
	POTASSIUM:	ppm	1.56				
		meq/l	0.04				
	SODIUM	ppm	1.72				
		meq/l	0.07				
PERCENT	Calcium		46.89				
	Magnesium		22.71				
	Potassium		10.71				
	Sodium		19.68				
TRACE ELEMENTS	Boron (p.p.m.)		< 0.02				
	Iron (p.p.m.)		1.05				
	Manganese (p.p.m.)		0.09				
	Copper (p.p.m.)		< 0.02				
	Zinc (p.p.m.)		0.03				
	Aluminum (p.p.m.)		3.47				
OTHER							

Logan Labs, LLC

How to Read Your Soil Test Results

by Joel Simmons
The Soil Probe, Winter-Spring 2004
Logan Labs Newsletter

A Biological Soil Management program provides the optimum soil environment to allow for the proliferation of beneficial microbes. These microbes are the "life of the soil", and are responsible for the breakdown of organic matter into useable humus. Humus helps to feed needed microbes, creating soil buffers, allowing for nutrient mobility, and most importantly, creating "checks and balances" for antagonistic pathogens. Providing foodstuffs to soil microbes is important, but the first step to allow for their growth is to balance soil chemistry. This is best done with the help of a true base saturation soil test, such as the standard soil test provided by Logan Labs.

Dr. William Albrecht did much of the research on the base saturation methodology. Dr. Albrecht was a Head of Agronomy at the University of Missouri and founder of Brookside Labs. Dr. Albrecht taught the following: until the chemistry is in balance, the soil cannot provide the environment for an adequate population of beneficial soil microbes. For example, if the Ca:Mg ratio is not 7:1, equaling 80% base saturation, the movement of air and water into the soil will significantly be restricted. This imbalance will limit the growth of needed microbes. Feeding the soil is very important but this process can be significantly limited by poor soil chemistry, thus the motto – "Balance the Chemistry – Feed the Soil."

Logan Labs offers a host of important soil tests. The "Standard Soil Test" is the basic soil colloid test, which describes the chemical "savings account." The lab also runs a Paste Extract Test, which is a water-soluble soil test that shows what nutrients may be soluble in the soil, or the chemical "checking account." These two tests together provide comprehensive information as to the overall health of the soil, and can be significant tools in balancing the soil. When comparing the two side by side, it is easy to see how nutrient mobility is affected by the health of the soil.

TOTAL EXCHANGE CAPACITY (TEC) – The holding capacity of the soil. This test provides TEC, not just cation exchange capacity (CEC), and may be higher than other labs that provide only CEC.

The TEC represents the ability of the soil to hold nutrients (positively charged cations) on colloidal site. Colloidal sites are plate-like structures made up of mostly clay and organic matter, although there are other elements that can increase TEC. In soils, such as sands, where clay and organic matter are low, the TEC is low and fewer nutrients will be available. In heavy soil the TEC will be greater as will be the pounds per acre (value found) of most nutrients.

pH – Measures the acidity or alkalinity of the soil

Representing the "percentage of Hydrogen" on the soil colloid, pH is responsible for the acidity and/or the alkalinity of the soil. Maximum biological activity in the soil occurs at a pH of about 6.2 – 6.7 (ideal varies with the lab). It is very important to understand that pH should not be the focus of any management program. pH only represents the balance of the basic cations found in the base saturation and is adjusted by managing Ca, Mg, K, Na and the other cations. Always ask "what is driving pH," it may not always be Ca.

ORGANIC MATTER, PERCENTAGE – This shows the percentage of organic matter. This does not represent pure humus in the soil, and the two should not be confused. Organic matter will encompass roots and thatch, both of which are long-chain forms of carbon and are not easily digested by soil microbes. Organic matter is, however, very important as a foundation for the development of humus and building soil buffers and TEC levels in the soil.

SULFUR (S) – Sulfur is expressed in parts per million (ppm), which, when multiplied by 2, equals pounds per acre. Sulfur levels should be maintained between 50 and 100 pounds per acre. Grasses will use about the same amount of sulfur as they do phosphorous. It is essential for the uptake of nitrogen and the development of many amino acid, enzyme and protein systems. Sulfur plays a major role in mobilizing excessive nutrients out of the soil.

EASILY EXTRACTED PHOSPHOROUS – Shown here as P_2O_5 in pounds per acre. P levels should be at least 250 pounds per acre but can afford to be even higher in heavy soils. Phosphorous is not very available in most soils - because of its negative charge it can "lock up" with other nutrients. Phosphorous is an essential building block for sugar development, the development of healthy roots, and the transportation of other nutrients into the plant.

CALCIUM – Is used more in weight and volume than any other nutrient, and is perhaps the most over looked. Calcium is noted here in pounds per acre, but more importantly, the base saturation percent shows the balance of calcium with other cations. It is this balance that is so important, and Ca should be mainainted at 68% base saturation on heavy soils, and 60% base saturation on sandy soils. The recommendations are calculated by an elaborate formula that will allow for the optimum Ca level to be achieved. Sources of Ca include high calcium lime (low Mg), dolomitic lime (high Mg), gypsum (calcium sulfate) and many liquid products. Depending on how much Ca is needed, a combination of high calcium and dolomitic lime may be needed to avoid driving off too much Mg. Calcium imbalances will severely affect soil compaction by restricting air and water movement through the soil, thereby limiting microbial activity.

MAGNESIUM – Also shown in pounds per acre, Mg has a very close relationship with Ca and should be managed by balancing base saturation and reducing deficiencies. Often it is high Mg that is driving pH up, resulting in a need to replace Mg on the colloid with Ca or other cations in order to lower pH. Ideal Mg levels should be 12% base saturation on heavy soils, and close to 20% on sandy soils. Mg is essential in photosynthesis and the development of many amino acid and enzyme systems. Good sources for supplying Mg to the soil include dolomitic lime, Pro-Mag or Sul-Po-Mag. Liquid forms of Mg are important to a balanced program.

POTASSIUM – Potassium (K) is a major player in root development and reducing plant stress but is needed in much smaller amounts than Ca or Mg. Again, manage K by base saturation and work hard at not over applying because it is a very mobile nutrient. Ideal K levels should be 5% base saturation. When pH is above 6.5, potassium availability becomes increasingly limited and building levels of K in the soil without organic sources becomes very hard.

SODIUM - An essential element for some plants, excesses can easily create toxicity. Levels should not exceed 40-50 pounds per acre, but should never exceed 3% base saturation. High levels of Na in the soil will severely restrict the activity of beneficial bacteria, which are so important in keeping pathogens in check. Watch the overuse of high salt fertilizers, top dressings, composts or other common sources of Na. The % of Na should not be higher than the % of K in the soil, or a sodium-induced wilt could result.

BASE SATURATION PERCENTAGE - The percent of cations on the soil colloid.
This is where management of the soil begins because it represents "balance." Manage to 68% Ca; 12% Mg; 5% K; 2% Na; 3% Other Bases (trace nutrients), and 10% Hydrogen. Remember that base saturation always adds up to 100%, so if one nutrient is high, another can be exchanged for it. If these numbers are in their "ideal" percentages, pH will always be between 6.0 to 6.5.

BORON- Try to maintain 1.2 ppm. Boron is a very soluble nutrient, and is needed in most soils on a small but frequent basis. Do not over apply because it can be very toxic, however if deficient, nitrogen uptake will be limited as well as many other plant/soil functions. Boron is the "gate keeper" for calcium.

IRON – Ideal soil levels are 100-150 ppm, but most soils can easily tolerate higher levels. Over-used in most turf programs because of its ability to affect photosynthesis and provide a greening effect. There is a critical Fe:Mn relationship, which should always be at least 1.5:1.

MANGANESE – Managed to a minimum level of 25 –40 ppm, with a maximum of 120 ppm. Mn will mobilize Fe in the soil, and can be a good Fe replacement when Fe is high. Mn, like most micro-nutrients, plays a subtle but important role in the metabolism of both plant and soil micro-organisms, but when deficient can create significant plant stress, which can encourage disease.

COPPER – Manage to a minimum of 5 ppm. Copper is a major player in disease suppression if levels in the soil are maintained at 5-10 ppm. Cu is a major ingredient in many popular fungicides, and can be very helpful in this role if available in the soil.

ZINC – Manage to a minimum of 6 ppm, with an optimum of 10-20 ppm. Zn can also play a major role in disease suppression if found in ample amounts in the soil, and biology is strong enough to create mobility.

WALLACE LABS
365 Coral Circle
El Segundo, CA 90245
(310) 615-0116

SOILS REPORT

Print Date Oct. 5, 2012 Receive Date 10/4/12

Location HCFCD

Requester Steve Diver, Agri Horticultural Consulting

graphic interpretation: * very low, ** low, *** moderate **** high, ***** very high

ammonium bicarbonate/DTPA

extractable - mg/kg soil	Sample ID Number	12-279-01		12-279-02		12-279-03	
Interpretation of data	Sample Description	Manor, 6"		Bing, 6"		Residential 6"	
low medium high	elements		graphic		graphic		graphic
0 - 7 8-15 over 15	phosphorus	8.21	***	9.25	***	4.15	**
0-60 60 -120 121-180	potassium	20.72	*	64.99	***	114.32	***
0 - 4 4 - 10 over 10	iron	212.45	*****	104.14	*****	43.99	*****
0- 0.5 0.6- 1 over 1	manganese	2.19	****	2.06	****	3.87	****
0 - 1 1 - 1.5 over 1.5	zinc	1.32	***	0.86	**	1.54	****
0- 0.2 0.3- 0.5 over 0.5	copper	0.65	****	1.13	****	1.85	****
0- 0.2 0.2- 0.5 over 1	boron	0.14	**	0.34	***	0.25	***
	calcium	159.95	**	370.00	***	376.29	***
	magnesium	17.36	*	81.82	***	160.44	*****
	sodium	4.41	*	8.94	*	51.70	**
	sulfur	7.11	*	9.00	*	12.91	*
	molybdenum	n d	*	n d	*	n d	*
	nickel	0.13	*	0.19	*	0.46	*
The following trace	aluminum	6.81	****	n d	*	n d	*
elements may be toxic	arsenic	0.21	*	0.16	*	0.28	*
The degree of toxicity	barium	1.75	*	2.62	*	1.41	*
depends upon the pH of	cadmium	0.01	*	0.02	*	n d	*
the soil, soil texture,	chromium	0.14	*	0.02	*	n d	*
organic matter, and the	cobalt	0.04	*	0.03	*	0.06	*
concentrations of the	lead	2.30	**	1.67	**	1.44	**
individual elements as	lithium	0.10	*	0.23	*	0.25	*
well as to their interactions.	mercury	n d	*	n d	*	n d	*
	selenium	0.10	*	n d	*	n d	*
The pH optimum depends	silver	n d	*	n d	*	n d	*
upon soil organic	strontium	0.80	*	1.00	*	1.01	*
matter and clay content-	tin	n d	*	n d	*	n d	*
for clay and loam soils:	vanadium	1.18	**	0.45	*	0.19	*
under 5.2 is too acidic							
6.5 to 7 is ideal	Saturation Extract						
over 9 is too alkaline	pH value	5.84	**	6.18	***	6.07	***
The ECe is a measure of	ECe (milli-	0.15	*	0.21	*	0.41	**
the soil salinity:	mho/cm)		millieq/l		millieq/l		millieq/l
1-2 affects a few plants	calcium	9.4	0.5	16.7	0.8	31.3	1.6
2-4 affects some plants,	magnesium	3.2	0.3	5.6	0.5	8.1	0.7
> 4 affects many plants.	sodium	10.1	0.4	7.7	0.3	28.7	1.2
	potassium	3.7	0.1	5.1	0.1	6.2	0.2
	cation sum		1.3		1.8		3.6
problems over 150 ppm	chloride	9	0.3	7	0.2	38	1.1
	nitrate as N	2	0.2	10	0.7	18	1.3
	phosphorus as P	0.2	0.0	0.2	0.0	0.3	0.0
toxic over 800	sulfate as S	6.0	0.4	6.7	0.4	11.5	0.7
	anion sum		0.8		1.4		3.0
toxic over 1 for many plants	boron as B	0.23	**	0.17	*	0.20	**
increasing problems start at 4	SAR	0.7	*	0.4	*	1.2	*
est. gypsum requirement-lbs./per 1,000 square feet		1		2		2	
	infiltration rate inches/hour	0.55		1.46		6.60	
	soil texture	sandy loam	gravel > 2 mm	sandy loam	gravel > 2 mm	sandy clay loam	gravel > 2 mm
	sand	62.8%	0.8%	61.6%	1.6%	52.2%	1.6%
	silt	31.2%	gravel > 1/4 inch	27.6%	gravel > 1/4 inch	25.1%	gravel > 1/4 inch
	clay	6.0%	0.1%	10.9%	0.0%	22.7%	0.6%
	lime (calcium carbonate)	no	gravel > 1/2 inch	no	gravel > 1/2 inch	no	gravel > 1/2 inch
	Total nitrogen	0.041%	0.0%	0.046%	0.0%	0.099%	0.0%
	Total carbon	0.451%		0.513%		1.201%	
	carbon:nitrogen ratio	11.0		11.2		12.2	
	organic matter based on carbon	0.90%		1.03%		2.40%	
	moisture content of soil	1.1%		3.3%		12.7%	
	half saturation percentage	13.1%		14.3%		27.0%	
ideal percentages of cations			% saturation		% saturation		% saturation
abt 5 % potassium	millieq K	0.06	2%	0.16	3%	0.31	2%
< 3% sodium	millieq Na	0.03	1%	0.03	1%	0.18	1%
abt 70% calcium	millieq Ca	1.15	33%	2.96	50%	8.24	60%
10 - 15% magnesium	millieq Mg	0.28	8%	0.83	14%	1.87	14%
5-10% hydrogen	millieq H	2.00	57%	1.92	33%	3.20	23%
	total millieq/100 grams	3.52		5.91		13.80	

Elements are expressed as mg/kg dry soil or mg/l for saturation extract.
pH and ECe are measured in a saturation paste extract. nd means not detected.
Analytical data determined on soil fraction passing a 2 mm sieve.

WALLACE LABS	SOILS REPORT	Print Date	Oct. 5, 2012	Receive Date	10/4/12
365 Coral Circle	Location	HCFCD			
El Segundo, CA 90245	Requester	Steve Diver, Agri Horticultural Consulting			
(310) 615-0116	graphic interpretation: * very low, ** low, *** moderate				
ammonium bicarbonate/DTPA		* * * * high, * * * * * very high			

extractable - mg/kg soil	Sample ID Number	12-279-04		12-279-05		12-279-06	
Interpretation of data	Sample Description	Commercial 6"		Upper Tucker 6"		Lower Tucker 6"	
low medium high	**elements**		graphic		graphic		graphic
0 - 7 8-15 over 15	**phosphorus**	1.91	*	5.41	**	7.77	**
0-60 60 -120 121-180	**potassium**	38.63	**	17.02	*	21.24	*
0 - 4 4 - 10 over 10	**iron**	12.98	****	95.90	*****	72.65	*****
0- 0.5 0.6- 1 over 1	**manganese**	0.84	***	6.29	****	5.73	****
0 - 1 1 - 1.5 over 1.5	**zinc**	0.57	**	0.86	**	0.86	**
0- 0.2 0.3- 0.5 over 0.5	**copper**	0.80	****	0.93	****	1.21	****
0- 0.2 0.2- 0.5 over 1	**boron**	0.17	**	0.10	**	0.14	**
	calcium	430.24	****	281.26	***	322.80	***
	magnesium	170.60	*****	61.66	***	46.04	**
	sodium	11.41	*	5.41	*	6.92	*
	sulfur	6.03	*	9.88	*	7.95	*
	molybdenum	n d	*	n d	*	n d	*
	nickel	0.39	*	0.42	*	0.41	*
The following trace	**aluminum**	n d	*	n d	*	n d	*
elements may be toxic	**arsenic**	0.24	*	0.24	*	0.13	*
The degree of toxicity	**barium**	3.14	**	4.09	**	4.00	**
depends upon the pH of	**cadmium**	0.01	*	0.03	*	0.04	*
the soil, soil texture,	**chromium**	n d	*	0.07	*	0.06	*
organic matter, and the	**cobalt**	0.04	*	0.03	*	0.04	*
concentrations of the	**lead**	1.11	**	2.17	**	2.07	**
individual elements as	**lithium**	0.27	*	0.17	*	0.20	*
well as to their interactions.	**mercury**	n d	*	n d	*	n d	*
	selenium	n d	*	0.06	*	n d	*
The pH optimum depends	**silver**	n d	*	n d	*	n d	*
upon soil organic	**strontium**	0.88	*	1.12	*	1.05	*
matter and clay content-	**tin**	n d	*	n d	*	n d	*
for clay and loam soils:	**vanadium**	0.20	*	0.30	*	0.31	*
under 5.2 is too acidic							
6.5 to 7 is ideal	**Saturation Extract**						
over 9 is too alkaline	**pH value**	7.41	***	5.36	**	5.54	**
The ECe is a measure of	**ECe (milli-**	0.31	*	0.20	*	0.15	*
the soil salinity:	**mho/cm)**		millieq/l		millieq/l		millieq/l
1-2 affects a few plants	**calcium**	36.4	1.8	15.8	0.8	9.6	0.5
2-4 affects some plants,	**magnesium**	7.6	0.6	5.7	0.5	4.0	0.3
> 4 affects many plants.	**sodium**	8.1	0.4	8.8	0.4	7.2	0.3
	potassium	2.6	0.1	1.8	0.0	4.5	0.1
	cation sum		2.9		1.7		1.2
problems over 150 ppm	**chloride**	8	0.2	3	0.1	4	0.1
	nitrate as N	15	1.1	15	1.0	9	0.6
	phosphorus as P	0.2	0.0	0.1	0.0	0.2	0.0
toxic over 800	**sulfate as S**	7.1	0.4	3.1	0.2	3.3	0.2
	anion sum		1.8		1.3		1.0
toxic over 1 for many plants	**boron as B**	0.11	*	0.11	*	0.20	*
increasing problems start at 4	**SAR**	0.3	*	0.5	*	0.5	*
est. gypsum requirement-lbs./per 1,000 square feet		1		2		1	
	infiltration rate inches/hour	18.03		5.39		3.35	
	soil texture	sandy loam	gravel > 2 mm	sandy loam	gravel > 2 mm	sandy loam	gravel > 2 mm
	sand	55.6%	1.1%	64.8%	1.0%	66.4%	1.8%
	silt	25.9%	gravel > 1/4 inch	26.7%	gravel > 1/4 inch	29.7%	gravel > 1/4 inch
	clay	18.5%	0.5%	8.5%	0.7%	3.9%	0.8%
	lime (calcium carbonate)	no	gravel > 1/2 inch	no	gravel > 1/2 inch	no	gravel > 1/2 inch
	Total nitrogen	0.044%	0.0%	0.083%	0.0%	0.086%	0.0%
	Total carbon	0.603%		0.906%		0.980%	
	carbon:nitrogen ratio	13.6		11.0		11.5	
	organic matter based on carbon	1.21%		1.81%		1.96%	
	moisture content of soil	10.4%		7.2%		5.0%	
	half saturation percentage	22.4%		16.4%		16.3%	

ideal percentages of cations				% saturation		% saturation		% saturation
abt 5 %	potassium	millieq K	0.09	1%	0.06	1%	0.05	1%
< 3%	sodium	millieq Na	0.05	0%	0.04	1%	0.02	0%
abt 70%	calcium	millieq Ca	10.18	70%	2.00	31%	2.19	38%
10 - 15%	magnesium	millieq Mg	1.86	13%	0.91	14%	0.59	10%
5-10%	hydrogen	millieq H	2.40	16%	3.44	53%	2.88	50%
	total millieq/100 grams		14.58		6.45		5.73	

Elements are expressed as mg/kg dry soil or mg/l for saturation extract.
pH and ECe are measured in a saturation paste extract. nd means not detected.
Analytical data determined on soil fraction passing a 2 mm sieve.

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October 5, 2012

Steve Diver, steved@ipa.net
Agri-Horticultural Consulting
106 North Cuernavaca Drive
Austin, TX 78733-3203

RE: HCFCD

Dear Steve,

Manor, 6" – The pH is highly acidic at 5.84. Exchangeable hydrogen is high at 57%. Salinity is very low at 0.15 millimho/cm. Iron is high. Manganese, zinc and copper are sufficient. Phosphorus is modest. Nitrogen, potassium, magnesium and sulfur are low. Exchangeable calcium is low at 33%. Soil organic matter is low at 0.90% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is moderately slow at 0.55 inches per hour. Cation exchangeable capacity is low at 3.52 milliequivalents per 100 grams.

Recommendations

Per acre for a 6-inch depth of amending, apply the following:

Ground limestone – 1,200 pounds, sufficient for a pH of about 6.5
K-Mag (sul-po-mag) (0-0-22) – 240 pounds
Potassium sulfate (0-0-50) – 100 pounds
Gypsum – 350 pounds
Organic matter – 22,000 pounds of actual organic matter, sufficient for 2% soil organic matter which will also help to provide boron and slow-release nutrients.

Bing, 6" – The pH is moderately acidic at 6.18. Exchangeable hydrogen is moderately high at 33%. Salinity is low at 0.21 millimho/cm. Iron is high. Manganese, magnesium, zinc and copper are sufficient. Phosphorus, potassium and nitrogen are modest. Zinc and sulfur are low. Exchangeable calcium is low at 50%. Soil organic matter is modestly low at 1.03% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is moderate at 1.46 inches per hour. Cation exchangeable capacity is modest at 5.91 milliequivalents per 100 grams.

Per acre for a 6-inch depth of amending, apply the following:

Ground limestone – 600 pounds, sufficient for a pH of about 6.5
Gypsum – 350 pounds
Organic matter – 19,000 pounds of actual organic matter, sufficient for 2% soil organic matter which will also help to provide slow-release nutrients.

Residential 6" – The pH is moderately acidic at 6.07. Exchangeable hydrogen is moderately high at 23%. Salinity is low at 0.41 millimho/cm. The fertility is moderate except for low phosphorus and sulfur. Exchangeable calcium is moderately low at 60%. Soil organic matter is modest at 2.4% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is rapid at 6.6 inches per hour. Cation exchangeable capacity is good at 13.80 milliequivalents per 100 grams.

Per acre for a 6-inch depth of amending, apply the following:

Ground limestone – 1,800 pounds, sufficient for a pH of about 6.5
Triple superphosphate (0-45-0) – 100 pounds
Gypsum – 350 pounds
Organic matter – 19,000 pounds of actual organic matter, sufficient for 2% soil organic matter which will also help to provide slow-release nutrients.

Commercial 6" – The pH is modestly alkaline at 7.41. Exchangeable hydrogen is 16%. Salinity is low at 0.31 millimho/cm. Nitrogen is modest. Phosphorus, potassium zinc and sulfur are low. Exchangeable potassium is 1%. Exchangeable calcium is good at 70%. Soil organic matter is modest at 1.21% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is rapid at 18.03 inches per hour. Cation exchangeable capacity is 14.58 milliequivalents per 100 grams.

Per acre for a 6-inch depth of amending, apply the following:

Potassium sulfate (0-0-50) – 150 pounds
Triple superphosphate (0-45-0) – 100 pounds
Gypsum – 350 pounds
Organic matter – 16,000 pounds of actual organic matter, sufficient for 2% soil organic matter which will also help to provide slow-release nutrients.

Upper Tucker 6" – The pH is strongly acidic at 5.36. Exchangeable hydrogen is high at 53%. Salinity is low at 0.20 millimho/cm. Iron is high. Nitrogen is modest. Phosphorus, potassium, zinc and sulfur are low. Exchangeable calcium is low at 31%. Exchangeable potassium is low 1%. Soil organic matter is modest at 1.81% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is moderately rapid at 5.39 inches per hour. Cation exchangeable capacity is modest at 6.45 milliequivalents per 100 grams.

Recommendations

Per acre for a 6-inch depth of amending, apply the following:

Ground limestone – 3,100 pounds, sufficient for a pH of about 6.5
Triple superphosphate (0-45-0) – 80 pounds
Potassium sulfate (0-0-50) – 100 pounds
Gypsum – 350 pounds

Lower Tucker 6" – The pH is strongly acidic at 5.54. Exchangeable hydrogen is high at 50%. Salinity is very low at 0.15 millimho/cm. Iron is high. Nitrogen is modest. Phosphorus, potassium, zinc and sulfur are low. Exchangeable calcium is low at 38%. Exchangeable potassium is low 1%. Soil organic matter is modest at 1.96% on a dry weight basis. The soil texture is sandy loam. The rate of water percolation is moderately rapid at 3.35 inches per hour. Cation exchangeable capacity is low at 5.73 milliequivalents per 100 grams.

Recommendations

Per acre for a 6-inch depth of amending, apply the following:

Ground limestone – 2,100 pounds, sufficient for a pH of about 6.5
Triple superphosphate (0-45-0) – 60 pounds
Potassium sulfate (0-0-50) – 100 pounds
Gypsum – 350 pounds

General Comments

Apply calcium nitrate (15.5-0-0) at 250 pounds per acre two or three times during the active growing season to the acidic areas. If not over applied, it will help to decrease the exchangeable hydrogen. Apply pH neutral nitrogen to the alkaline areas.

Monitor the soil and plant tissues with periodic testing. Apply nutrients as needed.

Sincerely,

Garn A. Wallace, Ph. D.
GAW:n

Soil Analyses Plant Analyses Water Analyses

SERVICE IN ACTION

COLORADO STATE UNIVERSITY COOPERATIVE EXTENSION

Soil test explanation

P. N. Soltanpour and R. H. Follett[1]

no. .502

Quick Facts

Colorado State University routinely analyzes soil samples for pH, soluble salts, organic matter, nitrate nitrogen, phosphorus, potassium, zinc, iron, copper, manganese, lime and soil texture.

Additional tests for gypsum and the sodium adsorption ratio (SAR) may be run in the laboratory.

Nutrient levels are reported as parts per million (ppm) of the elemental nutrient.

Included in a report from the CSU Soil Testing Laboratory are interpretations which relate results to fertilizer and management recommendations.

On July 1, 1977, the Colorado State University Soil Testing Laboratory adopted a new soil test developed by Dr. P.N. Soltanpour and Mr. A.P. Schwab. This test extracts phosphorus, potassium, zinc, iron, copper and manganese simultaneously. It replaces three separate tests previously used for extraction of these same nutrients. The new test is faster and more economical than the tests it replaces.

Following are the general interpretations for the new soil test (ammonium bicarbonate-DTPA) and other tests presently used by the CSU Soil Testing Laboratory.

Routine Soil Tests

Soil pH, determined by the saturated paste method, indicates the acidity or alkalinity of soil based on a scale of 0-14. On the pH scale, 7.0 is neutral, values below 7.0 are acid and those above are alkaline. Most Colorado soils are alkaline, having a pH between 7.0 and 8.0. A pH value above 8.5 indicates that the soil contains excess sodium.

Soluble salts are measured by the electrical conductivity of a soil extract from a saturated paste and are reported in mmhos/cm. Crops vary markedly in their tolerance to soluble salts. Therefore, the values must be interpreted in relation to the specific crop. (See Table 1.)

Detailed information on individual crops is given in Service in Action sheet .505, *Crop tolerance to soil salinity*.

Organic matter (O.M.), reported as percent of total soil, contains about 95 percent of all soil nitrogen (N). About 30 pounds (13.6 kilograms) N per acre, will be released (mineralized to nitrate) during the cropping season from each one percent O.M. present. Nitrogen release rates will be slower in mountain meadow and other high elevation soils.

Nitrate nitrogen, reported in ppm NO_3-N, is soluble and readily available for plant uptake and is therefore considered equally available as fertilizer N. To determine the approximate pounds NO_3-N/acre-foot (one acre to a depth of one foot), multiply the soil test value (ppm) by 3.6. For example, 10 ppm x 3.6 = 36 pounds NO_3-N/acre (to a depth of one foot).

**Phosphorus, potassium, zinc, iron, copper and manganese:* the interpretations for these nutrients are given in Tables 2 through 7. When the soil test is very low to medium, fertilizer response is expected. Fertilizer recommended for "high" testing soils is for maintenance (to maintain soil fertility at that desirable level). No fertilizer is recommended for soils testing "high" for dryland production. For the micronutrients, no fertilizer is recommended when the test indicates "adequate." To date there has been no confirmed field crop response to copper or manganese fertilization in Colorado.

Lime ($CaCO_3$) is reported as percent free lime. In the routine test, values are reported as low (0-1%), medium (1-2%), and high (above 2%). Specific values are determined and reported only when a sodium evaluation is requested on a sample. In this case the percent free lime content is important in determining whether elemental sulfur will be an effective amendment in sodium reclamation. The lime content has no direct bearing on soil test interpretations for fertilizer recommendations by the CSU Soil Testing Laboratory.

Texture is estimated by the "hand-feel" method. Nitrogen management suggestions are

[1]*P. N. Soltanpour and R. H. Follett, CSU professors, both department of agronomy (revised 2/1/85)*

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture, Kenneth R. Bolen, Director of Cooperative Extension, Colorado State University. Cooperative Extension programs are available to all without discrimination.

adjusted according to soil texture. It is important on sands, loamy sands and sandy loams that nitrogen applications be split to avoid mid- or late-season deficiency. It is also recommended that high nitrogen rates be split for many crops.

Additional Soil Tests

Sodium adsorption ratio (SAR) is determined by saturated paste extraction and is reported as a special ratio of sodium to calcium plus magnesium.

This test evaluates the sodium content of soil. A value of 15 or greater indicates an excess of sodium will be adsorbed by the soil clay particles. Excess sodium can cause soil to be hard and cloddy when dry, to crust badly, and take water very slowly.

Gypsum test is conducted in conjunction with the SAR test. Total gypsum is reported in meq. (millequivalent) $CaSO_4$/100g. If sufficient native gypsum is present, sodium-affected soils may be successfully treated without addition of amendments such as gypsum or sulfur. The gypsum supplies soluble calcium to replace the adsorbed sodium and reclamation can proceed if drainage of the land is possible.

Table 1: Tolerance levels of crops for soluble salts.

Test values in mmhos/cm	Interpretation
0-2	Satisfactory for crops
2-4	Affects sensitive crops
4-8	High for many crops
above 8	Very high for most crops

Table 2: Available phosphorus (ammonium bicarbonate-DTPA test).

	Interpretation	
Test values* in ppm	Irrigated production	Dryland production
0-3	Very low	Low
4-7	Low	Medium
8-11	Medium	High
12-15	High	
above 15	Very high	

Table 3: Available potassium (ammonium bicarbonate-DTPA test).

	Interpretation	
Test values* in ppm	Irrigated production	Dryland production
0-60	Low	Low-medium
61-120	Medium	High
121-180	High	
above 180	Very high	

Table 4: Available zinc (ammonium bicarbonate-DTPA test).

	Interpretation	
Test values* in ppm	Irrigated production	Dryland production
0-0.50	Very low	Low
0.5-0.99	Low	Marginal
1.0-1.50	Marginal	Adequate
above 1.50	Adequate	

Table 5: Available iron (ammonium bicarbonate-DTPA test).

	Interpretation
Test values* in ppm[1]	Irrigated and dryland production
0-3.0	Low
3.1-5.0	Marginal
above 5.0	Adequate

[1]Values below 10.0 may be deficient for turf and many ornamentals.

Table 6: Available manganese (ammonium bicarbonate-DTPA test).

Test values* in ppm	Interpretation
0-0.5	May be low
above 0.5	Adequate

Table 7: Available copper (ammonium bicarbonate-DTPA test).

Test values* in ppm	Interpretation
0-0.2	May be low
above 0.2	Adequate

**This test is an availability index. It does not measure the total amount in soil, but only that fraction extractable by the soil test.*

Soil
Foodweb Analysis

Report prepared for:
Agri-Horticultural Consulting
Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA

steved@ipa.net

Report Sent:
Sample#: 03-009407 | Submission:03-004208
Unique ID: HFCD upper tucker
Plant: prarie
Invoice Number: 0
Sample Received: 9/27/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Organism Biomass Data	Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results	**0.920**	33.2	207	37.5	1044	3.25
Comments	Too Dry	Excellent	Good	Excellent	Excellent	
Expected Range Low	0.45	1	175	1	175	
Expected Range High	0.85	5	300	5	300	

	Protozoa Numbers/g Flagellates	Amoebae	Ciliates	Total Nematodes #/g	Percent Mycorrhizal Colonization ENDO	ECTO
Results	**2316**	9001	**15**	**5.26**	**8%**	**0%**
Comments	Low	High	Low	Low	Low	Low
Expected Range Low	5000	5000	50	10	40%	40%
Expected Range High			100	20	80%	80%

Organism Biomass Ratios	Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results	5.05	**0.04**	0.16	1.13	50-75
Comments	High	Low	Good	Good	
Expected Range Low	0.8	0.15	0.15	0.75	
Expected Range High	1.5	0.2	0.2	1.5	

Nematodes per Gram of Soil Identification to genus		
Bacterial Feeders		
Monhystera		1.24
Plectus		0.53
Prismatolaimus		0.44
Fungal Feeders		
Discolaimus		0.35
Laimydorus		0.44
Pungentus		0.71
Fungal/Root Feeders		
Aphelenchus		0.62
Root Feeders		
Gracilacus	Pin nematode	0.27
Xiphinema	Dagger nematode	0.27

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Dry Weight:	The soil is too dry. This is a result of low organic matter and/or poor soil structure.
Active Bacteria:	Bacterial activity above expected levels; Bacterial biomass will increase as long as nutrients are available.
Total Bacteria:	Aerobic bacterial biomass in normal range for this plant group.
Active Fungi:	Fungal activity above expected levels; fungal biomass will increase as long as nutrients are available.
Total Fungi:	Excellent total fungal biomass.
Hyphal Diameter:	Mostly the more disease suppressive fungi present.
Protozoa:	Good amoebae, but the falgellates and ciliates are low. Nutrient cycling will be limited.
Total Nematodes:	Low numbers, but fair diversity. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization low, but at least present in sufficient amount that the inoculum is present. Provide humic acids to feed mycorrhizal fungi and improve colonization.
TF/TB:	The soil is too fungal for the best health of grasses. Need to improve beneficial bacteria to balance fungal biomass.
AF/TF:	Good fungal activity for this time of year.
AB/TB:	Good ratio of activity and total bacterial biomass for plant group and season.
AF/AB:	Soil is fungal dominated but becoming even more fungal; addition of bacterial foods might be necessary, depending on plant species desired.
Nitrogen Supply:	Fair plant available N supply from predators.

Interpretation Comments:

Soil Type: Sand, low organic matter, low to med., Irrigated: rain, Plant: prarie

Soil Foodweb Analysis

Report prepared for:
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Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA

steved@ipa.net

Report Sent:
Sample#: 03-009408 | Submission: 03-004208
Unique ID: HCFCD lower tucker
Plant: prarie
Invoice Number: 0
Sample Received: 9/27/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
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Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		**0.950**	30.9	241	18.1	1107	3
Comments		Too Dry	Excellent	Good	Excellent	Excellent	
Expected Range	Low	0.45	1	175	1	175	
	High	0.85	5	300	5	300	

		Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results		**1456**	**4482**	60	**5.45**	**12%**	**0%**
Comments		Low	Low	Good	Low	Low	Low
Expected Range	Low	5000	5000	50	10	40%	40%
	High			100	20	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results		4.58	**0.02**	**0.13**	**0.59**	50-75
Comments		High	Low	Low	Low	
Expected Range	Low	0.8	0.15	0.15	0.75	
	High	1.5	0.2	0.2	1.5	

Nematodes per Gram of Soil Identification to genus		
Bacterial Feeders		
Acrobeles		0.47
Cervidellus		0.71
Heterocephalobus		0.59
Monhystera		0.35
Plectus		0.82
Fungal Feeders		
Aporcelaimium		0.35
Pungentus		0.24
Thonus		0.24
Fungal/Root Feeders		
Aphelenchus		0.59
Bitylenchus		0.35
Root Feeders		
Gracilacus	Pin nematode	0.47

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Report Sent:
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Unique ID: HCFCD lower tucker
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soilfoodwebny@aol.co
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Consulting fees may apply

Dry Weight:	The soil is too dry. This is a result of low organic matter and/or poor soil structure.
Active Bacteria:	Bacterial activity above expected levels; Bacterial biomass will increase as long as nutrients are available.
Total Bacteria:	Aerobic bacterial biomass in normal range for this plant group.
Active Fungi:	Fungal activity above expected levels; fungal biomass will increase as long as nutrients are available.
Total Fungi:	Excellent total fungal biomass.
Hyphal Diameter:	Good fungal community is present.
Protozoa:	Flagellate and amoebae numbers lacking. Nutrient cycling will be limited. Need to improve protozoan numbers.
Total Nematodes:	Low numbers, but fair diversity. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization low, but at least present in sufficient amount that the inoculum is present. Provide humic acids to feed mycorrhizal fungi and improve colonization.
TF/TB:	The soil is too fungal for the best health of grasses. Need to improve beneficial bacteria to balance fungal biomass.
AF/TF:	Good fungal activity for this time of year.
AB/TB:	Good bacterial activity for this time of year.
AF/AB:	The soil is fungal dominated, but getting more bacterial.
Nitrogen Supply:	Fair plant available N supply from predators.

Interpretation Comments:

Soil Type: Sand, low organic matter, low to med., Irrigated: rain, Plant: prarie

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Soil
Foodweb Analysis

Report prepared for:
Agri-Horticultural Consulting
Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA

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Report Sent:
Sample#: 03-009388 | Submission:03-004197
Unique ID: Manor
Plant: prarie
Invoice Number: 0
Sample Received: 9/13/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		**0.990**	**5.71**	485	**7.61**	462	3
Comments		Too Dry	Low	Excellent	Low	Excellent	
Expected Range	Low	0.45	10	150	10	150	
	High	0.85	25	300	25	300	

		Protozoa Numbers/g			Total Nematodes	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates	#/g	ENDO	ECTO
Results		**140**	**2169**	**0**	**2.61**	**12%**	**0%**
Comments		Low	Low	Low	Low	Low	Low
Expected Range	Low	10000	10000	50	20	40%	40%
	High			100	30	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results		0.95	**0.02**	**0.01**	1.33	<25
Comments		Good	Low	Low	Good	
Expected Range	Low	0.8	0.1	0.1	0.75	
	High	1.5	0.15	0.15	1.5	

Nematodes per Gram of Soil Identification to genus		
Bacterial Feeders		
Acrobeles		0.52
Heterocephalobus		0.44
Fungal Feeders		
Aporcelaimium		0.22
Epidorylaimus		0.37
Laimydorus		0.29
Paraxonchium		0.22
Thonus		0.15
Fungal/Root Feeders		
Ditylenchus	Stem & Bulb nematode	0.15
Root Feeders		
Helicotylenchus	Spiral nematode	0.22

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Unique ID: Manor
Plant: prarie
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For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Dry Weight:	The soil is too dry. This is a result of low organic matter and/or poor soil structure.
Active Bacteria:	Low bacterial activity. Add soluble bacterial foods.
Total Bacteria:	Higher than normal bacterial biomass suggests high bacterial species diversity.
Active Fungi:	Low fungal activity. Soluble fungal foods are needed to quickly boost activity.
Total Fungi:	Excellent total fungal biomass.
Hyphal Diameter:	Good fungal community is present.
Protozoa:	All protozoa numbers are low. Nutrients will not be cycled in high enough amounts for the healthy growth of prarie. Inoculate protozoa with compost, compost teas or other inoculum. Improve soil structure to create a better environment for the proliferation of protozoa.
Total Nematodes:	Low numbers, good diversity of fungal feeders. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization of roots too low. Add an inoculum of mycorrhizal spores, then provide humic acids to feed mycorrhizal fungi and improve colonization. Reduce any inorganic fertilizer apps.
TF/TB:	Good fungal to bacterial ratio.
AF/TF:	Low activity; need add fungal foods to encourage fungi growth.
AB/TB:	Low activity: add bacterial foods.
AF/AB:	Good ratio of activity.
Nitrogen Supply:	Low plant available N supply from predators.

Interpretation Comments:

Good levels of fungi and bacteria are present, but the soil moisture is too low to maintain good activity of bacteria and fungi or prtozoa. Ther are some root feeding nematodes present.

Improving organic matter can help improve moisture retention. Improving soil structure and aggregation by improving the soil biology can also help increase moisture retention.

Annual composting can improve the organic matter and in conjunction with seasonal tea applications the beneficial soil foodweb organisms can be maintained at higher levels.

Soil Type: Sand, low organic matter, low, dryland, Plant: prarie

Soil Foodweb Analysis

Report prepared for:
Agri-Horticultural Consulting
Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA
steved@ipa.net

Report Sent:
Sample#: 03-009389 | Submission:03-004197
Unique ID: Bing
Plant: prarie
Invoice Number: 0
Sample Received: 9/13/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		**0.970**	**8.26**	776	21.4	846	3.25
Comments		Too Dry	Low	Excellent	Good	Excellent	
Expected Range	Low	0.45	10	150	10	150	
	High	0.85	25	300	25	300	

		Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results		**592**	**4743**	143	**3.93**	**7%**	**0%**
Comments		Low	Low	High	Low	Low	Low
Expected Range	Low	10000	10000	50	20	40%	40%
	High			100	30	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results		1.09	**0.03**	**0.01**	2.59	50-75
Comments		Good	Low	Low	High	
Expected Range	Low	0.8	0.1	0.1	0.75	
	High	1.5	0.15	0.15	1.5	

Nematodes per Gram of Soil
Identification to genus

Bacterial Feeders		
Heterocephalobus		0.90
Panagrolaimus		0.22
Plectus		0.45
Prismatolaimus		0.67
Rhabditis		0.22
Fungal Feeders		
Epidorylaimus		0.34
Laimydorus		0.45
Root Feeders		
Meloidogyne	Root-Knot nematode	0.56

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03-009389: Page 1 of 2

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Dry Weight:	The soil is too dry. This is a result of low organic matter and/or poor soil structure.
Active Bacteria:	Low bacterial activity. Add soluble bacterial foods.
Total Bacteria:	Higher than normal bacterial biomass suggests high bacterial species diversity.
Active Fungi:	Good active fungal biomass.
Total Fungi:	Excellent total fungal biomass.
Hyphal Diameter:	Mostly the more disease suppressive fungi present.
Protozoa:	The flagellates and amoebae are low and will result in reduced nutrient cycling. The ciliates are a tad high which can indicate the soil has some compaction.
Total Nematodes:	Low numbers, but good diversity of bacterial feeders. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization of roots too low. Add an inoculum of mycorrhizal spores, then provide humic acids to feed mycorrhizal fungi and improve colonization. Reduce any inorganic fertilizer apps.
TF/TB:	Good fungal to bacterial ratio.
AF/TF:	Good fungal activity for this time of year.
AB/TB:	Low activity: add bacterial foods.
AF/AB:	The soil is fungal dominated, and getting more fungal.
Nitrogen Supply:	Fair plant available N supply from predators.

Interpretation Comments:

Good levels of fungi and bacteria are present, but the soil moisture is too low to maintain consistent activity of bacteria and fungi or prtozoa. Ther are some root feeding nematodes present.

Improving organic matter can help improve moisture retention. Improving soil structure and aggregation by improving the soil biology can also help increase moisture retention.

Annual composting can improve the organic matter and in conjunction with seasonal tea applications the beneficial soil foodweb organisms can be maintained at higher levels.

Soil Type: Sand, low organic matter, low, dryland, Plant: prarie

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www.soilfoodweb.com

Soil
Foodweb Analysis

Report prepared for:
Agri-Horticultural Consulting
Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA

steved@ipa.net

Report Sent:
Sample#: 03-009390 | Submission:03-004198
Unique ID: HCFCD-Westgate
Plant: St Augestine Grass
Invoice Number: 0
Sample Received: 9/15/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.840	18.0	771	27.5	659	2.5
Comments		In Good Range	Good	Excellent	Excellent	Excellent	
Expected Range	Low	0.45	10	150	5	100	
	High	0.85	25	300	20	200	

		Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results		**510**	**3320**	**0**	**5.17**	**28%**	**0%**
Comments		Low	Low	Low	Low	Low	Low
Expected Range	Low	5000	5000	50	20	40%	40%
	High			100	30	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results		0.85	**0.04**	**0.02**	1.53	<25
Comments		High	Low	Low	High	
Expected Range	Low	0.5	0.1	0.1	0.75	
	High	0.75	0.15	0.15	1.5	

Nematodes per Gram of Soil — Identification to genus		
Bacterial Feeders		
Panagrolaimus		0.25
Plectus		0.25
Prismatolaimus		0.75
Rhabditidae		0.50
Tripyla		0.50
Fungal Feeders		
Aporcelaimium		0.33
Epidorylaimus		0.42
Mesodorylaimus		0.25
Pungentus		0.33
Thornia		0.33
Predatory		
Mononchus		0.08
Root Feeders		
Helicotylenchus	Spiral nematode	0.33

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03-009390: Page 1 of 2

Agri-Horticultural Consulting	Report Sent:	For interpretation of this report please contact:
Steve Diver	Sample#: 03-009390 | Submission:03-004198	Local Advisor: or regional lab
106 N. Cuernovaca Dr.	Unique ID: HCFCD-Westgate	Soil Foodweb New Yor
Austin, Texas 78733 USA	Plant: St Augestine Grass	soilfoodwebny@aol.co
	Invoice Number: 0	631-750-1553
steved@ipa.net	Sample Received: 9/15/2012	***Consulting fees may apply***

Dry Weight:	Good soil moisture content.
Active Bacteria:	Good active bacterial biomass.
Total Bacteria:	Higher than normal bacterial biomass suggests high bacterial species diversity.
Active Fungi:	Fungal activity above expected levels; fungal biomass will increase as long as nutrients are available.
Total Fungi:	Excellent total fungal biomass.
Hyphal Diameter:	Good fungal community is present.
Protozoa:	All protozoa numbers are low. Nutrients will not be cycled in high enough amounts for the healthy growth of turf. Inoculate protozoa with compost, compost teas or other inoculum. Improve soil structure to create a better environment for the proliferation of protozoa.
Total Nematodes:	Low numbers, but good diversity of nematodes. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization low, but at least present in sufficient amount that the inoculum is present. Provide humic acids to feed mycorrhizal fungi and improve colonization.
TF/TB:	The soil is too fungal for the best health of St Augustine grass. Need to improve beneficial bacteria to balance fungal biomass.
AF/TF:	Good fungal activity for this time of year.
AB/TB:	Good bacterial activity for this time of year.
AF/AB:	Soil is fungal dominated but becoming even more fungal; addition of bacterial foods might be necessary, depending on plant species desired.
Nitrogen Supply:	Low plant available N supply from predators.

Interpretation Comments:

The soil is a little too fungal for the best health of St Augustine grass. Improving the organic matter would be helpful to be able to sustain higher levels of bacteria.

Compost topdressings anduse of mulching mowers to allow the clippings to stay in the soil will help slowly build higher levels of organic matter. Routine compost teas with added bacterial foods should be applied. This will help balance the F to B ratio and improve the levels of predatory microbes.

Soil Type: Sand, low organic matter, low, Irrigated: sprinkler, Plant: St Augestine Grass, Notes: Urban sandy clay

Soil Foodweb Analysis

Report prepared for:
Agri-Horticultural Consulting
Steve Diver
106 N. Cuernovaca Dr.
Austin, Texas 78733 USA

steved@ipa.net

Report Sent:
Sample#: 03-009391 | Submission:03-004198
Unique ID: HCFCD-Kroger`s
Plant: grass
Invoice Number: 0
Sample Received: 9/15/2012

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb New Yor
soilfoodwebny@aol.co
631-750-1553
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		**0.90**	23.5	847	16.6	267	2.5
Comments		Too Dry	Good	Excellent	Good	Good	
Expected Range	Low	0.45	10	150	10	150	
	High	0.85	25	300	25	300	

		Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results		**154**	**2379**	**0**	**2.38**	**17%**	**0%**
Comments		Low	Low	Low	Low	Low	Low
Expected Range	Low	10000	10000	50	20	40%	40%
	High			100	30	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply (lbs/acre)
Results		**0.32**	**0.06**	**0.03**	**0.70**	<25
Comments		Low	Low	Low	Low	
Expected Range	Low	0.8	0.1	0.1	0.75	
	High	1.5	0.15	0.15	1.5	

Nematodes per Gram of Soil Identification to genus		
Bacterial Feeders		
Acrobeles		0.32
Tripyla		0.32
Fungal Feeders		
Laimydorus		0.71
Fungal/Root Feeders		
Aphelenchus		0.16
Ditylenchus	Stem & Bulb nematode	0.32
Predatory		
Mylonchulus		0.16
Root Feeders		
Helicotylenchus	Spiral nematode	0.16

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Report Sent:
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Plant: grass
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For interpretation of this report please contact:
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631-750-1553
Consulting fees may apply

Dry Weight:	The soil is too dry. This is a result of low organic matter and/or poor soil structure.
Active Bacteria:	Good active bacterial biomass.
Total Bacteria:	Higher than normal bacterial biomass suggests high bacterial species diversity.
Active Fungi:	Good active fungal biomass.
Total Fungi:	The fungal biomass is in good range, but needs to be increased in relation to the bacterial biomass.
Hyphal Diameter:	Good fungal community is present.
Protozoa:	All protozoa numbers are low. Nutrients will not be cycled in high enough amounts for the healthy growth of turf. Inoculate protozoa with compost, compost teas or other inoculum. Improve soil structure to create a better environment for the proliferation of protozoa.
Total Nematodes:	Low numbers, and limited diversity. Root-feeding nematodes are present. Need to add beneficial nematodes (including predatory nematodes), improve conditions to allow their survival.
Mycorrhizal Col.:	Mycorrhizal colonization low, but at least present in sufficient amount that the inoculum is present. Provide humic acids to feed mycorrhizal fungi and improve colonization.
TF/TB:	The soil is too bacterial for the best health of turf. Inoculate beneficial fungi to balance with bacterial biomass, and add fungal foods.
AF/TF:	Good fungal activity for this time of year.
AB/TB:	Good bacterial activity for this time of year.
AF/AB:	Soil is bacterial dominated, and becoming more bacterial. A source of fungal inoculum and fungal foods are needed.
Nitrogen Supply:	Low plant available N supply from predators.

Interpretation Comments:

The soil is too bacterial for the best health of grasses and the predators need to be increased.

Compost topdressings and use of mulching mowers to allow the clippings to stay in the soil will help slowly build higher levels of organic matter. Routine compost teas with added microbial foods should be applied. This will help balance the F to B ratio and improve the levels of predatory microbes. More fungal foods such as humic acid should be utilized with the teas.

Soil Type: Sand, low organic matter, low, Irrigated: sprinkler, Plant: grass, Notes: Urban sandy clay

Supplement 4.0
Water Infiltration Rates by Single Ring Infiltrometer

Infiltration Rates (in/hr) in the Cypress Creek Overflow: Prairie

Land Cover Type
Prairie

Upper Tucker

	Plot 1 Start	Plot 1 End	Plot 2 Start	Plot 2 End	Plot 3 Start	Plot 3 End	Average Time	Average IR	IR by Ave Time
1st Measurment (Soil Pre-wetting)	00:00:00	00:14:29	10:24:45	10:28:04	10:57:34	11:02:52			
IR Time (hr/min/sec)		00:14:29		00:03:19		00:05:18	00:07:42		
		14.29		3.19		5.18	7.42		
IR Rate (in/hr)		4.20		18.8		11.58		11.53	8.09
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	00:00:00	00:43:14	10:30:17	10:42:35	11:04:23	11:16:35			
IR Time (hr/min/sec)		00:43:14		00:12:18		00:12:12	00:22:35		
		43.14		12.18		12.12	22.34		
IR Rate (in/hr)		1.4		4.93		4.95		3.76	2.69
Variability									0.33

Lower Tucker

	Plot 1 Start	Plot 1 End	Plot 2 Start	Plot 2 End	Plot 3 Start	Plot 3 End	Average Time	Average IR	IR by Ave Time
1st Measurment (Soil Pre-wetting)	11:52:54	11:53:54	11:58:54	12:02:56	12:00:44	12:02:50			
IR Time (hr/min/sec)		00:01:00		00:04:02		00:02:06	00:02:23		
		1.00		4.02		2.06	2.23		
IR Rate (in/hr)		60.0		14.93		29.13		34.68	26.91
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	11:56:12	11:57:42	12:03:33	12:10:09	12:04:44	12:10:30			
IR Time (hr/min/sec)		00:01:30		00:06:36		00:05:46	00:04:37		
		1.30		6.36		5.46	4.37		
IR Rate (in/hr)		46.15		9.43		10.99		22.19	13.73
Variability									0.51
									Average IR for Land Cover Type
IR Rate (in/hr)									8.21

Infiltration Rates (in/hr) in the Cypress Creek Overflow: Open Space

Land Cover Type
Open Space

Manor	Plot 1		Plot 2		Plot 3		Average	Average IR	IR by
	Start	End	Start	End	Start	End	Time		Ave Time
1st Measurment (Soil Pre-wetting)	02:19:55	02:25:47	02:21:13	02:35:26	02:22:14	02:36:45			
IR Time (hr/min/sec)		00:05:52		00:14:13		00:14:31	00:11:32		
		5.52		14.13		14.31	11.32		
IR Rate (in/hr)		10.87		4.25		4.19		6.44	5.30
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	02:26:36	02:52:38	02:37:36	03:09:15	02:39:23	03:02:12			
IR Time (hr/min/sec)		00:26:02		00:31:39		00:22:49	00:26:50		
		26.02		31.39		22.49	26.50		
IR Rate (in/hr)		2.31		1.91		2.67		2.30	2.26
Variability									0.43

Bing	Plot 1		Plot 2		Plot 3		Average	Average IR	IR by
	Start	End	Start	End	Start	End	Time		Ave Time
1st Measurment (Soil Pre-wetting)	12:43:18	12:55:14	12:44:55	12:56:55	12:46:31	01:05:59			
IR Time (hr/min/sec)		00:11:56		00:12:00		00:19:46	00:14:34		
		11.56		12.00		19.46	26.50		
IR Rate (in/hr)		5.19		5.00		3.08		4.42	2.26
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	01:01:52	01:31:41	01:02:57	01:35:25	01:07:16	01:52:48			
IR Time (hr/min/sec)		00:29:49		00:32:28		00:45:32	00:35:56		
		29.49		32.28		45.32	35.56		
IR Rate (in/hr)		2.03		1.86		1.32		1.74	1.69
Variability									0.75
									Average IR for Land Cover Type
IR Rate (in/hr)									1.98

Infiltration Rates (in/hr) in the Cypress Creek Overflow: Developed

Land Cover Type
Developed

Westgate

	Plot 1		Plot 2		Plot 3		Average Time	Average IR	IR by Ave Time
	Start	End	Start	End	Start	End			
1st Measurment (Soil Pre-wetting)	03:39:41	04:03:14	03:40:48	03:43:23	03:45:00	05:22:16			
IR Time (hr/min/sec)		00:23:33		00:02:45		01:37:16	00:41:11		
		23.33		2.45		97.16	41.11		
IR Rate (in/hr)		2.57		24.49		0.62		9.23	1.46
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	04:06:37	07:42:30	03:47:37	03:52:06	05:22:16	07:42:30			
IR Time (hr/min/sec)		03:35:53		00:04:29		02:20:14	02:00:12		
		215.53		4.29		140.14	120.12		
IR Rate (in/hr)		0.28		13.99		0.43		4.90	0.50
Variability									0.34

Kroger

	Plot 1		Plot 2		Plot 3		Average Time	Average IR	IR by Ave Time
	Start	End	Start	End	Start	End			
1st Measurment (Soil Pre-wetting)	12:03:03	12:15:30	12:06:30	12:40:48	12:08:10	12:21:42			
IR Time (hr/min/sec)		00:12:27		00:34:18		00:13:32	00:20:06		
		12.27		34.18		13.32	20.06		
IR Rate (in/hr)		4.89		1.76		4.50		3.72	2.99
	Start	End	Start	End	Start	End			
2nd Measurment (Actual IR)	12:16:44	01:17:37	12:43:38	02:37:40	12:24:26	12:44:48			
IR Time (hr/min/sec)		01:00:53		03:04:02		00:20:22	01:28:26		
		60.53		184.20		20.22	148.26		
IR Rate (in/hr)		0.99		0.33		2.97		1.43	0.40
Variability									0.14
									Average IR for Land Cover Type
IR Rate (in/hr)									0.45