Total Maximum Daily Loads for Fecal Pathogens in the Clear Creek Watershed

Contract No. 582-0-80121

Work Order No. 582-0-80121-09

Final Report

Prepared by
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Prepared for

Total Maximum Daily Load Program
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CHAPTER 1

INTRODUCTION

Six water body segments in the Clear Creek Watershed, which is located south of Houston, Texas, are on the Texas Clean Water Act §303(d) list for bacteria impairments for the designated use of contact recreation. Segments located within the Clear Creek Watershed with bacteria impairments include Clear Creek Tidal (1101), Clear Creek Above Tidal (1102), Chigger Creek (1101B), Cowarts Creek (1102A), Mary's Creek/North Fork Mary's Creek (1102B), and Robinson Bayou (2425C). The segments are located in Harris, Galveston, Brazoria, and Fort Bend Counties in Texas and are shown in Figure 1.1. The objectives of this phase of the TMDL project are to assess the magnitude and frequency of bacteria exceedances and to begin the process of assessing the sources, fate, and transport of bacteria in the listed segments. This report is the final report for the project and it details progress accomplished from February through August 2005.

1.1 SCOPE OF THE PROJECT

The scope of work for this project includes: (i) an assessment of the *E. coli*, fecal coliform, and Enterococci levels and trends in the Clear Creek watershed based on historical data, (ii) a preliminary assessment of major sources, fate, and transport of bacteria contamination in the target water bodies based on historical and current data, (iii) development of a sampling plan and quality assurance project plan to collect data, (iv) an assessment of the methods that may be used to determine the components of the TMDL equation, and (v) participation in the

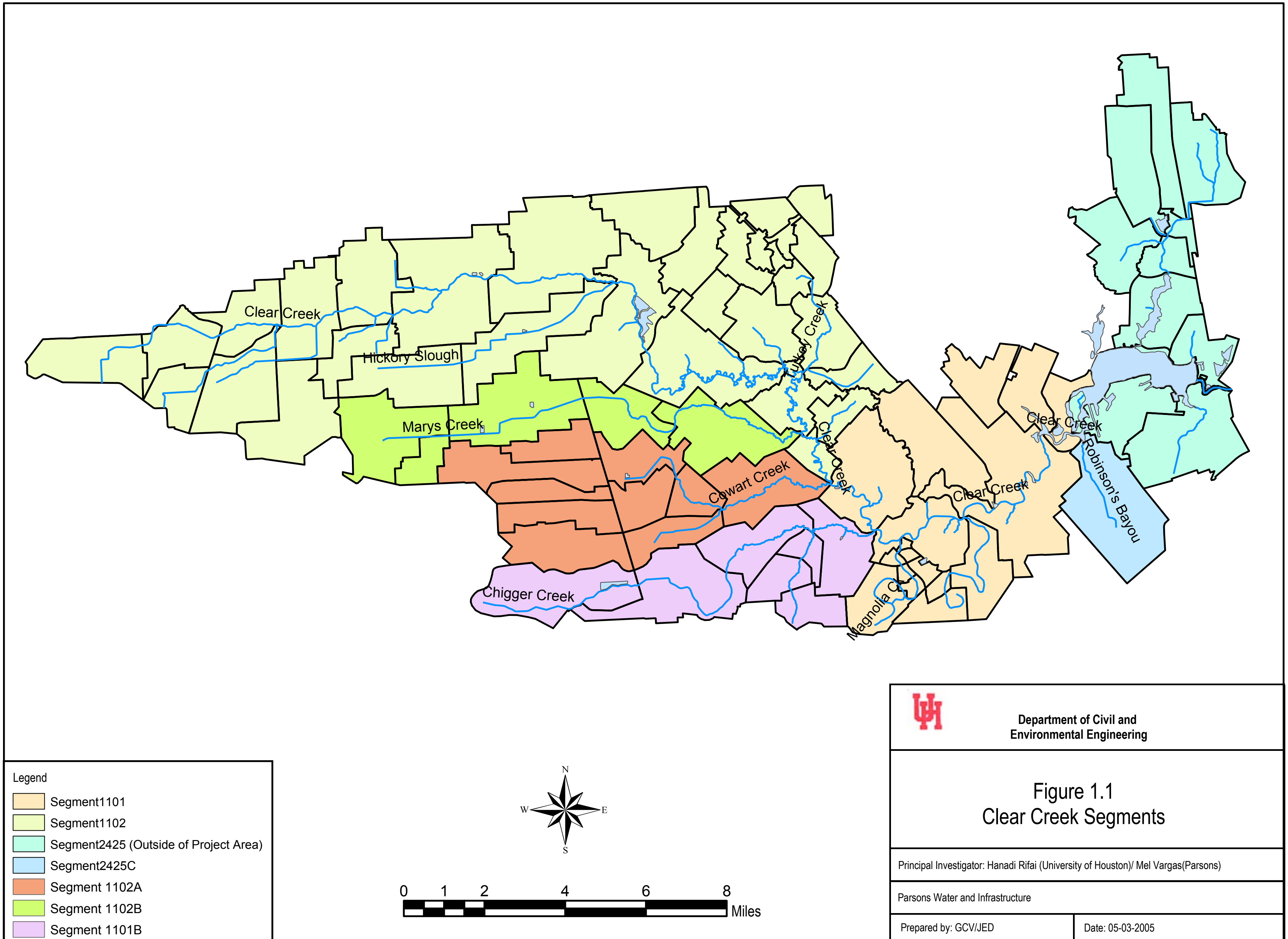

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Figure 1.1
Clear Creek Segments

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

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Prepared by: GCV/JED

Date: 05-03-2005

stakeholder process.

1.2 DESCRIPTION OF THIS REPORT

This document constitutes the final report for Work Order No. 9 and summarizes the activities undertaken by the University of Houston and Parsons Water and Infrastructure, Inc. from February 2005 through August 2005. The report reflects the progress towards many of the tasks delineated in the Project Scope of Work. Chapter 2 of this report describes the Clear Creek watershed. Chapter 3 details the historical data that have been gathered to assess the fecal pathogen levels of surface waters in the Clear Creek Watershed. Chapter 3 also includes an inventory of the major sources of fecal pathogens and an assessment of the methods that may be used to determine elements of the TMDL equation. Chapter 4 of this report discusses the Quality Assurance Project Plan (QAPP) development for the investigation; this addresses Task 4 of the Project Scope of Work. The QAPP specifies the data quality objectives, technical sample collection and analysis methods, and quality assurance procedures in accordance with the QAPP guidelines established by TCEQ and EPA. For Task 3, a QAPP was completed and submitted to TCEQ which details the methods for collection of field data and analytical sampling efforts. Chapter 4 also includes the monitoring and data collection procedures conducted during the project. Chapter 5 presents the conclusions from the sampling and analyses completed in the project. Appendix A of this report details the sampling plan.

CHAPTER 2

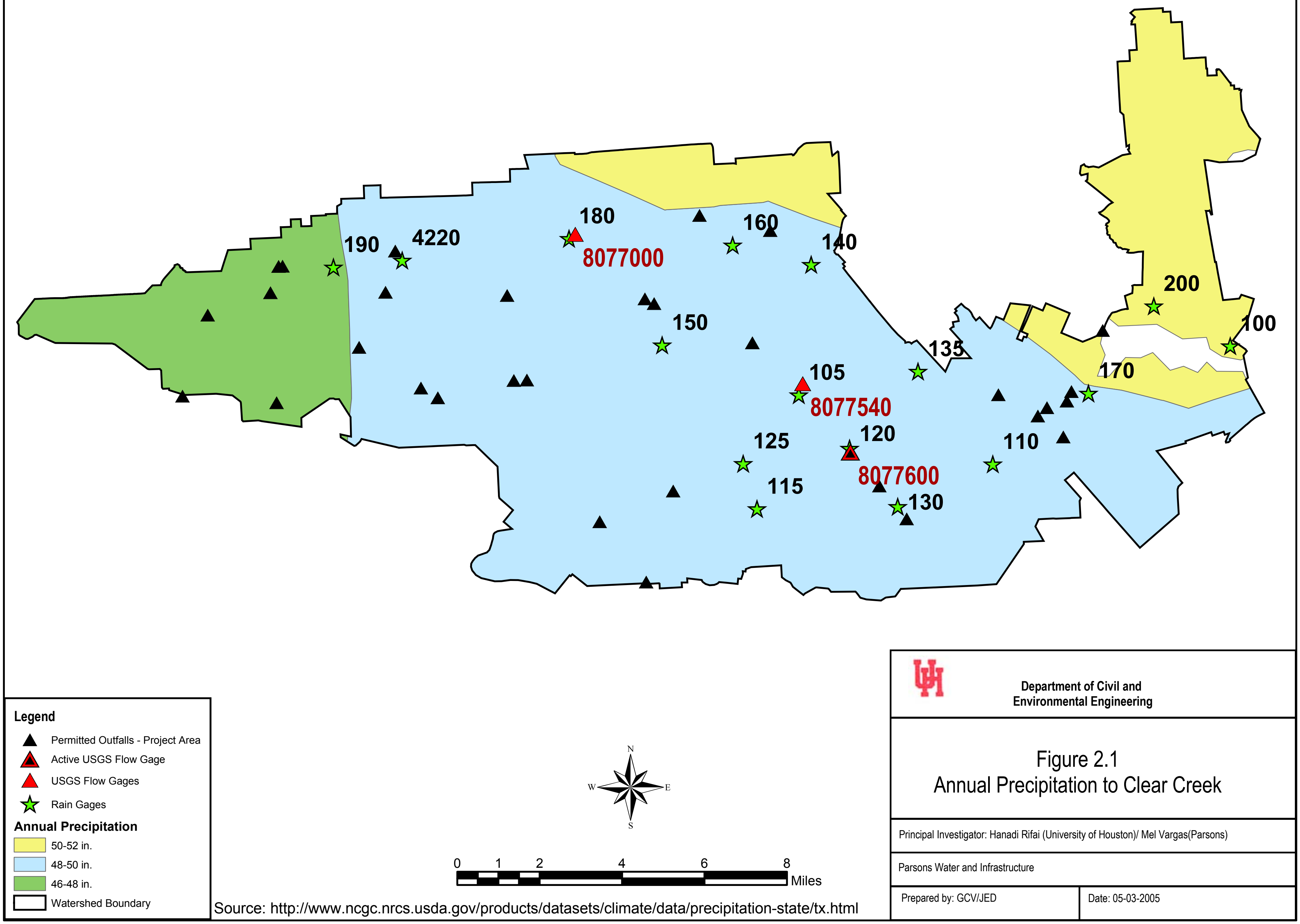
THE CLEAR CREEK WATERSHED

2.1 DESCRIPTION OF THE WATERSHED

The Clear Creek Watershed encompasses 200 square miles of land located just southeast of the city of Houston, Texas. The Clear Creek watershed that includes all of the area that contributes surface water to segments 1101, 1102, and 2425C drains into Clear Lake which in turn feeds to Galveston Bay. The watershed contains freshwater and tidally influenced segments.

The Clear Creek watershed contains upland and palustrine forest wetlands, wet and dry prairie-land, and supratidal, subtidal, intertidal and submerged aquatic vegetation marshes (USACE 2004). The region has high levels of humidity and receives an annual precipitation ranging between 46 to 52 inches per year. Figure 2.1 illustrates the historical annual precipitation ranges for the watershed obtained from the National Resource Conservation Service (NRCS). Sixteen rain gages are located within the watershed and are maintained by the Houston-Galveston Area Council (HGAC). Rain gage 4220 recorded erroneous data and was left out of these analyses of rainfall to preserve the accuracy of the data. The cumulative rainfall recorded at the remaining fifteen gages for each of the years 1999 through 2004 has been tabulated in Table 2.1. Based on the 1999 to 2004 data, the watershed average is around 57 inches.

The climate of the region is subtropical humid, with very hot and humid summers and mild winters (USACE 1985). The average maximum daytime temperature is 34 degrees Celsius while the temperature averages between 4 and 16 ºC during the winter. Summer month rainfall



Source: http://www.ncgc.nrcs.usda.gov/products/datasets/climate/data/precipitation-state/tx.html

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Figure 2.1
Annual Precipitation to Clear Creek

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

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Table 2.1 Annual Totals (in inches) at Rainfall Gages in Clear Creek Watershed

Gage Number	Year						Average
	1999	2000	2001	2002	2003	2004	
Gage 100	73.1	43.3	57.7	55.2	58.2	49.0	56.1
Gage 105	N/A	46.9	78.1	68.7	53.0	55.6	60.5
Gage 110	30.9	52.0	77.0	81.3	59.4	58.7	59.9
Gage 115	N/A	48.6	56.4	70.6	N/A	62.7	59.6
Gage 120	35.7	35.1	74.7	77.9	52.5	64.2	56.7
Gage 125	N/A	36.3	72.6	78.0	53.0	64.0	60.8
Gage 130	N/A	45.3	80.4	75.0	55.3	67.1	64.6
Gage 135	N/A	N/A	N/A	79.9	42.6	59.9	60.8
Gage 140	34.9	46.2	69.3	68.0	47.0	59.0	54.1
Gage 150	35.6	49.9	77.4	62.1	37.0	59.4	53.5
Gage 160	32.8	45.7	64.5	74.9	48.7	59.4	54.3
Gage 170	31.4	38.5	60.9	61.6	54.3	57.7	50.7
Gage 180	47.1	23.6	80.5	69.5	48.9	57.3	54.5
Gage 190	48.2	42.0	65.9	58.8	46.7	55.1	52.8
Gage 200	N/A	N/A	80.5	68.7	61.1	66.5	69.2

Average Annual for the Entire Watershed 57.3

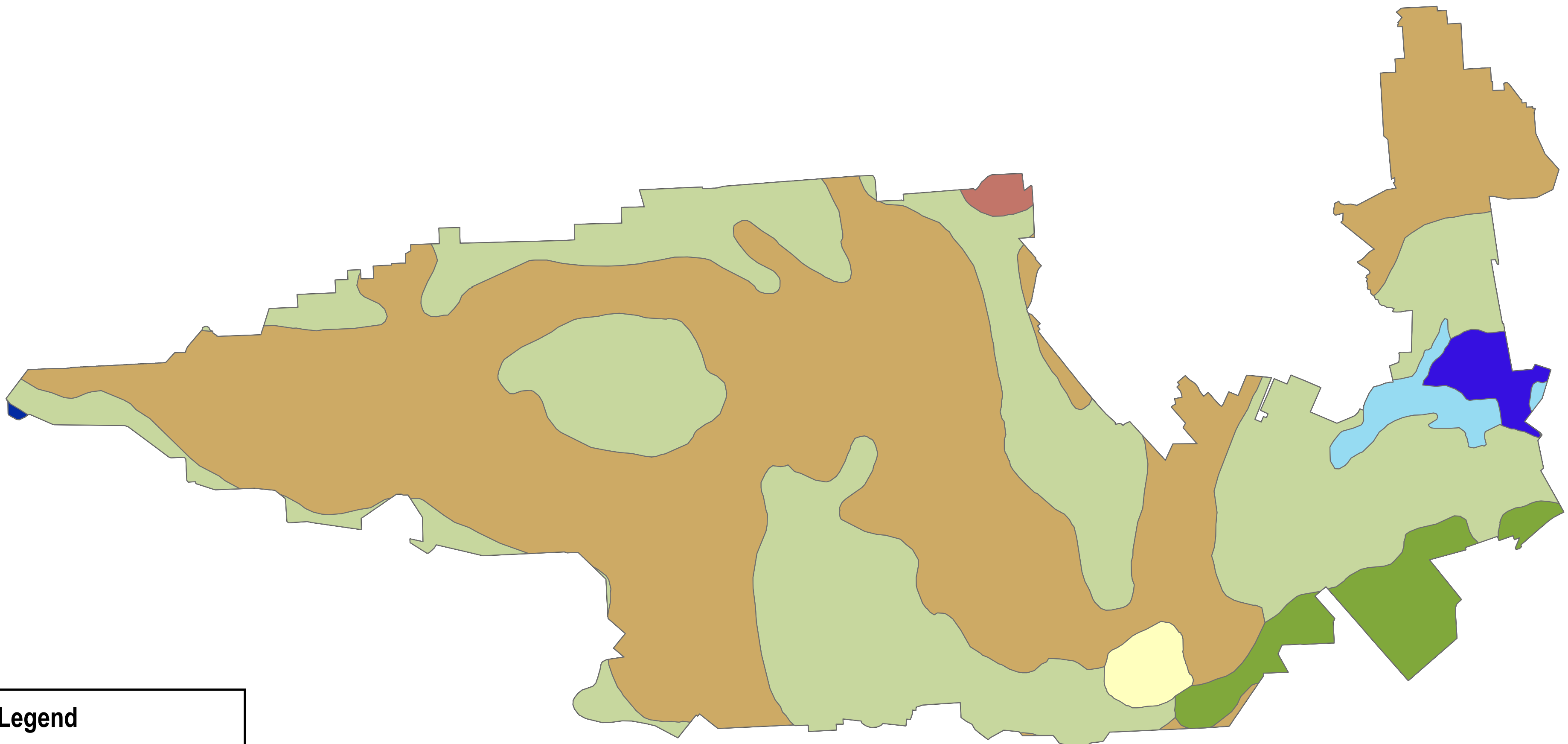
N/A = not available

See Figure 2.1 for gage locations

is dominated by sub-tropical convection, winter months by frontal storms, and fall and spring months by combinations of these two (Burian 2004).

The geology of the Clear Creek watershed region is comprised of unconsolidated clays, clay shale, and poorly-cemented sands that extend several miles in depth (TNRCC, 2005). The soils have a low bearing capacity, high-moisture content, low permeability, and a high shrink-swell potential. As can be observed in Figure 2.2, the soil types that dominate the watershed are TX276 and TX163 as defined by the NRCS. Other soil types within the boundaries include TX007, TX031, TX100, TX162, TX248, TX346, and TX423. Table 2.2 describes the attributes and compositions of each of these soil types. The land surface slopes at a percent change of only about 0.03% toward the southeast (USACE, 1985). The highest elevations within the watershed reach 75 feet above mean sea level. Near the mouth of Clear Creek where the flow discharges into Clear Lake, the land elevation decreases to mean sea level (USACE, 1985).

The Texas Commission on Environmental Quality (TCEQ) designated the Clear Creek Tidal (Segment 1101) portion of the Clear Creek and Robinson's Bayou (Segment 2425C) as tidally influenced streams. The other segments included in this TMDL study are designated by the TCEQ as freshwater streams, including Chigger Creek (1101B), Clear Creek Above Tidal (Segment 1102), Cowart Creek (1102A), and Mary's Creek/North Fork Mary's Creek (Segment 1102B). The tidal influence within Clear Creek creates a median high tide level of 2.0 feet; this level reaches an average of 3.3 feet above sea level on an annual basis during peak tide (Drainage 1985).

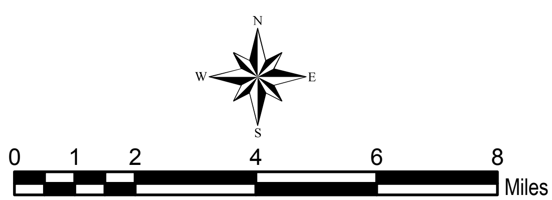


Legend

Soil Types

MUID

- TX007
- TX100
- TX162
- TX163
- TX248
- TX276
- TX346
- TXW
- Watershed Boundary



Note:
Descriptions of the soil types is found in Table 1.2A

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Figure 2.2
Clear Creek Region Soil Types

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

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Date: 05-03-2005

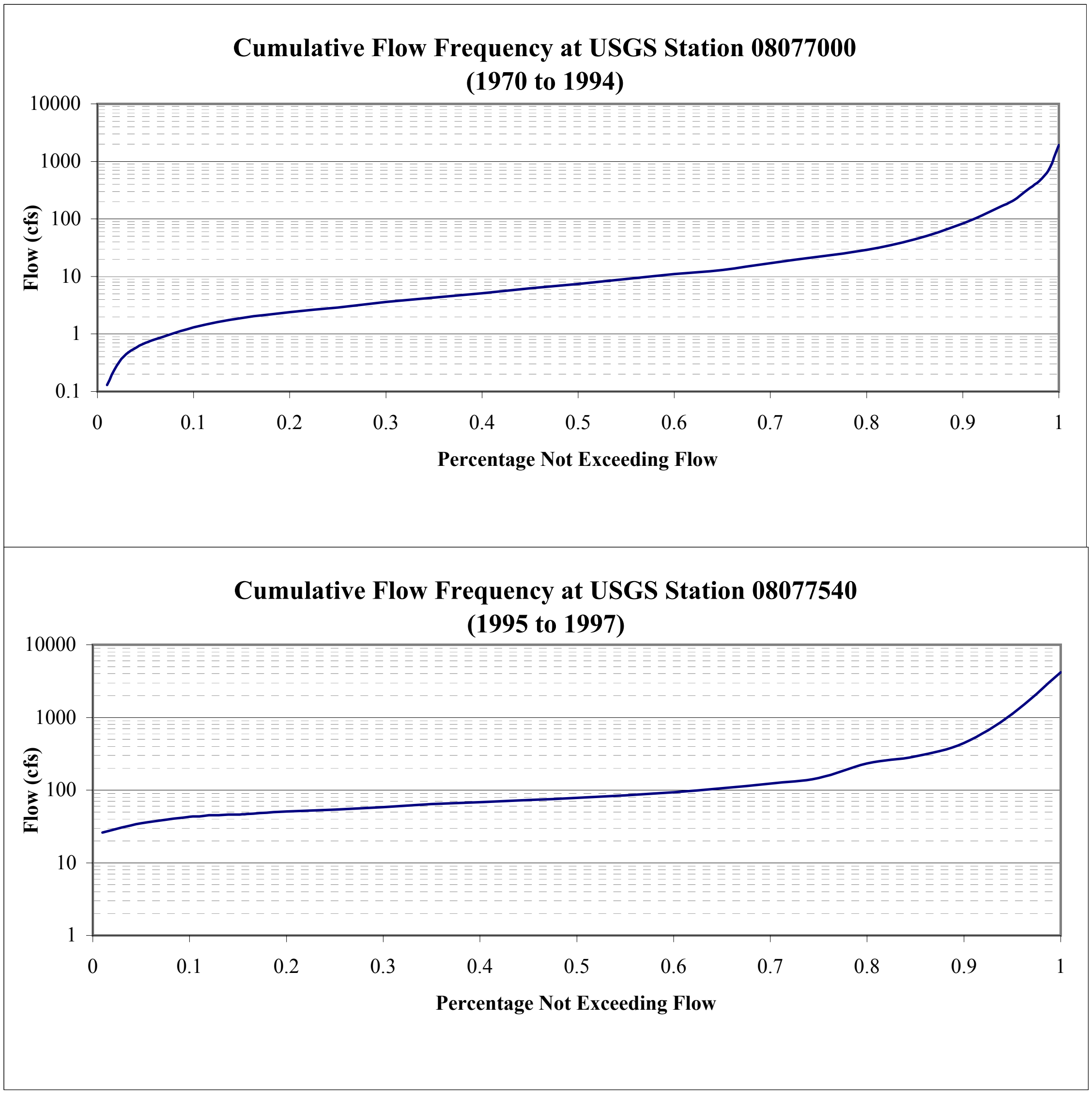
Table 2.2 Characteristics of Soil Types within the Clear Creek Watershed

NRCS Soil Type	Suface Texture	Hydrologic Soil Group	Soil Drainage Class	Total % Coarse Sand	Total % Medium Sand	Total % of Fine Sand	Total % of Sand	Total % of Silt	Total % of Clay	Avg. Sed. Diameter (in.)	Weighted Avg Water Capacity
TX007	Fine Sandy Loam	D	Somewhat Poorly Drained	0%	12%	33%	45%	42%	11%	0.0097	0.14
TX031	Silt Loam	B	Well Drained	0%	3%	12%	15%	56%	28%	0.0036	0.17
TX100	Loam	D	Poorly Drained	2%	3%	31%	36%	52%	11%	0.0069	0.16
TX162	Fine Sandy Loam	D	Somewhat Poorly Drained	1%	5%	24%	30%	50%	20%	0.0065	0.16
TX163	Fine Sandy Loam	D	Somewhat Poorly Drained	1%	6%	19%	27%	49%	24%	0.0066	0.17
TX248	Fine Sandy Loam	D	Somewhat Poorly Drained	1%	1%	43%	45%	43%	11%	0.0061	0.16
TX276	Clay	D	Somewhat Poorly Drained	1%	7%	7%	15%	47%	38%	0.0057	0.17
TX346	Silt Loam	D	Somewhat Poorly Drained	1%	3%	15%	19%	56%	24%	0.0050	0.17
TX423	Clay	D	Moderately Well Drained	0%	3%	5%	8%	30%	61%	0.0026	0.15

Notes:
All data obtained/calculated from STATSGO data
Weighted Avg H2O Capacity is in units of (inches of water/inch of soil)

The US Geological Survey set up flow gages at three locations along Clear Creek to measure flow and elevations. The locations of these gages are shown on Figure 2.1. The cumulative flows at USGS gages 08077000 and 08077540 were calculated and have been included in Figure 2.3. The USGS collected flow data at gage 08077000 from January 1, 1970 to September 4, 1994. The 50% value or median flow at this gage was 7.4 cubic feet per second for this period. The USGS collected flow data at gage 08077540 from October 1, 1995 to August 25, 1997. The median flow measured during this period was 78.5 cubic feet per second. The third USGS flow gage (8077600) collected eighteen discharge measurements between 10/8/1997 and 8/17/2002 and stream elevations between 2/14/2005 and 2/21/2005 and, as a result, cumulative flow frequencies over a substantial period of time could not be determined. The flows for this last gage ranged between 2290 and 10600 cfs with a median value of 4955 cfs. This gage is currently the only active flow gage in the watershed; therefore, this value may not be representative of normal flow conditions at this location. More data would need to be collected to calculate an accurate estimate of the flow.

The water bodies in this project have been designated by the TCEQ for contact recreation uses. As a result, the standard set for fecal pathogen indicator concentrations in bodies of water with this designation applies to each of the segments covered by this TMDL. The applicable standards are listed in Table 2.3. Clear Creek has seven incorporated cities, twelve independent utility districts, and seven drainage districts within its watershed. According to data obtained from the HGAC (2002), the Clear Creek region is 23.5 % developed, 39.0 % cultivated land/grassland, 18.2 % woody land, 4.4 % open water, 8.5 % wetland, and 6.4 % bare/transitional regions (see Figure 2.4).



Notes:
cfs = Cubic Feet per Second

Figure 2.3 Cumulative Flow Frequency Curves at USGS Stations along Clear Creek

Table 2.3 Water Quality Standards for Contact Recreation

Fecal Pathogen Indicator	Geomean Standard	Single Sample Limit
Fecal Coliform (cfu/100 mL)	200	400
Escherichia coli (MPN/100 mL)	126	394
Enterococci (MPN/100 mL)	35	89

Notes:
mL = milliliters,
cfu = colony forming unit
MPN = most probable number

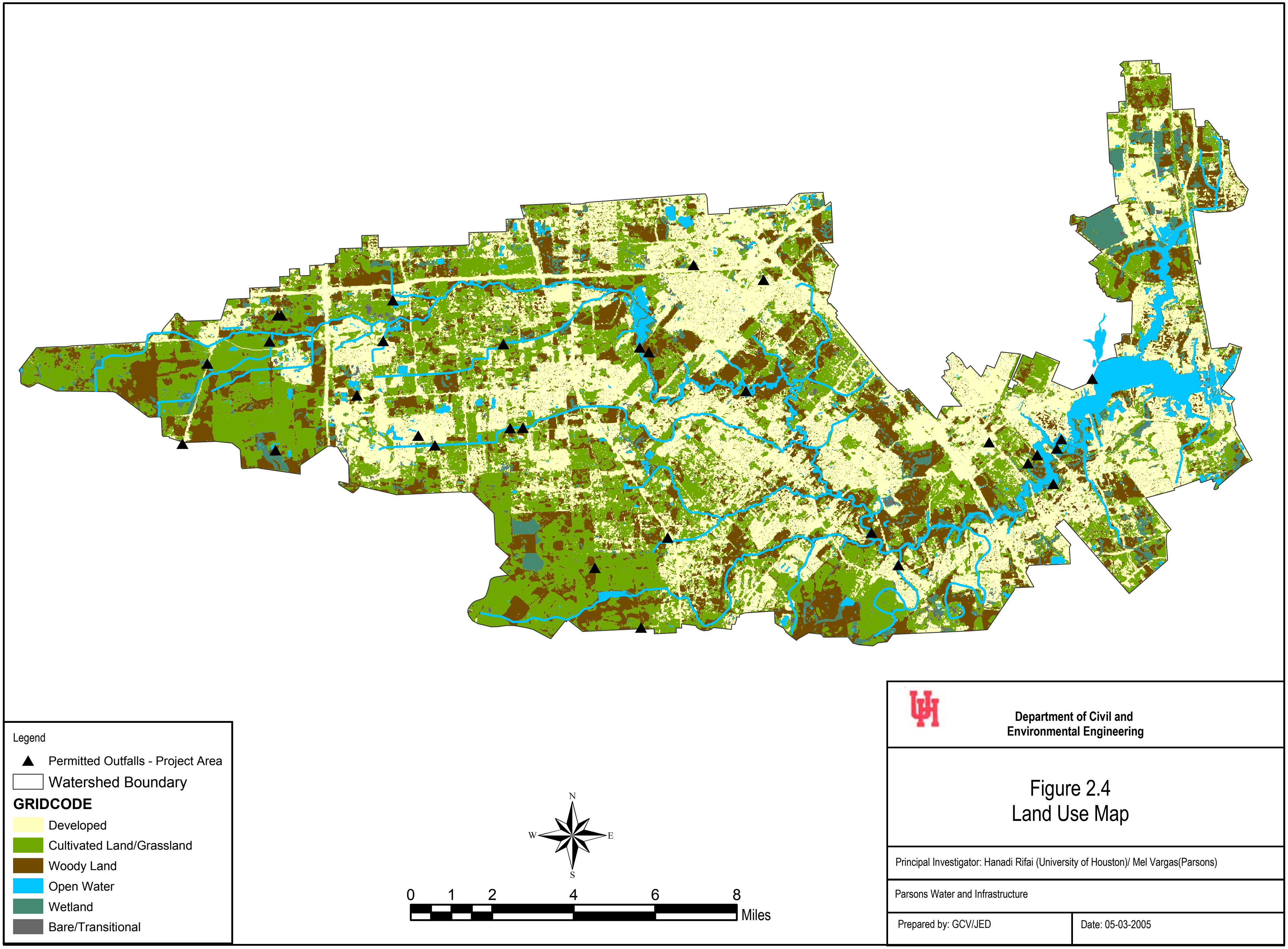


Figure 2.4
Land Use Map

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

Parsons Water and Infrastructure

Prepared by: GCV/JED

Date: 05-03-2005

2.1.1 Land Use

The Clear Creek watershed covers approximately 200 square miles, and stretches through Harris, Fort Bend, Brazoria and Galveston Counties. Approximately 34 to 39 percent of the land in the watershed is used for agricultural purposes, but a significant portion (approximately 24 to 26%) is developed land. Two land use classifications for the Clear Creek Watershed area have been developed. The National Land Cover Data set (NLCD) (Vogelmann 2001) was developed from Landsat satellite photographs taken in the early 1990s. A separate 2002 study by the Houston-Galveston Area Council (HGAC) defines the general distribution of land cover throughout the 13 county HGAC region. Created during the summer of 2002, this data set was based on 2001 and 2002 Landsat 5 Thematic Mapper (TM) and Landsat 7 Enhanced TM satellite imagery. Refer to Tables 2.4 and 2.5 and for details. Also, the floodplain encompasses about 10% of the drainage area of the basin, approximately 12,800 acres (20 square miles) (Dunbar, 1998)

2.1.2 Population Density: Humans and Pets

The population of the Clear Creek watershed in 2000 was estimated to be 182,261 with an overall average population density of 907 persons per square mile (U.S. Census Bureau 2000). Based on census projections, the July 1, 2005 population of the watershed may be estimated at 200,635 with an overall average population density of 998 persons per square mile (U.S. Census Bureau 2000). Approximately 50,000 cats and 44,000 dogs are also estimated to reside in households within the watershed, based on the 2005 census data projection along with national averages of pets per household from the American Veterinary Medical Association (2002).

Table 2.4 NLCD Land Use Classifications

NLCD Land Use Classification	Acres	% of Area
Open Water	3374	2.8%
Low Intensity Residential	13042	10.6%
High Intensity Residential	8865	7.2%
Commercial/Industrial/Transportation	10328	8.4%
Bare Rock/Sand/Clay	399	0.3%
Quarries/Strip Mines, Gravel Pits	44	0.0%
Deciduous Forest	19523	15.9%
Evergreen Forest	9999	8.1%
Mixed Forest	647	0.5%
Shrubland	1736	1.4%
Grasslands/Herbaceous	5114	4.2%
Pasture/Hay	35624	29.0%
Row Crops	5264	4.3%
Small Grains	494	0.4%
Urban/Recreational Grasses	3150	2.6%
Woody Wetlands	1380	1.1%
Emergent Herbaceous Wetlands	3850	3.1%
Total	122831	100%

Table 2.5 Houston Galveston Area Council Classifications

H-GAC Classifications (DATE)	Acres	% of Area
Developed	39104	23.5%
Cultivated Land/Grassland	64896	39.0%
Woody Land	30285	18.2%
Open Water	7322	4.4%
Wetland	14144	8.5%
Bare/Transitional Regions	10650	6.4%
Total	166400	100%

The 12 largest cities within the watershed are expected to increase in population by an average of 36 percent from 2000 to 2020, according to the TWDB (Montgomery Watson America, Inc. 2000). As a result, these 12 cities alone are projected to increase the demand for water from 23,071 acre-ft to 33,957 acre-ft. Table 2.6 lists TWDB population growth estimates for the 12 cities from 2000 to 2020 while Table 2.7 shows their estimated water demand growth. These cities are shown in Figure 2.5.

2.1.3 Sewered and Non-Sewered Areas

The method of sewage disposal for housing units in the Clear Creek watershed was estimated from the 1990 federal census at the block group level because these data were not collected in the 2000 census (U.S. Census Bureau 1990). Table 2.8 shows the sewered and non-sewered data for the Clear Creek watershed area. Because of rapid urbanization in the watershed, estimates based on these data may no longer be accurate. At that time, approximately 8 percent of households in the watershed utilized septic tanks for sanitary waste disposal, while approximately 92 percent were connected to a sanitary sewer system. Approximately 260 housing units in the watershed were reportedly not connected to a sanitary sewer system.

2.1.4 Livestock Populations

The smallest unit for which livestock census data are available is on a county level. The data indicate beef cattle to be the dominant livestock species in the watershed (Table 2.9). Other livestock species present in the watershed include horses, goats, chicken, and hogs. Livestock populations were estimated from the 2002 agricultural census of the National Agricultural Statistics Service of the U.S. Department of Agriculture, or from more recent estimates of the Texas Agricultural Statistics Service, when available.

Table 2.6 Clear Creek Watershed Population Increases by City, 2000 to 2020

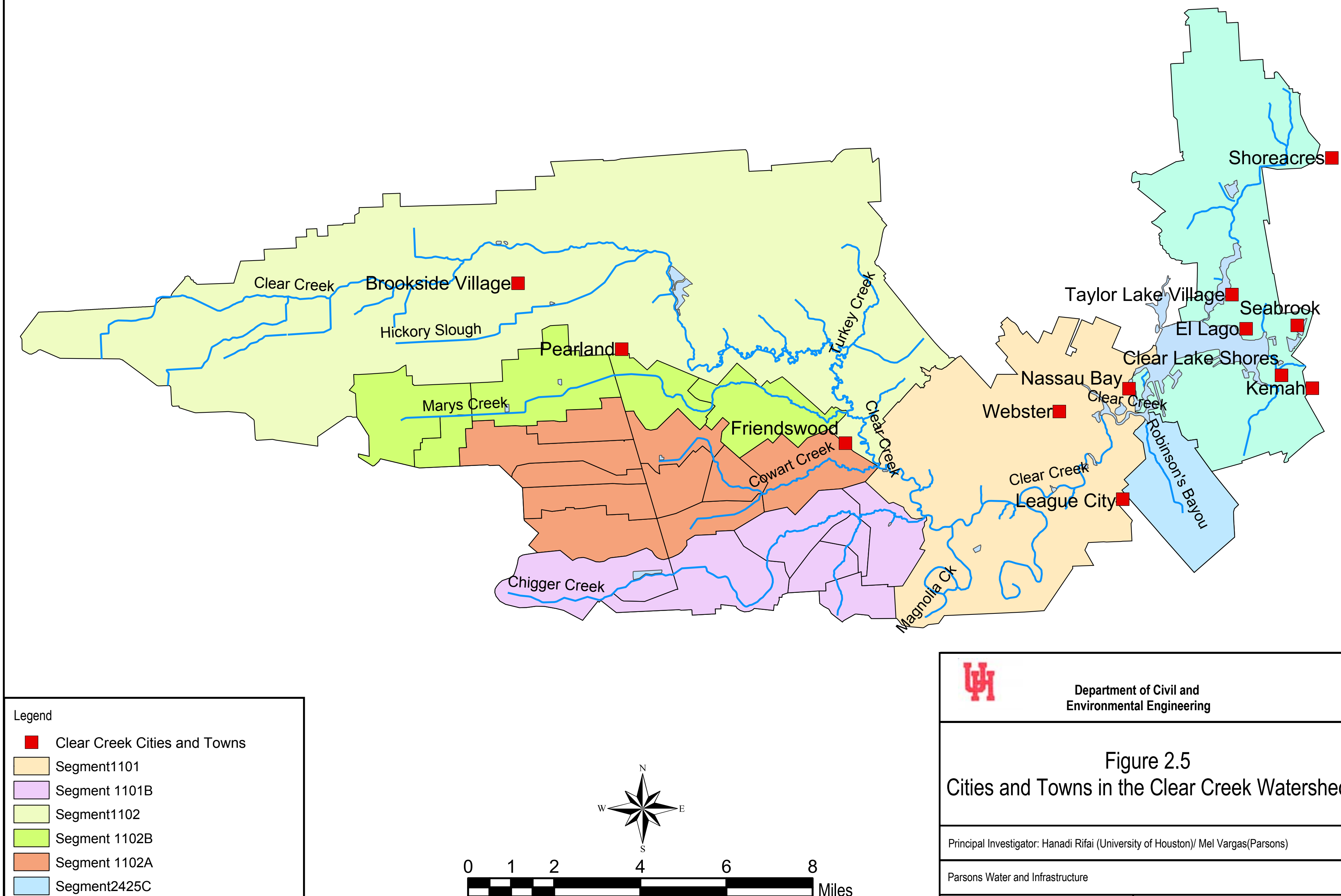
City	2000 Census Population	2010 Population	2020 Population	Growth Rate (2000-2020)
Brookside	2,059	2,282	2,551	40.1%
Clear Lake Shores	1,354	1,839	2,377	23.5%
El Lago	3,795	4,374	5,090	16.1%
Friendswood	32,416	44,762	61,567	42.1%
Kemah	1,625	1,708	1,815	48.5%
League City	46,961	54,711	63,313	55.7%
Nassau Bay	4,873	5,584	6,485	12.8%
Pearland	31,983	42,347	53,105	71.1%
Seabrook	9,478	10,921	12,710	41.8%
Shoreacres	1,650	1,900	2,212	25.4%
Taylor Lake Village	4,205	4,817	5,595	23.9%
Webster	6,242	7,152	8,309	33.4%

Source: http://www.twdb.state.tx.us/data/data.asp (June 2005)

Table 2.7 Clear Creek Watershed Water Demand Increases by City, 2000 to 2020

City	2000 City Water Demand (ac-ft)	2010 City Water Demand (ac-ft)	2020 City Water Demand (ac-ft)	Growth Rate (2000-2020)
Brookside Village	239	266	296	23.9%
Clear Lake Shores	273	282	287	5.1%
El Lago	548	534	524	-4.4%
Friendswood	3,968	4,276	4,537	14.3%
Kemah	227	278	322	41.9%
League City	6,617	7,497	8,273	25.0%
Nassau Bay	1,042	1,028	1,014	-2.7%
Pearland	5,650	9,544	11,873	110.1%
Seabrook	1,967	2,421	2,867	45.8%
Shoreacres	192	204	217	13.0%
Taylor Lake Village	629	664	650	3.3%
Webster	1,719	2,417	3,097	80.2%

Source: http://www.twdb.state.tx.us/data/data.asp (June 2005)
Notes:
ac-ft = Acre feet



Legend

- Clear Creek Cities and Towns
- Segment1101
- Segment 1101B
- Segment1102
- Segment 1102B
- Segment 1102A
- Segment2425C
- Segment2425 (Outside of Project Area)

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Figure 2.5
Cities and Towns in the Clear Creek Watershed

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Parsons Water and Infrastructure

Prepared by: GCV/JED | Date: 05-03-2005

Table 2.8 Clear Creek Watershed Septic Data

Area	Housing Units Connected to Public Sewer	Housing Units Connected to Septic Tank	Other	Approximate Area (square miles)
All Census Tracts in/around Clear Creek WS	119,530	10,419	484	372
Estimate for Clear Creek WS*	64,218	5,598	260	200

Source:

U.S. Census Bureau 1990

Notes:
* The estimate for the Clear Creek watershed is calculated by multiplying the total connections for the Census Tracts in/around the Clear Creek watershed by watershed's percentage of the total area in square miles.

Table 2.9 Livestock Populations in Clear Creek

Livestock	Harris County	Fort Bend County	Brazoria County	Galveston County	Estimated Watershed Population
Cattle & Calves-All	49,000 †	51,000 †	91,000 †	15,000 †	8,899
Beef cows	30,000 †	36,000 †	55,000 †	11,000 †	5,677
Milk cows	5 ‡	0 ‡	0 ‡	0 ‡	0
Horses	6,093 ‡	3,400 ‡	4,496 ‡	1,353 ‡	669
Mules, burros, & donkeys	122 ‡	116 ‡	109 ‡	57 ‡	18
Hogs & Pigs	589 ‡	1,367 ‡	3,536 ‡	140 ‡	234
Goats-all	4,739 ‡	1,041 ‡	3,043 ‡	1,627 ‡	549
Sheep & Lambs	926 ‡	622 ‡	895 ‡	80 ‡	99
Rabbits	453 ‡	N/A	234 ‡	14 ‡	32
Llamas	237 ‡	N/A	55 ‡	135 ‡	28
Bison	N/A	27 ‡	‡	21 ‡	3
Domestic Deer	788 ‡	82 ‡	36 ‡	N/A	34
Chickens	11,875 ‡	2,226 ‡	154,616 ‡	1,539 ‡	8,543
Ducks-Domestic	1,082 ‡	172 ‡	N/A	255 ‡	76
Geese-Domestic	275 ‡	390 ‡	449 ‡	103 ‡	50
Ostriches-Domestic	N/A	N/A	53 ‡	32 ‡	7
Turkeys-Domestic	219 ‡	49 ‡	234 ‡	104 ‡	34
Pheasants-Domestic	36 ‡	220 ‡	N/A	N/A	4
Pigeons & Squabs- Domestic	158 ‡	N/A	N/A	N/A	6
Quail-Domestic	208 ‡	1,382 ‡	N/A	300 ‡	58
Emus	118 ‡	47 ‡	58 ‡	68 ‡	16
Other poultry*	1,069 ‡	200 ‡	1,413 ‡	126 ‡	132

Notes:

† As of January 1, 2005 Texas Agricultural Statistics Service

‡ 2002 Agricultural Census, USDA

*Other poultry that did not have a bar on the Census Form

** Watershed populations were calculated using the fraction of each county that lies within the Clear Creek Watershed

CHAPTER 3

BACTERIA IN THE CLEAR CREEK WATERSHED

3.1 REGULATORY BACKGROUND

The TCEQ adopted the limit of 394 per 100 mL for single samples of *E. coli* and a geometric mean limit of 126 per 100 mL for bodies of water that have been designated for contact recreation uses (Table 2.2B). Within tidal streams and salt-water bodies, however, the EPA determined that Enterococci concentrations provide the greatest correlation to those of fecal pathogens. The TCEQ adopted a limit of 89 per 100 mL for Enterococci in any single sample and a limit of 35 per 100 mL for the geomean of all samples at any location for Enterococci concentrations within any Tidal stream that has been designated for contact recreation uses (TCEQ - Texas Water Quality Standards - adopted July 26, 2000). During the process of switching over to the new standards, the EPA has recommended that the fecal coliform concentrations (400 per 100 mL in any single sample and 200 per 100 mL for the geomean of all samples) be used until at least ten data points have been collected for either of the two new standards that will be used for each segment.

3.2 GENERAL INFORMATION ON HISTORICAL DATA

Much of the fecal pathogen indicator data from Clear Creek and its tributaries has been collected by the Galveston County Health District and the TCEQ Region 12 that includes the Clear Creek watershed, Harris, Brazoria, Fort Bend, Galveston Counties, and several other counties. Additional data collection has been performed by the Houston Health and Human Services, the City of Houston Department of Public Works and Engineering, the City of Pearland, and the Environmental Institute of Houston (EIH). These organizations worked in collaboration with the TCEQ, the Houston-Galveston Area council, and the City of Houston to collect and analyze the data. Table 3.1 shows the number of samples that have been collected and submitted to the TCEQ from each of these sources.

Table 3.2 shows the number of fecal pathogen indicator samples that have been collected prior to this study, as well as the geomean of the concentrations for each indicator and the number and percentage of single sample exceedances in the TCEQ database at each monitoring station throughout the Clear Creek Watershed. For many of the stations, data for all three of the fecal pathogen indicators were found: fecal coliform, *E. coli*, and Enterococci. Based on the guidelines set by the EPA, one indicator was selected to assess fecal pathogen levels at each monitoring station depending on the location of the station and the amount of data collected. The indicators shown for each location in Table 3.2 correspond to the indicator that will be used to assess the water quality for that segment. At twenty-five of the monitoring stations, *E.coli* concentrations will best approximate the level of fecal contamination in the segment, at eleven of the monitoring stations, Enterococci concentrations were used for the analysis of fecal pathogen concentrations, and at the remaining seven stations, fecal coliform concentrations will be used until enough data is gathered to allow analysis based on Enterococci or *E. coli* concentrations.

At thirty-one of the forty-three monitoring stations (72%) with data provided in Table 3.2, the geomean of the indicator concentrations exceeds the standards (fecal coliform – cfu per 100 ml, Enterococci - 35 cfu per 100 ml, and E.coli - 126 cfu per 100 ml). In addition, at thirty-two of the forty-three stations (74%), over twenty five percent of the samples

Table 3.1 Number of Indicator Samples Collected by Agencies in Clear Creek

Station	Indicator	Agencies that Conducted Sampling				
		TCEQ Regional Office	Galveston County Health	Houston Health and Human	City of Pearland	Environmental Institute of Houston
1101	Fecal Coliform	0	6	41	0	0
	E. coli	0	0	0	0	1
	Enterococci	16	198	0	0	3
1101B	Fecal Coliform	0	1	0	0	0
	E. coli	0	136	0	0	2
	Enterococci	0	0	0	0	0
1102	Fecal Coliform	42	0	0	0	0
	E. coli	23	379	0	45	1
1102A	Fecal Coliform	0	17	0	0	0
	E. coli	0	83	0	5	0
1102B	Fecal Coliform	0	0	0	0	0
	E. coli	0	102	0	25	1
2425C	Enterococci	0	48	0	0	1
	Total	81	970	41	75	9

Notes:
Samples shown were collected between 10/30/1970 and 3/15/2005
Number of samples reflects total samples collected throughout the entire Clear Creek Watershed
All data were collected in stream

Segment	Location ID	Fecal Coliform Geo Mean (cfu/100 mL)	# Exceedances of the Single Sample Limit (400 cfu/100 mL)	Total Samples Collected	% of Exceedance of Single Sample
1101	15458	**46**	**0**	**6**	**0**
1101B	16674	**10**	**0**	**1**	**0**
	17072	**193**	**5**	**14**	**36**
	17078	**160**	**3**	**8**	**38**
1102	11453	**439**	**24**	**42**	**57**
1102A	11425	**628**	**9**	**17**	**53**

Shaded Values > 200 cfu/100 mL

Segment	Location ID	*E coli* Geo Mean (cfu/100 mL)	# Exceedances of the Single Sample Limit (394 cfu/100 mL)	Total Samples Collected	% of Exceedance of Single Sample
1101	16611	**238**	**1**	**1**	**100**
1102	11449	**225**	**15**	**48**	**31**
	11450	**385**	**23**	**57**	**40**
	11451	**367**	**15**	**30**	**50**
	11452	**152**	**7**	**22**	**32**
	14229	**332**	**26**	**52**	**50**
	17068	**147**	**8**	**27**	**30**
	17069	**430**	**12**	**23**	**52**
	17070	**342**	**17**	**31**	**55**
	17071	**158**	**6**	**23**	**26**
	17073	**159**	**10**	**30**	**33**
	17074	**132**	**8**	**28**	**29**
	17076	**351**	**12**	**28**	**43**
	17077	**142**	**9**	**29**	**31**
	17079	**165**	**5**	**20**	**25**
1102A	11426	**169**	**0**	**5**	**0**
	16477	**283**	**18**	**49**	**37**
	16478	**313**	**15**	**34**	**44**
1102B	16473	**354**	**20**	**50**	**40**
	16803	**40**	**2**	**13**	**15**
	17914	**43**	**2**	**9**	**22**
	17915	**51**	**3**	**14**	**21**
	17916	**48**	**1**	**13**	**8**
	17917	**71**	**2**	**14**	**14**
	17918	**52**	**2**	**15**	**13**

Shaded Values > 126 cfu/100 mL

Segment	Location ID	Enterococci Geo Mean (cfu/100 mL)	# Exceedances of the Single Sample Limit (89 cfu/100 mL)	Total Samples Collected	% of Exceedance of Single Sample
1101	11446	**48**	**11**	**38**	**29**
	11447	**126**	**14**	**27**	**52**
	11448	**244**	**16**	**26**	**62**
	16572	**17**	**6**	**21**	**29**
	16575	**60**	**14**	**29**	**48**
	16576	**81**	**11**	**27**	**41**
	16577	**192**	**15**	**26**	**58**
1101B	16472	**171**	**13**	**26**	**50**
	16493	**301**	**18**	**24**	**75**
2425C	16475	**71**	**13**	**30**	**43**
	16486	**684**	**16**	**19**	**84**

Shaded Values > 35 cfu/100 mL

analyzed exceed the standards (fecal coliform - 400 cfu per 100 ml, Enterococci - 89 cfu per 100 ml, *E. coli* – 394 cfu per 100 ml) based on single sample concentrations. The monitoring stations were plotted spatially according to the percentage by which the geomean of samples collected at each exceeds the standard in Figure 3.1.

As discussed previously, Table 3.2 shows the exceedances of the enterococci geomean values for the monitoring stations located in the Clear Creek Watershed. At ten of the eleven monitoring stations shown in bold, the geomean of the indicator concentrations exceed the enterococci standards. The percent exceedances for the single sample limit at each station can also be observed in this table. These sample values exceeded the standard at stations within this segment between 29 and 84 percent of the time.

3.3 SEGMENT 1101 DATA ANALYSIS

3.3.1 Usability of Historical Data

Figure 3.2 presents graphs of the data that were collected by each of the organizations at each of the monitoring stations located within Segment 1101. Segment 1101 contains the tidally influenced portions of Clear Creek and its tributaries and, thus, each of the graphs shows Enterococci data. To evaluate if significant differences among data from different organizations that could prevent combining the datasets exist, *t*-test analyses were performed on the data at each station for which more than one organization collected samples. The results of these analyses are located in Appendix B. Data were collected by separate organizations at only two stations located along segment 1101. At station 11446, the TCEQ Regional Office, the Galveston County Health District, and the Environmental Institute of Houston collected water

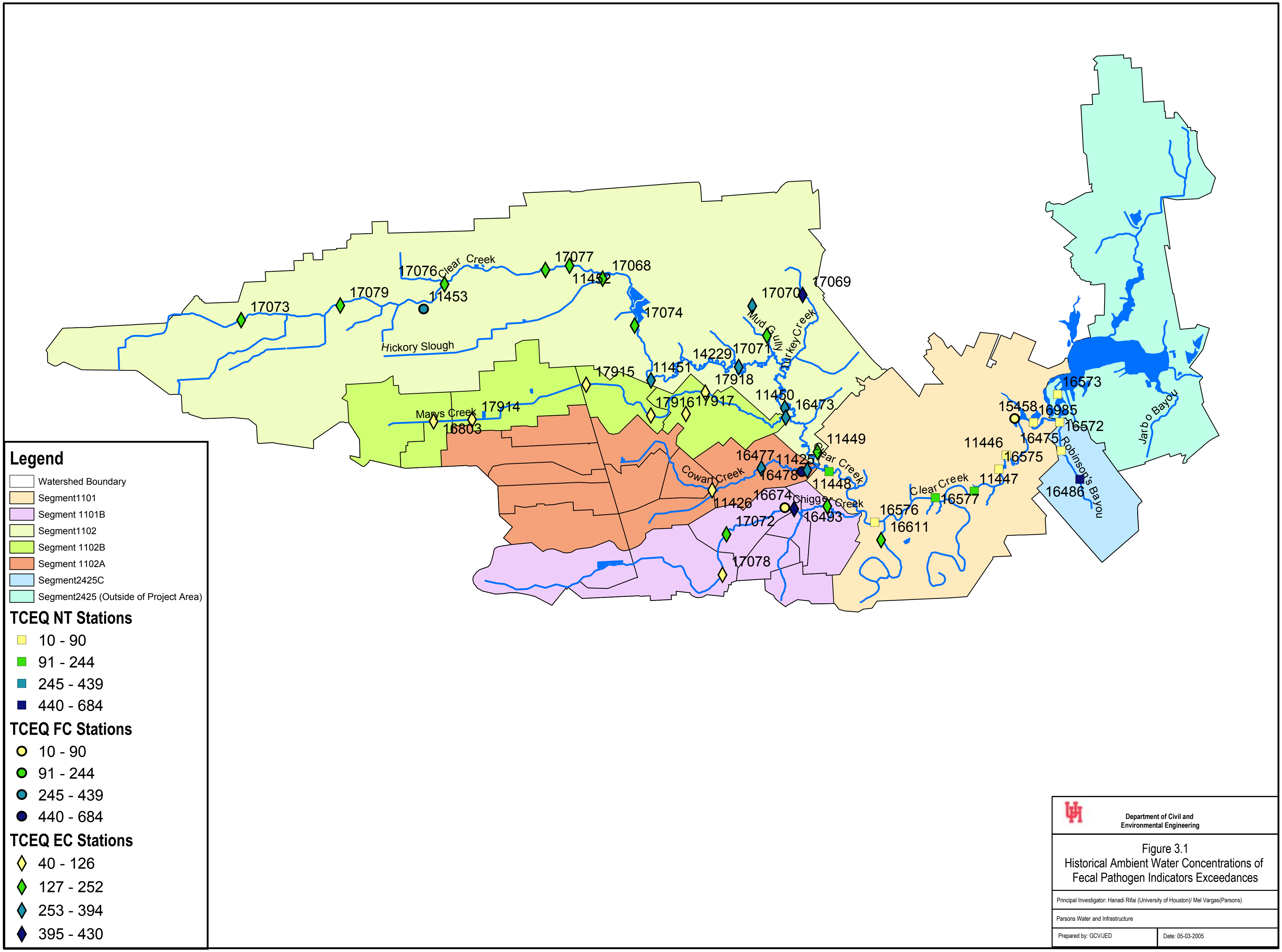
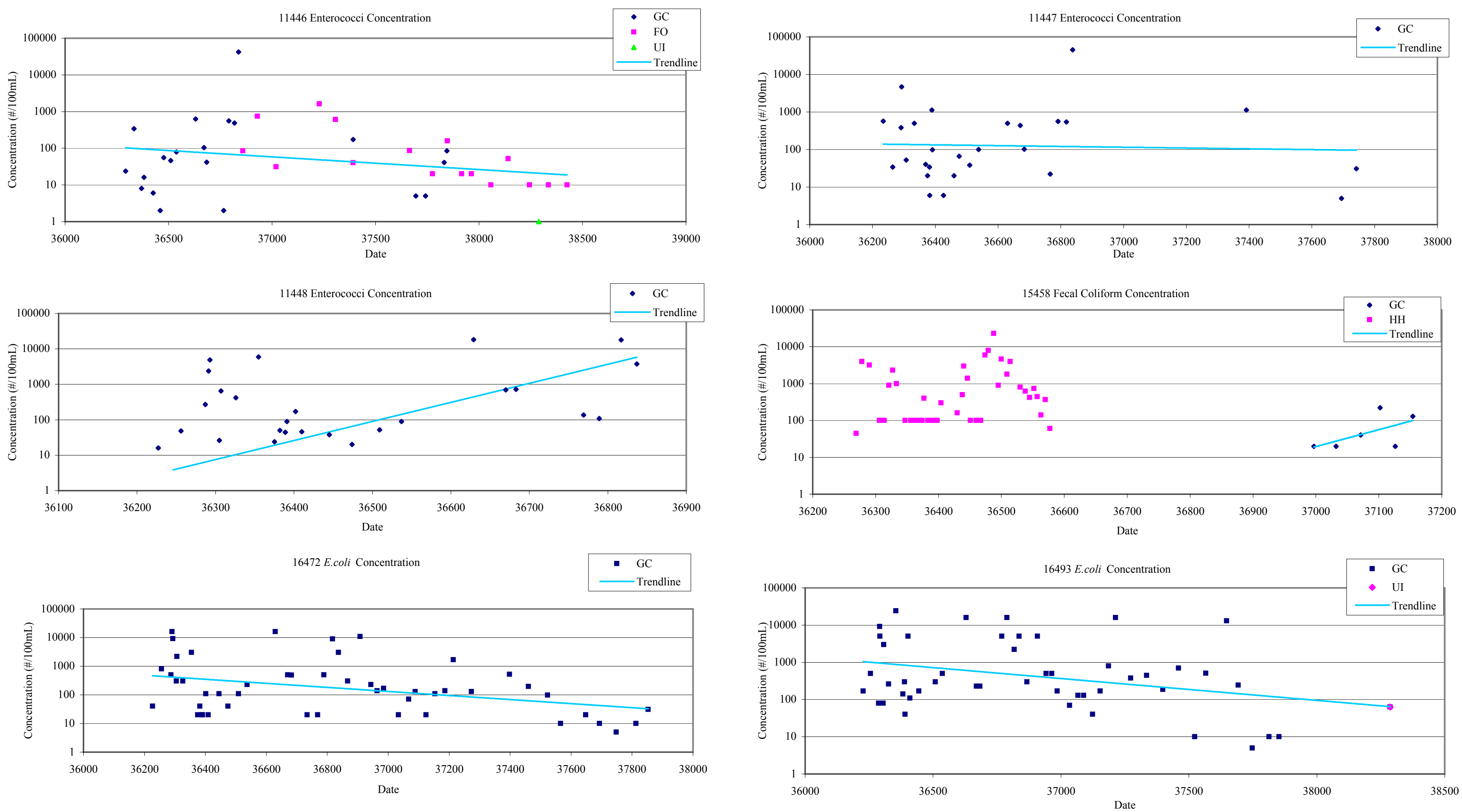


Figure 3.1
Historical Ambient Water Concentrations of Fecal Pathogen Indicators Exceedances

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

Parsons Water and Infrastructure

Prepared by: GCV/JED | Date: 05-03-2005



Legend:

GC - Galveston County Health District
FO - TCEQ Regional Office
UI - Environmental Institute of Houston
HH - Houston Health and Human Services
PL - City of Pearland

Figure 3.2 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1101

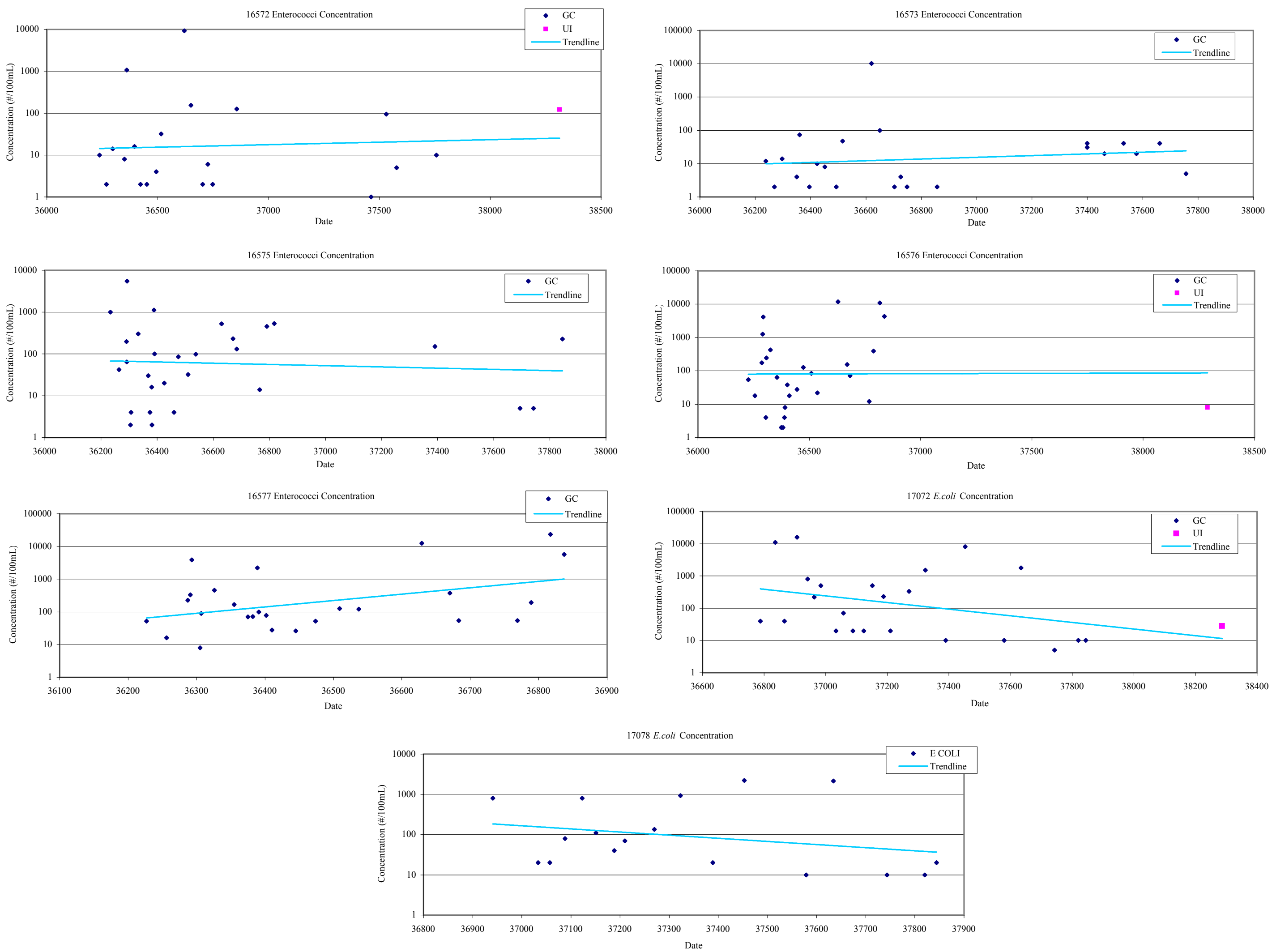


Figure 3.2 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1101 (Cont'd)

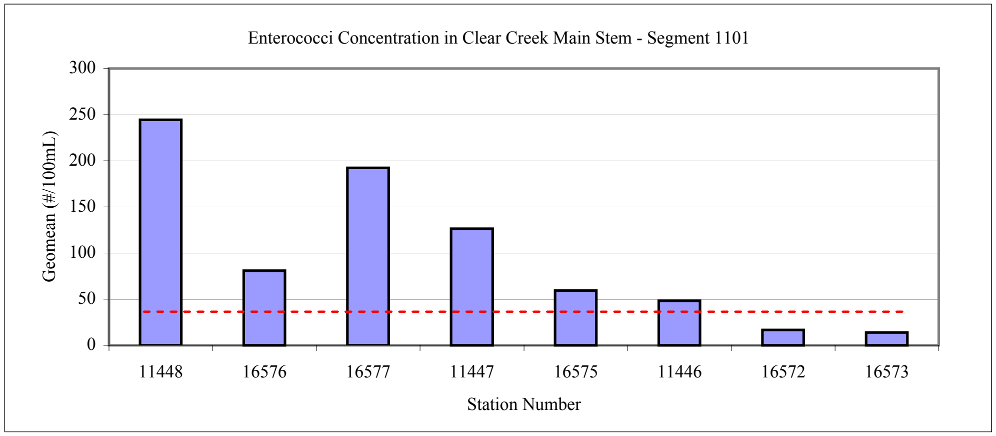
samples for analysis. Unfortunately, only one sample concentration value from the EIH was available within the TCEQ database and more than one data point is required to perform the statistical analysis. No statistical difference was observed between the data sets obtained by the other two organizations. At station 15458, the data collected by the Galveston County Health District and by Houston Health and Human Services showed a statistical difference. This is the only site within the segments analyzed using this statistical test where samples were collected by Houston Health and Human Services but the sample sets were separated by a year from those collected by the county. The Galveston County Health District (GCHD), however, collected data at sixteen other locations along with other entities. At each of these sixteen sites no statistically significant difference was observed between the data sets collected by the GCHD and other entities. The analysis of the data is included in Appendix B and shows a large amount of variability between indicator concentrations as has commonly been observed with bacteria data around the country. The trendlines illustrated in Figure 3.2 will be discussed in section 3.3.3 - Temporal Analysis of Historical Data.

3.3.2 Spatial Analysis of Historical Data

The fecal pathogen geomean values and the contact recreation limits have been plotted for Segment 1101 of the Clear Creek main stem and Chigger Creek (Figure 3.3). The stations shown in each graph are presented moving from upstream to downstream in the left to right direction so that the spatial variability of indicator concentrations could be analyzed. The graphs also separate tributaries from the main stem. The two major segments of Clear Creek were plotted separately because of the use of different indicators for each segment. Enterococci and *E. coli* have different limits and may not indicate equivalent levels of fecal contamination. The graphs in Figure 3.3 show variable results although a distinct trend can be discerned in the main stem of Clear Creek. The stations located along this segment show a decreasing trend as the stations move further downstream. The two furthest downstream stations are the only stations where the geomean is below the limit. The first three stations along Chigger Creek exhibit increases while the furthest downstream station shows a decrease from the upstream indicator concentrations. These trends were determined by visual inspection.

3.3.3 Temporal Analysis of Historical Data

A temporal trend analysis was also undertaken for the data collected for segment 1101 and shown in Figure 3.2. The trend values and probability associated with these have been included in Table 3.3. Trends could only be determined with 95% or greater confidence at five of the thirteen stations analyzed because of the high level of variability in the data. Four of the five stations showed large temporal increases with trend values of greater than 3,100 colony forming units per year. The fifth station showed a much more modest downward trend of about -140 colony forming units per year.



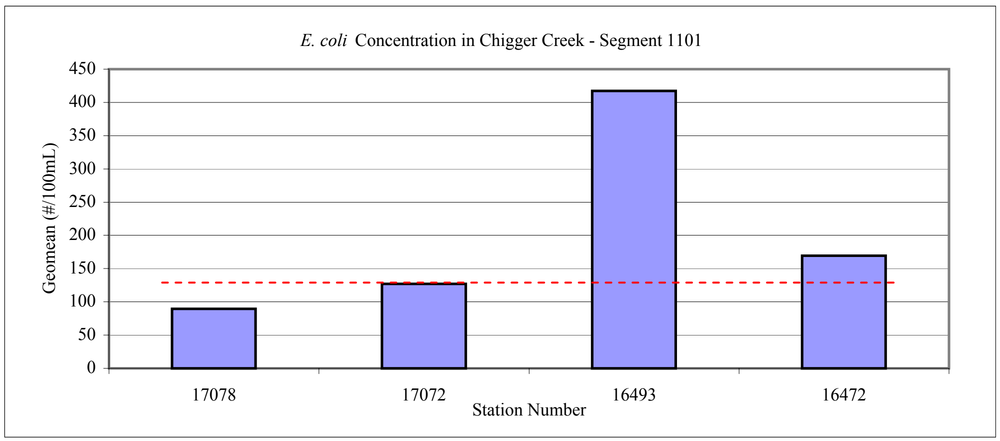


Figure 3.3 Indicator Concentration Trends for Segment 1101 (Moving Upstream to Downstream)

Notes:
mL = Milliliter
Red line = Geomean standard

Table 3.3 Summary of Temporal Trend Analysis

Segment	Station	Indicator	Trend	P-Values
1101	11446	EN	-0.096	0.368
	11447	EN	-0.395	0.046
	11448	EN	9.854	0.058
	15458	FC	-1.497	0.517
	16572	EN	-0.282	0.728
	16573	EN	-0.344	0.706
	16575	EN	-0.356	0.409
	16576	EN	0.997	0.527
	16577	EN	12.737	0.015
1101B	16472	EC	-1.762	0.125
	16493	EC	-1.442	0.342
	17072	EC	-2.665	0.238
	17078	EC	0.215	0.744
1102	11449	EC	-2.092	0.054
	11450	EC	-2.004	0.160
	11451	EC	-4.623	0.038
	11452	EC	-0.538	0.307
	11453	FC	0.128	0.915
	14229	EC	-1.103	0.240
	17068	EC	-2.193	0.130
	17069	EC	-10.152	0.027
	17070	EC	-3.505	0.041
	17071	EC	-2.396	0.012
	17073	EC	-1.975	0.252
	17074	EC	-4.246	0.089
	17076	EC	-2.189	0.153
	17077	EC	-2.140	0.103
	17079	EC	0.453	0.238
1102A	11425	FC	-15.226	0.558
	11426	EC	-1.022	0.136
	16477	EC	-1.342	0.421
	16478	EC	-5.015	0.005
1102B	16473	EC	-0.757	0.397
	16803	EC	0.214	0.193
	17914	EC	-0.265	0.742
	17915	EC	-0.612	0.780
	17916	EC	-0.137	0.290
	17917	EC	-0.576	0.131
	17918	EC	-0.280	0.035
2425C	16475	EN	0.883	0.695
	16486	EN	2.678	0.545

Notes:
Trend is the slope of the best-fit line (see Figures 3.2, 3.4, and 3.6)
Confidence values calculated as 1 minus p-value of trend-line
Shaded areas indicate the stations at which the trend is significant at or above the 95% confidence level
Negative slopes indicate decreasing temporal trends

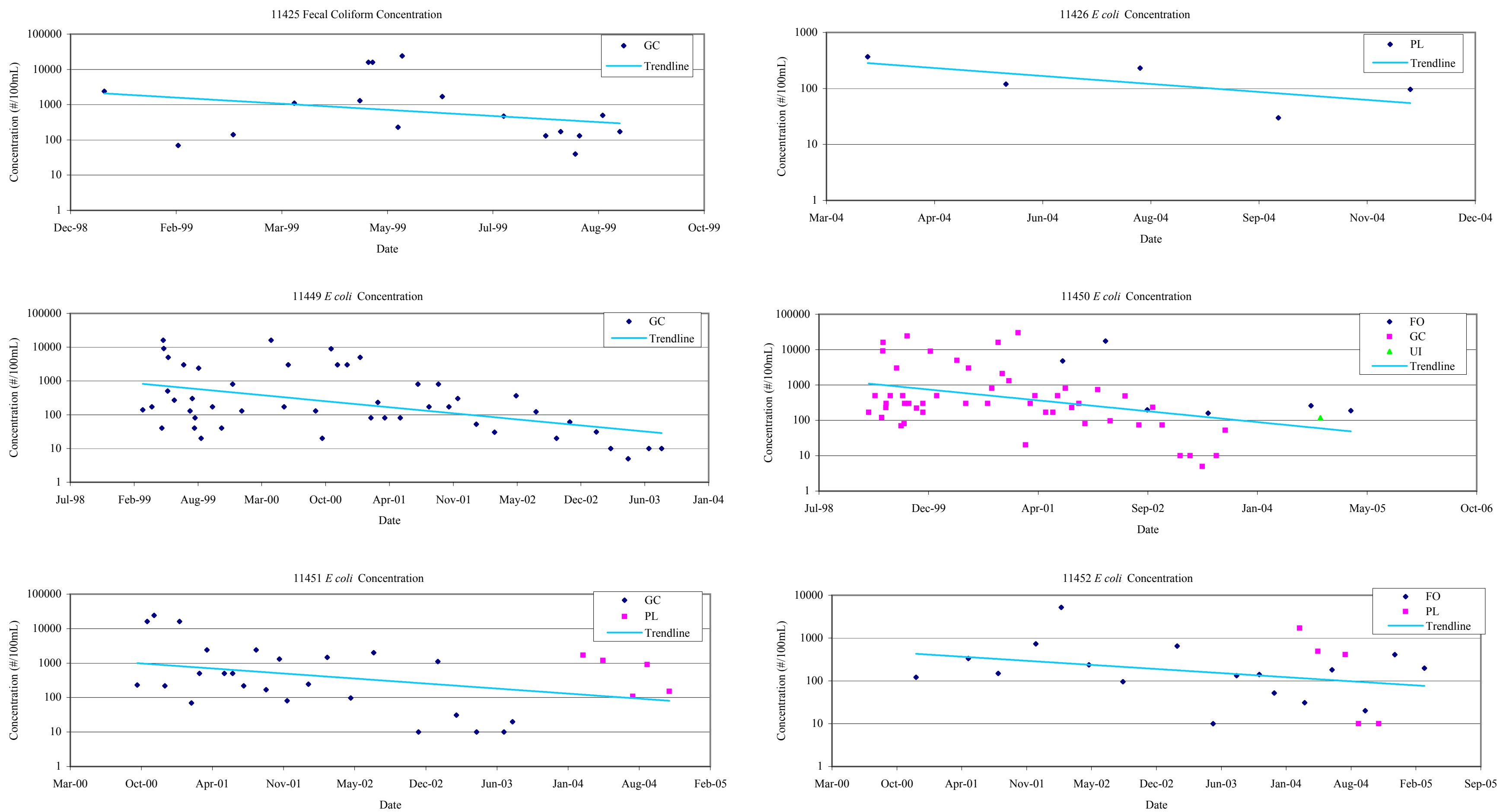
3.4 SEGMENT 1102 DATA ANALYSIS

3.4.1 Usability of Historical Data

The data collected at monitoring stations within segment 1102 of the watershed have been plotted in Figure 3.4. This segment consists of freshwater streams only and, as a result, *E. coli* concentrations were used to analyze the fecal pathogen concentrations. The concentrations plotted at each location have been separated symbolically to reflect the organization that performed the sample collection. T-test analyses were performed for each of the sites at which more than one sampling organization collected data. The results of these analyses have been included in Appendix B. At fifteen monitoring station locations along this segment enough samples were collected to perform the t-test analysis. At station 11450, three organizations collected data, but the TCEQ database included only one sample from EIH. Since more data points are required to run the analysis, the EIH data point were not included. Data sets collected by the TCEQ Region 12 (Houston) Office, the Galveston County Health District, and the City of Pearland were analyzed. No statistical differences were observed between the data sets collected by any of these organizations. As a result, all of the data collected for this segment were used for the analysis performed in this study.

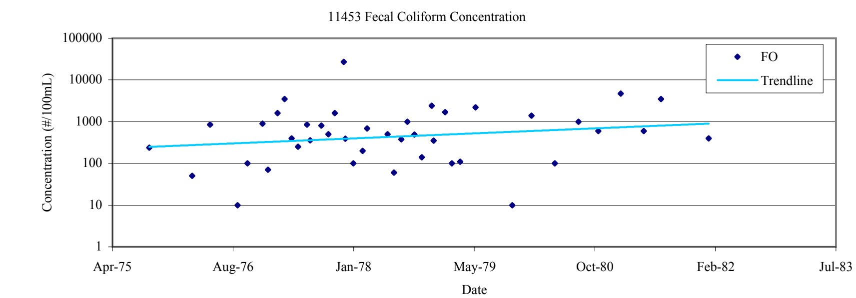
3.4.2 Spatial Analysis of Historical Data

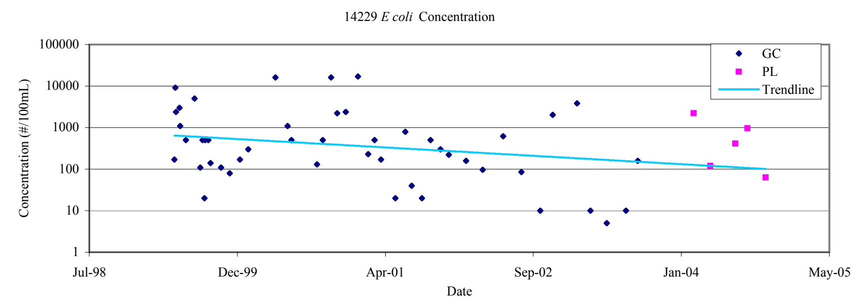
The geomean of the fecal pathogen indicator concentrations obtained from samples collected along segment 1102 and the EPA geomean limits have been plotted in Figure 3.5. Graphs of indicator concentration geomean values at stations along segment 1102 (Clear Creek Above Tidal), on Mary's Creek, and at two unnamed tributaries have been included in this figure. The concentrations in Cowart creek increase moving from upstream to downstream from 124 *E. coli* per 100 mL at station 11426 to 313 *E. coli* per 100 mL, 3.1 miles downstream at

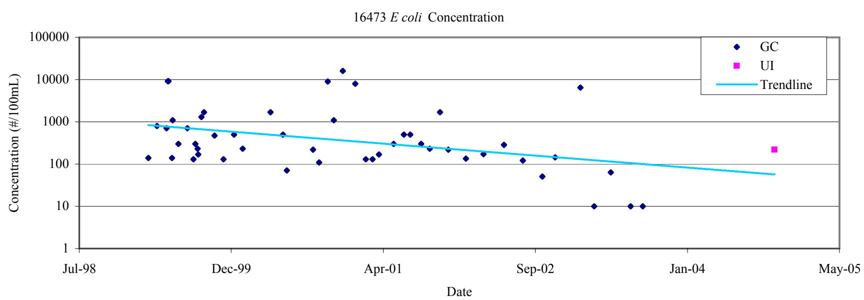


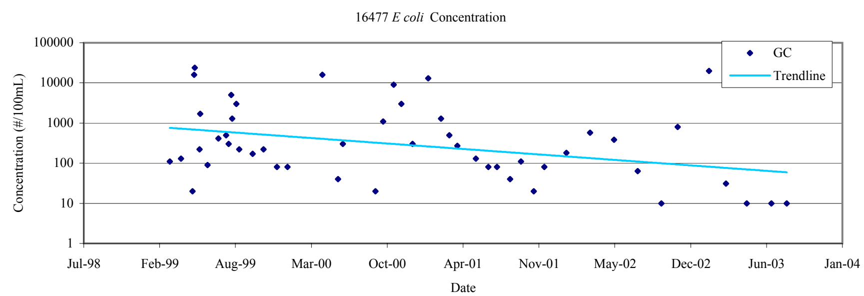
Legend:
GC - Galveston County Health District
HH - Houston Health and Human Services
FO - TCEQ Regional Office
PL - City of Pearland
UI - Environmental Institute of Houston

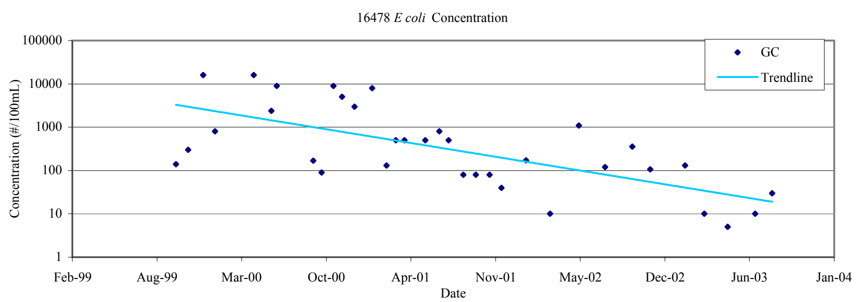
Figure 3.4 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1102











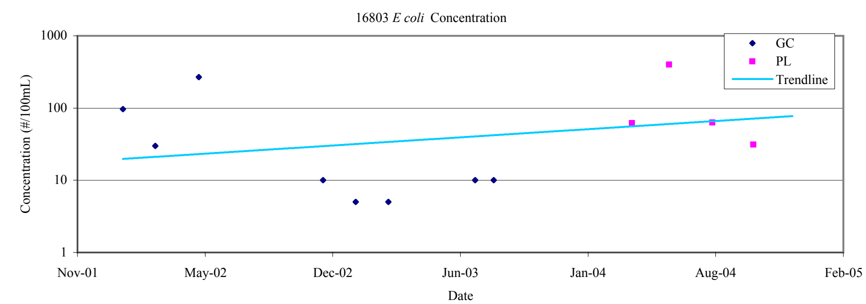


Figure 3.4 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1102 (Cont'd)

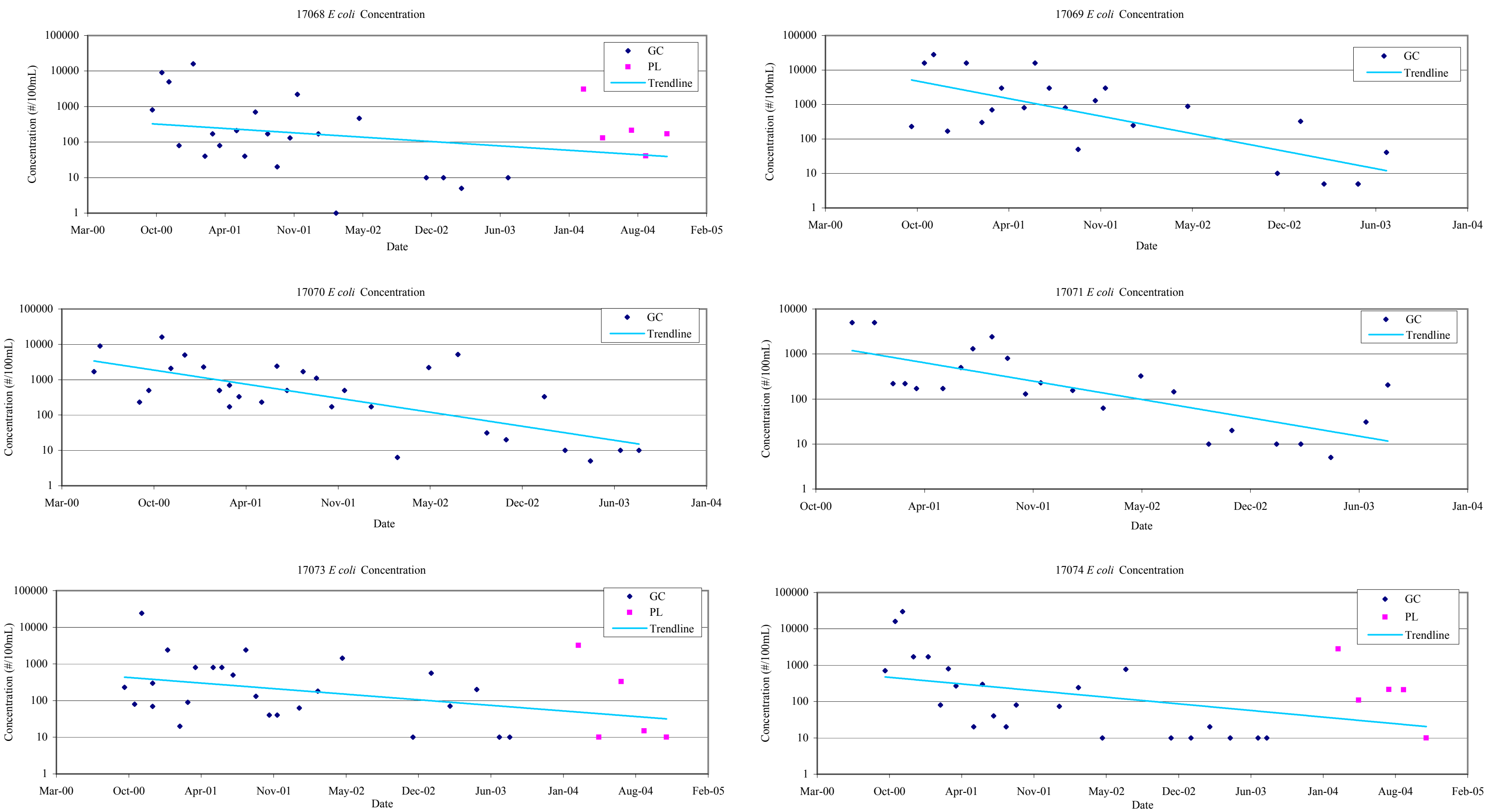


Figure 3.4 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1102 (Cont'd)

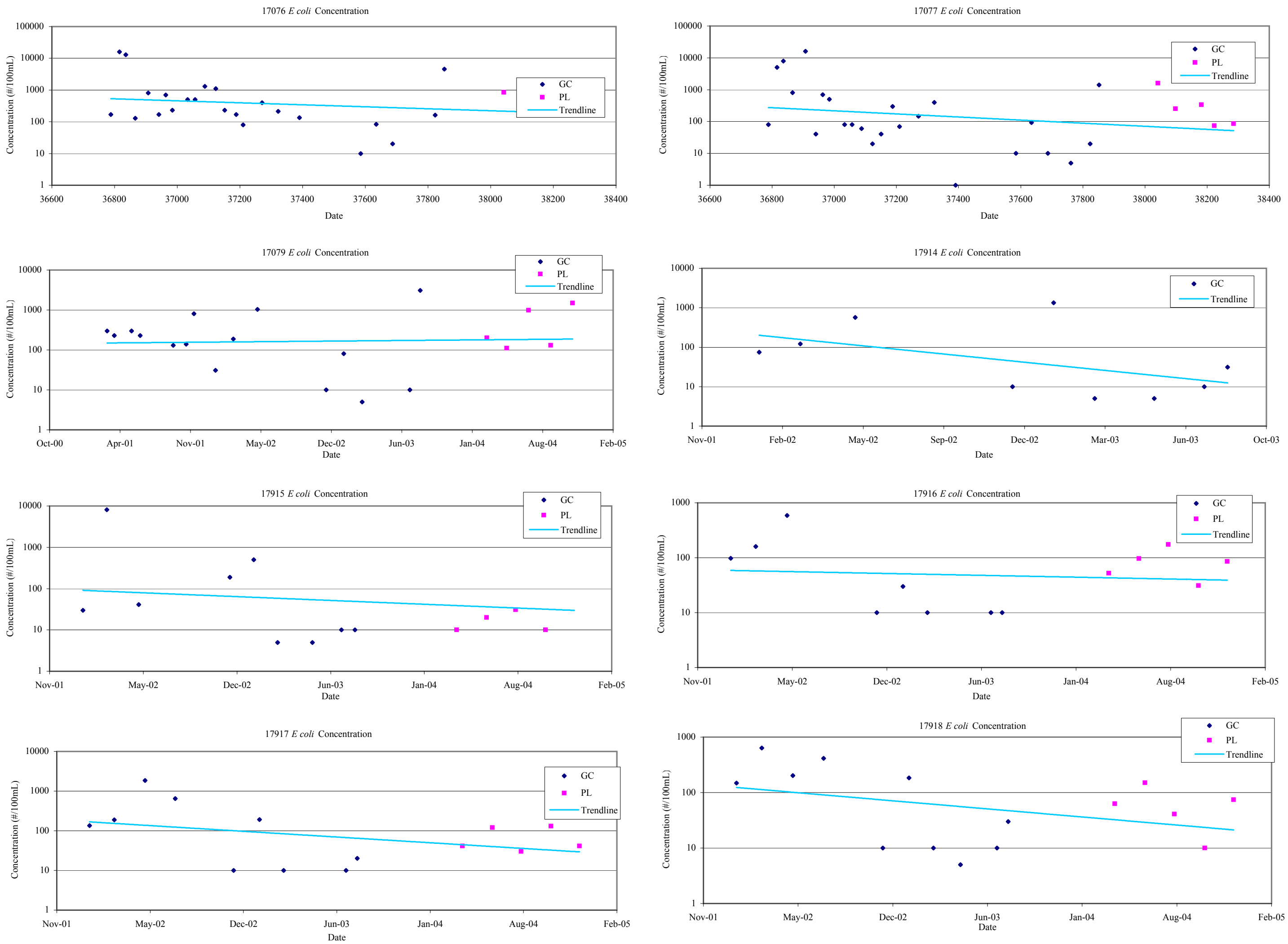


Figure 3.4 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 1102 (Cont'd)

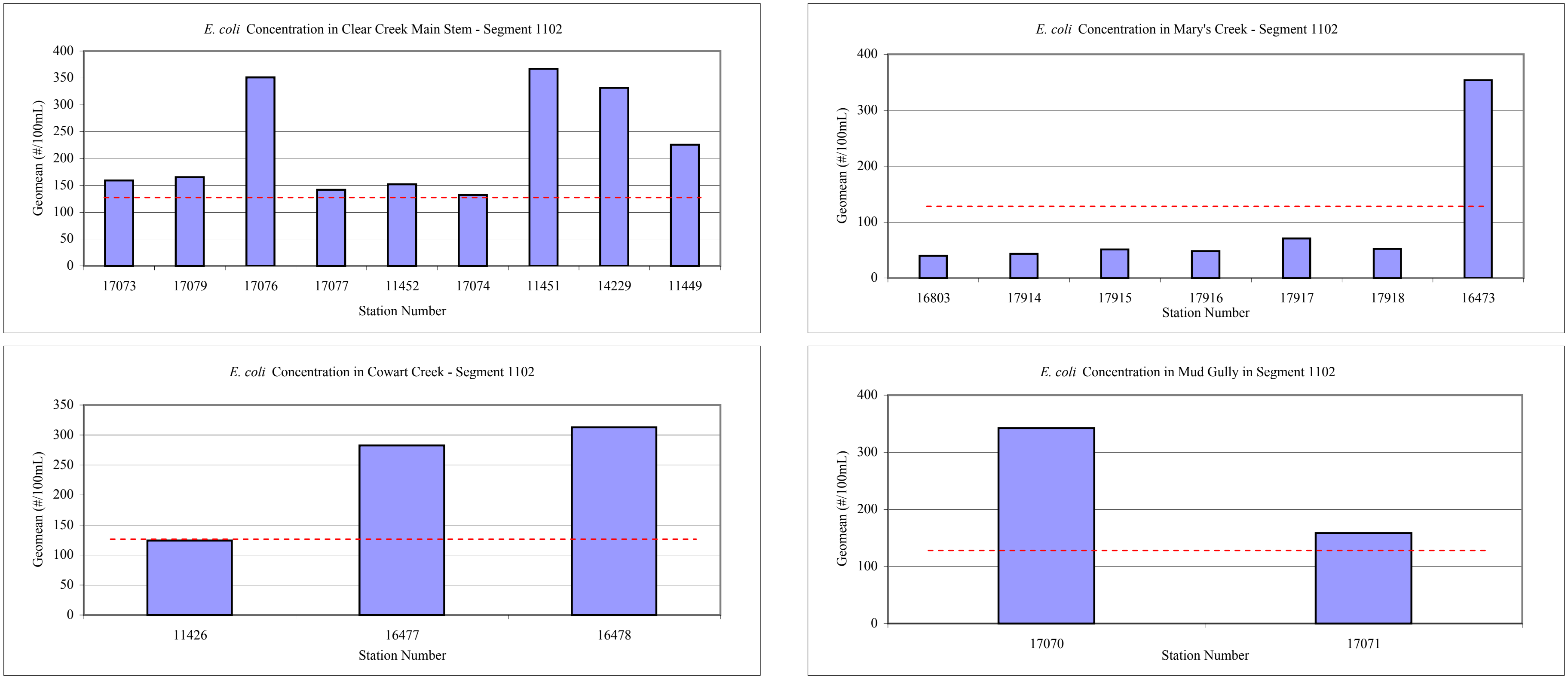


Figure 3.5 Indicator Concentration Trends for Segment 1102 (Moving Upstream to Downstream)

Note:
Red line = Geomean standard

station 16478. Along Clear Creek Tidal and these tributaries, the indicator concentrations display no clear dominating trends, every station in the main stem of Clear Creek, Cowart Creek, and Mud Gulley exceeded or met the geomean standard; whereas, only one station out of seven in the Mary's Creek branch exceeded the geomean standard. The exceedances of the geomean and of single samples above the adopted TCEQ values at several of the stations within this region have been included in Table 3.2.

3.4.3 Temporal Analysis of Historical Data

The results of a temporal trend analysis performed on segment 1102 are included in Table 3.3. and displayed in Figure 3.4 Trends could be determined with 95% or greater confidence at seven of the twenty-six stations located along this segment that were analyzed. These stations are represented in the table with shaded values. In contrast with the analysis results for stations along segment 1101, each of the 1102 stations shows a decreasing trend. The data collected at station 17069 produced the sharpest trend with a decrease of over 3700 colony forming units per year. Five of the remaining six stations show reductions of between 764 and 1830 colony forming units per year. Station 17918 produced a downward trend of 102 colony forming units per year. Sixteen of the remaining nineteen stations observed negative trends but the data collected exhibited a large amount of variability (as can be observed by the large variance of values presented in Appendix B) and, as a result, these trends are not statistically significant.

3.5 SEGMENT 2425C DATA ANALYSIS

3.5.1 Usability of Historical Data

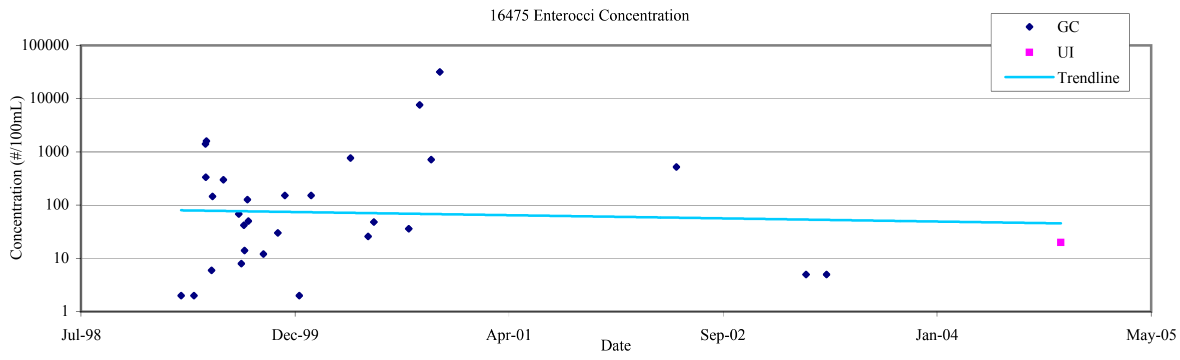
The graphs presented in Figure 3.6 illustrate the historical data for fecal pathogen indicator concentrations that were collected at two stations along segment 2425C (Robinson's Bayou): stations 16475 and 16486. As a result of the tidal influence to segment 2425C, Enterococci concentrations were used to assess fecal bacteria concentrations. The Galveston County Health District obtained all of the samples within this segment except for one sample collected by the EIH. As a result, no t-test analysis could be performed to compare the statistical significance of any difference in the data sets. There were no statistically significant trends in the data collected at either of these two stations.

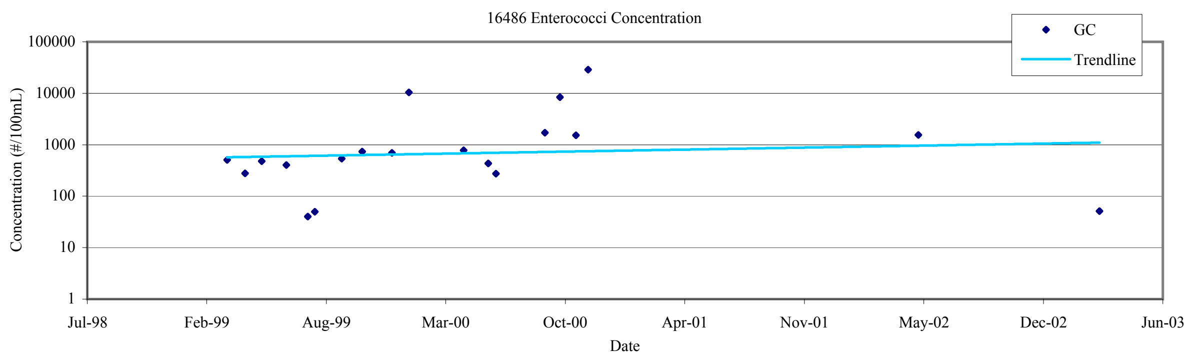
3.5.2 Spatial Analysis of Historical Data

As shown in Table 3.1, the geomean of the concentrations of samples collected at the two stations along Robinson's Bayou exceed the contact recreation standard adopted by the TCEQ for Enterococci. In addition, samples collected at station 16475 exceed the single sample limit of 89 colony forming units 43% of the time and those collected at station 16486 exceed the limit 84% of the time. Station 16486 is located further upstream of 16475 and the geomean of the indicator concentrations, as well as the percentage of exceedances decrease between these two sites moving downstream, shown in Figure 3.7.

5.5.3 Temporal Analysis of Historical Data

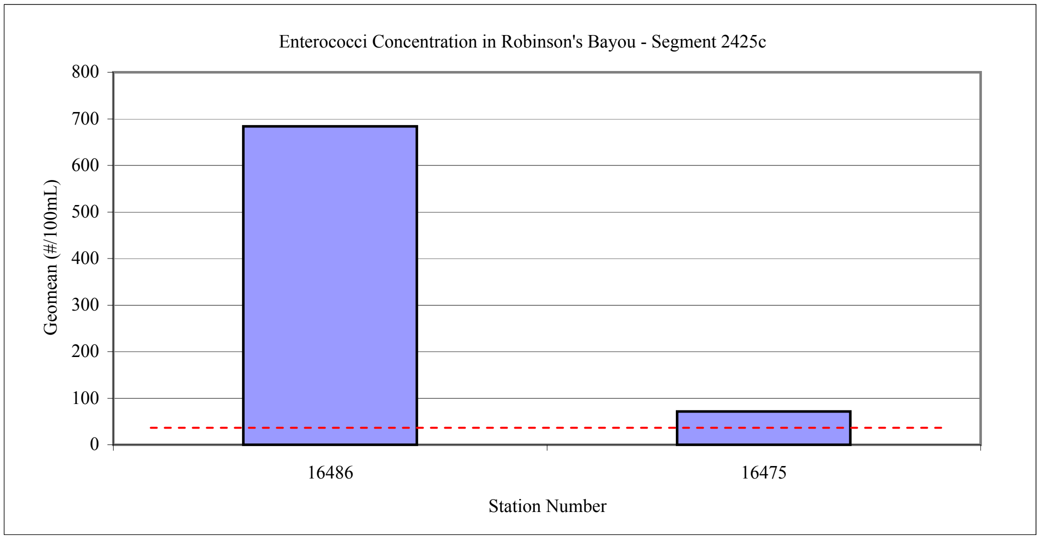
Due to the variability of the data, temporal trends at each of these stations could not be determined with any accuracy (Figure 3.6).





Legend:
GC - Galveston County Health District
UI - Environmental Institute of Houston

Figure 3.6 Temporal Trends and Sources of Data of Water Quality Data at Stations in Segment 2425C



Note:
Red line = Geomean standard

Figure 3.7 Indicator Concentration Trends for Segment 2425c

3.6 INVENTORY OF MAJOR BACTERIAL SOURCES

3.6.1 Permitted Wastewater Discharges

Under the Texas Pollution Discharge Elimination System (TPDES), there are 23 municipal facility permits within the Clear Creek watershed that discharge wastewater (see Table 3.4). The majority (16) of the municipal discharge points fall within segment 1102 (Clear Creek Above Tidal). Table 3.5 shows all entities that hold active TPDES discharge permits (including 13 industrial permits with 26 discharge points) within the watershed. This table shows the subwatershed locations and the permitted flows for many of the dischargers. From approximately 2000 to mid-2004, the reported average daily domestic wastewater discharge to Clear Creek was 23.70 MGD (see Appendix C), which was well below the permitted daily flow of 45.96 MGD (see Table 3.4). The increasing limits and quantities of municipal permits within the segment indicate a steadily increasing wastewater input into the segments.

The Gulf Coast Waste Disposal Authority and City of League City National Pollutant Discharge Elimination System (NPDES) permits allow the largest discharge of the domestic wastewater facilities at over 7.5 MGD each. The other domestic wastewater facilities with permitted wastewater discharges of greater than 1 MGD are City of Pearland (4 separate facilities), City of Houston (2 separate facilities), City of Webster, Nassau Bay, and Brazoria County MUD #1. Most of the wastewater permits do not include specific limits and monitoring requirements for fecal coliform concentrations in their effluents, but most do require disinfection of wastewaters.

Table 3.4 Municipal Wastewater Dischargers to Clear Creek Watershed

TPDES Number	Facility Name	Permitted Flow (MGD)	Outfall	DTYPE	County	LAT_DD	LONG_DD	Segment
10134-002	Pearland (STP #2)	3.1	001	W	BRAZORIA	29.57363300000	-95.25911300000	1102
10134-007	Pearland	2.0	001	W	BRAZORIA	29.54634500000	-95.31299300000	1102
10134-007	Pearland	--	002	W	BRAZORIA	29.54633400000	-95.30771500000	1102
10134-008	Pearland	2.0	001	W	BRAZORIA	29.57995600000	-95.40994000000	1102
10134-010	Pearland	2.5	001	W	BRAZORIA	29.55690100000	-95.21640200000	1102
10134-010	Pearland	--	002	W	BRAZORIA	29.55690100000	-95.21640200000	1102
10243-001	Harris Co. WCID #50	0.54	001	D	HARRIS	29.56300800000	-95.04631800000	2425
10495-075	Houston	6.14	001	W	HARRIS	29.59634300000	-95.20771200000	1102
10495-079	Houston (Southeast)	5.33	001	W	HARRIS	29.60245400000	-95.23604500000	1102
10520-001	Webster	1.65	001	W	HARRIS	29.53578700000	-95.11798700000	1101
10526-001	Nassau Bay	1.33	001	W	HARRIS	29.53273100000	-95.09048600000	1101
10526-001	Nassau Bay	--	002	W	HARRIS	29.53606400000	-95.08854100000	1101
10568-003	League City	0.66	001	D	GALVESTON	29.49301100000	-95.15659900000	1101
10568-005	League City	7.5	001	W	GALVESTON	29.52013100000	-95.09240800000	1101
11571-001	Gulf Coast Waste Disposal Auth	9.25	001	W	HARRIS	29.50495500000	-95.16715400000	1101
12295-001	Brazoria Co. MUD #5	0.95	001	D	BRAZORIA	29.57884400000	-95.36354900000	1102
12332-001	Brazoria Co. MUD #1	2.4	001	W	BRAZORIA	29.54106700000	-95.34382700000	1102
12680-001	Korenek, Albert Henry	0.012	001	D	BRAZORIA	29.54467800000	-95.35049400000	1102
12822-001	Walker Water Works	0.035	001	D	BRAZORIA	29.49551300000	-95.28021400000	1102
12849-001	CMH Parks	0.075	001	D	BRAZORIA	29.57640800000	-95.31459100000	1102
12935-001	K.C. Utilities	0.05	001	D	BRAZORIA	29.47369700000	-95.26224500000	1104
12939-001	Harris Co. WCID #89	0.15	001	D	HARRIS	29.59328900000	-95.35910500000	1102
13864-001	CELL-U-FORM WWTP	0.0084	001	D	FORT BEND	29.57273400000	-95.43549700000	1102
13865-001	Tiki Leasing	0.049	001	D	BRAZORIA	29.50551300000	-95.25021300000	1102
14135-001	Brazoria Co. MUD #19	0.15	001	D	BRAZORIA	29.55973400000	-95.37491700000	1102
14160-001	Harvard Estates WWTP	0.08	001	D	BRAZORIA	29.54106800000	-95.40882900000	1102
	Total	45.96						

Notes:

MGD = Million Gallons per Day

DTYPE

C = Cooling Water

D = Domestic <1 MGD

S = Stormwater

W = domestic >=1 MGD or industrial process water, including water treatment plant discharge

Table 3.5 All Permitted Wastewater Discharges to Clear Creek Watershed

TPDES Number	Facility Name	Permitted Flow (MGD)	Outfall	Status	DTYPE	County	LAT_DD	LONG_DD	Segment	Basin
01044-000	Texas Genco II, LP	340	001	C	C	HARRIS	29.54633000000	-95.05450700000	2425	11
01044-000	Texas Genco II, LP	190	002	C	C	HARRIS	29.55723000000	-95.07510800000	2425	11
01044-000	Texas Genco II, LP		003	C	W	HARRIS	29.53063100000	-95.09860800000	1101	11
01044-000	Texas Genco II, LP		004	C	W	HARRIS	29.52783100000	-95.10240800000	1101	11
01220-000	PPG Industries		002	C	S	HARRIS	29.65255900000	-95.03577700000	2421	11
01910-000	Texas Genco II, LP	0.05	001	C	W	HARRIS	29.57190000000	-95.25549100000	1102	11
02182-000	Akzo Nobel Chemicals		001	C	W	HARRIS	29.63800700000	-95.06520700000	2425	11
02500-000	Rohm and Haas		001	C	S	HARRIS	29.64606200000	-95.03992900000	2425	11
02594-000	Lubrizol		001	C	S	HARRIS	29.64050700000	-95.05798500000	2425	11
02756-000	Lyondell Chemical		001	C	S	HARRIS	29.62050700000	-95.05159600000	2425	11
02756-000	Lyondell Chemical		002	C	S	HARRIS	29.62217300000	-95.05242900000	2425	11
02756-000	Lyondell Chemical		003	C	S	HARRIS	29.62411800000	-95.05354000000	2425	11
03593-000	Syntech Chemicals		001	C	W	HARRIS	29.58916900000	-95.40475200000	1102	11
03593-000	Syntech Chemicals		002	C	W	HARRIS	29.58914900000	-95.40632500000	1102	11
03608-000	Bayshore Industrial	0.05	001	C	W	HARRIS	29.62952900000	-95.03420700000	2425	11
03608-000	Bayshore Industrial		002	C	S	HARRIS	29.62911800000	-95.03465100000	2425	11
03608-000	Bayshore Industrial		003	C	S	HARRIS	29.62995100000	-95.03576300000	2425	11
03686-000	Chusei (USA)		001	C	W	HARRIS	29.64050700000	-95.03965100000	2425	11
03686-000	Chusei (USA)		002	C	W	HARRIS	29.63911800000	-95.03965100000	2425	11
03686-000	Chusei (USA)		003	C	S	HARRIS	29.63689600000	-95.03909600000	2425	11
04330-000	Air Liquide Large Industries		001	C	W	HARRIS	29.62078500000	-95.04409600000	2425	11
04330-000	Air Liquide Large Industries		002	C	W	HARRIS	29.62579100000	-95.04538000000	2425	11
04330-000	Air Liquide Large Industries		003	C	S	HARRIS	29.62372500000	-95.04498400000	2425	11
04330-000	Air Liquide Large Industries		004	C	W	HARRIS	29.62188900000	-95.04454600000	2425	11
04112-000	Matheson Tri-Glass	0.04	001	C	W	HARRIS	29.60722900000	-95.05020700000	0815	08
04594-000	Dixie Chemicals		001	C	W	DALLAM	29.61242900000	-95.04900700000	2425	24
10134-002	Pearland (STP #2)	3.1	001	C	W	BRAZORIA	29.57363300000	-95.25911300000	1102	11
10134-007	Pearland	2.0	001	C	W	BRAZORIA	29.54634500000	-95.31299300000	1102	11
10134-007	Pearland		002	C	W	BRAZORIA	29.54633400000	-95.30771500000	1102	11
10134-008	Pearland	2.0	001	C	W	BRAZORIA	29.57995600000	-95.40994000000	1102	11
10134-010	Pearland	2.5	001	C	W	BRAZORIA	29.55690100000	-95.21640200000	1102	11
10134-010	Pearland		002	C	W	BRAZORIA	29.55690100000	-95.21640200000	1102	11
10243-001	Harris Co. WCID #50	0.54	001	C	D	HARRIS	29.56300800000	-95.04631800000	2425	11
10495-075	Houston	6.14	001	C	W	HARRIS	29.59634300000	-95.20771200000	1102	11
10495-079	Houston (Southeast)	5.33	001	C	W	HARRIS	29.60245400000	-95.23604500000	1102	11
10520-001	Webster	1.65	001	C	W	HARRIS	29.53578700000	-95.11798700000	1101	11
10526-001	Nassau Bay	1.33	001	C	W	HARRIS	29.53273100000	-95.09048600000	1101	11
10526-001	Nassau Bay		002	C	W	HARRIS	29.53606400000	-95.08854100000	1101	11
10568-003	League City	0.66	001	C	D	GALVESTON	29.49301100000	-95.15659900000	1101	11
10568-005	League City	7.5	001	C	W	GALVESTON	29.52013100000	-95.09240800000	1101	11
11571-001	Gulf Coast Waste Disposal Auth	9.25	001	C	W	HARRIS	29.50495500000	-95.16715400000	1101	11
12295-001	Brazoria Co. MUD #5	0.95	001	C	D	BRAZORIA	29.57884400000	-95.36354900000	1102	11
12332-001	Brazoria Co. MUD #1	2.4	001	C	W	BRAZORIA	29.54106700000	-95.34382700000	1102	11
12680-001	Korenek, Albert Henry	0.012	001	C	D	BRAZORIA	29.54467800000	-95.35049400000	1102	11
12822-001	Walker Water Works	0.035	001	C	D	BRAZORIA	29.49551300000	-95.28021400000	1102	11
12849-001	CMH Parks	0.075	001	C	D	BRAZORIA	29.57640800000	-95.31459100000	1102	11
12935-001	K.C. Utilities	0.05	001	C	D	BRAZORIA	29.47369700000	-95.26224500000	1104	11
12939-001	Harris Co. WCID #89	0.15	001	C	D	HARRIS	29.59328900000	-95.35910500000	1102	11
13864-001	CELL-U-FORM WWTP	0.0084	001	C	D	FORT BEND	29.57273400000	-95.43549700000	1102	11
13865-001	Tiki Leasing	0.049	001	C	D	BRAZORIA	29.50551300000	-95.25021300000	1102	11
14135-001	Brazoria Co. MUD #19	0.15	001	C	D	BRAZORIA	29.55973400000	-95.37491700000	1102	11
14160-001	Harvard Estates WWTP	0.08	001	C	D	BRAZORIA	29.54106800000	-95.40882900000	1102	11

Notes:
MGD = Million Gallons per Day
Status
C = Current
DTYPE
C = Cooling Water
D = Domestic <1 MGD
S = Stormwater
W = domestic >=1 MGD or industrial process water, including water treatment plant discharge

Table 3.6 lists the eight TPDES point sources that monitor discharge for fecal coliform. Discharge Monitoring Reports (DMRs) and the design flow of the discharges were used to determine the number of fecal coliform analyses that were performed for the eight TPDES point sources, the average flow during the reporting period, the maximum concentration during the reporting period, and the fecal coliform daily loads. The data used to generate Table 3.6 are provided in Appendix G. Table 3.7 lists the number of reported monthly exceedances of the geometric mean concentration of 200 cfu/100 ml, and the number of reported daily exceedances of the single sample standard of 400 cfu/100 ml. As shown in Table 3.7, only two permits had violations of fecal coliform standards during the monitoring time frame. Both of the permits are held by the City of Pearland.

3.6.2 Sanitary Sewer Overflow (SSO) Data

The TCEQ maintains a database of SSO data collected from wastewater operators in the Clear Creek watershed. TCEQ Region 12, Houston provided two database queries for SSO data – one is collected by the City of Houston and the other is compiled from the remainder of the wastewater dischargers in the Clear Creek watershed (Jim Rice, August 22, 2005). These data are included in Appendix E. As shown by the data, there have been approximately 631 sanitary sewer overflows reported in the Clear Creek watershed during the period of record of January 2002 through July 2005. For the portion of the Clear Creek Watershed located in the City of Houston, volumes were reported for 130 of the reported events and averaged 2,950 gallons per event. For the regions of the Clear Creek Watershed located outside of the City of Houston, volumes were reported for 425 of the events and averaged 13,600 gallons per event.

Table 3.6 DMR Data for Permitted Wastewater Discharges to Clear Creek (December 1999 - May 2005)

TPDES Permit ID	Facility Name	TCEQ Segment Number	Dates Monitored		# of Records	Monthly Average Flow (MGD)	Permitted Flow (MGD)	FC Daily Load (cfu)	
			Start	End				90 Percentile Monthly Average	Maximum Monthly Average
11571-001	GULF COAST WASTE DISPOSAL AUTH	1101	05/31/00	04/30/05	60	5.36	9.25	4.16E+09	9.84E+09
10568-003	LEAGUE CITY, CITY OF	1101	09/30/01	09/30/01	1	0.38	0.66	NA	2.18E+08
10568-005	LEAGUE CITY, CITY OF	1101	03/31/04	03/31/05	13	5.90	7.5	3.13E+09	5.90E+09
12332-001	BRAZORIA COUNTY MUD NO. 1	1102	12/31/99	03/31/00	2	0.63	2.4	2.14E+08	2.35E+08
12822-001	WALKER WATER WORKS, INC.	1101	03/31/00	06/30/00	2	0.01	0.035	6.82E+07	7.34E+07
12849-001	CMH PARKS, INC (RAINTREE ACRES	1102	12/31/99	12/31/99	1	0.04	0.075	NA	1.32E+06
10134-007	PEARLAND, CITY OF	1102	02/29/00	05/31/05	58	1.18	2.0	2.59E+10	2.16E+11
10134-008	PEARLAND, CITY OF	1102	08/31/03	05/31/05	22	0.18	2.0	9.53E+08	2.96E+09

Source:
TCEQ, August 2005

Notes:
FC = Fecal Coliform
NA = Not Applicable
MGD = Millions of Gallons per Day
cfu = Colony Forming Unit

Table 3.7 Fecal Coliform Exceedance Data for permitted Wastewater Discharges to Clear Creek (December 1999 -May 2005)

Facility Name	TPDES Number	Number of Records	Number of MCMX Exceedances	Number of MCAV Exceedances	Percentage of MCMX Exceedances	Percentage of MCAV Exceedances
GULF COAST WASTE DISPOSAL	11571-001	60	0	0	0%	0%
LEAGUE CITY, CITY OF	10568-003	1	0	0	0%	0%
LEAGUE CITY, CITY OF	10568-005	13	0	0	0%	0%
BRAZORIA CO MUD #1	12332-001	2	0	0	0%	0%
WALKER WATER WORKS	12822-001	2	0	0	0%	0%
CMH PARKS (RAINTREE ACRES)	12849-001	1	0	0	0%	0%
PEARLAND, CITY OF	10134-007	58	14	13	24%	22%
PEARLAND, CITY OF	10134-008	22	3	2	14%	9%

Source:

TCEQ, August 2005

Data was obtained by open records request from Robert Organ of the TCEQ Records Department

Notes:

MCMX = Measurement: Concentration Maximum

MCAV = Measurement: Concentration Average

3.6.3 Permitted Stormwater Discharges

A portion of the northeast Clear Creek watershed is covered under two storm water permits, including one for the City of Pasadena and one for Harris County, Harris County Flood Control District (HCFCD), City of Houston and Texas Department of Transportation. However, these agencies do not have any monitoring points located on water bodies that drain into the Clear Creek watershed (e.g., Armand Bayou), Sarah Metzger, City of Pasadena; Trent Martin, HCFCD (personal communications, August 2005). Therefore, there is no stormwater monitoring data available for the Clear Creek watershed under these permits.

3.6.4 Galveston County Health District Study

The Galveston County Health District (GCHD) conducted a study of the storm sewer discharges into Clear Creek and its tributaries. Their data collection and analysis was performed in collaboration with the Houston-Galveston Area Council (HGAC) with funding from the Clean Rivers Program. The purposes of their study were to locate all of the storm water outfalls, to sample the dry weather flows for fecal pathogen indicators, to investigate any contaminated discharges, and to locate and eliminate all cross connections between the sanitary and storm sewer systems in the region. The GCHD study found that 385 of 1,140 storm water outfalls in the region had dry weather discharges and that 22 percent of these (83 outfalls) had contaminated flows. Contaminated flows were defined as flows that had fecal coliform concentrations greater than 1000 MPN per 100 mL. During the study, the GCHD eliminated 12 of these illicit discharges by working with the responsible parties to determine solutions. The GCHD also found that 18 of the illicit sources were not discharging any longer or dropped below the fecal concentration of 1000 MPN per 100 mL. In addition, 22 of the sources could not be identified through the investigation process that was used and, therefore, remain sources of contamination. Due to the time constraints of their project, 29 of the GCHD pipes could not be investigated (GCHD 2001).

During the research performed for the GCHD study, two separate phases of sampling were carried out to determine the water quality of each outfall within the watershed and to determine the effect that the outfalls had upon the water quality of the impaired segments. The GCHD sampled every source of discharge into Clear Creek and its tributaries that they could locate. Because no comprehensive outfall maps existed at the time of the study, the field personnel walked the entire length of Clear Creek and its tributaries and identified each of the discharge outfall locations. Figure 3.8, shows the locations of each of the outfalls that were identified and sampled. A total of 1,132 separate outfall locations are shown on the map. A sample was obtained at each outfall that had flow and was tested in the GCHD lab facilities for fecal coliform concentrations. During the latter portion of the study, the samples were also tested for Enterococci and *E. coli*. To evaluate the effect of these discharges on the water quality within the stream itself, ambient sampling stations were setup along the stream. The illicit discharge data that were obtained by the GCHD have been included in Table 3.8. These stations are identified by the classifications designated in Figure 3.8 (GCHD 2001).

Unfortunately the GCHD was unable to correlate reductions in point source discharge loads from these illicit sources to reductions in the receiving ambient water concentrations. This could be the result of survival rates of the fecal indicators in the natural environments or the large amount

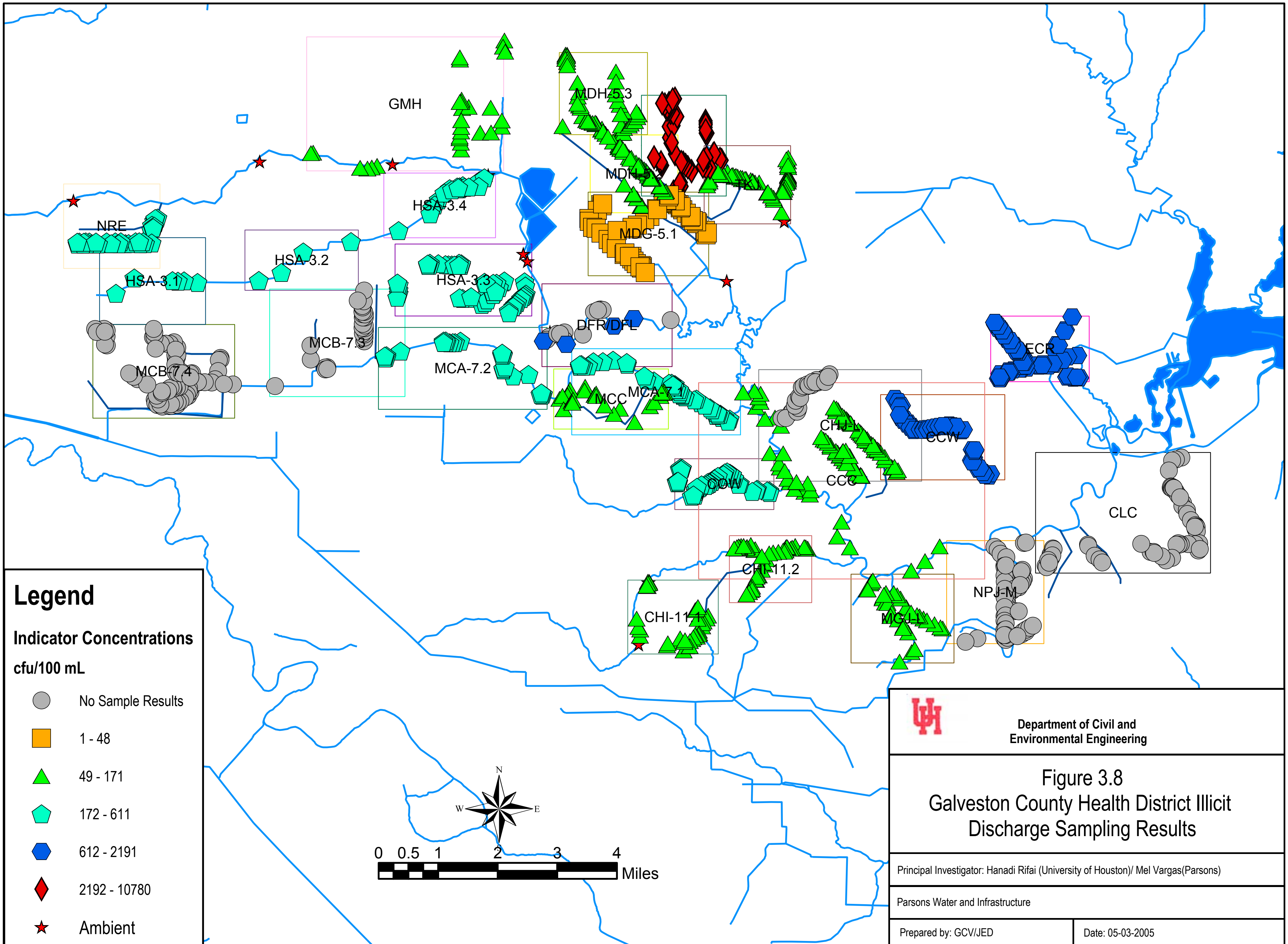


Figure 3.8
Galveston County Health District Illicit Discharge Sampling Results

Table 3.8 Fecal Pathogen Indicator Concentrations (cfu/100mL) from GCHD Discharge Study

Region	Fecal Coliform		Enterococci		*E.coli*	
	Count (# of Samples)	Geomean (cfu/100mL)	Count (# of Samples)	Geomean (cfu/100mL)	Count (# of Samples)	Geomean (cfu/100mL)
Clear Creek (CCC)	7	171	N/A	N/A	N/A	N/A
Webster Ditch (CCW)	5	1917	N/A	N/A	N/A	N/A
Chigger Creek (CHI)	31	230	3	114	24	185
Harris County Ditch (CHJ-K)	21	545	2	1974	2	110
Cowarts Creek (COW)	11	481	N/A	N/A	N/A	N/A
Clear Creek (DFR)	2	2191	N/A	N/A	N/A	N/A
Cow Bayou (ECR)	49	1790	11	133	12	1547
Hickory Slough (HSA)	74	273	4	611	26	689
Gulf Meadows (GMH)	7	83	N/A	N/A	N/A	N/A
Mary's Creek (MCA)	29	302	2	598	8	342
Mary's Creek (MCC)	33	160	N/A	N/A	7	50
Mary's Creek (MCD)	35	1011	25	516	25	723
Mud Gulley (MDG)	28	421	3	48	7	1167
Mud Gulley (MDH)	9	92	1	104	1	80
Magnolia Creek (MGJ-L)	15	84	N/A	N/A	N/A	N/A
Nolan Ryan Expy Ditch (NRE)	29	537	N/A	N/A	N/A	N/A
Turkey Creek (TKJ)	5	96	N/A	N/A	N/A	N/A
Turkey Creek (TKK)	18	106	1	10780	1	24000

N/A = not applicable
mL = Milliliters

of variability that was found in samples that were taken throughout the length of Clear Creek and its tributaries (GCHD 2001).

3.7 EFFECT OF RAINFALL ON FECAL PATHOGEN CONCENTRATIONS

Rainfall has the potential to transport large concentrations of fecal pathogens to surface water bodies through several pathways. Runoff from urban regions has been identified by the EPA as "the leading cause of impairment of the nation's surface waters" (EPA 2004). In addition, rainfall increases the potential for storm sewer overflows and biosolids releases, as a result of, inflow and infiltration.

Based on historical data, the days since rainfall were determined for each sampling event at each monitoring station within the Clear Creek Watershed. The geometric means of indicator concentrations on the day of a rainfall event and subsequent days at each of the monitoring stations are included in Table 3.9. Throughout the watershed, relatively high values are observed for samples collected the day of a rainfall event. These tend to increase sharply through the day following a rainfall event, and then decrease over the next two to three days. After the third to fourth day following a rainfall event the concentrations appear to return to a significantly lower baseline level although the strong variation common for indicator levels in surface water is still seen.

To analyze the significance of these trends, regression analyses were performed for various scenarios. The strongest trend occurred from one day following a rain event to four days after a rain event. For this period of time, the average indicator concentrations decreased at a rate of 1160 bacteria per 100 mL of ambient water per day with a confidence of over 99.99% and an R squared value of 0.48. A less significant trend was observed between the samples collected

Table 3.9 Rainy Day Tables

	E. coli													
	Samples Collected on the Day of Event		Samples Collected the Day After Event		Samples Collected 2nd Day After Event		Samples Collected 3rd Day After Event		Samples Collected 4th Day After Event		Samples Collected 5th Day After Event		Samples Collected 6+ Days After Event	
	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Avg Conc (MPN100mL)
		0		1		2		3		4		5		
11426	0	N/A	0	N/A	2	300.5	0	N/A	2	75	0	N/A	1	96
11449	12	2068	9	5626	5	240	3	330	4	132	0	N/A	14	122
11450	17	4666	8	6351	5	1111	4	2392	4	311	1	733	15	202
11451	8	7353	5	538	2	45	4	108	2	1205	0	N/A	8	917
11452	3	111	3	2533	4	112	3	403	0	N/A	1	121	7	132
14229	15	1618	10	5810	4	303	4	542	3	180	1	616	14	206
16473	15	842	8	6674	4	525	4	418	4	174	1	135	13	273
16477	14	1954	10	8814	3	510	3	67	3	463	2	283	13	85
16478	8	1755	5	7426	3	553	3	6400	4	351	0	N/A	10	96
16803	2	340	2	8	1	400	2	8	0	N/A	0	N/A	6	71
17068	4	7510	3	1093	4	604	4	86	0	N/A	0	N/A	11	123
17069	6	13195	1	882	1	5	2	312	1	246	3	1247	7	224
17070	9	2347	3	4776	0	N/A	2	2050	5	1673	2	102	7	204
17071	5	1093	3	1677	0	N/A	2	323	3	171	2	167	7	192
17073	7	3989	6	698	3	204	2	15	0	N/A	2	515	8	188
17074	8	6311	5	210	1	10	4	95	2	140	0	N/A	7	197
17076	5	6254	4	1561	4	157	3	187	0	N/A	0	N/A	11	224
17077	4	7270	4	953	4	60	4	224	0	N/A	0	N/A	12	68
17079	3	407	6	669	3	794	1	10	0	N/A	1	230	5	157

Notes:
MPN = Most Probable Number
mL = Milliliters

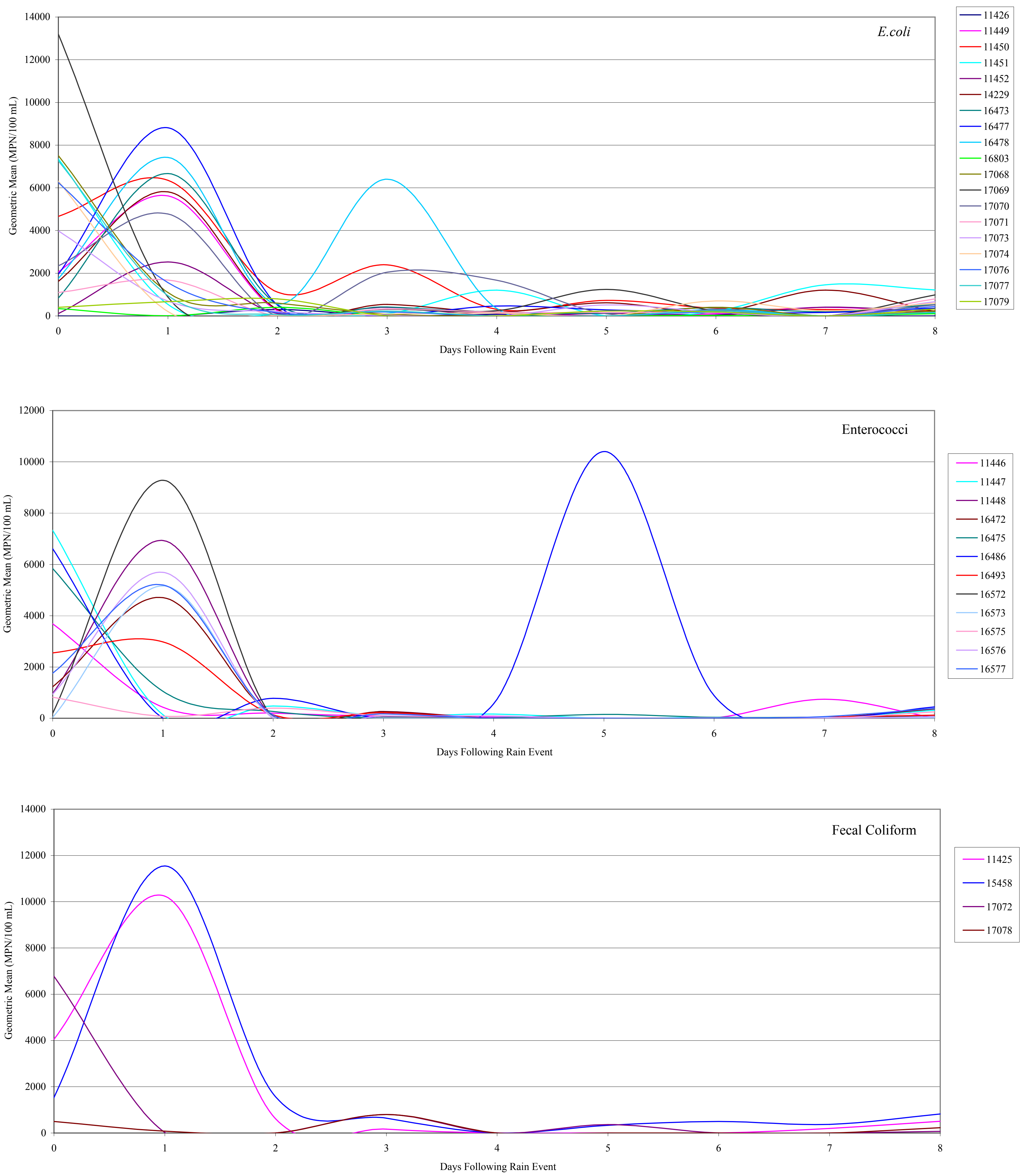
Table 3.9 Rainy Day Tables (cont.)

Enterococci														
	Samples Collected on the Day of Event		Samples Collected the Day After Event		Samples Collected 2nd Day After Event		Samples Collected 3rd Day After Event		Samples Collected 4th Day After Event		Samples Collected 5th Day After Event		Samples Collected 6+ Days After Event	
	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Avg Conc (MPN100mL)
11446	12	3680	4	425	7	201	2	83	3	51	2	6	7	114
11447	7	7332	4	135	6	477	1	100	3	167	0	N/A	6	47
11448	7	964	7	6935	3	76	3	266	0	N/A	0	N/A	6	58
16472	7	1229	7	4707	3	121	3	260	0	N/A	0	N/A	6	46
16475	7	5837	3	1049	5	267	0	N/A	3	16	1	152	11	30
16486	6	6613	0	N/A	4	778	0	N/A	2	566	1	10400	6	241
16493	5	2547	7	2979	3	135	3	213	0	N/A	0	N/A	6	49
16572	7	195	1	9280	1	32	3	44	1	4	3	6	5	11
16573	6	33	2	5161	1	48	3	14	1	2	3	6	6	11
16575	8	824	4	80	6	390	1	98	3	92	0	N/A	7	23
16576	5	937	4	5688	1	2	1	84	2	89	0	N/A	5	26
16577	6	1755	7	5194	1	122	3	173	0	N/A	0	N/A	9	79

Fecal Coliform														
	Samples Collected on the Day of Event		Samples Collected the Day After Event		Samples Collected 2nd Day After Event		Samples Collected 3rd Day After Event		Samples Collected 4th Day After Event		Samples Collected 5th Day After Event		Samples Collected 6+ Days After Event	
	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Geo Conc (MPN/100mL)	Count	Avg Conc (MPN100mL)
11425	5	4054	4	10243	2	615	1	170	0	N/A	0	N/A	5	219
11453	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A	0	N/A
15458	14	1534	2	11550	6	1563	3	640	0	N/A	2	333	19	225
17072	4	6778	1	20	0	N/A	1	800	0	N/A	3	367	4	37
17078	1	500	1	80	0	N/A	1	800	0	N/A	0	N/A	4	82

Notes:
MPN = Most Probable Number
mL = Milliliters

the day of a rain event through those a day following the rain event. Over this period of time an increase of 626 bacteria per 100 mL of ambient water per day was observed. This trend has a confidence level of slightly under 90% and an R squared value of 0.20. The fecal pathogen indicator concentrations were not found to exhibit any significant trends after the fourth day past a rainfall event. The geometric mean values for each monitoring station are shown in Figure 3.9 to help visualize the trends.



Notes:
MPN = Most Probable Number
mL = Milliliter

Figure 3.9 Effects of Rainfall on Indicator Concentrations in Clear Creek

CHAPTER 4

MONITORING AND DATA COLLECTION

This chapter presents a description of the sampling procedures and results obtained from sampling activities within the Clear Creek Watershed for Work Order No. 9.

4.1 QAPP DEVELOPMENT

The goal of this task was to develop a quality assurance plan for all field data and sample collection efforts specified in the approved Sampling Plan (Appendix A). A first draft of the Quality Assurance Project Plan for field data collection was forwarded to the TCEQ on March 23, 2005. Comments from TCEQ on the first draft were received on April 29, 2005 and a revised QAPP was submitted to TCEQ on May 10, 2005. A second set of comments from TCEQ was received on May 31, 2005 and, accordingly, a second revision of the QAPP was prepared and submitted to TCEQ on June 1, 2005. The second revision of the QAPP has been reviewed and approved by the EPA.

4.2 QC/DATA VALIDATION ACTIVITIES

Analysis of the quality control methods employed for the water and sediment samples collected from the Clear Creek Watershed was performed to ensure the accuracy of the data. In addition, methods were used to ensure proper collection of samples. The quality control methods included, but were not limited to, collection of field duplicates, equipment blanks, laboratory duplicates, laboratory blanks, and use of the IDEXX quanti-cult analysis to test the viability of the Colilert reagent. The Surface Water Quality Monitoring (SWQM) procedures manual defines a ten percent frequency for collection of blanks and duplicates in the field and analysis of each of these within the lab. The quality control frequency for collection of field blanks and duplicates is included in Tables 4.1 and 4.2. As shown in the tables, both types were collected in sufficient numbers. In addition, bacterial analysis was repeated in triplicate for each dilution value of the sample material and lab blanks were prepared and analyzed at a minimum of once per day for a total of fourteen lab blanks for the twenty six water and thirty-two sediment samples collected.

Analysis of the quality control procedures employed by the North Water District Laboratory Services, Inc. was also performed. The results of this analysis and other QC documents are included in Appendix G. Tables G-1, G-2a, G-2b, and G-2c in Appendix G show the frequency and agreement of the QC sample results. Tables G-3a and G-3b verify the compliance of the collection and lab analyses of the samples with holding time requirements. Tables G-4a and G-4b show completeness of the analyses.

Table 4.1: Frequency of Field Blank Collection and Testing

media	# samples	# blanks	frequency
water	26	4	15%
sediment	32	4	13%

Table 4.2: Frequency of Field Duplicate Collection and Testing

media	# samples	# dups	frequency
water	26	4	15.4%
sediment	32	4	12.5%

4.3 QC ISSUES

The QC issues encountered in the project are detailed in the "Data Verification Summary Report for Water and Sediment Samples Collected From Clear Creek, Houston Texas" included in Appendix G. During shipping of the samples to the North Water District Laboratory Services, Inc., three bottles that held samples for ambient water collected for total organic carbon (TOC) analysis were broken. One of these bottles held the TOC for a bottle that had been collected in duplicate so that the TOC for the original could be analyzed and data for the site was obtained. The relative percent difference (RPD) remained well within acceptance criteria as shown in Table G-2c in Appendix G. Thus the batch was considered acceptable and no flags were applied to any of the sample results. To correct this problem, all subsequent samples that were shipped were wrapped in bubble wrap to minimize the likelihood of breakage.

Some samples included in the first shipment to NWDLS froze during storage prior to shipping. These samples arrived at the laboratory frozen. After discussion of the issue with the QC data manager for this project and the NWDLS, the decision was made that the quality of the samples for these analyses had not been compromised and the tests could be performed and the results could be included in the project data. To correct the freezing problem, signs were posted where the samples had been stored directing the staff as to which storage facilities should be used to store samples at the appropriate temperature.

4.4 DESCRIPTION OF SAMPLING ACTIVITIES

Sampling of the ambient water and sediment for the Clear Creek TMDL consisted of two phases. First, the fecal pathogen indicator concentrations and related parameters were tested. Samples were collected at twenty-five stations located along the main stem and the tributaries of Clear Creek. Second, the fecal pathogen indicator concentrations and related parameters were tested at seven locations along a cross section of the creek at one of the monitoring stations sampled during the first phase. From the sampling results, the relationship between sediment concentrations and the overlying water column were analyzed and an understanding of the input of bacterial loads to Clear Creek and its tributaries from in-stream sediments can begin to be understood. Also, from the data collected during the second phase, the relative fecal pathogen concentrations along a cross section of the creek can be analyzed.

At each location, samples were collected following the procedures outlined in the Standard Operating Procedures (for Clear Creek TMDL Project) included in Appendix H. Grab samples of water to be tested for bacteria were collected first to prevent contamination from other sources. Samples of water for total suspended solids (TSS), total organic carbon (TOC), ammonia concentration, and orthophosphorous concentration tests were then collected. Next, composite samples of sediment were collected from the creek. These samples were mixed well in a sterilized plastic bucket and then distributed into separate containers for bacteria analysis and to be analyzed for percent moisture and volatile solids. Finally, the total stream width, depth measurements (at several intervals), and other parameters such as the weather, water appearance, wildlife, number of days since last rainfall event, and flow (at twenty-one of the stations) were recorded in the field.

One focus of the sampling performed for this work order was to analyze the relationship between water and sediment fecal pathogen concentrations in Clear Creek. For sampling conducted during the first phase, the point of intersection of the edge of the water surface and the sediment banks was chosen to help achieve this goal. The results from research study by T. R. Desmarais, H. M. Solo-Gabriele, and C. J. Palmer in 2002 to show that the highest bacteria concentrations occur in tidally influenced rivers at the intersection of the water surface and the sediment banks (Desmarais, et al. 2002).

The choice of the interface between the water surface and the sediment banks for the sampling of ambient water and sediment fecal pathogen indicator concentrations provides benefits for several reasons. First, one important factor in the analysis of contamination in sediments is the analysis of all deposited sediment types. Sampling of very fine sediments is often difficult because of the ease with which these can be re-suspended by minor disturbances of the nearby water column. When sampling at the edge of the water surface, however, it is much easier to collect all of the sediments using a trowel and not lose sediment of any particular size.

Second, high sediment concentration is beneficial for the laboratory analysis procedure. The fecal pathogen enumeration method chosen for this project was developed by the IDEXX Corporation. To analyze the concentrations of fecal pathogens in the sediment, the sediment samples must be mixed thoroughly with sterilized water and tested following the IDEXX procedure. High sediment concentrations can inhibit the IDEXX trays from sealing properly and this may adversely affect the accuracy of the test. In addition, the concentration of fecal pathogen indicators must be within a certain range to be accurate. To reduce the potential for incomplete sealing yet ensure a high enough concentration so that the values are within the required range, it is beneficial to obtain sediment from regions of highest potential fecal pathogen indicator concentrations.

Finally, the sediments located along the water surface edge often have a higher potential for disturbance than in-stream sediments. This is due to the direct contact of these sediments by organisms that live both inside and near the creek. Many different animals live along the banks of creeks or spend large amounts of time there. These animals often re-suspend large amounts of sediment from these regions as they move around. In addition, people who use rivers and creeks for recreational purposes often directly re-suspend large amounts of sediment upon accessing the body of water. This could lead to high levels of exposure of people to fecal pathogens living in these bank sediments. Therefore, it is of high importance to analyze the concentrations of the fecal pathogen indicators here. It is important to note that although these sediment samples were collected using a composite method, each of the samples was collected at the same region of the creek taking care not to mix samples from regions that may have variations that result from spatial variability.

To provide data for the variation in fecal pathogens between the banks, samples were collected at a cross section of the creek at site 17071. These data provide a method of comparison for concentrations at each of the other locations. The concentrations along the creek bed at each location can then be extrapolated from the concentration measured at the sediment-water interfaces.

At each of the sampled locations, several parameters were measured to analyze their relationships with fecal pathogen concentrations. Using the YSI meter, the conductivity, turbidity, pH, and the dissolved oxygen levels were measured at each monitoring station. The concentrations of ammonia and orthophosphorous were also tested using the HACH colorimeter.

Samples of water were sent to the North Water District Laboratory Services, Inc. (NWDLS) located in the Woodlands in Texas to be tested for total organic carbon (TOC) and total suspended solids (TSS). Samples of sediment from the same locations for which sediment concentrations of fecal pathogens were collected were sent to NWDLS to test for volatile solids and percent moisture.

Flow was measured at locations of sample collection so that the load of fecal pathogens in the water could be calculated. Flow was measured at twenty-one of the twenty-five total stations. Three different methods were used to measure flow. The first method involved the measurement of the cross sectional area and the velocity using the Marsh McBirney Flowmeter. The second method used the RiverCat flow measuring equipment and software. At monitoring stations where the elevation of the creek was too low to use either of these methods, flow was calculated from the cross-sectional area of the creek and the surface velocity.

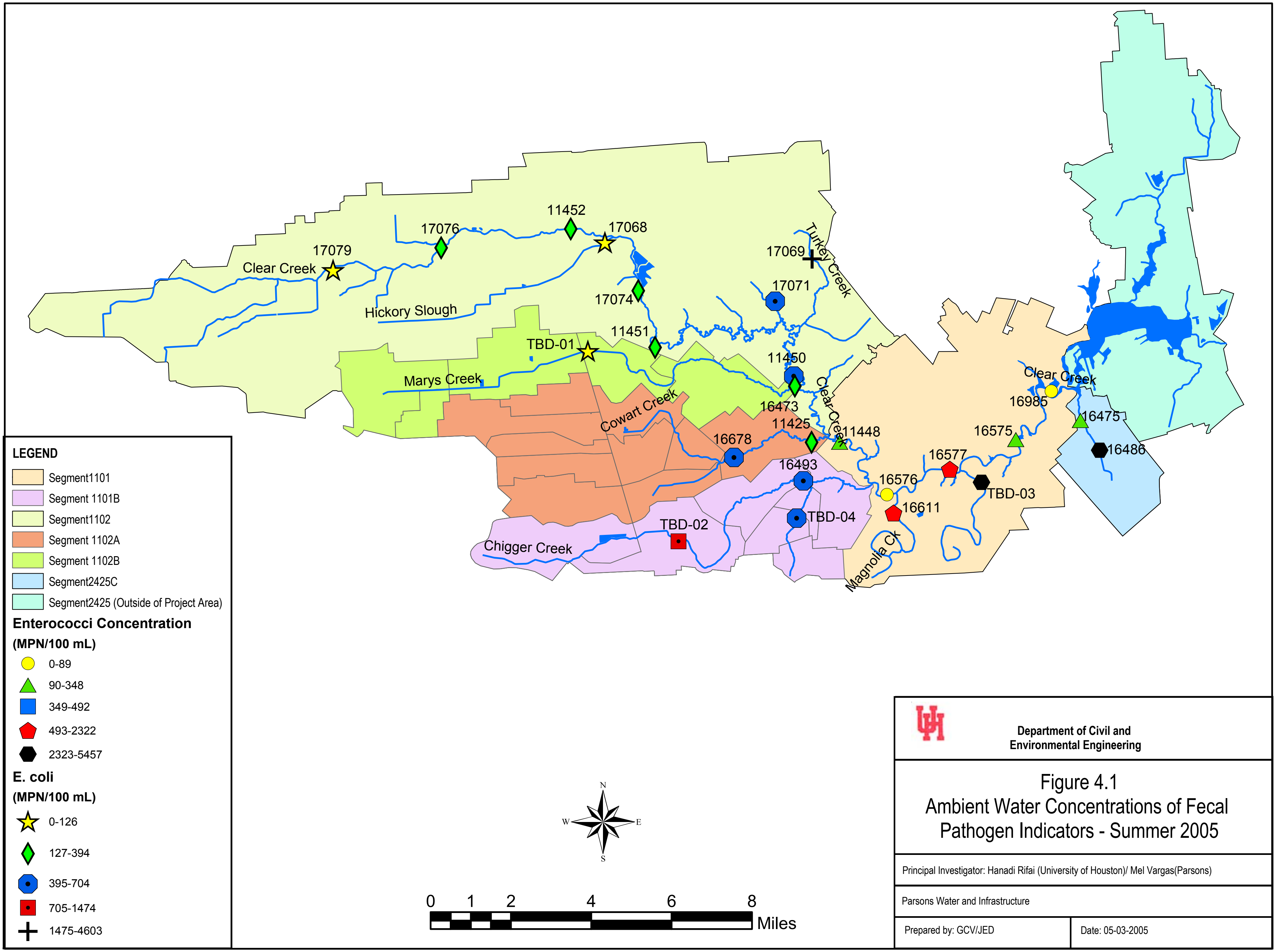
The locations at which samples were collected are outlined in Table A.4 and shown in Figure 4.1. One of the stations (TBD-05) was dry and, therefore, no samples were collected. In addition, one of the stations originally scheduled for sample collection was changed. Station 16572 could not be accessed because the site was located on private property that could only be accessed through a private gate (at The Preserve community). An alternate site, station 16475, located just upstream of station 16572 at the intersection of Robinson's Bayou and Farm to Market Road 270, was sampled instead.

The second phase of sampling involved the collection of seven sediment samples along a cross-section of the creek to analyze the variation of fecal pathogen concentrations along a transect. One goal of this phase was to help relate the sediment fecal pathogen concentrations obtained during the first phase to the concentrations throughout the creek bed. Sediment samples were collected at the midpoint of the stream, at the both edges of the water surface, halfway between the midpoint and the edges of the water surface, and one foot from either edge moving away from the creek. Water samples were collected for fecal pathogen analysis so that the concentration at each sediment location could be compared to the water concentration.

The IDEXX Colilert®-24 method was used to quantify *E.coli* concentrations for each of the stations in freshwater segments. According to the TCEQ (2003), interference may be caused by high conductivity values in freshwater streams. None of the monitoring stations located in freshwater segments of the Clear Creek watershed had conductivity values above 3000 micromhos/cm (the threshold designated for interference from high conductivity values). Thus, the IDEXX Enterolert® method was used for the quantification of Enterococci concentrations at monitoring stations located in tidal stream segments.

Reconnaissance of pipes discharging into Clear Creek was undertaken from June 29, 2005 to August 19, 2005. A preliminary reconnaissance effort was performed on June 29, 2005 to gauge the speed at which the reconnaissance work could be performed, to insure the reconnaissance team received proper training and equipment, and to determine the sections of Clear Creek that could be surveyed on foot, by wading, on a kayak, or would require a small boat and motor.

The majority of the reconnaissance work was performed from August 4, 2005 through August 19, 2005. This time period exhibited normal to lower than normal rainfall amounts in the watershed, which allowed the team to locate pipes and safely navigate the waterway. Reconnaissance efforts were suspended on days that the creek water levels would impede the identification of outfall pipes that discharge into the creek.



Clear Creek
Hickory Slough
Marys Creek
Cowart Creek
Chigger Creek
Turkey Creek
Clear Creek
Magnolia CK
Clear Creek
17079
17076
11452
17068
17074
11451
TBD-01
17069
17071
11450
16473
11425
11448
16678
16493
TBD-02
TBD-04
16576
16611
16577
TBD-03
16575
16985
16475
16486
LEGEND
Segment1101
Segment 1101B
Segment1102
Segment 1102A
Segment 1102B
Segment2425C
Segment2425 (Outside of Project Area)
Enterococci Concentration
(MPN/100 mL)
0-89
90-348
349-492
493-2322
2323-5457
E. coli
(MPN/100 mL)
0-126
127-394
395-704
705-1474
1475-4603
N
W
E
S
0
1
2
4
6
8
Miles
Department of Civil and
Environmental Engineering
Figure 4.1
Ambient Water Concentrations of Fecal
Pathogen Indicators - Summer 2005
Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)
Parsons Water and Infrastructure
Prepared by: GCV/JED
Date: 05-03-2005

Safety procedures, goals of the reconnaissance task, and training with field equipment were covered with the team prior to deployment in the field. The safety issues addressed included common waterway hazards, animal and plant hazards; weather threats including lightning, rainfall, and flash flooding; the limited access to the waterway; and heat and sun related dangers to the team. The primary goals of the task were to document the location, diameter, and drainage classification (flowing or not flowing) of all pipes that outfall into the waterway. In addition, the following information was documented when observable: general physical description of the pipe location, river bank of the pipe (in reference to facing downstream on the waterbody), and Global Positioning System (GPS) information. Digital photos were taken of the outfall pipes, except when inclement weather prohibited use of the digital camera outdoors. The photos are included in Appendix I. It should be noted that the accuracy of GPS equipment in a heavily wooded waterway is limited due to tree canopy interference with satellite data acquisition.

The reconnaissance was performed in an upstream to downstream manner on the mainstem waterbody of Clear Creek. Reconnaissance began at Hiram Clarke Road and Clear Creek near the Harris County - Fort Bend County line, on the southwest edge of Houston. This is just south of the Sam Houston Tollway-Beltway 8 roadway. The reconnaissance continued to near the Interstate 45 Bridge in League City.

Field notes were documented in a water resistant field notebook. This information has been entered into a Microsoft Excel database for future analysis and summarization. The data entry was quality verified by performing a second check on 20% of the lines of data in the computer file against the original field logbook accounts.

4.5 SAMPLING RESULTS

The sampling in the Clear Creek watershed was conducted to gather additional data for the TCEQ water quality database, to calculate the loads of fecal pathogen indicators in Clear Creek and its tributaries, to analyze the relationship between water and sediment concentrations of fecal pathogen indicators and the variability of sediment concentrations along the creek bed, and to analyze the relationships between water concentrations and several other parameters including total suspended solids (TSS), total organic carbon (TOC), pH, ammonia, and turbidity.

To calculate the loads of fecal pathogen indicators throughout the main stem and the tributaries of Clear Creek, both the concentrations of the bacteria in the water column and the flow were determined. TCEQ (2003) bacteria methods were used for collection of all samples. Once the samples were collected, they were brought to the University of Houston laboratory for analysis. The IDEXX Colilert®-24 method was performed to measure the concentration of *E.coli* in freshwater samples, whereas the IDEXX Enterolert® method was performed to measure the concentrations of Enterococci in tidally influenced samples.

Table 4.3 lists the measured concentrations for both *E.coli* and Enterococci (EC – *E.coli*, NT – Enterococci) at the locations that were sampled. The concentrations for *E.coli* ranged from 38 cfu per 100 mL to 4,790 cfu per 100 mL. The standard set by the EPA for the geometric

Table 4.3 Concentrations of Fecal Pathogen Indicators in the Clear Creek Watershed

Location ID	Indicator	WATER Concentration (MPN/100 mL)	SEDIMENT Concentration (MPN/100g)
11425	EC	2.57E+02	5.43E+05
11450	EC	9.05E+02	5.39E+04
11451	EC	1.87E+02	2.47E+03
11452	EC	1.49E+02	4.86E+05
16473	EC	1.50E+02	3.29E+03
16493	EC	5.00E+02	1.04E+04
16678	EC	6.75E+02	1.78E+03
17068	EC	3.87E+01	2.99E+03
17069	EC	4.42E+03	4.99E+05
17069-DUP	EC	4.79E+03	
17071	EC	5.05E+02	2.57E+04
17074	EC	1.35E+02	4.25E+04
17074-DUP	EC		4.70E+04
17076	EC	1.38E+02	1.04E+05
17079	EC	9.54E+01	6.78E+04
TBD-01	EC	6.06E+01	3.78E+04
TBD-01-DUP	EC		4.17E+04
TBD-02	EC	1.47E+03	1.96E+03
TBD-04	EC	7.04E+02	1.38E+04
11448	NT	1.04E+02	1.05E+05
16475	NT	2.35E+02	1.80E+05
16475-DUP	NT		1.24E+05
16486	NT	2.32E+03	1.63E+05
16575	NT	3.48E+02	4.36E+03
16576	NT	3.99E+01	8.05E+04
16576-DUP	NT		8.90E+04
16577	NT	4.92E+02	3.45E+04
16611	NT	2.11E+03	9.75E+04
16985	NT	8.53E+01	1.11E+04
TBD-03	NT	4.28E+03	>8.07E+06
TBD-03-DUP	NT	6.63E+03	

Notes:

EC = *E. coli*

NT = Enterococci

MPN = Most Probable Number

mL = milliliter

g = grams

mean of *E.coli* is 126 cfu per 100 mL and the limit for single samples is 394 cfu per 100 mL. The single sample concentration standard was exceeded at seven of the sixteen stations that were tested for *E.coli*. The geometric mean of the samples collected within the freshwater segments was 326 cfu per 100 mL which is greater than the geometric mean standard. The concentrations of the samples analyzed for Enterococci concentrations ranged from 39 cfu per 100 mL to 5,460 cfu per 100 mL (taken as the average of the measured concentrations at site TBD-03). The standard for the geometric mean of Enterococci concentrations within tidally influenced and saltwater bodies is 35 cfu per 100 mL. The geometric mean of Enterococci concentrations for tidal segments was 417 cfu per 100 mL. This value exceeds the geometric mean standard by 368%. The single sample limit is 89 cfu per 100 mL (TNRCC 2000). The single sample standard was exceeded at seven of the nine stations. Figure 4.1 shows the locations and concentrations for the stations sampled.

The flow was calculated at twenty-one stations throughout the main stem and tributaries of Clear Creek using the procedure outlined in TCEQ (2003). This procedure involves breaking the cross section into a number of intervals (dependant upon the size of the creek), measuring the velocity and calculating the area of each, and taking the sum of the products of the area by the velocity for each to find the flow for the entire cross section. Table 4.4 shows the flow values for each of the stations, the creek/tributary where the station is located, and the method that was used to measure the flow at each. The flow measured at station 11425 was -8.97 cubic feet per second. Negative flow values would most easily be explained by tidal influence, although this station is located outside of the region that the TCEQ has designated as tidally influenced. As a result, this value is likely to be the result of increased water volumes in the main stem of Clear Creek that are pushing into Cowart Creek causing backflow. The Marsh McBirney device was

Table 4.4 Flow Measurements for Clear Creek and Tributaries

Station	Flow (ft^3/s)	Creek/Tributary Name	Measurement Method
17079	32.39	Clear Creek Main Stem	Marsh McBirney Flo-Mate
17076	32.07	Clear Creek Main Stem	Marsh McBirney Flo-Mate
11452	33.69	Clear Creek Main Stem	Marsh McBirney Flo-Mate
17068	3.73	Hickory Slough	Marsh McBirney Flo-Mate
17074	44.12	Clear Creek Main Stem	Marsh McBirney Flo-Mate
11451	34.26	Clear Creek Main Stem	Marsh McBirney Flo-Mate
17071	4.05	Mud Gulley	Marsh McBirney Flo-Mate
17069	4.02	Turkey Creek	Marsh McBirney Flo-Mate
11450	71.69	Clear Creek Main Stem	RiverCat
TBD-01	16.73	Mary's Creek	Marsh McBirney Flo-Mate
16473	9.60	Mary's Creek	Marsh McBirney Flo-Mate
16678	0.95	Cowart Creek	Surface Velocity
11425	-8.97	Cowart Creek	Marsh McBirney Flo-Mate
TBD-02	0.58	Chigger Creek	Marsh McBirney Flo-Mate
16493	0.45	Chigger Creek	Marsh McBirney Flo-Mate
16576	118.56	Clear Creek Main Stem	RiverCat
16611	2.29	Magnolia Creek	Marsh McBirney Flo-Mate
TBD-03	0.13	Unnamed Tributary	Surface Velocity
16575	396.23	Clear Creek Main Stem	RiverCat
16486	2.18	Robinson's Bayou	Marsh McBirney Flo-Mate
16475	11.16	Robinson's Bayou	RiverCat

Notes:
ft^3/sec = Cubic Feet per Second
Negative flows could be the result of backflow from the mainstream.

used to measure the flow at this station and this device was calibrated during sampling to ensure accuracy.

The furthest upstream monitoring station located on the main stem of Clear Creek had a flow of 32.39 ft^3/s. Station 11450 is the furthest downstream location in Segment 1102 (Clear Creek Above Tidal) where flow was measured. The flow at this station was 71.69 ft^3/s. At the furthest downstream location measured in Segment 1102 (Clear Creek Tidal), the flow increased to 396.23 ft^3/s. Each of the tributaries provides substantially less flow than is observed at even the furthest upstream station on Clear Creek. The largest flow into Clear Creek was measured at station 16475 on Robinson's Bayou. Mary's Creek had a maximum flow of 16.73 ft^3/s but its furthest downstream measured location (station 16473) showed 9.60 ft^3/s. Chigger Creek, Magnolia Creek, and the unnamed tributary convey relatively small flows of less than 3 ft^3/s.

The fecal pathogen indicator loads illustrate the relative contribution of different sources to surface bodies of water. Using the flow measurements made for this phase and the indicator concentrations tested from the water, the contributions of several of the tributaries into the main stem of Clear Creek can be analyzed. The results of these loading calculations are presented in Section 4.5.

Figure 4.2 shows the relationship between the concentrations of fecal pathogens in water and in the sediment at the twenty-five monitoring stations where data was collected. For the samples collected from water, the concentration was calculated in MPN (most probable number) of fecal pathogen indicator bacteria per 100 mL of water to match the TCEQ standards. For fecal pathogen concentrations of sediment samples there is no standard set by the TCEQ. The MPN of indicator bacteria per 100 g of sediment was chosen. A regression analysis was

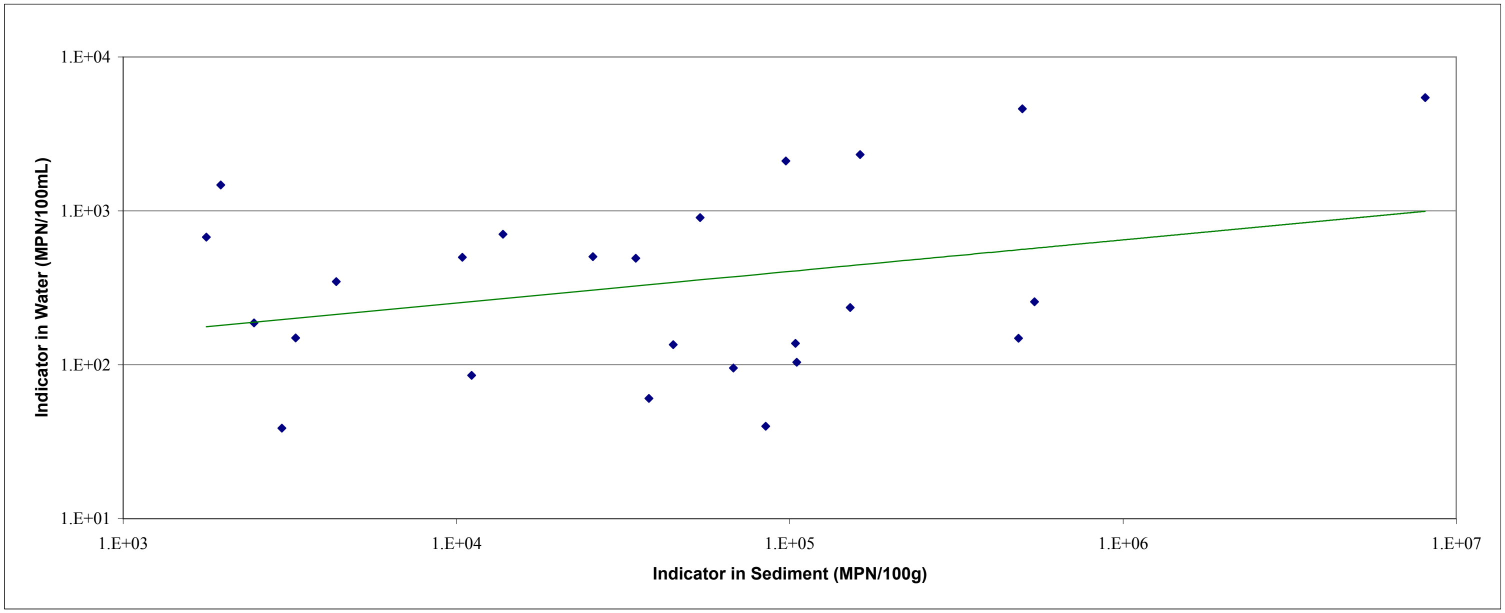


Figure 4.2: Data Analysis of Relationship Between Water and Sediment Bacterial Concentrations in Clear Creek

Location ID	Indicator	WATER Concentration (MPN/100 mL)	SEDIMENT Concentration (MPN/100g)
11425	EC	2.57E+02	5.43E+05
11450	EC	9.05E+02	5.39E+04
11451	EC	1.87E+02	2.47E+03
11452	EC	1.49E+02	4.86E+05
16473	EC	1.50E+02	3.29E+03
16493	EC	5.00E+02	1.04E+04
16678	EC	6.75E+02	1.78E+03
17068	EC	3.87E+01	2.99E+03
17069	EC	4.60E+03	4.99E+05
17071	EC	5.05E+02	2.57E+04
17074	EC	1.35E+02	4.48E+04
17076	EC	1.38E+02	1.04E+05
17079	EC	9.54E+01	6.78E+04
TBD-01	EC	6.06E+01	3.78E+04
TBD-02	EC	1.47E+03	1.96E+03
TBD-04	EC	7.04E+02	1.38E+04
11448	NT	1.04E+02	1.05E+05
16486	NT	2.32E+03	1.63E+05
16575	NT	3.48E+02	4.36E+03
16576	NT	3.99E+01	8.47E+04
16577	NT	4.92E+02	3.45E+04
16611	NT	2.11E+03	9.75E+04
16985	NT	8.53E+01	1.11E+04
16475	NT	2.35E+02	1.52E+05
TBD-03	NT	5.46E+03	8.07E+06

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.70843286
R Square	0.50187711
Adjusted R Square	0.4802196
Standard Error	1008.22671
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	23556194.08	2E+07	23.17334508	7.40513E-05
Residual	23	23379985.15	1E+06		
Total	24	46936179.23			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	607.844012	208.9117738	2.9096	0.007894084	175.6776697	1040.01035
X Variable 1	0.00061904	0.000128595	4.8139	7.40513E-05	0.000353021	0.00088506

performed on these data to determine whether a relationship existed between the sediment and water concentrations. As the concentration of indicators in the sediment increased, the water concentrations increased, with a slope of 0.00062. The concentrations show a significant correlation with a confidence level above 99.9 percent and have an R^2 value of 0.50. The concentrations of fecal pathogens in the sediment located across the entire stream bed may be re-suspended and increase the concentration of the overlying water. As a result, it is important to understand the variation in concentration of fecal pathogen indicators across the stream bed.

Phase 2 of the sampling conducted at Clear Creek involved collection of sediment samples along a cross-section of Mud Gulley. Mud Gulley is eleven feet wide at the location where samples were collected. The samples were collected at both of the intersections of the water surface and the stream bed, at 2.75 feet from the left bank, in duplicate at the midpoint (5.5 feet from the bank), at 8.25 feet from the left bank, and at both sides one foot outside of the edge of the water. Table 4.5 lists the concentrations for the samples collected at each of the locations. The values for the concentrations of fecal pathogens in water average at 732 MPN/100 mL. This is close to the 505 MPN/100 mL value measured during phase one. The sediment samples tested had *E. coli* that ranged from 287 MPN/100 mL to 57,100 MPN/100 mL. The highest values were analyzed from the sediment samples collected one foot outside of Mud Gulley. The arithmetic average of the concentrations measured at these locations is 29,500 MPN/100 g. The average concentration measured at locations at and within the edge of the stream for the sediment samples is only about 5% of this value: 572 MPN/100 g. It appears that sediment from the banks of the stream may be a source of bacteria into the stream.

Table 4.5 Concentrations of Fecal Pathogen Indicators Along a Cross Section at Station 17071

Location ID	Location (ft)*	Indicator	WATER	SEDIMENT
			Concentration (MPN/100 mL)	Concentration (MPN/100g)
17071-4A	-1	EC		5.71E+04
17071-3A	0	EC		3.22E+02
17071-2A	2.75	EC		2.87E+02
17071	5.5	EC	7.96E+02	
17071-DUP	5.5	EC	6.68E+02	
17071-1	5.5	EC		8.04E+02
17071-1-DUP	5.5	EC		9.04E+02
17071-2B	8.25	EC		4.09E+02
17071-3B	11	EC		7.07E+02
17071-4B	12	EC		1.87E+03

Notes:
* Locations are listed by distance from left bank (looking downstream)
(Values increase moving southwest from left bank. Negative value lies outside of stream)

EC = *E. coli*

MPN = Most Probable Number

mL = Milliliter

g = Grams

ft = feet

Table 4.6 Additional parameters measured at Clear Creek Watershed

STATION ID	TEMP	SAL	COND	SPC	DO	DO	DEPTH	pH	TURB	Ammonia	Phosph	TSS	TOC	% SOLIDS	VOL SLDS	Indicator	Water	Sediment
	˚ C	ppt	µs/cm	µs/cm²	%	mg/L	ft		NTU	mg/L	mg/L	mg/L	mg/L	%	%		MPN/ 100 mL	MPN/ 100 mL
11425	29.72	0.05	1003	919	63.6	4.86	1.0	7.95	55.6	0.08	1.19	26.60	9.93	59.60	6.20	EC	257	542971
11450	30.27	0.29	669	608	92.7	6.94	1.0	7.72	35.9	0.00	0.83	51.20	5.82	70.60	3.95	EC	519	53863
11451	28.68	0.28	622	581	71.2	5.50	1.0	7.67	61.8	0.18	0.84	64.00	*	73.00	6.85	EC	187	2471
11452	31.22	0.27	574	642	54.3	4.01	1.0	7.46	39.7	0.00	1.71	58.00	5.79	63.90	7.79	EC	149	485809
16473	30.09	0.33	758	691	100.7	7.57	1.0	8.05	8.3	0.10	2.12	15.40	5.77	71.80	3.82	EC	150	3293
16493	29.14	0.55	1209	1121	34.2	2.64	1.3	7.54	5.1	0.08	0.39	7.80	10.30	80.60	3.55	EC	500	10420
16678	30.58	0.46	1053	951	77.6	5.82	0.5	7.80	35.1	0.00	0.87	52.60	11.50	75.90	5.17	EC	675	1776
17068	32.22	0.15	314	353	114.3	8.30	0.3	8.11	15.3	0.00	0.00	16.00	6.28	71.10	7.44	EC	39	2993
17069	30.59	0.36	832	750	92.9	6.11	0.5	7.41	11.4	0.62	6.06	28.40	7.63	32.60	14.60	EC	4603	498770
17071	34.15	0.31	767	653	145.2	10.17	1.0	8.23	18.4	0.18	2.45	26.40	6.53	78.50	3.68	EC	505	25666
17071	28.73	0.37	812	758	65.0	5.01	0.5	7.79	24.3	0.00	1.81					EC	505	25666
17074	32.3	0.25	518	590	67.5	4.90	1.0	7.12	54.9	0.14	0.87	96.80	5.75	62.30	7.18	EC	135	44763
17076	29.05	0.23	474	509	57.5	4.20	1.0	7.70	24.5	0.21	0.58	25.60	5.39	61.50	8.46	EC	138	104047
17079	28.71	0.24	495	530	53.6	4.13	1.0	8.07	33.5	0.15	0.57	30.80	5.59	68.60	9.75	EC	95	67831
TBD-01	34.37	0.30	746	633	64.1	-	0.5	8.65	-22.6	0.22	2.53	26.00	6.17	76.15	1.68	EC	61	37822
TBD-02	29.17	0.39	866	798	40.2	-	1.0	7.40	-25.9	0.06	0.48	9.60	13.20	76.90	1.74	EC	1474	1964
TBD-04	27.67	0.39	817	772	37.0	2.89	0.3	7.45	268.0	0.26	0.45	65.80	3.15	41.50	9.11	EC	704	13786
11448	31.26	0.31	735	657	59.1	4.39	1.0	7.72	17.0	0.11	1.50	56.00	*	62.90	4.61	NT	104	104998
16475	29.59	1.68	3562	3279	111.0	8.11	1.9	8.10	17.9	0.00	0.00	23.20	5.34	68.10	4.68	NT	235	151893
16486	28.52	0.12	263	246	54.6	4.28	1.0	8.56	146.1	0.16	0.09	74.60	2.63	67.90	6.62	NT	2322	162735
16575	36.03	0.17	396	362	104.7	7.49	1.0	7.75	5.6	0.25	1.34	22.60	7.39	66.60	4.03	NT	348	4364
16576	32.04	0.26	618	544	69.9	5.16	1.0	7.86	22.3	0.07	1.86	26.60	7.09	66.90	7.24	NT	40	84726
16577	30.94	0.16	379	346	106.8	8.50	1.0	7.58	51.1	0.31	1.14	26.20	7.10	73.80	3.59	NT	492	34517
16611	28.24	0.36	794	748	80.3	-	1.0	7.32	29.5	0.25	0.75	17.60	6.45	79.30	0.88	NT	2110	97464
16985	31.02	2.62	5505	4943	74.8	5.33	-	8.51	35.2	0.30	0.81	26.80	8.93	77.00	2.66	NT	85	11111
TBD-03	29.28	0.29	627	580	85.0	6.53	0.5	8.45	449.4	0.76	0.53	50.00	16.90	66.70	5.25	NT	5457	8068444

Notes:

µs/cm = Microsiemens per Centimeter

mg/L = Milligrams per Liter

ft = feet

NTU = Nephelometric Turbidity Units

EC = *E. coli*

NT = Enterococci

MPN=Most Probable Number

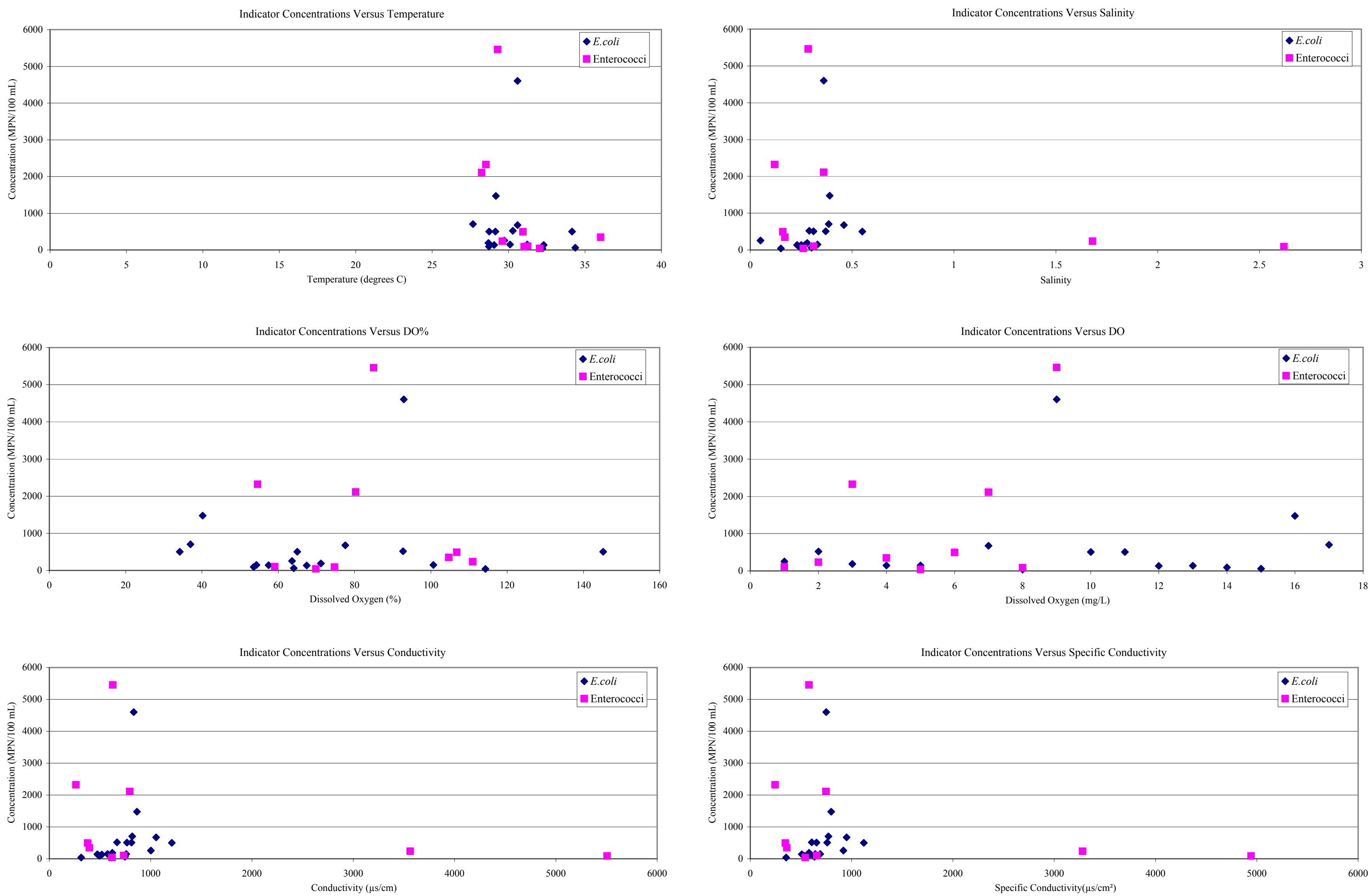
mL=Milliliter

˚ C = Degrees Celsius

Table 4.6 lists the additional parameters that were measured. The relationship of these parameters to the fecal pathogen indicator concentrations is of interest for several reasons. First, if a strong relationship between a parameter and fecal pathogen concentrations is found, this parameter could potentially be used as a quick and simple method of estimating fecal pathogen contamination. In addition, these data will improve the understanding and modeling of the transport of fecal pathogens. Regression analyses of the data shows relationships of significance above the 95% confidence level between the ammonia, turbidity, and total organic carbon concentrations and the fecal pathogen concentrations. The strongest relationship appears to be that between ammonia and fecal bacteria concentrations. This trend has an R^2 value of 0.62 and a confidence over 99.9%. Graphs of the fecal pathogen indicator concentrations and related parameters are shown in Figure 4.3. For the relationships that were found to be significant above the 95% confidence level, the trendlines are shown.

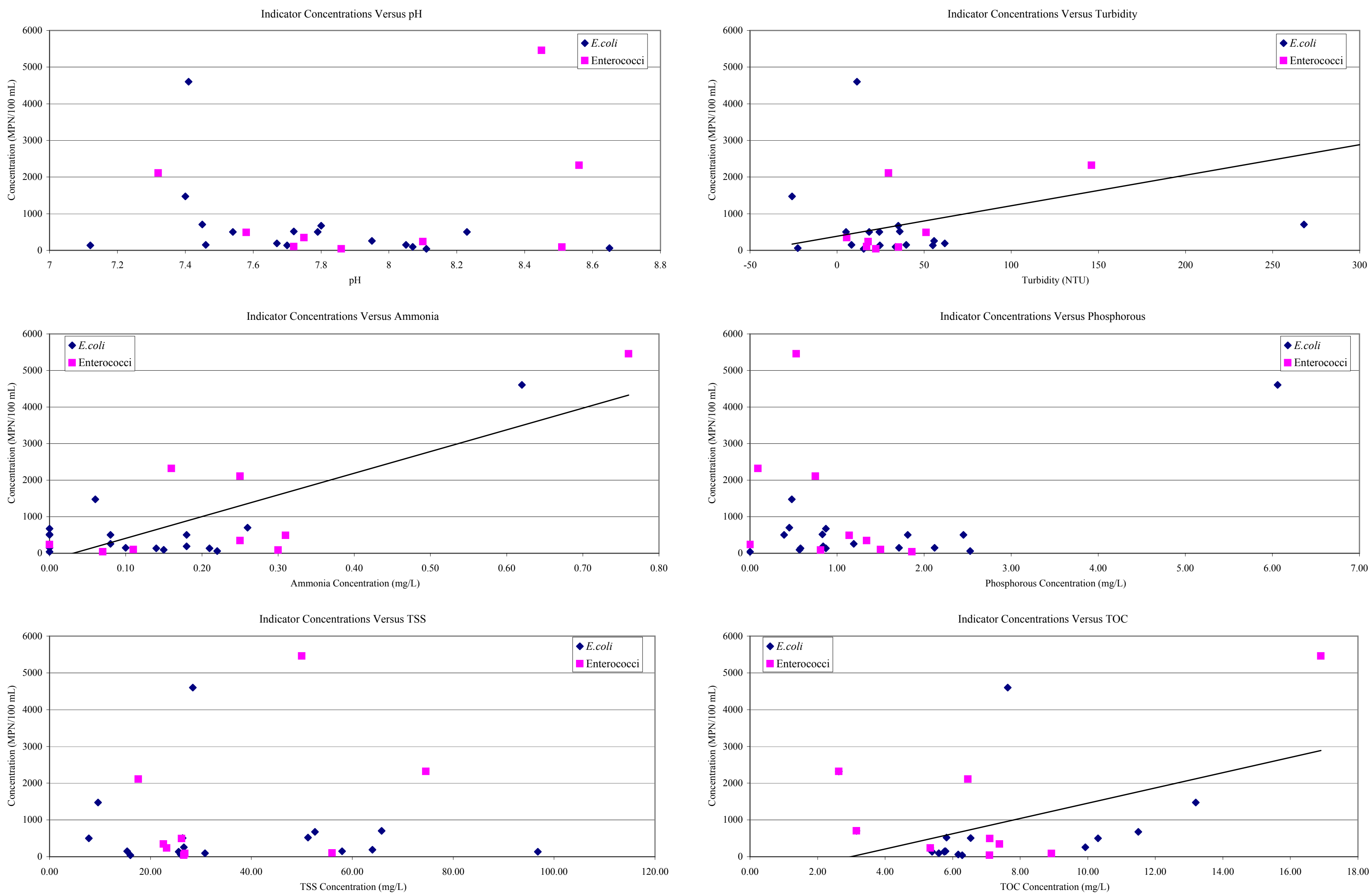
4.6 RESULTS FROM INVENTORY OF OUTFALLS

The pipe reconnaissance identified one-hundred-sixty-eight (168) pipes that terminate in the portion of Clear Creek watershed that was surveyed. Discharge was observed at thirty-seven (37) of these pipes during the survey. During the field survey, the Clear Creek Watershed received some typical sporadic and isolated rain showers. As a result, some of the discharge from these pipes may have been storm water. Figure 4.4 shows the locations of the pipes found during both the reconnaissance performed for this project and the GCHD study (described in Section 3.6.4) in addition to the locations of permitted dischargers. The majority of the data collected during the GCHD study were collected on tributaries of Clear Creek and those during



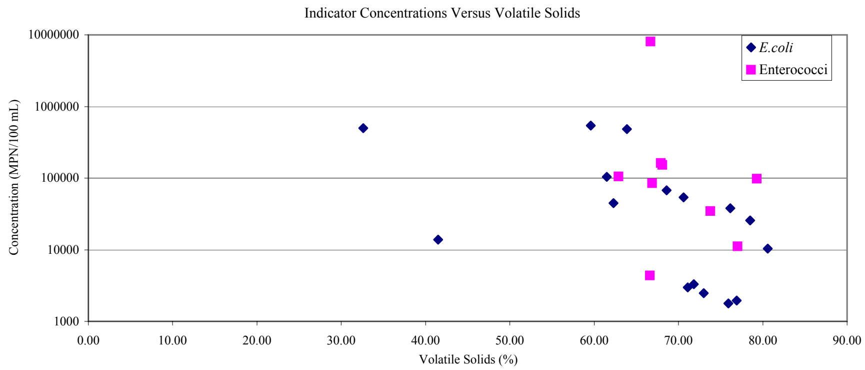
Notes:
MPN = Most Probable Number
mL = milliliter
µs/cm = Microsiemens per Centimeter
mg/L = Milligrams per Liter

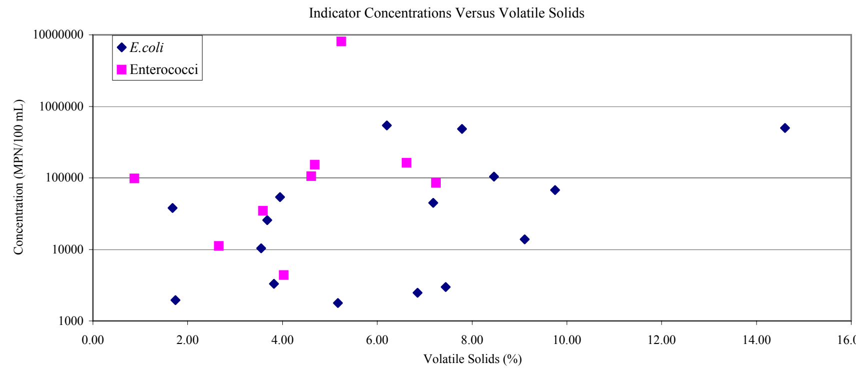
Figure 4.3 Relationship between Indicator Concentrations and Additional Parameters



Notes:
MPN = Most Probable Number
mL = milliliter
mg/L = Milligrams per liter
NTU = Nephelometric Turbidity Units

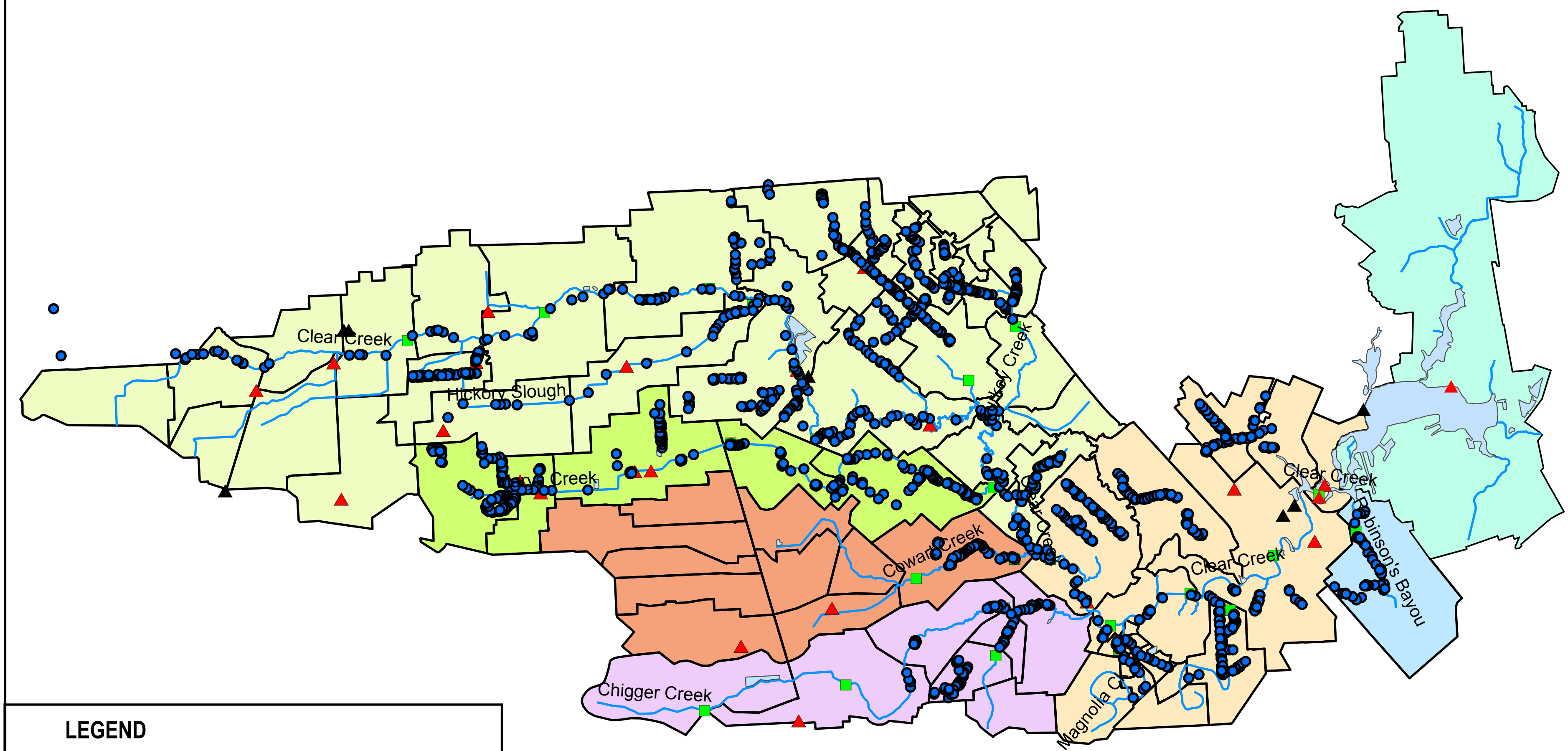
Figure 4.3 Relationship between Indicator Concentrations and Additional Parameters (cont.)





Notes:
MPN = Most Probable Number
mL = milliliter

Figure 4.3 Relationship between Indicator Concentrations and Additional Parameters (cont.)



LEGEND

- Pipe Location
- Municipal WWTP
- Sampling Station - TMDL Study
- Permitted Outfalls - Project Area
- Segment1101
- Segment 1101B
- Segment1102
- Segment 1102A
- Segment 1102B
- Segment2425C
- Segment2425 (Outside of Project Area)

Department of Civil and Environmental Engineering

Figure 4.4
Pipes Observed by Recon and in GCHD Study

Principal Investigator: Hanadi Rifai (University of Houston)/ Mel Vargas(Parsons)

Parsons Water and Infrastructure

Prepared by: GCV/JED

Date: 05-03-2005

the pipe reconnaissance focused on the main stem of the creek. The map also shows locations of municipal wastewater treatment plants, other permitted outfalls, and the locations at which ambient samples were collected. The map shows that eleven wastewater treatment plant outfalls were identified during the GCHD and TMDL studies; and that fourteen wastewater treatment plant outfalls were not identified during either study. The fourteen unaccounted wastewater treatment plants are located far upstream on Clear Creek, in the upstream regions of Cowart Creek and Chigger Creek, and near the confluence of Clear Creek and Clear Lake.

4.7 ESTIMATION OF LOADING IN THE CHANNEL

As discussed previously, the estimation of loads within and into Clear Creek enables the quantification of different sources and the estimation of the impact that each source has on the fecal pathogen concentrations found in the body of water. To calculate the loads within Clear Creek and its tributaries, the flow and concentrations of fecal pathogen indicators at specified locations are needed. A review of the data from organizations that monitor the Clear Creek Watershed found no gages currently measuring flow. As a result, at each location where *E. coli* were measured, the flow was also measured in the field.

Table 4.7 shows the loads at the stations where flow was measured as well as the location of each of the stations and the indicator that was tested (EC – E.Coli, NT – Enterococci). As shown in this table, the two tributaries that carry the largest fecal pathogen loads into Clear Creek were both located in tidal streams. Magnolia Creek appears to carry the largest fecal pathogen load into Clear Creek, followed by Robinson's Bayou. From freshwater segments, it appears that Cowart Creek carried the largest fecal pathogen load; Mary's Creek carried the next largest.

Table 4.7 Fecal Pathogen Indicator Loads Throughout the Clear Creek Watershed

Location ID	Creek/Tributary Name	Indicator	Flow ft^3/sec	LOAD (MPN/d)
11425	Cowart Creek	EC	-8.97	5.65E+10
11450	Clear Creek Main Stem	EC	71.69	1.59E+12
11451	Clear Creek Main Stem	EC	34.26	1.57E+11
11452	Clear Creek Main Stem	EC	33.69	1.23E+11
16473	Mary's Creek	EC	9.60	3.51E+10
16493	Chigger Creek	EC	0.45	5.49E+09
16678	Cowart Creek	EC	0.95	1.57E+10
17068	Hickory Slough	EC	3.73	3.53E+09
17069	Turkey Creek	EC	4.02	4.34E+11
17071	Mud Gulley	EC	4.05	5.00E+10
17074	Clear Creek Main Stem	EC	44.12	1.46E+11
17076	Clear Creek Main Stem	EC	32.07	1.08E+11
17079	Clear Creek Main Stem	EC	32.39	7.56E+10
TBD-01	Mary's Creek	EC	16.73	2.48E+10
TBD-02	Chigger Creek	EC	0.58	2.11E+10
16475	Robinson's Bayou	NT	11.16	6.43E+10
16486	Robinson's Bayou	NT	2.18	1.24E+11
16575	Clear Creek Main Stem	NT	396.23	3.37E+12
16576	Clear Creek Main Stem	NT	118.56	1.16E+11
16611	Magnolia Creek	NT	2.29	1.18E+11
TBD-03	Unnamed Tributary	NT	0.13	1.31E+10

Notes:
EC = *E. coli*
NT = Enterococci
TMDL = Total Maximum Daily Load
MPN/d = Most Probable Number per Day
ft^3/sec = Cubic Feet per Second
Negative flows could be the result of backflow from the mainstream.

CHAPTER 5

CONCLUSIONS

Historical indicator bacteria data for the Clear Creek Watershed were analyzed temporally and spatially. Temporal trend analyses showed statistically significant (p=0.05) decreasing trends for one station in Segment 1101 and seven stations in segment 1102. Visual inspection of geometric mean concentrations along the main stem and main tributaries showed that concentrations seem to decrease from upstream to downstream for segment 1101, while no clear trend was observed for Segment 1102, Chigger Creek, and Mary's Creek.

The inventory of major bacterial sources found 23 municipal facility permits within the Clear Creek Watershed that discharge wastewater. The current permitted daily flow to Clear Creek is 45.96 MGD and the average domestic wastewater discharge to Clear Creek was 23.7 MGD from approximately 2000 to mid-2004. In addition, 631 sanitary sewer overflows were reported in the Clear Creek Watershed from January 2005 through July 2005.

An analysis of the impact of rainfall on fecal pathogen concentrations showed a rapid increase in fecal pathogen concentrations during the first 24 hours after a rain event. A statistically significant decreasing trend ($p < 0.01$) of about -1160 cfu per 100 mL of water per day was found between one and four days after a rain event.

The sampling for Work Order #582-0-80121-09 was completed and the data were analyzed to assess sources, contamination levels, and trends of indicator bacteria in the Clear

Creek Watershed. The sampling was comprised of four main components: (i) monitoring of E. coli and Enterococci in the project segments, (ii) an assessment of dry-weather discharge locations, (iii) an assessment of contributions from sediment; and (iv) flow measurements at various locations within the project segments. The single sample standard was exceeded at fourteen of the twenty-five stations. The data show a statistically significant ($p < 0.001$) correlation between sediment and ambient water concentrations of the fecal pathogen indicators. Statistically significant trends were also found between total organic carbon concentrations and fecal pathogenic bacteria and ammonia concentrations and fecal pathogenic bacteria.

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APPENDIX A

SAMPLING PLAN

APPENDIX B

T-TEST ANALYSES FOR HISTORICAL DATA

APPENDIX C

FLOW DATA FOR MUNICIPAL WASTEWATER PERMITS IN THE CLEAR CREEK WATERSHED

(Electronic)

APPENDIX D

DMR DATA FOR MUNICIPAL WASTEWATER PERMITS IN THE CLEAR CREEK WATERSHED

APPENDIX E

SSO DATA FOR CITY OF HOUSTON WASTEWATER PERMITS IN THE CLEAR CREEK WATERSHED

(Electronic)

APPENDIX F

QAPP Rev 2

(Electronic)

APPENDIX G

QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION

(Electronic)

APPENDIX H

STANDARD OPERATING PROCEDURES (SOP) FOR SAMPLE COLLECTION

APPENDIX I

PIPE RECONAISSANCE SURVEY

(Photos on CD)