Cypress Creek Source Identification Study

prepared by

Turner Collie & Braden

in cooperation with the

Houston-Galveston Area Council

and the

Texas Commission on Environmental Quality

under the authorization of the Texas Clean Rivers Act

Final Report

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Abbreviations and Acronyms

AWRL	Ambient Water Reporting Limits
cfs	cubic foot per second
CN	Curve Number
COC	chain-of-custody
COH	City of Houston
CRP	Clean Rivers Program
FGDC	Federal Geographic Data Committee
GIS	geographic information system
GPS	global positioning system
H_2SO_4	sulfuric acid
HCFCD	Harris County Flood Control District
HCOEM	Harris County Office of Emergency Management
HCPC	Harris County Pollution Control
H-GAC	Houston-Galveston Area Council
IH	Interstate Highway
mg/l	milligram per liter
ml	milliliter
MPN	most probable number
NH_3	ammonia
NPS	non-point source
NRCS	Natural Resources Conservation Service
QAPP	Quality Assurance Project Plan
ROW	right-of-way
SCC	Sample Condition Checklist
SH	State Highway
SSURGO	NRCS Soil Survey Geographical Database
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TRACS	TCEQ Regulatory Activities and Compliance System
TSS	total suspended solids
USGS	U.S. Geological Survey
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Section 1

1.1 Introduction

Turner Collie & Braden was retained through funding provided by the Texas Clean Rivers Program (CRP), Houston-Galveston Area Council (H-GAC), in September 2004, to conduct an investigation into sources of ammonia and bacteria in the main stem of Cypress Creek (Segment 1009) of the San Jacinto River Basin. While many urban watersheds are experiencing extreme levels of bacterial contamination, Cypress Creek watershed has bacteria levels that currently appear manageable. Although the creek is not meeting its contact recreation use at this time, bacteria levels are commonly near designated *E. Coli* standard of 126 colonies/100 ml (milliliters).

Cypress Creek is one of six major Lake Houston tributaries and the tributary most impacted by point source and non-point source (NPS) discharges (*Figure 1*). Cypress Creek begins several miles south of the City of Waller in Waller County and flows southeast along the Waller/Harris County boundary turning eastward and ending at its confluence with Spring Creek (Texas Department of Water Resources [TDWR] 1980). The total length of Cypress Creek is approximately 53 miles and has a drainage area of approximately 322 square miles (Texas Natural Resource Conservation Commission [TNRCC], now Texas Commission on Environmental Quality [TCEQ] 1994).

The upper portion of Cypress Creek consists of prairie land and grasslands used for agriculture. Downstream of US 290 is heavily wooded with increasing residential development. Development is moving westward resulting in urban storm water drainage systems being developed along tributaries. As a result of the rapid growth, numerous wastewater treatment plants (WWTPs) discharge into Cypress Creek and its tributaries. There are currently 95 wastewater permits authorized to discharge into the Cypress Creek watershed. Bacterial contamination was evaluated in an attempt to restore contact recreation status before the levels become unmanageable.

In an effort to control these bacterial levels and prevent higher concentrations as development continues, H-GAC proposed to study this watershed in detail to identify bacteria sources, reduction/prevention options, and public outreach strategies. H-GAC also worked closely with Harris County Flood Control District's (HCFCD) Cypress Creek Storm Water Management Plan Committee to coordinate water quality management strategies.

1.2 Work Tasks

Three objectives were identified for the project:

- Use methods of small watershed analysis that can be applied to similar watersheds to identify potential and current bacteria and ammonia sources and loadings
- Develop a water quality baseline dataset to be used in future 319 NPS projects in the watershed
- Provide information that can be used in future work to define possible NPS mitigation strategies for these types of pollutants

To achieve these objectives, the following tasks were completed:

- Conduct Watershed Reconnaissance (Task 1)
- Prepare Watershed Maps/Databases (Task 2)
- Prepare Quality Assurance Project Plan and Sampling Plan (Task 3)

- Conduct Field Sampling and Analysis (Task 4)
- Perform Runoff Analysis (Task 5)
- Evaluate Data and Report Results (Task 6)

These tasks are described fully in the following subsections.

1.2.1 Watershed Reconnaissance (Task 1)

Reconnaissance was limited to the main stem of Cypress Creek. A detailed review of aerial photographs was conducted to identify land uses and assist in identifying areas that provided access to the creek channel. Logistical planning for field reconnaissance included compilation and preparation of all field data sheets, field maps, global positioning system (GPS) equipment. In addition, personnel briefings were conducted and assignments made for field reconnaissance visits to the areas previously identified.

TCB's geographic information system (GIS) analysts and project team members developed field reconnaissance data sheets to guide information gathering efforts. Field data sheets categorized the type of pollutant sources identified, and flowing sources were categorized as pipes, ditches, or tributaries. All dry weather discharges not associated with a known wastewater permit or storm sewer pipe were assumed to be illicit discharges or illicit connections. Other potential sources of pollution were categorized as disturbed areas. The following were identified as potential pollutant sources to be found during reconnaissance.

- Dry weather storm sewer system discharges
- Potential illicit discharges
- WWTP discharges
- Significant animal populations (birds or livestock)
- Illegal dumping areas or large, significant accumulations of trash

Field reconnaissance was conducted to verify information gathered and physically identify sources of pollution. Teams of two were utilized for safety reasons. This included some out-of-bank surveying and riparian buffer characterization. Bayou survey work was conducted on foot in waders via canoe depending on stream conditions. Data were recorded using a handheld GPS unit and later downloaded to in-house computers. All objects identified as a potential pollutant source were assigned a unique identification number to facilitate database creation. Existing digital aerial photography (obtained from H-GAC) was used to prepare watershed maps for use during fieldwork. During this phase of the study, sources contributing flows into Cypress Creek were identified as follows:

- Permitted discharges along the Cypress Creek segment
- Potential illicit discharges
- Locations and frequencies of CRP monitoring data collected by other entities – H-GAC CRP data-clearinghouse, City of Houston (COH), TCEQ, Harris County Pollution Control (HCPC)
- Locations of U.S. Geological Survey (USGS) flow gauging stations
- Locations of rainfall gauging stations
- Land use categories from the H-GAC Land Use dataset
- Storm sewer outfalls within the segment
- Subwatersheds draining into the main stem of Cypress Creek

1.2.2 Watershed Maps/Databases (Task 2)

Based on field data collected during Task 1, the project team developed watershed maps that identified storm water outfalls with dry weather flows, potential illicit discharges, permitted wastewater outfalls, significant animal populations, significant illegal dumping areas and subwatersheds flowing into the main stem of Cypress Creek.

All GPS field-collected information was converted to GIS with corresponding identification and data classification fields added to assist in generating tabular inventory data sheets. In addition, each digital data file was created in ArcView shapefile format, Texas State Plane, NAD 83, South Central Zone, with units in feet. Corresponding Federal Geographic Data Committee (FGDC) metadata was generated for each file. FGDC metadata was used to describe each dataset's accuracy and coordinate information, field names, descriptions, and all other description categories pertinent to the data. The FGDC format was standardized by the federal government and is widely accepted in all GIS data management circles.

Dry weather discharges from outfalls found during Task 1 were compared to existing wastewater discharge coordinates obtained from TCEQ. USGS flow gauge data, when available, were included in the database.

1.2.3 Quality Assurance Project Plan and Sampling Plan (Task 3)

Based on information gathered under Task 1 and maps prepared in Task 2, the project team identified appropriate dry weather and wet weather sampling locations and frequencies. A Quality Assurance Project Plan (QAPP) was prepared in accordance with CRP and H-GAC guidelines. The QAPP was electronically submitted for review and comments. A final QAPP was prepared addressing all comments. No field sampling was conducted prior to the formal QAPP approval. The QAPP included figures of the Cypress Creek watershed illustrating proposed sampling locations. Data obtained during this study will not be loaded into the TCEQ Regulatory Activities and Compliance System (TRACS) database but will be housed separately as NPS information.

1.2.4 Field Sampling and Analysis (Task 4)

Both dry and wet weather sampling were performed in accordance with the approved QAPP. Field sampling procedures conformed to the *Surface Water Quality Monitoring (SWQM) Procedures Manual*, RG-415 (TCEQ 2003). Physicochemical parameters were measured using one of several multi-probe instruments available during the project. These included a Hydrolab H20 multi-probe with a Scout II display unit and a Hydrolab Minisonde with a Surveyor IV display unit provided by H-GAC. During wet weather sample collection, a YSI 600 XL with YSI display unit was also utilized. Streamflow measurements were completed using American Sigma portable velocity meters with top-setting wading rods also provided by H-GAC.

Sampling station maps were prepared to improve efficiency of the sampling team during sampling trips. The following parameters were obtained from each designated discharge sampling location: dissolved oxygen, temperature, pH, and specific conductance. Number of days since last significant rainfall was also documented before each sampling trip using data from the Harris County Office of Emergency Management (HCOEM) rain gauge network website. Streamflow measurements were obtained using a Sigma electronic flow meter or from a USGS flow gauging station via the Internet. Otherwise, flow estimates were calculated using pipe or channel size, depth of flow, and approximate exit velocity. Water samples were collected from each designated sampling location to analyze parameters specified in the project QAPP. These parameters include *E. Coli* bacteria, ammonia-nitrogen, nitrate, total phosphorus, total suspended solids (TSS), and total dissolved solids (TDS). Approved analytical methods are specified in the QAPP. Dry weather samples did not include total phosphorus or nitrates whereas wet weather samples included all parameters.

During dry weather, 28 predetermined sites were sampled to characterize the pollutant contributions from significant pollutant sources in the study area. These sites were sampled at the outfall as well as once upstream and once downstream of each identified source to document bacteria and ammonia loadings.

Wet weather sampling was scheduled to be conducted at four sites in the study area. The goal was to obtain a sample set consisting of a maximum of six grab samples from each designated location. However, record drought conditions in the Houston area interfered with sample collection. Due to these record drought conditions, two of the four, selected wet weather sites were not sampled. Initial wet weather samples were collected as close to the start of runoff as feasible. Subsequent samples were collected at 15-minute intervals until the maximum number of samples had been achieved.

1.2.5 Runoff Analysis (Task 5)

A runoff analysis was conducted using a Curve Number (CN) method developed by the Natural Resources Conservation Service (NRCS). Composite CN values were determined upstream of each sample site based on a GIS-based CN dataset provided by H-GAC. These composite values were used to calculate estimated runoff for the Cypress Creek Watershed. The GIS-based CN dataset identifies estimated CN values throughout the entire watershed based on a land cover database and the Soil Survey Geographical Database (SSURGO).

The GIS-based CN dataset was developed for H-GAC by comparing H-GAC's land cover database with the NRCS CN table based on the definition and hydrologic application of land cover and soil type (PBS&J 2003). A connection was developed between 57 soil types and four NRCS hydrologic soil groups through examination of the characteristics of these 57 soil types and assigning them into the four hydrologic soil groups. In addition, each H-GAC land cover category was assigned to an NRCS category. From these relations, the GIS-based CN dataset was prepared.

1.2.6 Data and Report Results (Task 6)

Field results (including identified sources and sampling results) were reviewed and evaluated. Evaluation included identification of any significant ammonia and bacteria sources in the watershed based on field reconnaissance and sampling data obtained. Bacteria and ammonia loadings were calculated by H-GAC where flow data were obtained.

This report, describing project approach, methods, QA/QC, and results, was prepared in draft form for H-GAC's and TCEQ's review. Results include findings and lessons learned as well as a description of how the approach used could be applied to identify and mitigate similar pollutant sources in other watersheds. A final report will be prepared addressing all review comments.

1.3 Project Planning

On December 2, 2004, TCB project team members held a planning meeting to discuss project scope of work, overall project approach, and personnel assignments. As a result, the following items were developed:

1. Standard nomenclature for pollutant sources identified during the reconnaissance phase to facilitate creating a project database.

2. Reconnaissance data sheets to record information that would be collected during the reconnaissance phase.

1.4 Standard Nomenclature Development

As a result of a watershed aerial photography review and multiple discussions, TCB decided to make the nomenclature consist of three elements. Pollutant sources would be identified by their location within the watershed, source type, and an individual number representing the sequential order for occurrence of that source type in a given area. The project team first divided the watershed into four different sections each designated by a letter—A, B, C, or D. The section boundaries were defined by major highway crossings throughout the watershed. Section A included that portion of Cypress Creek located west of US 290; Section B, Cypress Creek between US 290 and SH 249; Section C, Cypress Creek between SH 249 and IH 45; and Section D, Cypress Creek east of IH 45. Each letter is immediately followed by *The Key Map* page designation. The second component of the nomenclature represents the type of source. A letter "T" represents a tributary while the letter "P" identifies a pipe, and "D" a roadside ditch. Next, a three digit number represents which number that source is. If the word "up" or "down" is placed at the end of the nomenclature, it means the sample was collected upstream of a particular source or vice versa for downstream. The standard convention for each pollutant source identified during the project follows this example. Pollutant source A364T003 means the source is located west of US 290 ("A"), located in Harris County on Key Map page 364. It is a tributary as designated by the "T" and the tributary is the third tributary (003) when traveling downstream in Section A.

Wet weather sampling sites are all located on Cypress Creek proper and do not represent a source type. Therefore, these sites are labeled with the location letter designation (A, B, C, or D), the Key Map location followed by "WET," and a number designating the site as wet weather site 1, 2, 3, or 4. For example: C330WET3 means it is in Section C, Key Map page 330; and it is wet weather site 3.

1.5 Datasheet Development

Based on a review and discussions of the project scope of work, field data sheets were developed to capture all necessary information and facilitate efficient field data collection. The reconnaissance data sheet included the following fields.

- Stream name
- Date
- Time
- Geographic position
- Source identification number
- Conduit type
- Conduit size
- Observers
- Weather conditions
- Antecedent dry period in number of days
- Photo number
- Source flow estimate
- Streamflow estimate
- Stream width estimate
- Associated land use

- Substrate type
- Source location by area using the nomenclature developed

Additional information was recorded, if applicable, such as presence or absence of foam, odor, color, oil sheen, algae, and floatables. *Attachment 1* illustrates the field reconnaissance data sheet. Field data sheets for dry and wet weather sampling were also developed and are presented as *Attachments 2, 3,* and *4.*

Section 2

2.1 Watershed Reconnaissance

This section describes the preliminary and field reconnaissance activities executed during this project. The reconnaissance efforts focused on the main stem of Cypress Creek.

2.2 Aerial Photography Review

Preliminary reconnaissance included detailed aerial photography review of the watershed. Photography obtained from H-GAC consisted of 1-square meter photography resolution flown in 2004. The photo review identified land use, potential access points, and discernable potential pollutant sources such as WWTPs. Coordinates of permitted WWTPs were obtained from H-GAC and TCEQ and were digitally overlaid on existing aerial photographs. This combined interpretation was used to help ensure that all WWTPs were included in field surveys. Other features digitally overlaid on existing aerial photographs included Harris County storm sewer outfalls, Clean Rivers Program monitoring sites, USGS flow gauging stations, HCOEM rain gauge stations, and the Little Cypress Creek subwatershed. Photography was reviewed and compared to the land use dataset provided by H-GAC.

2.3 Field Reconnaissance

2.3.1 Cypress Creek Field Reconnaissance

Field reconnaissance to identify pollutant sources was performed using a four wheel drive vehicle, on foot, and via canoe. Field reconnaissance efforts also served in determining feasibility, accessibility, study limits and monitoring approach.

The upper reaches of Cypress Creek (Section A) west of US 290 is dominated by prairie land and grasslands used for agriculture. Characteristically, large parcels of privately owned land limited public access in this section necessitating the use of a canoe. It is evident that development in the watershed continues westward, and is becoming more urbanized to the west of US 290. Section B, that portion of Cypress Creek between US 290 and SH 249, is predominantly forested land along the main creek channel but has high intensity and low intensity development areas mainly along the tributaries. Section C, located between SH 249 and IH 45, is characterized by even greater areas of both low and high intensity development. This section had the most development adjacent to the Cypress Creek Channel itself providing more access to the stream through bridge crossings and public right-of-ways (ROWs). Section D of Cypress Creek, beginning just east of IH 45 and continuing to the Spring Creek confluence, is heavily wooded and characterized by forested land. This area provided less access to the creek channel via bridge crossings and public ROWs. Most development on this reach is along the tributaries.

Field reconnaissance was conducted during the last two weeks of December 2004. All sources actively flowing were identified using nomenclature previously developed and photographed using a Sony Mavica digital camera. Photographs of Cypress Creek were also taken to provide an upstream and downstream view of the main creek channel. A Trimble GPS unit was used to geo-reference all sources identified and facilitate creation of the project geo-database. Observations were recorded on the field reconnaissance data sheets.

In some cases, areas of Cypress Creek required more than one visit as access limitations were encountered during the first visit. Those areas identified as needing further evaluation were marked on field maps and later visited by using canoe and inner tube. The sources identified during subsequent visits would not follow the same convention for identification because the numeric sequence on the upper reaches of Cypress Creek was already established as field crews continued reconnaissance efforts in a downstream direction on the watershed. These sources were identified by the letter designation corresponding to that reach of Cypress Creek and were numbered sequentially from upstream to downstream, beginning with number one (1).

2.3.2 Field Reconnaissance Summary

Seventy flowing sources were identified in the main stem of Cypress Creek. The majority were pipe outfalls and natural tributaries outfalls draining large parcels of land. Only three, roadside drainage ditches draining smaller areas of the road adjacent to private property were identified. Sixteen flowing sources were identified in Section A (*Figures 2* and *3*). Of these, five were tributaries, eight were pipe outfalls, and three were roadside drainage ditches. In Section B, 22 were identified as flowing sources (*Figure 4*). Twelve were tributaries, and 10 were pipe outfalls. Twenty-four flowing sources were identified in Section C; five were tributaries and 19 were pipe outfalls (*Figure 5*). Section D had eight flowing sources; three were tributaries and five were pipe outfalls (*Figure 6*). Results of the reconnaissance work, including all identified sources, field data sheets and photographs, are included in *Appendix A*.

During the reconnaissance efforts it became evident that most pipe outfalls, including permitted WWTP outfalls and storm water outfalls discharging into this stream segment, were flowing into Cypress Creek through other conveyances, such as HCFCD ditches or other tributaries, as opposed to discharging directly into Cypress Creek. This characteristic is typical for most large streams where the majority of drainage from community developments occurs through storm sewer systems and smaller conveyances such as drainage ditches into the main channel of the larger stream.

Section 3

3.1 Quality Assurance Project Plan

3.2 Introduction

This section describes the development and approval of the QAPP document plus development of the sampling plan including site selection process and key provisions for the QAPP.

3.3 QAPP Development and Approval

QAPP development was initiated in December 2004. The document is version 1 of *Appendix K* in H-GAC's basin-wide QAPP (H-GAC 2004/2005). The first draft of the document was prepared and submitted to H-GAC for comments in December 2004. Comments were received and addressed in mid-January 2005, then submitted to TCEQ for review. TCEQ's comments were received and addressed in March. Final approval from TCEQ and H-GAC was obtained in early April 2005.

3.3.1 Sampling Site Selection

Field reconnaissance results (including photographs, flow estimates, and characterizations of the nature of flow coming from potential pollutant sources) were reviewed to determine appropriate sampling locations. Resources were available to conduct sampling at 28 outfalls including sampling in Cypress Creek upstream and downstream of each outfall during dry weather conditions. Dry weather sampling sites were selected and distributed so that a representative snapshot of water quality in Cypress Creek would be obtained during dry weather. Sites were selected so that each of the four sections (A, B, C, and D) on Cypress Creek contained approximately the same number of each type of source identified (WWTP outfall, pipe outfall, or tributary). The following criteria were used in selecting the dry weather sampling sites:

- Sites represented by each of the major land uses within the watershed
- Sources containing the highest anticipated load based on reconnaissance information
- Sources more likely to be flowing (based on size of drainage area served, type of source, etc)

Sampling would be conducted at four wet weather, instream sites on Cypress Creek. Wet weather sampling sites were selected so that a representative snapshot of water quality in Cypress Creek would be obtained during wet weather. Each site was strategically selected to capture storm water runoff from major land uses within the segment and was located at major bridge crossings where a USGS flow gauging station was available.

Five alternate sampling sites were selected and identified in the QAPP to provide additional sampling locations in case primary sites were not flowing at the time of sampling. The QAPP was later amended to add additional alternate sites because five alternate sites were not enough to cover possible intermittent flows. A complete list of primary and all alternate sites and their sampling frequencies is shown in *Table 1*. Sampling locations are illustrated on *Figures 7, 8, 9, 10*, and *11*.

3.4 Key Provisions of the QAPP

The QAPP contained EPA- and TCEQ-required components including:

- Project/Task Description
- Quality Objectives and Criteria for Measurement Data
- Special Training/Certification
- Sampling Methods
- Sample Handling and Custody
- Analytical Methods
- Quality Control
- Instrument/Equipment Testing, Inspection, and Maintenance
- Instrument Calibration and Frequency
- Inspection/Acceptance for Supplies and Consumables
- Non-Direct Measurements
- Data Management
- Assessment and Response Actions
- Reports to Management
- Data Review, Verification, and Validation
- Verification and Validation Methods

Additional aspects outlined below reflect specific requirements for sampling under CRP and/or provide additional clarification.

The QAPP specified how *E. Coli* concentrations would be quantified in all project samples. Dilutions of 2:1 and 100:1 were prepared from each sample collected. As shown in *Table 2*, this allowed quantification of *E. Coli* levels between 2 and 241,920 most probable number (MPN)/100 milliliter. To address overlap in coverage by two dilutions, the contract laboratory used data reporting guidelines for reporting bacteria results as outlined in Chapter 4 of the *Surface Water Quality Monitoring (SWQM) Procedures Manual*, RG-415 (TCEQ 2003). *Attachment 5* illustrates laboratory data sheets used for enumeration of *E. Coli* results.

3.5 Training

Prior to any field sampling activities, a training session was held for sampling staff. Training was conducted by staff with previous experience in the TCEQ SWQM Program. Training included classroom review of sampling procedures in the *Surface Water Quality Monitoring (SWQM) Procedures Manual Volume 1*, RG-415 (TCEQ 2003). Specific items covered included Chapter 3 – Flow Measurements, Chapter 4 – Collecting Bacteriological Samples, Chapter 5 – Water Sample Collection, and Chapter 8 – Calibrating and Maintaining Multi-Parameter Instruments. Training also included a field session with demonstrations of sampling techniques, streamflow measurement, and a hands-on mock sampling session.

Section 4

4.1 Watershed Sampling and Results

4.2 Introduction

This section describes sampling, analytical results, and project database structure.

4.3 Sampling and Analysis Methods

Sampling and analysis were conducted in accordance with the project QAPP (H-GAC and TC&B 2005). All selected sampling sites and alternate sites were plotted on aerial photography maps with a base layer of city streets to facilitate the field effort. Field sampling staff used maps to identify access points and to establish driving directions and sampling order.

All field-sampling procedures followed the *Surface Water Quality Monitoring (SWQM) Procedures Manual Volume 1*, RG-415 (TCEQ 2003). *Table 3* identifies sample containers and preservatives used for sample collection during the project.

4.3.1 Dry Weather Sampling

Dry weather sampling was conducted from April 5, 2005, through May 13, 2005. Each dry weather sample site was visited once except where subsequent visits were necessary to verify flow measurements due to unreliable data or equipment malfunction. In addition to sampling each identified source once, samples were also collected upstream and downstream of the source to document bacteria and ammonia loadings. Upstream locations were sampled approximately 100 feet upstream of the source, and downstream locations were sampled approximately 300 feet downstream of the source.

Dry weather sampling occurred at each site when the antecedent dry period was greater than or equal to 72 hours prior to sample collection. Antecedent dry periods and rainfall data were documented using HCOEM real-time rain gauge network accessed on its website. *Appendix B* contains rainfall data. When no flow was observed at a selected sample site, the closest alternate sample site was substituted and sampled. During the first week of sampling, additional alternate sites were selected. Some sample sites exhibited intermittent flows and were dry during the dry weather sample visit. To address this situation and prevent running out of alternate sites in the future, an amendment to the QAPP was requested and approved. Additional alternate sampling sites were added to the list of dry weather sampling sites. That complete list of all primary and all alternate sites and their sampling frequencies is listed in *Table 1*.

The upper reaches (Section A) of Cypress Creek were targeted first. During each batch of samples collected, sampling activities took place from downstream to upstream at each site. Downstream of the outfall was sampled first, the outfall was sampled second, and upstream of the outfall was sampled last. This was done to minimize instream substrate disturbance and reduce the effects on downstream water samples. In some cases, sampling occurred simultaneously at two locations within the sample site depending on resources and personnel available during each sampling trip. The majority of dry weather sample sites were accessed by vehicle, thence by foot where vehicle access was limited or prohibitive. A 150-quart ice chest filled with ice was carried in the vehicle at all times during all sampling trips. In cases where a hike was required to a sampling site, multi-probe instruments and flow meters were carried by back-pack or tote bags, and one or two 10-quart ice chest(s) were carried with ice for immediate sample preservation. Upon completion of sampling and returning to the vehicle, samples were transferred to the larger ice chest and completely covered with ice. The upper reaches (Section A) of the watershed required the use of a canoe and inner tube for sampling access. In this case, personnel and sampling gear were loaded into the canoe and inner tube for transport.

4.3.2 Water Sample Collection

Initial observations and standard site information were recorded on field data sheets upon arrival at each site. An *E. Coli* bacteria sample was collected first using a new, 110-ml sterile plastic jar containing a sodium thiosulfate tablet for chlorine neutralization. A new one-liter sterile plastic container with no preservative was used to collect TSS and TDS samples. An ammonia (NH_3) sample was collected using a new one-liter sterile plastic container preserved with 2 milliliters of sulfuric acid (H_2SO_4). All samples were collected directly from the source at outfalls. Upstream and downstream samples were collected from centroid of flow in Cypress Creek. Because NH_3 sample jars supplied by the laboratory already contained H_2SO_4, there was a risk of losing preservative during in-situ sampling. The bucket technique was used to collect these samples from the centroid of flow to prevent losing preservative. However at each location, a new sterile one-liter plastic sample jar was used as a bucket. All sampling procedures were followed as if sampling with a bucket, including triple-rinsing the jar with ambient water between samples. All samples were immediately iced in coolers upon sample collection. In some cases, sample containers were prelabeled with standard sample site information before each sampling trip; however, sample jar labels were occasionally prepared by a sampling team member during sample collection. QA/QC field splits for conventional parameters were collected on a 10 percent basis according to the project QAPP using the same techniques as an actual sample.

4.3.3 Physical Measurements

Distances were determined using an analog range finder to determine where sampling would take place at downstream and upstream locations. All physicochemical parameters were measured using one of several multi-probe instruments available during the project. These included a Hydrolab H20 multi-probe with a Scout II display unit and a Hydrolab Minisonde with a Surveyor IV display unit. All field readings were taken directly from the centroid of flow when possible. In instances where the water level of discharge or flows from pipe outfalls did not facilitate this type of data collection, a 2.5-gallon bucket was used to collect enough discharge to completely cover probe sensors. All parameters were recorded on field data sheets including notes describing whether the multi-probe was placed in the bucket or stream. Streamflow measurements were made using American Sigma portable velocity meters with top-setting wading rods following procedures outlined in the *Surface Water Quality Monitoring (SWQM) Procedures Manual Volume 1*, RG-415 (TCEQ 2003). Downstream and upstream velocity readings were made directly in the stream. Tributary measurements were made using the same methods; however, in cases of very low pipe outfall flows, a graduated 2.5-gallon plastic bucket and stopwatch were used to measure flow. In cases where WWTP pipe outfalls discharged high volumes directly into Cypress Creek, instantaneous discharge readings were obtained from the WWTP operator at the time of sample collection. For sample sites that were located either just upstream or downstream of a USGS flow gauging station without any flowing sources between them, USGS flow data were reported. USGS flow gauging station measurements were used for sample sites that were located just upstream or downstream of the USGS gauge as long as there were no additional sources of flow between the sample site and the USGS gauge.

4.3.4 Sampling Completion and Delivery to the Laboratory

When all sampling activities were completed, chain of custody forms were completed and samples were either delivered to the laboratory directly or relinquished to a laboratory representative that provided delivery service from the sample site. Transportation of samples to the laboratory varied from day to day depending on sampling site locations and travel time needed for delivery. The limiting factor for sampling activities was the 6-hour hold time for *E. Coli* samples. All sample hold times were met.

A&B Laboratory received the chain-of-custody (COC) and logged in the samples as they received them. Time of collection, time of reception, and sample temperature were measured during the log in procedure. Complete copies of the COCs and "Sample Condition Checklist" (SCC) are provided along with the analytical results in *Appendix C*. There were no discrepancies or non-conformances noted on any of the SCCs for any samples collected during the entire project.

Water samples were analyzed by A&B Laboratory using the analytical methods approved in the project QAPP. *Table SS-A-7* "Measurement Performance Specifications" in the project QAPP outlines analytical methods used including specified Ambient Water Reporting Limits (AWRLs) and Laboratory QA/QC requirements.

4.3.5 Wet Weather Sampling

Wet weather sampling was conducted at two sites on May 29, 2005. Because of record drought conditions in the Houston area, only two of the four selected wet weather sites were sampled. The lack of qualifying rain during the study period prevented any sampling activities from taking place at the other two sites. Wet weather sampling events occurred when qualifying (>0.10") storm events occurred and when the antecedent dry period was greater than or equal to 72 hours prior to sample collection. Antecedent dry periods and rainfall amounts were documented using HCOEM real-time rain gauge network accessed on its website. Rainfall data is contained in *Appendix B*. An attempt was made to arrive at sampling sites before the beginning of each storm event to try and capture the initial flush; however, because of the unpredictability of summer scattered showers, fast moving storms and mobilization time, sample teams did not always arrive at sampling sites before the storm. During the wet weather sampling event, watershed discharge measurements were obtained from USGS gauges located at sample sites. Streamflow measurements were not conducted by sampling crews during high flows because of safety issues. The order in which wet weather sites were sampled was dictated by the weather. Because each sample site was located at a major bridge crossing where a USGS flow gauging station was available, all wet weather sampling sites were accessible by vehicle. A complete list of all sites and their sampling frequencies is shown in *Table 1*.

Initial observations and standard site information were recorded on the field data sheets upon arrival at each site. Field data sheets for wet weather sampling are presented in *Attachment 4*. Sampling was conducted from the middle of the bridge to ensure sampling the centroid of flow and always took place on the upstream side of the bridge. A graduated 2.5-gallon plastic bucket filled with ambient water was lowered with a rope and brought back up for rinsing. This procedure was repeated three times between all samples while dumping rinse water on the road surface towards the downstream side of the bridge. Six sets of samples were collected at each site in 15-minute increments. Samples were collected for the same parameters collected during dry weather sampling with the addition of total phosphorus (TPO_4) and nitrate (NO_3). Total phosphorus (TPO_4) was collected in the same container with ammonia (NH_3) and preserved with H_2SO_4. Nitrate (NO_3) was collected in the same container with TSS and TDS. Samples were immediately placed in a 150-quart ice chest and covered with ice. Samples were either delivered to the laboratory or relinquished to a laboratory representative who picked them up.

Field measurements were made using the Hydrolab H20 multi-probe with a Scout II display unit and a YSI 600 XL with YSI 650 display unit.

4.4 Dry Weather Results

Section A, the upstream reach of the watershed, was characterized by low flows and pools that presented complications in measuring the velocity for flow calculations. Evidently, some of the stagnant pools within the upper reaches of the watershed represent natural low flow conditions in this portion of Cypress Creek. After discussions with the H-GAC project manager, this area was visited again, and a weir was constructed using plywood to decrease the width of the channel while increasing the depth resulting in greater head pressure, thus, greater measurable velocities. Throughout the rest of the project, some individual sites within the downstream reaches of the watershed were re-visited to verify or re-measure velocity readings when best professional judgment indicated that flow numbers were questionable or unreasonable. Foam was present in all sections except for Section A, with the majority of foam observed in Sections B and C. Almost all of the odors observed were from chlorinated wastewater effluent.

Although the discharge from the outfall at site A3 smelled of sewage, the sampling data did not indicate any elevated levels. Outfall B367P003 had a strong ammonia odor similar to that of an aquarium needing a water change. Generally, the creek was brownish-green, becoming pale green at wastewater outfalls. Throughout the creek, fish, turtles, and snakes were found usually in areas of dense vegetation. All dry weather data sheets and lab reports are presented in *Appendix B*.

Dry weather water quality sampling results are summarized in the following tables.

- *Table 4* contains all dry weather water quality data
- *Table 5* contains only *E. Coli* results
- *Table 6* contains ammonia data only
- *Table 7* contains field data only

E. Coli levels in Cypress Creek ranged from 2 to 241,920 per 100 ml. Of the 87 samples collected, 20 exceeded the single-sample, water quality criterion of 394 MPN/100 ml. The highest number of *E. Coli* bacteria, 241,920 MPN/100ml, was found discharging from outfall B367P003. Of the 20 samples with the highest *E. Coli* levels, seven were located in the more rural area designated as Section A, where land cover is dominated by agricultural grasslands and cultivated land.

Agriculture in Section A is typified by cattle and/or horses grazing in open fields and field-row crops. Livestock (cattle and horses) grazing areas are shown in *Figure 7*, which depicts upper Cypress Creek near the Harris County/Waller County boundary. The livestock or cattle grazing areas are located near or adjacent to Cypress Creek. Cypress Creek presumably serves as a water source for livestock grazing along the creek, so animals standing or drinking in the creek can potentially contribute high levels of *E. Coli* bacteria to Cypress Creek. Although seven samples exhibited elevated levels of *E. Coli* bacteria in Section A, only two of the samples were from outfall sources while the other five were instream samples from Cypress Creek. However, it should be noted that there was a clustering of elevated *E. Coli* values around outfall A-8. There are only seven WWTPs in Section A.

Section B is more urbanized than Section A and transitions from agricultural use to high/low intensity development along the creek. Identified outfall sources included large corrugated metal pipes for drainage, two major tributaries and a 6-inch PVC pipe discharging from an amenity pond directly into Cypress Creek (outfall B367P003). The 6-inch outfall not only had the highest bacteria level recorded during dry weather sampling, but both upstream and downstream sampling sites of this outfall also had elevated *E. Coli* values. Seven of the 20 sites with the highest levels of bacteria were located in Section B. Three were from outfall sources while the other four were instream samples from Cypress Creek. There are 28 WWTPs located in Section B.

Section C is characteristically similar to Section B in regard to land cover, but only one outfall source exceeded the grab sample criterion of 394 MPN/100 ml for *E. Coli* bacteria. This sample was from outfall C330P010, which is a 72-inch reinforced concrete pipe draining a park and recreational complex containing soccer fields and playgrounds. The high bacteria value observed at this outfall source could possibly originate from landscape irrigation waters mixing with mulch or animal waste sources from dogs, birds, squirrels or other wildlife. There are 37 WWTPs located in Section C.

Five of the 20 samples exceeding the grab sample criteria were found in Section D. Land cover in Section D also contains large areas of high/low intensity development but also includes a large percentage of forested land along the creek. The outfall sources identified in Section D include tributaries and storm water pipe outfalls. All of the elevated bacteria levels were found instream either upstream or downstream of outfall locations, rather than discharging from the actual outfall sources.

In general, *E. Coli* results from instream samples collected in this section of Cypress Creek were the highest among all elevated instream samples. These higher instream values may be the result of Section D having a greater drainage area given its downstream proximity in the watershed. The flow into the beginning of Section D is already influenced by discharges from 72 WWTPs. An additional 23 WWTPs discharge into Section D.

Ammonia levels in Cypress Creek ranged from 0.06 to 16 mg/l. Thirty-four of the 93 ammonia samples collected exceeded the 0.17 mg/l state screening level. Of the 34 samples with elevated ammonia levels, only one outfall source was identified in Section A. Outfall No. A8, a natural tributary draining cultivated land, was the source. This may suggest a contribution of ammonia into Cypress Creek from fertilizers carried in irrigation runoff.

Eight samples with elevated levels of ammonia were found in Section B. Two of those samples were from outfall sources, while the other six were instream samples from Cypress Creek. One of the outfall sources, a 6-inch PVC outfall pipe for the amenity pond (outfall No.B367P003), discharged 16 mg/l of ammonia, the maximum amount recorded during dry weather sampling. Both the upstream and downstream sampling locations also had elevated ammonia levels. This same outfall source was described above as having the highest recorded bacteria level and elevated bacteria levels both upstream and downstream. Outfall B368P009, a 108-inch corrugated metal drainage pipe, along with its upstream and downstream sampling locations, also had elevated ammonia levels.

In Section C, 13 samples had elevated ammonia levels. Four were from outfall sources and the other nine were from instream samples. Outfall C330-P008 is a WWTP discharge point and had elevated ammonia levels. While its upstream sampling site met the ammonia criterion of 0.17 mg/l, its downstream sampling site did not. Immediately downstream is outfall C330P010, the park and recreation complex identified above as discharging elevated bacteria levels. It also discharged high ammonia levels at the outfall and at its upstream and downstream sampling locations. This outfall's elevated ammonia could be the result of fertilizer use on irrigated landscaped park areas**.**

Ammonia levels from outfall C331P016 were below the criterion, and this outfall's discharge may have a diluting effect on elevated instream ammonia concentrations. The outfall source's upstream ammonia level is higher than its downstream location. Although the instream ammonia levels meet the criterion at the beginning of Segment C, downstream sampling points indicate elevated levels in the lower part of the segment.

Section D had 12 samples exceeding the ammonia screening level. Section D is the lowest downstream section just prior to the confluence with Spring Creek (Segment 1008 of the San Jacinto River Basin). Although this section is highly developed, it is mainly concentrated within the drainage areas of the tributaries rather than along the immediate proximity of Cypress Creek's heavily wooded main channel.

Of the 12 samples exceeding the ammonia screening level, only one was directly from an outfall source, while the other 11 were instream samples. This source was outfall D333T002, a tributary draining residential land coverage before reaching Cypress Creek. It is interesting to note that although five outfall sources had ammonia levels below the criteria of 0.17 mg/l, these outfall's respective upstream and downstream sampling locations had elevated ammonia levels, suggesting that these outfalls were not the source of the elevated ammonia levels downstream. These outfalls may have a diluting effect on instream ammonia discharges. The 11 instream samples with elevated levels of ammonia may result from this Section's downstream proximity of the watershed and the high number of WWTPs discharging into these four segments of Cypress Creek.

TSS levels in Cypress Creek ranged from 3 to 1,025 mg/l. The greatest number of samples exhibiting high TSS levels were upstream in Section A and the beginning portion of Section B, decreasing in Section C, and increasing again in Section D. The predominate land cover in Section A is agricultural. It should be noted that in addition to apparent direct livestock access to numerous areas of the creek, there is a very large construction project in progress along the southern boundary of Cypress Creek (*Figure 8*). Disturbed ground cover, whether from livestock or construction activity, could result in increased turbidity and discharge of suspended solids into the creek. The highest single sample result of 1,025 mg/l was from an instream sample on Cypress Creek at the downstream location near outfall D332P004. This outfall is an 18-inch corrugated metal pipe located adjacent to an area undergoing construction associated with new development.

TDS criteria, a measure of the total dissolved minerals as inorganic salts; anions-carbonate, chloride, sulfate, nitrate and cations-sodium, potassium, calcium, and magnesium, are listed in *Appendix A* of 30TAC §307 Texas Surface Water Quality Standards. TDS criteria are segment specific and are listed as maximum annual averages for individual segments. TDS levels in Cypress Creek ranged from 58 to 674 mg/l. Generally, TDS levels were highest in Sections B and C; however, only two samples exceeded the criteria of 600 mg/l of TDS for Segment 1009, including one sample observed at 600 mg/l. The highest level, 674 mg/l, was taken from outfall B369P015, a 96-inch corrugated metal pipe draining a large parcel of heavily wooded, undeveloped land surrounded by an intensely developed urban setting in Section B. The second highest TDS level of 634 mg/l was observed at outfall D332P004, an 18-inch corrugated metal pipe draining an area currently undergoing development. Although the criterion applies to the creek itself and not the discharge, the two outfalls discussed were the only elevated levels observed and no exceedances were observed instream.

Specific conductance, a measure of the electrical current carrying capacity of water at 25 degrees C, is related to TDS as a function of the dissolved substances in water. The specific conductance measurements followed the same trend as the TDS results, with higher levels observed in Sections B and C. The specific conductance ranged from 39 to 1,100 mg/L with the highest level observed at outfall C332T005.

Dissolved oxygen (DO) levels in Cypress Creek ranged from 4.46 to 14.55 mg/l. According to 30TAC §307.7 Texas Surface Water Quality Standards, Cypress Creek is designated as High Aquatic Life Use. The corresponding DO values to meet a High Aquatic Life Use Designation are listed as a 24 hr. average of 5.0 mg/l and a minimum of 3.0 mg/l. Although 24 hr. DO measurements were not conducted as part of this study, only two DO grab samples were below 5.0 mg/l and none were measured below 3.0 mg/l. Of the 2 lowest measurements, only one was an instream reading in Cypress Creek while the other was an outfall. The lowest DO measured was 4.46 mg/l at outfall B367P003 located in section B, the 6-inch outfall for the amenity pond that was discussed above for its high bacteria and ammonia levels.

The second lowest reading was in Cypress Creek, upstream of outfall A367T010. This location is downstream of an area undergoing intense development just west of US 290. The highest DO value measured in Cypress Creek was 14.55 mg/l upstream of outfall No. C331P016. High levels of DO were measured at various locations throughout the stream indicating possible algal blooms as suggested by the intense green color of the water and corresponding high pH values that are typical with algal blooms. Algal blooms can certainly represent eutrophication of a water body and can indicate nutrient rich sources or high nutrient loads into the stream.

The pH ranged from 6.8 to 9.1 mg/l in Cypress Creek. The pH values in 30TAC §307, Texas Surface Water Quality Standards are listed as a minimum and a maximum at any site within the segment. For Segment 1009, the listed range is 6.5- 9.0. Only one pH value exceeded the maximum criteria with a pH level of 9.1 while none fell below the minimum of 6.5. The pH was generally lower in the upstream portion of the creek and increased as investigators moved downstream in Cypress Creek. Section D exhibited the highest pH levels. Outfall D332P003 exceeded the criterion with a measurement of 9.1.

High DO levels coupled with high pH values and the intense green water color observed at the site were probably a result of algal blooms. The general trend of higher pH measurements coupled with higher DO measurements downstream may indicate eutrophication of the stream at the lower portions of the watershed. Again, this could possibly be explained by the increasing size of the drainage areas within the downstream reaches of the watershed and the 95 WWTPs that discharge into these four sections of Cypress Creek.

During sampling, the temperature of the creek ranged from 18.6 to 25.9 degrees C with an average of 22.4 degrees C. Temperatures from outfalls had a broader range of 15.5 to 26.0 degrees C with an average of 21.7 degrees C. Temperature values in 30TAC §307, Texas Surface Water Quality Standards are listed as a maximum for any site within the segment. The listed maximum temperature is 32.2 degrees C. Dry weather flows in Cypress Creek ranged from 0.12600 to 52.08440 cubic feet/sec with a mean value of 12.14711 cubic feet/sec.

4.5 Wet Weather Results

Wet weather sampling was conducted at two of the sites on May 29, 2005. These locations were Cypress Creek at Grant Road (B369Wet2) and Cypress Creek at Stuebner-Airline Road (C330Wet3). Six measurements were collected at each location during the sampling event. Wet weather sampling results are summarized in the following tables.

- *Table 8* contains all wet weather water quality data
- *Table 9* contains only *E. Coli* bacteria results
- *Table 10* contains only nutrient results
- *Table 11* contains only field data with flow measurements

The Grant Road site (B369Wet2) exhibited *E. Coli* results ranging from 36 to 3782 MPN/100 ml. Ammonia nitrogen levels ranged from 0.12 to 0.20 mg/l. Total phosphorus ranged from 1.51 to 1.7 mg/l and nitrates ranged from 4.6 to 5.1 mg/l. TSS levels averaged 36.3 mg/l, while TDS levels averaged 418 mg/l. The mean dissolved oxygen value was 7.18 mg/l while the mean pH value was 8.5. Mean temperature was 25.8 degrees C and the mean flow at this site was 14.8 cubic feet/sec during the sampling event. No foam, odors, or floatables were observed.

E. Coli levels at the Stuebner-Airline site (C330Wet3) ranged from 3,233 to 48,840 MPN/100 ml. Ammonia nitrogen levels ranged from 0.25 to 0.35 mg/l. Total phosphorus levels ranged from 1.04 to 1.57 mg/l and nitrate levels ranged from 3.2 to 5.1 mg/l. TSS levels averaged 119 mg/l while TDS levels averaged 283 mg/l. The mean dissolved oxygen level was 7.40 mg/l while the mean pH level was 8.0. Mean temperature was 25.1 degrees C and the mean flow at this site was 126 cubic feet/sec during the sampling event. Foam and odors were not observed but small vegetation debris was observed in the samples. All wet weather data sheets and lab reports are presented in *Appendix B*.

Nine out of 12 ammonia samples taken exceeded the state screening level of 0.17 mg/l. Of the nine exceedances, six were from sample site C330Wet3 at Cypress Creek and Stuebner-Airline. The other three exceedances occurred at the Grant Road site (B369Wet2). The Grant Road site (B369Wet2) is located in Section B, approximately 3 miles downstream of the Little Cypress Creek confluence. The Stuebner-Airline Road site (C330Wet3) is located farther downstream in Section C of the watershed. While both of these sample sites are located in areas representing highly developed urban settings within the watershed, site C330Wet3 is subject to a greater drainage area. Sampling results indicate higher values of ammonia at this site. The elevated values could possibly be explained by the larger drainage area and potentially greater number of upstream sources. Because these data represent wet weather conditions, no direct connection can be made to any one specific source without more sampling data. There are many variables that can affect the water quality during wet weather events including antecedent dry weather period, WWTP excursions, non-point source runoff from adjacent areas to the creek channel, fertilizer runoff, and rainfall amount.

Of the 12 samples taken between both sites, 10 samples exceeded the *E. Coli* single-sample water quality criterion of 394 MPN. Of the 10 exceedances, 4 occurred at the Grant Road site (B369Wet2) and 6 occurred at the Stuebner-Airline site (C330Wet3). While both of these sites are located in highly developed areas within the watershed, the downstream site (C330Wet3) is subject to a larger drainage area and could explain the greater number of exceedances.

4.6 Sampling QA/QC

QA/QC data for the field splits collected are presented in *Table 12*. Two ammonia and one TSS sample field splits fell greater than the 30 percent Relative Percent Difference used to determine excessive variability. Those data were flagged in the project database as not meeting the evaluation criteria. Post calibration data for the multi-probe instruments used during sampling are presented in *Table 13*. All calibration records are provided in *Appendix C.*

4.7 Project Database

The project database was developed for storing all the spatial and non-spatial data associated with this project as one single geo-database. The project database is provided on a CD in *Appendix D*. The geo-database can be defined as a relational database containing geographic information. It contains feature classes and tables. A feature class is a collection of features with the same geometry: point, line, or polygon. Following are the feature classes and tables that are stored in this geo-database:

Feature Classes:

- Disturbed Areas
- GPS_Data

Non-Spatial Tables

- Dry_Sample_Downstream
- Dry_Sample_Location
- Dry_Sample_Upstream
- Dry_Sampling
- Field_Data
- Lookup_ExistingFeature

- Lookup_FeatureType
- Lookup_QualityValue
- Sample_Results
- Type_Lookup
- USGS Flow Gauging Stations
- Wet_Samples
- Wet_Sampling

4.7.1 Feature Class Description

Disturbed Areas – The fields associated with this feature class:

Field	Type	Description
OBJECTID	Autonumber	GIS generated identifier
Shape	OLE Object	GIS managed feature shape
Type	Text	Description of disturbed area
Shape_Length	Double	GIS managed perimeter length in feet
Shape_Area	Double	GIS managed area in square feet

GPS Data **-** The various fields that are associated with this feature class are:

Field	Type	Description
OBJECTID	Autonumber	GIS generated identifier
SHAPE	OLE Object	GIS managed feature shape
Source_ID	Text	Station ID
Quality_Value	Integer	Identifies the spatial quality of the point. See the lookup table Lookup_QualityValue. The Geodatabase also contains a domain (QV) describing the quality values
Distance	Long Integer	If the point was GPS'd at a location not at the feature, this field records the estimated distance to the feature
Feature_Type	Integer	Type of feature. See the lookup table Lookup_FeatureType. The Geodatabase also contains a domain (FT) describing the feature type
Existing_Feature	Integer	Identifies as an existing or new feature. See the lookup table Lookup_ExistingFeature. The Geodatabase also contains a domain (EF) describing the existing feature
GPS_Date	Date	GPS Unit recorded data
GPS_Time	Text	GPS Unit recorded time
GPS_Height	Double	GPS Unit recorded height
Vert_Prec	Double	GPS Unit recorded vertical precision

Field	Type	Description
Horz_Prec	Double	GPS Unit recorded horizontal precision
Northing	Double	Northing or Y coordinate in TX State Plane South Central Zone, NAD 83 datum
Easting	Double	Easting or X coordinate in TX State Plane South Central Zone, NAD 83 datum
Point_ID	Long Integer	Point identifier created by GPS unit
ArcGIS_Lat_DD	Double	ArcGIS calculated latitude in decimal degrees
ArcGIS_Long_DD	Double	ArcGIS calculated longitude in decimal degrees
ArcGIS_Lat_DMS	Text	ArcGIS calculated latitude in degrees-minutes-seconds

4.7.2 Non-Spatial Table Description

Lookup Table containing the description for the field [Type] in the table Field_Data.

Field	Type	Description
Type	Text	Lookup code for point type
Description	Text	Description of point type

USGS Flow Gauging Stations in Cypress Creek identified by H-GAC. Location information is from the website **http://waterdata.usgs.gov**

Field	Type	Description
Station_No	Double	USGS Station Number
Station_Name	Text	Station Name
LATD	Double	Latitude Degrees
LATM	Double	Latitude Minutes
LATS	Double	Latitude Seconds
LONGD	Double	Longitude Degrees
LONGM	Double	Longitude Minutes
LONGS	Double	Longitude Seconds
Real_Time	Text	"Y" identifies real time data is available
Peak	Text	"Y" identifies peak data is available
Daily	Text	"Y" Identifies daily data is available
LAT	Double	Latitude decimal degrees
LONG	Double	Longitude decimal degrees
LONGM	Double	Longitude Minutes

Dry Weather Sample Data Taken at the Sampling Location

Field	Type	Description
OBJECTID	Autonumber	Database generated field
Source_ID	Text	Station ID. Links to [Source_ID] in the table Dry Sampling
Sample_Time	Date	Time Sample was taken
Temp_Celcius	Single	Temperature in degrees Celsius
pH	Single	Measured pH level
Conductivity	Single	Measured conductivity level
Dissolved_Oxygen	Single	Measured dissolved oxygen levels
pH_Calibration	Boolean	Verifies that pH calibration test was passed
Conductivity_ Calibration	Boolean	Verifies that conductivity calibration test was passed
Dissolved_Oxygen_ Calibration	Boolean	Verifies that dissolved oxygen calibration test was Passed
Foaming	Boolean	Verifies that foaming was observed
Odor	Boolean	Verifies that an odor was observed
Color	Text	Identifies the color of the sample
Oil_Sheen	Boolean	Verifies that an oil sheen was observed
Floatables	Boolean	Verifies that floatables were observed
Total_Flow_CFS	Single	Measured flow
Notes	Memo	Comments

Dry Sampling Results/Wet Sampling Results – Both these tables share the same table structure except for the naming convention. The Dry Sampling Results table stores information collected during dry weather sampling and the Wet Sampling Results table stores information collected during wet weather sampling. These two tables are in direct relationship with the "Sample Sites" feature class. The various fields associating these tables are:

Dry Weather Sample Data Taken Downstream of the Sampling Location

Field	Type	Description
OBJECTID	Autonumber	Database generated field
Source_ID	Text	Station ID. Links to [Source_ID] in the table Dry_Sampling.
Sample_Time	Date	Time Sample was taken
Temp_Celcius	Single	Temperature in degrees Celsius
pH	Single	Measured pH level
Conductivity	Single	Measured conductivity level
Dissolved_Oxygen	Single	Measured dissolved oxygen levels
pH_Calibration	Boolean	Verifies that pH calibration test was passed

Field	Type	Description
Conductivity_ Calibration	Boolean	Verifies that conductivity calibration test was passed
Dissolved_Oxygen_ Calibration	Boolean	Verifies that dissolved oxygen calibration test was passed
Foaming	Boolean	Verifies that foaming was observed
Odor	Boolean	Verifies that an odor was observed
Color	Text	Identifies the color of the sample
Oil_Sheen	Boolean	Verifies that an oil sheen was observed
Floatables	Boolean	Verifies that floatables were observed
Total_Flow_CFS	Single	Measured flow
Notes	Memo	Comments

Dry Weather Sample Data Taken Upstream of the Sampling Location

Field	Type	Description
Comments	Autonumber	Database generated field
Source_ID	Text	Station ID. Links to [Source_ID] in the table Dry_Sampling. Database generated field
Sample_Time	Date	Time Sample was taken at Station ID. Links to [Source_ID] in the table Dry_Sampling.
Temp_Celcius	Single	Temperature in degrees Celsius. Time Sample was taken
pH	Single	Measured pH level Temperature in degrees Celsius
Conductivity	Single	Measured conductivity level. Measured pH level
Dissolved_Oxygen	Single	Measured dissolved oxygen levels. Measured conductivity level
pH_Calibration	Boolean	Verifies that pH calibration test was passed. Measured dissolved oxygen levels
Conductivity_ Calibration	Boolean	Verifies that conductivity calibration test was passed. Verifies that pH calibration test was passed
Dissolved_Oxygen_ Calibration	Boolean	Verifies that dissolved oxygen calibration test was passed. Verifies that conductivity calibration test was passed
Foaming	Boolean	Verifies that foaming was observed. Verifies that dissolved oxygen calibration test was passed
Odor	Boolean	Verifies that an odor was observed. Verifies that foaming was observed
Color	Text	Identifies the color of the sample. Verifies that an odor was observed
Oil_Sheen	Boolean	Verifies that an oil sheen was observed. Identifies the color of the sample

Field	Type	Description
Floatables	Boolean	Verifies that floatables were observed. Verifies that an oil sheen was observed
Total_Flow_CFS	Single	Measured flow.
Notes	Memo	Comments measured flow

Common Dry Sampling Data Information. Results for dry sampling are stored in the tables: Dry_Sample_Downstream, Dry_Sample_Location, and Dry_Sample_Upstream.

Field	Type	Description
OBJECTID	Autonumber	Database generated field Station ID. Links to [Source_ID] in the table Dry_Sampling.
Source_ID	Text	Station ID. Links to [Source_ID] in the table GPS_Data.
Sample_Date	Date	Date the samples were taken
Sampler	Text	Initials of samplers
Antecedent	Boolean	Verifies that there was a dry period of over 72 hours prior to the samples being taken
Days_Since_Rain	Integer	Number of days since the last rainfall
USGS_Gauge	Long Integer	USGS Stream Gauge
USGS_Flow	Single	Flow at USGS Stream Gauge

Wet Weather Sample Data taken at the sampling location. Six samples were collected for analysis of the same parameters at a time interval of 15 minutes.

Field	Type	Description
OBJECTID	Autonumber	Database generated field
Source_ID	Text	Station ID. Links to [Source_ID] in the table Wet_Sampling
SampleNum	Integer	Sample number. Six samples are taken at a site. Restricted to a value between 1 and 6.
Sample_Time	Date	Time the sample was taken
Temp_Celcius	Single	Temperature in degrees Celsius
pH	Single	Measured pH level
Conductivity	Single	Measured conductivity level
Dissolved_Oxygen	Single	Measured dissolved oxygen levels
pH_Calibration	Boolean	Verifies that pH calibration test was passed
Conductivity_ Calibration	Boolean	Verifies that conductivity calibration test was passed
Dissolved_Oxygen_ Calibration	Boolean	Verifies that dissolved oxygen calibration test was passed
Foaming	Boolean	Verifies that foaming was observed

Field	Type	Description
Odor	Boolean	Verifies that an odor was observed
Color	Text	Identifies the color of the sample
Oil_Sheen	Boolean	Verifies that an oil sheen was observed
Floatables	Boolean	Verifies that floatables were observed
USGS_Flow	Single	USGS flow rate
Notes	Memo	Comments

Common Wet Sampling Data information. Results for wet sampling are stored in the table Wet_Sample. There are 6 wet sample records for each wet sample.

Field	Type	Description
OBJECTID	Autonumber	Database generated field Station ID. Links to [Source_ID] in the table Dry_Sampling.
Source_ID	Text	Station ID. Links to [Source_ID] in the table GPS_Data.
Sample_Date	Date	Date the samples were taken
Sampler	Text	Initials of samplers
Antecedent	Boolean	Verifies that there was a dry period of over 72 hours prior to the samples being taken
Days_Since_Rain	Integer	Number of days since the last rainfall
USGS_Gauge	Long Integer	USGS Stream Gauge

4.7.3 Relationships

In a relational database, all or some of the tables are in relationship with one another. Information stored in each of the tables can be linked using fields that are common to each table or feature class. Following are the relationships that were established in this database:

- Dry_Sampling!Source_ID to Dry_Sample_Downstream!Source_ID 1:0 or 1
- Dry_Sampling!Source_ID to Dry_Sample_Location!Source_ID 1:0 or 1
- Dry_Sampling!Source_ID to Dry_Sample_Upstream!Source_ID 1:0 or 1
- Lookup_QualityValue!Code to Field_Data!Quality_Value 1:Many
- Lookup_FeatureType!Code to Field_Data!Feature_Type 1:Many
- Lookup_ExistingFeature!Code to Field_Data!Existing_Feature 1:Many
- GPS_Data!Source_ID to Field_Data!Source_ID 1:1
- GPS_Data!Source_ID to Dry_Sampling!Source_ID 1:0 or 1
- GPS_Data!Source_ID to Wet_Sampling!Source_ID 1:0 or 1
- GPS_Data!Source_ID to Sample_Results!Source_ID 1:0 or 1
- Type_Lookup!Type to Field_Data!Type 1:Many
- Wet_Sampling!Source_ID to Wet_Samples!Source_ID 1:Many

Section 5

5.1 Surface Water Runoff Analysis

5.2 Introduction

A runoff analysis was conducted using a Curve Number (CN) method that was developed by NRCS. Composite CN values were determined for the area upstream of the sample stations based on a GIS-based CN dataset provided by H-GAC to calculate the estimated runoff for the Cypress Creek Watershed. The GIS-based CN dataset identifies estimated CN values throughout the entire watershed based on a land use/land cover database and SSURGO.

The GIS-based CN dataset was developed for H-GAC by comparing H-GAC's land use/land cover database with the NRCS CN table based on the definition and the hydrologic application of the land use and soil type (PBS&J 2003). A connection was developed between the 57 H-GAC soil types and the four NRCS hydrologic soil groups by examining the characteristics of these 57 soil types and assigning them into the four hydrologic soil groups. In addition, each H-GAC land use category was assigned to a NRCS category. The GIS-based CN dataset was prepared from these relationships.

5.3 Curve Number and Flow Calculation

The CN method developed by NRCS, which was used to estimate runoff for the Cypress Creek Watershed, is based on a GIS-based CN dataset provided by H-GAC. The GIS-based CN dataset identifies estimated CN values throughout the entire watershed based on a land use/land cover database and SSURGO. The basin was divided into 65 sub-basins based on the Tropical Storm Allison Recovery Project (TSARP) sub-basin boundaries to calculate the estimated runoff for the Cypress Creek Watershed (*Figure 12*). An average CN value weighted by the area of the land with the specific CN value was calculated for each sub-basin using the formula:

$$CN = \frac{CN_1A_1 + CN_2A_2 + ... + CN_nA_n}{A_1 + A_2 + ... + A_n}$$

Where,

CN = Curve Number

A = the area of the land associated with the curve number (acres)

The estimated runoff from each sub-basin was then calculated using the standard equations below as described in *A Guide to Hydrologic Analysis Using SCS Methods* (NRCS, formally SCS 1982).

$$R = [P - 0.2(S)]^2 \div [P + 0.8(S)] \text{ for } P > 0.2(S)$$

Where,

R = Estimated runoff volume (inches)

P = Event rainfall volume (inches)

$S = (1000 \div CN) - 10$

All average CN values from sub-basins located upstream of individual sampling sites were average weighted by the drainage area of the sub-basin. This method was used to calculate a composite CN value for the area draining into each individual wet weather sampling station. In addition, the estimated runoff for each sub-basin in cubic feet was calculated by multiplying the estimated runoff volume (R) by the area of the sub-basin. The estimated runoff to each of the wet weather sampling sites could then be calculated by adding all estimated runoff values from each sub-basin upstream of the sampling station together. The composite CN values and estimated runoff produced by a 2-inch rainfall event for the wet weather sampling stations are as follows:

Station ID	Station Name	Composite CN	Estimated Runoff (cubic foot)*
A366Wet1	House-Hahl Road	45.11	476,203
B369Wet2	Grant Road	43.86	549,499
C330Wet3	Stuebner-Airline	44.18	741,581
C332Wet4	IH 45	44.36	762,123

* Calculated for a 2-inch storm event.

The estimated runoff values were calculated based on a standard 2-inch rainfall event, as opposed to the 0.43 inches of rain received in the drainage basins flowing to the Grant Road Station (B369Wet2) and the 0.31 inches of rainfall in the drainage basins flowing to the Stuebner-Airline Station (C330Wet3) during the rain events. The composite CN values calculated for each sub-basin indicate that, at the lower rainfall volume, no runoff will be produced because of the low composite CN values. The 2-inch rainfall event was used to give an idea of the estimated runoff that would be expected with these composite CN values.

These composite CN values provide an average indication of the extent of development and impervious cover for the areas upstream of the sampling stations; however, it does not necessarily provide an accurate indication of the expected runoff. Calculating a composite CN value for a sub-basin does not take into consideration the spatial relation of the CN values within the sub-basin. For instance, there are areas within some of the sub-basins with CN values over 70. These areas will have significant impervious cover with storm sewers that discharge directly to a receiving stream. The composite CN values do not take this into consideration when calculating the estimated runoff. The composite CN assumes an average land condition for the entire sub-basin, which allows estimated runoff to be calculated as though areas with low CN values will be able to accept runoff from impervious areas for infiltration. This may not be true in all instances.

5.4 Application to Other Watersheds

Further review of the CN values assigned to the land use/land cover and soil types is needed, as some of the values may need to be adjusted for future use. The CN values used in the GIS-based CN tool include many values that are at or below 40. Although this may be appropriate in other regions, it may not be applicable for the entire Harris County region. The moisture content of the soil will affect the volume and rate at which the soil is able to infiltrate rainfall. The CNs for some of these land use/land cover and soil types may need to be increased to better reflect the high humidity, historical rainfall amounts, and the high water table of the region. Also, the substrate in Cypress Creek is primarily sand which does not represent the entire region, whereas other watersheds within Harris County contain a higher clay content.

In addition, the distance of the sub-basin to the sampling station should be considered when using the estimated runoff values in conjunction with the sampling data. The estimated runoff values are the total estimated runoff from the areas upstream of the sampling stations without regard to time. It does not take into account the time required for runoff in the upper sub-basins to reach the sampling station. Spatial elements are not considered and the tool does not allow for routing discharges through conveyances such as concrete-lined channels. The CN tool does not account for discharges over large areas of various types of impervious cover or discharges directly into Cypress Creek. The watershed should be modeled based on the discrete CN values, the climatology and soil conditions for the watershed, and the time variation of runoff from the various sub-basins in order to achieve a more accurate runoff estimate. Appropriate adjustments should be made to the CN tool in order to make this applicable to other watersheds.

5.5 Conclusions/Lessons Learned

Cypress Creek is approximately 53 miles long from its headwaters in Waller County to its confluence with Spring Creek in Harris County. The drainage area for this watershed, including the Little Cypress Creek sub-watershed, is approximately 322 square miles (TNRCC 1994).

Access to the upper portions of the creek channel is very limited due to large parcels of privately owned land and the lack of bridge crossings and public right-of-way (ROW). These areas required additional fieldwork effort for both reconnaissance and sampling activities. The more urbanized areas within the watershed provided more access through public ROW and bridge crossings for launching canoes and inner tubes and facilitating hikes along the streambank. Cypress Creek is characterized by very steep sandy bluffs, heavily wooded terrain, and dense vegetation. Log-jams and debris snags were common obstructions in the upper reaches of the creek.

It is evident that the majority of pipe outfalls located in the watershed do not discharge directly into Cypress Creek. Rather, storm water pipes draining upper watershed areas discharge into flood control channels or natural tributaries prior to reaching Cypress Creek. This study focused on the main-stem of Cypress Creek and included a windshield survey of sub-watershed areas adjacent to Cypress Creek. However, by focusing sampling efforts only along the main-stem of Cypress Creek, the data represents a composite of the 65 sub-watershed drainage areas, rather than characterizing the sub-watershed drainage areas. According to land cover data from 2002, these individual sub-watersheds include some land uses that are not found along the main-stem of Cypress Creek. Sampling at 28 outfall sources when there are 65 sub-watershed areas may not adequately describe the water quality shifts along the creek's main-stem as these sub-watershed areas flow into Cypress Creek. Also, water quality problems in the sub-watershed drainage areas themselves will not be readily identified. One of the lessons learned that can be applied to urban watersheds of this magnitude is to also focus dry and wet weather sampling activities on significant sub-watershed drainage areas so as to develop information on the effects of specific land uses or specific activities within those sub-drainage areas.

Overall, more exceedances of *E. Coli* bacteria during dry weather were observed in Sections A and B of the watershed; however, bacteria levels were also elevated in Section D. Although development is occurring within Section A, land cover data from 2002 indicates that this section is characterized mainly by grasslands with small pockets of development. Section A contains large areas of cultivated land and pastures where grazing livestock are present. If the livestock have free access to Cypress Creek as a drinking water source, then these agricultural areas adjacent to the creek may contribute high levels of bacteria to the creek. Implementing BMPs for these types of agricultural activities, such as fencing off the creek and installing water troughs for the livestock to drink from, could assist in decreasing bacteria loads from agricultural sources into Cypress Creek. Outfall A-8 discharged elevated bacteria and ammonia levels to Cypress Creek. This subdrainage area should be evaluated further for pollutant sources and development of pollutant source controls.

Another possible source of pollutants in Section A includes areas where development was observed and documented. As development continues westward in the watershed, disturbed areas from construction activities can potentially discharge various pollutants to the creek. The highest TSS results were observed in Section A and at the beginning of Section B. *Figure 8*, illustrates a large area of intense development, and the associated construction activities may explain the high TSS levels.

Section B is characterized by high and low intensity developments and is currently a developing watershed. The land coverage changes abruptly between Sections A and B. However, some of the sub-watersheds in Section B are still undeveloped within their upper reaches. Section B exhibited numerous exceedances of bacteria concentrations. One outfall source was a 6-inch PVC pipe discharging from an amenity pond directly into Cypress Creek. This was in a highly developed area of Section B that contained a corporate retreat with recreational facilities and an amenity pond, providing habitat for ducks, fish and turtles as observed. The intense smell similar to that of an aquarium, and the intense green color of the water indicated highly eutrophic conditions. This sample exhibited the highest overall level of bacteria, ammonia, and the lowest DO in the entire study. Drawing a conclusion from the observations, an assumption could be made that the source of bacteria in this case is from domesticated waterfowl and other wildlife. This outfall is a significant point source and should be investigated further for opportunities to mitigate pollutant loadings, such as using wetlands or filtering media before discharging into Cypress Creek. These types of BMPs, along with public education efforts on water quality management, would assist in controlling loads from these types of sources into the stream.

Because the sampling during this study resulted in a greater number of bacteria exceedances in the less developed areas, a conclusion can be drawn from this dataset that less developed areas can also contribute significant bacteria loadings to the watershed. For example, the Little Cypress Creek sub-watershed drains large portions of undeveloped grasslands and cultivated land associated with agricultural uses in its upper reaches. Although the upper reaches of the Little Cypress Creek sub-watershed were not sampled in this project, land cover data indicate that land uses are similar to those of Section A of Cypress Creek. These may include equestrian centers, stables, and smaller areas where livestock are raised. These types of activities can potentially contribute bacteria to the Cypress Creek watershed, and similar controls identified for Section A may be appropriate for these type of activities in Section B.

Section C is also highly developed, but more so within the sub-watershed areas than Section B. It is interesting to note that the instream bacteria and ammonia criteria are met in the first portion of this section up to the upstream sampling site of outfall C330P008. This outfall source is a WWTP discharge point, and it discharged elevated ammonia levels. Its downstream sampling site also had elevated ammonia levels. However, bacteria remained below the criterion at the outfall and its upstream and downstream locations. Immediately downstream, outfall C330P010, a park and recreation complex, had high bacteria and ammonia levels in its discharge. In addition, elevated ammonia levels were detected at its upstream and downstream sampling sites. Bacteria levels were elevated in the discharge from this outfall, but not at its upstream and downstream sampling locations.

However, all ammonia levels for the three sets of upstream and downstream sampling points that follow outfall C330P010 in Section C remain elevated above the criteria. Two of the three outfalls (outfalls C332T005 and C32P019) also discharged elevated ammonia levels above the criteria. The trend of elevated ammonia levels at most of the instream upstream and downstream sampling sites continued through Section D. This trend may be explained by the increasing dominance of WWTP effluent comprising the flow of Cypress Creek. Seventy-two WWTPs discharge above Section D, and 95 plants discharge in all four sections of the creek. Given this high number of plants, perhaps a regional wastewater facility master-plan should be evaluated for use in this area.

The bacteria levels behave somewhat differently than the ammonia levels in Sections B and D. The bacteria levels are met in both instream and outfall discharges in Section C, with the exception of the discharge from outfall C330P010, the park, and recreation complex. Both upstream and downstream sampling sites meet the bacteria criteria until outfall D333P005. Starting at this outfall location and continuing downstream, the upstream and downstream (instream) sampling sites have elevated bacteria levels, but the outfall source discharges do not.

A runoff analysis for Cypress Creek was conducted using a Curve Number (CN) method developed by the NRCS. Composite CN values were determined using a GIS-based dataset provided by H-GAC. Upon review of the CN values assigned to the land cover and soil types, some of the values may need to be adjusted for future use. The composite numbers used in the GIS-based CN tool include many values that are at or below 40 which significantly influence the average sub-basin CN value. Although this may be appropriate in other regions, it may not be appropriate for the Cypress Creek watershed. It is expected that the sandy substrate in Cypress Creek will have greater infiltration rates than other substrate types found in other watersheds within Harris County or the H-GAC region.

The CN values for some of these land cover and soil types may need to be increased to better reflect the high humidity, historical rainfall amounts, and the high water table of the region. In order to achieve a more accurate runoff estimate, the Cypress Creek watershed should be modeled based on the discrete CN values, the climatology and soil conditions for the watershed, and the time variation of runoff from the various sub-watersheds. The tool does not consider the spatial elements and does not account for routing discharges through conveyances such as concrete-lined channels. These types of conveyances contribute significant flows into Cypress Creek especially in areas of high intensity development (*Figure 1*). The CN tool does not account for discharges over large areas of various types of impervious cover or discharges directly into Cypress Creek. The TSARP sub-watershed boundaries were used in this analysis as these delineations are the latest, most current and accepted delineations available for this area (*Figure 13*). The CN tool used to evaluate runoff in this study should be adjusted to increase effectiveness during its application to other watersheds in the region.

Although this study served to characterize the entire watershed with regard to ammonia and bacteria sources, more intensive surveys or long-term studies should be conducted to better understand nutrient and bacteria loadings into Cypress Creek. Further studies should focus on the sub watersheds within Segment 1009 to more effectively evaluate the effects of individual pollutant sources on the Cypress Creek segment. Further evaluation and perhaps bacteria source tracking (BST) analysis would provide useful information in developing and implementing long-term watershed management plans within this watershed and could perhaps assist in better understanding water quality dynamics and pollutant loadings in other urban watersheds.

Further evaluation of bacteria sources and determination of bacteria origins would provide information for developing long-term watershed management strategies as development continues westward in the watershed. After statewide indices are fully developed, bacteria source tracking or simply differentiating between human and non-human origins may be beneficial for implementing long-term management strategies in the watershed with regard to bacteria loading.

Section 6

6.1 References

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